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# Spatial And Temporal Comparison Of Agricultural Production In The Semi-Arid Region Of Ceará State, Brazil In The Years 1996, 2006 And 2017

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***Abstract:***
*The study evaluated the synergy between rainfall and indicators of vegetation cover, land productivity and wealth generation in the rural sector of municipalities in the semi-arid region of Ceará. Data from the 1995/96, 2006 and 2017 Agricultural Censuses were used. The study also sought to assess the behavior of Ceará's climatic regions with regard to rainfall. Rainfall data was collected from the Ceará Foundation for Meteorology and Water Resources (FUNCEME), and information on vegetation cover, land productivity in crop and animal production was collected from the 1995/96, 2006 and 2017 IBGE Agricultural Censuses. Information on the GDP of the municipalities was also sought from other IBGE documents that publish this information. The study created the agricultural production preservation index (IPCP), which was used to capture the synergy between the indicators. Factor analysis was used for this purpose. The results found served to answer the guiding question of the research, which was to assess the synergy between rainfall and the other variables. It also showed that the climatic regions of Ceará presented different average values and instabilities, with the region with the greatest climatic difficulties being the Sertão Central and Inhamuns Central Hinterland and Inhamuns). The results showed that 1996 had the best rainfall levels and the highest IPCP values compared to 2006 and 2017. Therefore, there was an interaction between rainfall and preservation indicators applied in the semi-arid region of Ceará during the study period.*

***Key Word:*** *Environmental degradation; Land productivity; Northeast region of Brazil; Productive capacity; Rainfall instability; Soil preservation.*

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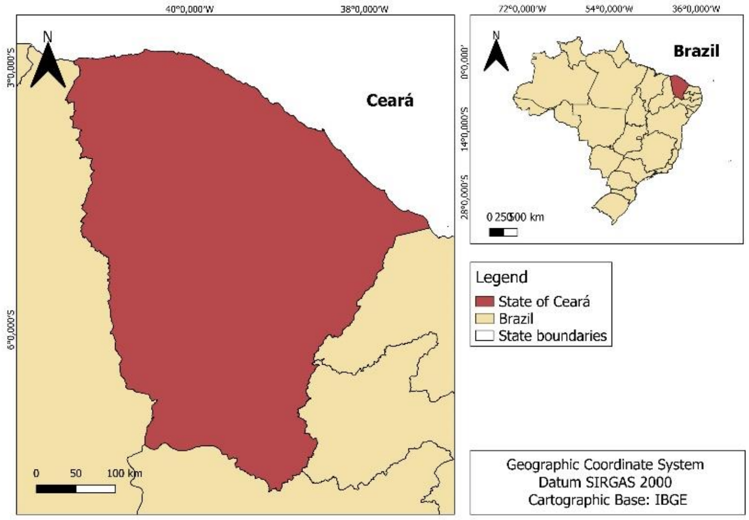
## I. Introduction

Agricultural production in the Northeast region of Brazil faces major obstacles associated with a complex synergy of factors that contribute to the depredation of the region's natural resource base and make it difficult or even impossible to produce agricultural goods in many of the municipalities in the nine states that make up the region.

In Ceará State (FIGURE 1), the situation is not very different, given that the levels of productivity achieved by agricultural and pastoral activities are very low. This is possibly due to the still low technological standard in which agricultural and livestock activities are practiced in the state.

**Figure 1:** Geographic location map of the State of Ceará, Brazil.




Source: IBGE (2022).

The impact accumulated over centuries of inadequate exploitation of these activities has drastically reduced not only the production and productivity of the land, but has also contributed to the loss of resilience of agricultural production systems to the water stresses to which the state is cyclically subjected[1].
Ceará currently has 171 of its 184 municipalities officially recognized as belonging to the semi-arid climate region[2]. In this state, in addition to the vulnerabilities imposed by the irregular rainfall of the semi-arid region, which prevails over practically the entire territory, a very significant part of the soil is degraded and has seriously compromised its vegetation cover[3].

In the semi-arid region of Ceará, rainfall is intermittent both, in space and time. Between 2010 and 2017, the state, like the entire Northeast region, experienced a long period of drought which had major repercussions on plant production, animal husbandry, floral cover, the diversification of fauna, the replenishment of underground aquifers (mainly the water table) and surface aquifers, including the dams built to store water.

