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Family farming and the water crisis in the Sertão of Ceará

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Summary
The objective of this study was to assess the resilience of family farming based on the most practiced crops (corn and beans) in the Sertão dos Inhamuns in response to the stress caused by water instability between the years 1977 and 2013. The evolution of the value of production, harvested areas and yields of these crops were evaluated. To estimate this resilience index, we used the decomposition method in principal components of factor analysis aiming to find the weights associated with the indicators employed in the index formatting. The results showed the great instability of the cultures, which even exceeds the instability of the rainfall regime, because besides this climatic irregularity, there are problems associated with technological delay, which was not the object of the study, and the fluctuation of prices demonstrated in the research.
Keywords: Family farming. Resilience. Water stress.

A agricultura familiar e a crise da água no Sertão Cearense

Resumo
O objectivo deste estudo era avaliar a capacidade dos agricultores familiares em recuperar das culturas mais praticadas (milho e feijão) no Sertão dos Inhamuns em resposta ao stress causado pela instabilidade hídrica entre 1977 e 2013. Foi avaliada a evolução do valor da produção, as áreas colhidas e os rendimentos destas culturas. A fim de estimar este índice de resiliência, utilizamos o método de decomposição nos principais componentes da análise factorial para encontrar os pesos associados aos indicadores utilizados no formato do índice. Os resultados mostraram a grande instabilidade das culturas, que ultrapassa mesmo a instabilidade do regime pluviométrico, porque para além desta irregularidade climática existem problemas associados ao atraso tecnológico, que não foi o objecto do estudo, e à flutuação dos preços mostrada na pesquisa.
Palavras-chave: Agricultura Familiar. Resiliência. Stress hídrico.

1 Introduction

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The Brazilian semi-arid is a natural region delimited by a set of integrated soil and climate characteristics that differentiate it from the surrounding geographical space. The characteristic biome of this region is the caatinga, which stands out for having a diverse biological heritage and for being an exclusively Brazilian biome, not found anywhere else in the world. The characteristics of this biome are predominantly high temperatures, scarce precipitation concentrated in a short period of time, water deficit due to the high potential of evapotranspiration, which is higher than precipitation, and shallow and rocky soils. The native vegetation is composed of low bushy or arboreal plants, twisted and resistant to water stress.

The semi-arid region in Brazil extends over eight states in the Northeast region and part of the state of Minas Gerais. The rural economy of this region is based on family agriculture. In the Northeast region, which has the largest portion of its territory inserted in the semi-arid region, 90.2% of the agricultural establishments are characterized by family farming, the employer category represents only 6.4% of the total number of establishments. However, despite occupying almost the entire extension of the rural area, family farming represents only 52.2% of the Gross Value of Production, while the employer sector corresponds to 42.5% of the GVA (SABINO, 2013). These data show the extent of the problem, since they portray the situation of vulnerability to environmental factors, technological backwardness and lack of technical and economic structure to which agriculture is subjected that is practiced by most farmers living in the semi-arid region.

The State of Ceará has more than 90% of its territory belonging to the semi-arid region. It is the Brazilian state with the largest proportional insertion in this biome. Of the 184 municipalities of Ceará, 150 are officially included in the semi-arid region (LEMOS; BOTELHO, 2014). The state is divided into eight macro-regions of planning: Metropolitan Region of Fortaleza (RMF), West Coast, Sobral/Ibiapaba, Inhamuns Hinterland, Central Hinterland, Baturité, East Coast/Jaguaribe and Cariri/South-Center. The region discussed in this work is the macro-region of Sertão dos Inhamus. It is made up of sixteen municipalities: Aiuaba, Ararendá, Arneiroz, Catunda, Crateús, Independência, Ipaporanga,

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Ipueiras, Monsenhor Tabosa, Nova Russas, Novo Oriente, Parambu, Poranga, Quiterianópolis, Tamboril and Tauá (IPECE,2010). It covers an area of 26,227.3 km² and has a population of 411,407 inhabitants of which the rural population corresponds to 45% of this total (IBGE, 2010).