In addition, temperatures are high, with low amplitudes and the relative humidity is very low[4]. The soils are shallow and generally have low natural fertility. In addition, considerable parts of the state's surface are covered by crystalline outcrops. Crystalline shields, or ancient massifs, represent a very resistant type of geological formation and are generally formed in low-altitude areas. They are made up of metamorphic and magmatic crystalline rocks that are highly resistant to erosion and weathering. The vegetation cover characteristic of the semi-arid region of Ceará, like that which prevails in this climate regime in Brazil, is the caatinga. This cover is very degraded by the actions of human activities that come from predatory agriculture practiced by both: family farmers and farmers in the employer segment. Another factor that contributes to the collapse of the regional and state caatinga is the removal of the cover to serve as firewood or charcoal that is used to cook food in rural homes, most of which are very poor, or to burn in furnaces in bakeries and potteries, in many cases located far from the areas of removal.[5,6]

This synergy between human and natural agents means that the semi-arid region of Ceará has levels of preservation of its productive capacity in difficult situations, also due to the heterogeneous geographical diversity of the state, which has coastal, hinterland and mountain environments. Each of these regions has its own specific climate, reflected in temperatures and rainfall[4].

Growing rainfed crops depends directly on weather conditions, especially rainfall. As, it is impossible to exercise any control over nature, the oscillations in dryland farming are due to the variability of climatic conditions, which farmers have no defense mechanisms against. They are therefore high-risk activities. The weaknesses of this production system are reflected in the fluctuations in harvested areas, productivity, prices and income associated with these activities. [7,8,9,10,11,12]

According to Fischer *et al* (2002), rainfed agricultural crops for most small family farmers depend on the availability of natural resources. Crops such as beans, manioc and corn, which are grown by family farmers according to this regime in the semi-arid states, are strongly dependent on the spatial and temporal distribution and, ultimately, the instability of rainfall, which is the rule in the semi-arid region. [4,6,13]

In view of the above, this research attempts to answer the following question: Is there synergy between rainfall and indicators of vegetation cover, land cover and income generation in the rural sectors of the municipalities in Ceará that are officially recognized as being part of the Brazilian semi-arid region?

In order to answer this question, the research has the following objectives: a) To estimate the averages as well as the levels of rainfall instabilities in the eight (8) climatic regions into which Funceme has divided Ceará; b) To evaluate, in a comparative way, among the municipalities of the semi-arid region of Ceará, indicators of vegetation cover, land productivity and the relative share of the rural sector's GDP in the aggregate GDP of the municipalities, as well as the way in which these indicators interacted with the rainfall that occurred in these municipalities according to the 1996, 2006 and 2017 Agricultural Censuses; c) Draw up a scale to define the productive capacities of these municipalities in each year; d) List the twenty (20) most preserved and twenty (20) least preserved municipalities in the semi-arid region of Ceará State in the studied years.

**Concepts involved in the research**

The research works with the concepts of preservation of productive capacity in the rural sector, and its contradiction which is environmental degradation, as the theoretical anchors for the selection of indicators and for the construction of the instrument that was used to assess how plant, animal and agricultural production in general has evolved in the municipalities of Ceará officially recognized as part of the semi-arid region in three periods of records in the last Agricultural Censuses of 1996, 2006 and 2017.

**Environmental degradation**

The term environmental degradation recurs in technical literature, but not only in it. According to a Brazilian Law Nº. 6.938, of August 31, 1981, which instituted the National Environmental Policy, Article 3, item II, established the following concept: "degradation of environmental quality is the adverse alteration of the characteristics of the environment".[14]

Degradation of the environment implies its depredation, causing a potential reduction in the availability of productive assets by a process, or by a synergy of them, acting on natural and environmental resources such as: air, water, soil, deterioration of ecosystems and, if not stopped, makes life in environments with such characteristics unfeasible. [15, 16, 17]

In the long term, there is a reduction in the diversity of natural vegetation and wildlife, salinization and solidification of the soil. All of these impacts can be contributed to, or even induced, by anthropogenic action through the practice of deforestation, predatory agriculture, the use of vegetation cover as an energy source, the incorporation of marginal land into the agropastoral production process, incorrect irrigation, cultivation of large areas without proper diversification, the use of fire as a means of clearing areas, among other things. Pollution resulting from the emission of effluents from factories and vehicles is also blamed for environmental degradation. Another cause is inadequate sanitation, which dumps waste into streams, creeks, rivers and seas. The accumulation of solid waste that is not collected and/or properly treated and packaged.[6,7]