According to data from IPECE (2013), in 2011 agriculture and cattle ranching represented a participation in the GDP of this region of 14.67%. Although this is the activity exercised by almost half the population, its participation in the GDP is the lowest, behind the services sector (74.7%) and transformation (10.62%). The predominant agricultural activities in the Sertão dos Inhamuns are dryland agriculture, dairy and beef cattle raising, and small animal husbandry in extensive systems with low technological levels. There are no large continuous areas of mechanized agriculture, and family agriculture is predominant throughout its extension.

Environmentally, it is characterized by a semi-arid climate and the predominant vegetation is the caatinga, composed of xerophytic plants, with high resistance to hydric stress; the soil is shallow and rocky. The region is bathed by four important hydrographic basins: Alto Jaguaribe, Sertões de Crateús, Serra da Ibiapaba and Acaraú. The hydrogeographical potential of the municipalities of this region, as well as of the entire semi-arid region, is small due to the predominance of crystalline rocks represented by lithologies of the Precambrian. This lithology is characterized by shallow soils with the occurrence of rocky outcrops (OLIVEIRA, 2008). These factors favor the low infiltration of water into the subsoil and, consequently, the lack of water table supply, the surface runoff causes soil erosion, the characteristics of the xerophytic vegetation also collaborate with the reduced water infiltration capacity and the soil carry-over into the waterways. Adding up all these aspects, what we see is a desertification scenario, which has already been discussed by some authors.

Other relevant aspects that characterize this region are the high population, large rural areas, average annual rainfall below 800 mm, high average annual temperatures and, consequently, high evaporation rate. The anthropic actions that are developed in this region are predatory, mainly due to the precarious socioeconomic situation of the population that

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uses the natural resources as a means of subsistence in a negligent way. As an example, there is the extraction of wood from the caatinga for the production of charcoal and firewood, burning of native forest areas, irrational use of the soil until it is exhausted, deforestation in hillside areas, river springs, and riparian forests for agricultural and pasture use.

The objective of this work is to evaluate the resilience of agricultural production of corn and bean crops to water stress in the macro-region of Sertão dos Inhamuns between the years 1977 and 2013. Specifically, the research aims to: (a) Estimate the average, maximum and minimum values of harvested area, production, yield and gross value of corn and bean production, comparing them with the average rainfall regimes under which they occurred; (b) Analyze comparatively the maximum, average and minimum values relative to the Sertão dos Inhamuns with the State of Ceará; (c) To estimate comparatively, the capacity or recovery or the resilience of corn and bean crops to water stress, caused by the variation of rainfall in the region between the years 1977 and 2013; (d) To estimate the resilience of corn and bean crops in response to variations in rainfall regime in the Sertão dos Inhamus in the period under investigation.

2 Theoretical framework

The concept of resilience has different definitions depending on the branch of science in which it is applied. For Turner et al. (2003), in ecology studies resilience is used to characterize the ability of a system to recover from disturbance or stress to a reference state and to maintain certain structures and functions. The concept of resilience is based on the idea that ecological and social systems should be understood as systems that are in constant change and not necessarily in static equilibrium (NELSON et al. 2007).

For Carpenter et al. (2001) resilience has three properties: the amount of change that the system can withstand and still maintain its structure and function; the degree of self-organization of the system; the degree to which the system can build the capacity for learning and adaptation. Lemos and Botelho (2014) define resilience as the ability of a

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system to absorb external impacts and reorganize itself while preparing for change to continue to maintain the same functions, structures, identities, and capacity to provide returns.

For Holling (1973), resilience is defined as the propensity of a system to retain its organizational structure and productivity following a disturbance. Thus, a resilient agroecosystem will continue to provide a vital service such as food production even if there is a severe drought or a major reduction in rainfall. The development of resilient agricultural systems is an essential topic of study, as many communities are heavily dependent on the provisioning of ecosystem services such as food, fodder, fuel, and others for their livelihoods (ALTIERI, 1999).

The irregularity of rainfall, water deficiency, low adaptive capacity and poverty of the population makes the semi-arid region in northeastern Brazil is considered one of the vulnerable to climate variability (OBERMAIER, 2011). Climate change and climate variability emerge as one of the most serious global problems affecting many sectors in the world and is considered to be one of the most serious threats to sustainable development with negative impact on the environment, food security, economic activities and natural resources (MARY; MAJULE, 2009).

Agriculture in relation to other sectors of the economy is an activity that has high vulnerability to environmental factors, since the climate is the most important factor in determining the sustainability of agricultural production systems. Communities that depend on agricultural activities for their survival are among the most severely affected and the most vulnerable population of this group are those with lower income and educational level (MONTEIRO, 2007).

In the Brazilian semiarid region, drought is part of daily life, formation of culture, environment, politics and society. In this poverty-stricken region, farmers anxiously await the annual arrival of the rainy season and the promise of a promising harvest. In case of drought, agricultural production is compromised and human suffering prevails (LEMOS et al., 2002).

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The State of Ceará presents characteristics of semi-arid regions, with typical Caatinga vegetation cover and, for not having perennial rivers and being one of the Northeastern states most vulnerable to drought, suffers severe limitations. The absence of perennial rivers combined with the frequency of droughts is an obstacle to the development of the semi-arid region, because problems with shallow and saline soils and low rainfall, associated with intermittent rivers, make unviable, along with other factors of socioeconomic character, the progress of family farming (VIDAL; SANTOS, 2014).

Drought not only influences the rural sector, since the northeastern economy depends on the primary sector. The scarcity of raw materials, unemployment in cities that are part of the semi-arid region, the retraction of the economy and the decrease in tax collection are examples of the extent of the problem caused by droughts on the various sectors of the northeastern economy (ARAUJO FILHO et al.,1987).

It is known, however, that in addition to the problems caused by edaphoclimatic conditions, the shortage of rainfall, the lack of running water due to prolonged droughts, it is also necessary to consider the structural conditions, with respect, mainly, to the ownership and use of land and the cultural context in which family farming is carried out in the northeastern semi-arid region (DUARTE, 2002).

For Siniscalchi (2010), the agricultural sector in the semiarid region is dynamic and quite heterogeneous, with different processes of technological modernization, but the predominant production system is traditional family-based agriculture. The basis of the economy in the semi-arid region is dry farming, in which the risks of crop losses are high and increase during the dry season. The climatic factors are decisive in this type of agriculture, especially rainfall, because in this type of agricultural activity there is no water source available as occurs in irrigated areas. The occurrence of low rainfall or poorly distributed rainfall leads to decrease or even complete loss of production (COUTINHO et al., 2013).

However, there is an apparent paradox, because on the one hand there is the vulnerability of family farmers to climatic and socioeconomic risks, and on the other, the

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socio-environmental resilience of family farming as a whole to absorb or recover from such shocks. In short, while family farming in the Sertão is highly vulnerable, it is also extremely resilient (OBERMAIER, 2011)..

3 Methodology

3.1 Geographic Study Area

The geographical area defined for the study was the macro-region of Sertão dos Inhamuns, which is among the regions with the lowest rainfall index. However, in the processing of the data the municipalities of Ararendá, Catunda, Ipaporanga and Quiterianóplis were excluded for having been created in the late 1980s and early 1990s, i.e., after the beginning of the historical series..