The result of the intersection of these factors is a process of depredation of the natural resource base, largely corroborated by global population growth which, acting together, induces an increase in environmental degradation, affecting its productive capacity for the production of food and raw materials and generating continued occupation of population contingents, especially in rural areas.[15, 18, 19, 20]

Environmental degradation leads to the impoverishment of ecosystems which, in the case of arid, semi-arid and dry sub-humid areas, can induce the formatting of desertification processes, which is considered to be a continuous process of alterations in the soils, vegetation and rainfall regime which, due to environmental deterioration, can cause localized pressures on climatic factors and hinder the resilience of productive capacity in the rural sector. [7, 11, 13, 17, 21, 22]

According to the Brazilian Agricultural Research Corporation (EMBRAPA), Brazil has an estimated of 60 to 100 million hectares of soils in various levels of degradation. In addition, this study indicates that more than half of the areas with pastures (cultivated or natural) are degraded.[23]

In the Northeast, these problems are compounded by rainfall instability, both over the years (temporal) and within the same year (spatial). In fact, between 2010 and 2017, this region and Ceará experienced a shortage of rainfall. In those eight years, the average rainfall in Ceará was just 546.4 mm, or 69% of the average observed for the state between 1950 and 2019. In 1996, Ceará's average rainfall was 1064.10 mm. In 2006 it rained an average of 830.10 mm in Ceará, while in 2017 the average rainfall in the state was 698.20 mm. In the Central and Inhamuns sub-region, which is made up of forty (40) municipalities, the average rainfall that year was 590.3 millimeters. This is undoubtedly the sub-region with the greatest rainfall problems in Ceará.[4]

The interaction between these factors that cause degradation in the productive capacity of the municipalities has a negative impact on land productivity in plant production and animal husbandry, making it difficult and often even impossible to produce raw materials for food and/or for the market.

Generally, these are small areas and, since they have to provide for their families, they cultivate them to exhaustion and for years on end, without giving up, so that the areas are left to rest from cultivation in order to form copses that would help regenerate, at least partially, the vegetation cover. In addition, the remaining vegetation cover is subjected to other very severe impacts, resulting from its removal to be used as firewood or charcoal, that will be used in homes to cook food or in the furnaces of industries of various sizes that are often located far from the collection areas. In the semi-arid region, these problems are exacerbated by the systematic occurrence of droughts. This means that the state of material poverty induces people to use natural resources to the point of exhaustion. This corroborates to the reduction in the productive capacity of environments in the semi-arid region.[24, 25]

## II. Methodology

The data used in the research is secondary. Information on rainfall in the municipalities was collected from the Ceará Foundation for Meteorology and Water Resources (FUNCEME). Information on agricultural production was obtained from the 1995/96, 2006 and 2017 Agricultural Censuses of the Brazilian Institute of Geography and Statistics (IBGE) for the state of Ceará. The aggregate Gross Domestic Products (GDP) of the municipalities for the years 1999, 2006 and 2017 made available by the IBGE were also used. This is because the IBGE only began to publish the GDP of municipalities from 1999 onwards, which is why, this will be the base period for comparison for this indicator.

The observation units used are the municipalities in Ceará that existed in the three years studied and that are included in the semi-arid region according to the latest Sudene (Superintendence for the Development of the Northeast) report. It is worth noting that, according to the latest definition by the Development Council of the Northeast Development Superintendence (CONDEL/SUDENE), Ceará now has 171, of its 184 municipalities, officially recognized as being in the Brazilian semi-arid region, for the purposes of all public policies designed for this climate regime.[2]

Since 1996, Ceará has had the same number of municipalities (184 municipalities). However, in 17 municipalities recognized as being part of the semi-arid region, the indicators used in the research showed values that characterize them as outlies. For this reason, the observations from these municipalities were discarded. Thus, the research works with 168 of the 171 municipalities in Ceará that are inserted under this climatic regime in the state.

**Methodology used to reach objective "a".**

Objective "a" consists in estimating the averages as well as the levels of rainfall instabilities in the eight (8) climatic regions into which Funceme has divided Ceará. To achieve this objective, the averages and coefficients of variation (CV) of the rainfall observed in the municipalities that make up the eight climatic regions were estimated. By definition, the CV measures the percentage relationship between the standard deviation and the mean of a random variable. CV is used as a measure of the homogeneity/heterogeneity or stability/instability, which are the same thing, of the distribution of the observed values of a variable around its mean. The higher the CV, the more heterogeneous or unstable the distribution.[26, 27, 28] According to Gomes (1985)[29] CVs can be classified as low ($CV<10\%$); medium ($10\% \leq CV< 20\%$); high ($20\% \leq CV < 30\%$); and very high ($CV \geq 30\%$).

**Indicators used to measure productive capacity**

Based on the definition and the rationale presented in this paper and the justification given for each of them, five (5) indicators were constructed to make it possible to gauge the productive capacity of the municipalities. A comparative statics study was carried out. The indicators tested are: 1 - Annual rainfall of the municipalities ($RAIN_{it}$) = annual rainfall observed for municipality i (i = 1, 2, ..., 168) in year t (t= 1 for 1996; t= 2 for 2006 and t= 3 for 2017). These sub-indices have the same interpretations as the other indicators. 2 - Biological (BIOLit) = the sum of the areas with woods, forests (native and planted) and areas with crops (perennial and temporary) in municipality "i" for each year "t", divided by the total area of productive land in the municipality (in hectares). 3 - Livestock Production Productivity $LIVE_{it}$) = the real value of aggregate livestock production, corrected by the General Price Index (GPI) provided by the Getúlio Vargas Foundation (FGV), for 2020, and then corrected to US dollars considering the average exchange rate of 2020, divided by the total area devoted to pasture (in hectares) in municipality i in year t. 4 - Plant Productivity ($VEGE_{it}$) = real value of aggregate production of perennial and temporary crops, corrected by the GPI for 2020, and then corrected to US dollars considering the average exchange rate of 2020, divided by the areas harvested with these crops (in hectares) in municipality "i" and in year "t". 5 - Agricultural GDP in relation to the municipality's aggregate GDP ($GDPA_{it}$) = agricultural GDP of the municipality / total GDP of municipality "i" in year "t".

**Construction of the agricultural production preservation index (IPCP)**

As we have seen, the indicators used in the research are measured in different units. To be aggregated, they need to be measured in dimensionless units. In this research, the strategy used to do this was to construct the agricultural production preservation index (IPCP), to aggregate the five (5) indicators.

Indices are dimensionless measurement tools that are built when you want to summarize a larger amount of information in a single number. The advantages of these indices are that, as well as aggregating variables measured in different units, they are useful for understanding a phenomenon, as long as you are aware of these construction problems. In order to be useful in assessing and understanding a problem, indices must have certain characteristics such as simplicity, the ability to be reproduced and ease in obtaining and measuring indicators.[30]

Treating the indicators generically as $Y_{ijt}$ (i = 1, 2, ..., 168; j = 1, 2, 3, 4, 5; t = 1, 2, 3), these indicators are transformed into partial indices that vary between zero (0) and one hundred (100), using the transformations shown in equation (1):

$$\hat{Y}_{ijt} = [(Y_{ijt} - Y_{mn}) / (Y_{mx} - Y_{mn})].100 \quad (1)$$

In equation (1) the variable $\hat{Y}_{ijt}$ refers to the value observed for indicator "j" in the i[th] municipality and in year "t"; $Y_{mn}$ is the lowest value observed for the indicator in the three observed years; $Y_{mx}$ is the highest value observed for the indicator in the three studied years. This way of constructing the partial indices shows that they are relativized and vary between zero and one (1). The IPCP is defined as shown in equation (2):

$$IPCP_{ijt} = \Sigma w_{ijt}.\hat{Y}_{ijt} \quad (2)$$

In equation (2) the variable Ŷijt refers to the already defined partial and relativized indicators that make up the IPCP. The wit weights are values greater than zero (0) and less than one (1), which together must add up to one (1) ($0 < w_{jt} < 1$; $\Sigma w_{jt} = 1$). Factor analysis (FA) was used to estimate these weights, using the principal component decomposition (PCD) technique. The following section provides a summary of FA and DCP as they apply to this work.