3. 2 Source of Data

To carry out this study we used historical series from the Brazilian Institute of Geography and Statistics (IBGE), between the years 1977 and 2013, of harvested area, productivity and Gross Value of Production (GVP) of corn and bean crops, which are the crops most practiced by family farming in the study region. The nominal values of GPV were corrected to 2013 values using as correction factor the IGP-DI of the Getúlio Vargas Foundation. We also used the historical series of rainfall, collected from the Meteorology Foundation of Ceará (FUNCEME) with a period equal to that of the crops.

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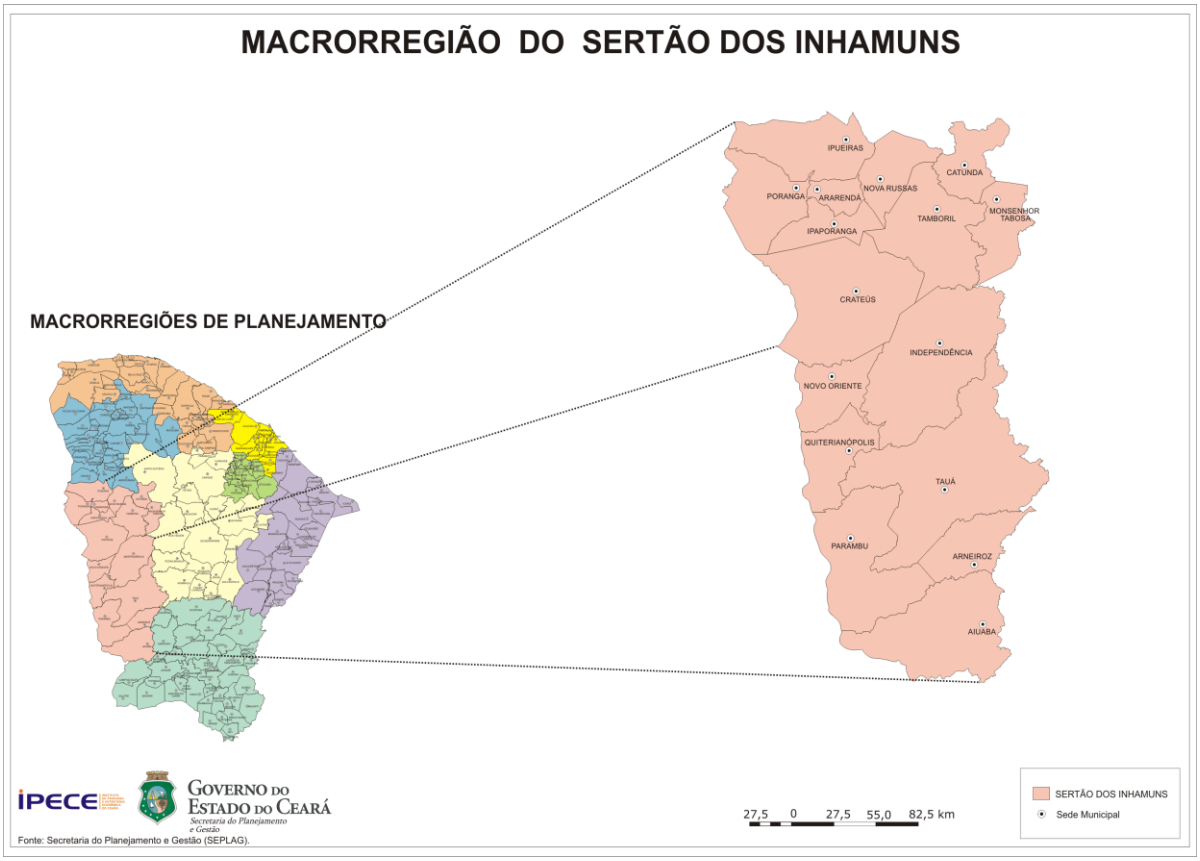
Figure 1. Geographic position of the macro-region Sertão dos Inhamuns in the state of Ceará.



Fuente: IPECE, 2013.