**Brief summary of the factor analysis (FA) procedure that applies to the study**

The technical foundations of FA lie in the correlation between the variables used. For the technique to be viable, the correlation matrix between the variables must not be an identity.[11, 12, 13, 31, 32, 33, 34]

Basically, factor analysis (FA) can be broken down into the following stages: a) analysis of the correlation matrix and the appropriateness of using the method; b) extraction of the initial factors and determination of the number of factors; c) rotation of the factors, when more than one factor is extracted; and d) interpretation of the factors, which includes the possibility of generating weights from the estimated factor scores.[32]

In order for the FA to be carried out properly, the following steps must be taken: analyze and to test whether the correlation matrix between the indicators used in the study is not an identity; check the Kaiser-Meyer-Olkin (KMO) statistic, whose minimum acceptable value is 0.5; evaluate the percentage of explanation of the accumulated variation of the estimated components. The variables are transformed into the standardized normal, which has zero mean and unit variance.

The method used in this study to extract the factors was principal component decomposition (PCD), which has the characteristic of searching for a linear combination of the observed variables in order to maximize the total variance explained.[33, 36]

Checking the differences between the averages of the indicators and the IPCP in the years evaluated

The following equation model was used to assess whether there is a statistical difference between the averages of the indicators and the IPCP estimated in 1996, 2006 and 2017:

$$Yit = \beta_0 + \beta_1 D1 + \beta_2 D2 + \varepsilon_{it} \quad (3)$$

In equation (3) the indicator to be tested, as well as the estimated index, are represented generically by $Y_{it}$, where i is the number of municipalities (i = 1, 2, ..., 168) and t are the years studied (t = 1996; 2006 and 2017). D1 is a binary variable defined as follows: D1 = 1 for the values observed in 1996; D1 = 0 for the observations in 2006 and 2017. The binary variable D2, in turn, is defined as follows: D2 = 1 for observations in 2006; D2 = 0 for the values observed in the municipalities in 1996 and 2017. The linear coefficient $\beta_0$ will measure the average of the indicator (or index) in 2017, when D1=D2=0. With regard to the angular coefficient β1, if it is statistically different from zero, it implies that the average of the variable in 1996, in the 168 municipalities studied, is statistically different from the averages in the other two years. If the angular coefficient β2 is statistically different from zero, means that the average of the indicator in 2006 is different from the averages estimated for 1996 and 2017. The random term εit, by hypothesis, is white noise. Therefore, the parameters $\beta_0$, $\beta_1$ and $\beta_2$, of equation (3) can be estimated using the ordinary least squares (OLS) technique.[37]

**Methodology for classifying municipalities according to IPCP magnitudes**

The municipalities were classified according to their IPCP magnitudes, using the mean (MD) and standard deviation (SD) of the index in the three years evaluated as a reference. This decision was made so that the classifications adopted can be directly compared. Those are the classification of IPCP according to these criteria:

i - Municipalities with very high IPCP ($IPCP^{VH}$). Those in which the Index is higher than the average, plus one standard deviation [$IPCP^{VH} > (MD + SD)$]; ii - Municipalities with high IPCP ($IPCP^{HI}$). Those in which the Index is higher than the average and lower than, or equal to, the average plus one standard deviation: [$MD < IPCP^{HI} \leq (MD + DP)$]; iii - Municipalities with medium IPCP ($IPCP_{ME}$). Those in which, at the same time, the Index is less than or equal to its average value and greater than this value subtracted from a standard deviation: [$(MD - DP) < IPCP^{ME} \leq MD$]; iv - Municipalities with low IPCP ($IPCP^{LO}$). Those in which the Index is less than or equal to the average value subtracted from a standard deviation: [IPCPLO ≤ (MD - DP)]. After 6 weeks of follow up it was found that LDL-C ,went down by -32.81%on regular dose of Atorvastatin 40 mg,-37.28% on Rosuvastatin 20 mg daily and -37.53% on Rosuvastatin 20 mg alternate day.

## III. RESULTS AND DISCUSSION

The results found to assess objective "a" of the research are shown in Table 1. The results in this Table show that the highest average rainfall occurred in 1996 in all climatic regions and the lowest in 2017. It can also be seen that in 2017 rainfall was the least unstable in all regions. In 1996 and 2006, there were four years (each) with the greatest instability. Instabilities ranged from 18.94% (average) in the Baturité Massif in 2017 to 30.59% (very high) in the Ibiapaba region in 2006 (Table 1).

**Table 1:** Averages and coefficients of spatial variations (CV) in the municipalities of the climatic regions of Ceará in 1996, 2006 and 2017

| | Rainfall in 1996 (mm) | | Rainfall in 2006 (mm) | | Rainfall in 2017(mm) | |
|---|---|---|---|---|---|---|
| **Region** | **Average** | **CV (%)** | **Average** | **CV(%)** | **Average** | **CV(%)** |
| Cariri | 1021.88 | 21.41 | 891.47 | 23.70 | 765.60 | 19.60 |
| Ibiapaba | 1132.99 | 28.33 | 945.17 | 30.59 | 798.82 | 19.45 |
| Jaguaribana | 1146.50 | 26.48 | 1011.88 | 24.22 | 843.55 | 17.27 |
| Litoral of Fortaleza | 1038.73 | 19.62 | 941.10 | 17.45 | 817.26 | 15.34 |
| Litoral of Pecém | 1088.05 | 27.05 | 969.11 | 24.67 | 814.05 | 20.47 |
| Litoral Norte | 1084.50 | 25.94 | 919.33 | 26.96 | 807.44 | 19.02 |
| Maciço of Baturité | 1014.75 | 21.94 | 906.35 | 26.80 | 773.68 | 18.94 |
| Sertão Central and Inhanuns | 1049.13 | 28.30 | 908.75 | 27.46 | 772.91 | 20.42 |

Source: Funceme, 2020.

The results of the factor analysis to estimate the weights used to construct the index of production capacity prevention index (IPCP) for the agricultural sector of the 168 semi-arid municipalities in Ceará studied are shown in Table 2.

**Table 2:** Results of the decomposition into principal components to estimate the weights used in the IPCP in the municipalities of Ceará in 1996, 2006 and 2017.

| **Variables** | **Components** | **Factor scores coefficiens** | **Weights** |
|---|---|---|---|
| RAIN | 0.618 | 0.367 | 0.22 |
| BIOL | 0.790 | 0.469 | 0.28 |
| LIVE | 0.575 | 0.341 | 0.20 |
| VEGE | 0.452 | 0.268 | 0.16 |
| AGNP | 0.381 | 0.226 | 0.14 |
| KMO | 0.753 | | |
| Chi-square | 174.751 | | |
| Degrees of freedom (DF) | 10 | | |
| Sig. | 0.000 | | |
| Explained variance (%) | 50.842 | | |

Sources: Values estimated from original IBGE data from 1995/96, 1999, 2006 and 2017 and from Funceme, 2020.

It can be seen that the results found are robust, from a statistical point of view, as all the relevant statistics used to carry out the model adequacy tests proved to be significant. The magnitude of the KMO test was greater than the minimum acceptable value of 0.5. The chi-square statistic used to perform Bartlett's test shows that the hypothesis that the correlation matrix is identity is rejected. The weights generated from the components, or estimated factor scores, show that the indicators that contribute the highest weights are, respectively, vegetation cover (BIOLOGICAL) and rainfall (RAINFALL).

The next step was to assess whether the indicators used to estimate the IPCP in the three years, as well as whether this index, differed statistically in 1996, 2006 and 2017. This test was carried out using the model with binary variables presented in Equation (3) in the methodology section. These results are shown in Table 3.

It can be seen that rainfall (RAIN), on average, was statistically higher in 1996 than in the other two years. The same was true of the vegetation cover indicator (BIOL) and the relative share of agricultural GDP in total GDP and IPCP (AGDP). With regard to livestock productivity (LIVE), this was the only indicator where the average was higher in 2017 than in the other years. The plant productivity indicator (VEGE), on the other hand, was higher in 2006 (Table 3 and Table 4).

**Table 3:** Results obtained with the tests to assess whether the indicators used and the IPCP are statistically different in 1996, 2006 and 2017.

| | | Constant | | D1 | | D2 | |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Variables** | **Adjusted $R^2$** | **Estimated** | **Sign.** | **Estimated** | **Sign.** | **Estimated** | **Sign.** |
| RAIN | 0.079 | 737.000 | 0.000 | 276.620 | 0.000 | 73.580 | 0.003 |
| BIOL | 0.330 | 0.396 | 0.000 | 0.281 | 0.000 | 0.257 | 0.000 |
| LIVE | 0.018 | 1057.109 | 0.000 | -42.915 | 0.722 | -39.253 | 0.745 |
| VEGE | 0.066 | 1218.855 | 0.000 | 503.324 | 0.001 | 896.927 | 0.000 |
| AGDP | 0.112 | 0.146 | 0.000 | 0.073 | 0.000 | 0.053 | 0.000 |
| IPCP | 0.283 | 30.656 | 0.000 | 14.577 | 0.000 | 12.266 | 0.000 |

Sources: Values estimated from original IBGE data from 1995/96, 1999, 2006 and 2017 and from Funceme, 2020.

Thus, in general, it can be seen that, rainfall influenced the definitions of all the indicators used to construct the IPCP. These behaviours are summarized in Table 4, which shows the averages for each of these IPCP indicators, as well as their hierarchies represented by the super-indices, A, B and C, where A>B>C.

**Table 4:** Averages of rainfall indicators, vegetation cover, value of livestock production per hectare of pasture, value of crop production (perennial and temporary crops) per hectare and ratio between agricultural GDP, total GDP of municipalities and IPCP in 1996, 1999, 2006 and 2017.

| | **Anos** | | |
|---|---|---|---|
| **Indicadores** | **1996** | **2006** | **2017** |
| RAIN | $1013.62^{A}$ | $810.58^{B}$ | $737.00^{C}$ |
| BIOL | $0.68^{A}$ | $0.65^{B}$ | $0.40^{C}$ |
| LIVE | $1014.19^{B}$ | $1017.86^{B}$ | $1057.11^{A}$ |
| VEGE | $1722.18^{B}$ | $2115.78^{A}$ | $1218.86^{C}$ |
| AGDP | $0.22^{A}$ | $0.20^{B}$ | $0.15^{C}$ |
| IPCP | $45.23^{A}$ | $42.92^{B}$ | $30.66^{C}$ |

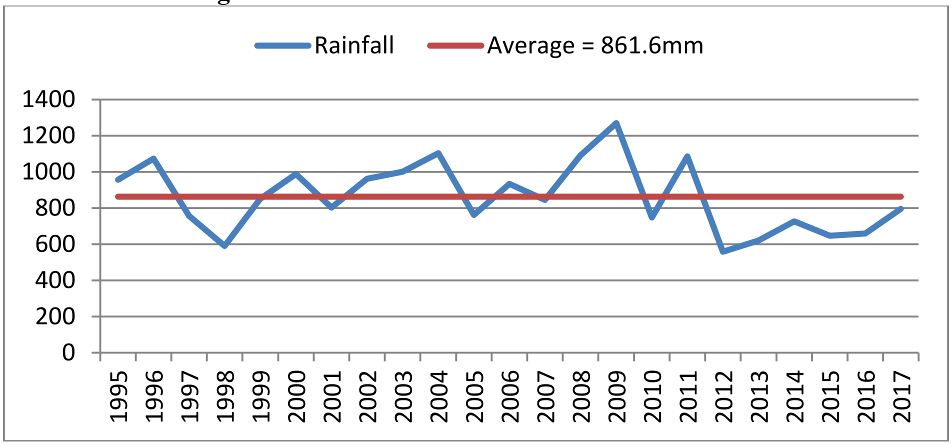
Sources: Values estimated from original IBGE data from 1995/96, 1999, 2006 and 2017 and from Funceme, 2020.Notes: the super-indices A, B, C, mean that the averages can be ranked as follows: A > B > C

These results are also reflected in the hierarchy of the estimated IPCP averages for the three years. The average IPCP for 1996 is 2.3% higher than that observed in 2006 and 14.6% higher than that observed for 2017. This is a significant difference in the reduction of productive capacity in the semi-arid region of Ceará in the two periods (2006 and 2017) compared to the base year (1996). It is worth remembering that between 2012 and 2017 there were years of drought in most of Ceará's municipalities. These events had an impact on agricultural production in almost all of the state's municipalities during that period.

Figure 1 shows the evolution of rainfall in the state of Ceará between 1995 and 2017. The estimated average for the period was 839.6mm. It can be seen that in 1995, the year preceding the collection of information for the 1996 Agricultural Census, the average rainfall in Ceará was 1067.10 mm and in 1996 it rained an average of 1064.10 mm. In 2006, it rained 830.10 mm in Ceará. The year 2017, according to

Funceme (2020), ended a cycle of drought in Ceará which, in 2014, recorded 551.20 mm; in 2015 it rained 532.70 mm; in 2016 the rainfall recorded in the state was 554.60, culminating in rainfall of just 698.20 millimeters in 2017. This sequence of rainfall difficulties that preceded 2017 and influenced the year itself can therefore be blamed for the results associated with practically all the indicators used to gauge Ceará's productive capacity, as well as the IPCP in 2017. It can also be seen that the average rainfall between 1996 and 2017 was 849.5 mm. The rainfall for 1995 was calculated because it must also have contributed, via the formation of expectations, to the more favorable results in 1996. It can be seen that the level of rainfall in 1996 was the most abundant compared to the other two years studied in the study.

**Figure 2:** Rainfall in Ceará State from 1995 to 2017.




Source: Funceme (2020).

Table 5 shows the number of municipalities classified according to the magnitudes of their respective IPCPs, based on the averages and standard deviations observed for the index in 1996, 2006 and 2017. As the scales were constructed based on these values in the three years of evaluation, the classifications presented can be compared with each other. Thus, the evidences in table 5 shown that the situation is quite unfavorable for the municipalities studied in 2017 compared to the other years, especially based on 1996.

**Table 5:** Number of municipalities according to the IPCP measured in 1996, 2006 and 2017.

| | **Year of 1996** | | **Year of 2006** | | **Year of 2017** | |
|---|---|---|---|---|---|---|
| | Municipalities | Averages | Municipalities | Averages | Municipalities | Averages |
| Very High | 39 | 56.68 | 32 | 58.63 | 8 | 55.72 |
| High | 86 | 44.84 | 67 | 44.65 | 35 | 45.70 |
| Medium | 41 | 36.10 | 65 | 34.57 | 44 | 32.97 |
| Low | 2 | 26.26 | 4 | 23.93 | 81 | 20.43 |
| **Total** | **168** | **45.23** | **168** | **42.92** | **168** | **30.66** |

Sources: Values estimated from original IBGE data from 1995/96. 2006 and 2017 and Funceme. 2020.

For example, in 2017 there were 81 (48.2%) municipalities with HPIs considered low. compared to 4 municipalities in 2006 and only 2 in 1996. On the other hand, in 1996 and 2006, 39 (23.21%) and 32 (19.1%) municipalities, respectively, had their IPCP classified as Very High. In 2017, only 8 (4.8%) municipalities had their estimated IPCP considered in this category. On the other hand, in 1996, 86 (51.2%) municipalities had their IPCP classified as High. In 2006 there were 67 (40.0%) and in 2017, only 35 (20.8%) could be classified in this category (Table 4).

## IV. CONCLUSIONS

The study aimed to answer the following question: Is there synergy between rainfall and indicators of vegetation land cover and income generation in the rural sectors of the municipalities in Ceará that are officially recognized as being part of the Brazilian semi-arid region?

The question was answered in full, given that the study created the agricultural production preservation index (IPCP) which incorporates, in a weighted way, five indicators: annual rainfall in the municipalities; plant cover; land productivity in plant production; land productivity in livestock production; and the relative share of the municipalities' agricultural GNP in relation to the municipalities' aggregate GNP in 1996, 1999, 2006 and

2017. The indicators were constructed in a relativized way. To do so, they were transformed into indices using the maximum-minimum technique.

The results showed that in the interaction of these five indicators, the year 1996. which was taken as the reference year, showed the best results in terms of preserving productive capacity. And in that year, the average rainfall was higher than that observed in 2006 and 2017.

On the other hand, 2017, which culminated a long period of drought in Ceará. was the year that showed the least ability to preserve productive capacity in the agricultural sector of the state's semi-arid municipalities.

This difference in rainfall observed in the three years studied may have contributed to the differences between the indicators observed in general in the three years. Only livestock productivity, which measured the ratio between the value of livestock production and the area occupied by this activity in the municipalities of the semi-arid region of Ceará, showed a higher average in 2017 than in the other investigated years.

Evidence of the importance of rainfall in the rural production capacity of the semi-arid region is confirmed in the study when the list of the twenty (20) best-positioned municipalities in relation to the agricultural production preservation index (IPCP) is presented, which are located in the mountainous and coastal areas where rainfall is more abundant. This can be seen in the three investigated years.

On the other hand, the municipalities that showed the lowest capacity for preserving agricultural production are located in the areas with the greatest rainfall difficulties in the state of Ceará. which are mainly the Sertão Central and Inhamuns region.

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