3.3 Analysis Method

The method of analysis for this work was based on the methodology of Lemos and Botelho (2014). First, the maximum and minimum values were estimated, as well as the coefficients of variation of harvested areas, yield, GVA, and rainfall in the period. The years in which the extreme values occurred for each item were identified.

To estimate the resilience of each crop to drought stress, the maximum values of GVP, yield and harvested area were taken and transformed into indices in which the maximum values are converted into one hundred (100) and the other values are adjusted proportionally. The indexes of VBP (INVBP), Indices of cClhida Areas (INAREA) and the Indices of yields (INREN) for corn and bean crops are constructed with the respective

peaks between the years 1977 and 2013 as a reference base. It is assumed in this study, that the maximum values reached by each of these indicators is the potential capacity of the crops in question in the Sertão dos Inhamuns. From the construction of the indices, it is admitted that by reaching the maximum magnitudes in a given year, it is assumed that the non-attainment of those values in the other years or discrepant values of the maximum index must be attributed to some or the synergy of several causes, being the scarcity of rain the most relevant. In this way, the scales in which the indexes are constructed from zero to one hundred, are transformed, by hypothesis, into the recovery capacity, in a given year, of each of the indicators. The closer to one hundred, the greater the resilience of the specific indicator.

The magnitude of each year's value relative to the maximum can be taken as an indicator of that indicator's resilience. In this study, the indicators will be aggregated, properly weighted, to transform them into the joint resilience of all of them or the resilience of the crop. This will be done by building the Resilience Index (INRES) for the corn and bean crop. The "INRES", by hypothesis, will capture in a weighted way, the synergies existing between production value, harvested area and yield of each crop. The partial indexes presented above will be aggregated into the following equation:

INRESTi = P1INVBPTi + P2 INAREATi + P3 INRENDTi (1)

In equation (1), P1, P2 and P3 are weights to be estimated and that are associated with each of the indicators that make up INRESTi in year "T" (1977, 1978, ..., 2013) for crop "i" (bean or corn). Since the indicators presented in equation (1) are measured in percentages and the weights are dimensionless values contained in the interval zero to one and adding one (1), INRESTi will be measured in percentage. It is assumed, in this work, that its magnitude will be an approximation of the percentage of resilience that estimates the resilience of food production in Ceará, to stresses caused by rainfall variations and/or by the other factors listed, which will not be investigated in this study. Its range is contained in the interval varying from zero percent (total inability to resilience) to one hundred percent (100%), perfect resilience.

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The weights associated with equation (1) were estimated using factor analysis methods with principal component decomposition. SPSS software was used to arrive at these values.

Having estimated the annual value of the resilience index for each crop one can graphically illustrate its trajectory, comparatively to thedistribution in time of rainfall in the Inhamuns macro-region between 1977 and 2013. The work estimates the average, maximum and minimum values of the resilience indices for beans and corn for the region under study in the period under investigation and identifies the respective rainfall regimes under which those values were recorded.

To test the influence of rainfall on the estimated resilience index for each crop the following equation is used:

INRESTi = β0 + β1 INCHT + €Ti (2)

The variable INCHT is the rainfall transformed into an index, where the largest rainfall observed in the region is worth one hundred (100) and the rainfall of the other years is adjusted proportionally. Equation (2) being constructed in this way, the regression coefficient "β1", associated with the rainfall precipitation index, will show estimates of the percentage change in the resilience index of crop "i" to percentage changes in rainfall precipitation. This coefficient is expected to be positive. The coefficient β0 is the linear parameter. Assuming that the random term €Ti will also capture the probable impacts of the other variables that were not included in this research, for lack of information, assumes the properties of not being autoregressive and being homoscedastic, the coefficients β0 and β1, of equation (2), can be estimated by the ordinary least squares method.

Based on the estimated results, from equation (2), it is possible to assess, in addition to the relationship between the resilience of each crop and the annual rainfall regime of the region, as defined in this work, which of the two crops studied will have higher (or lower) average resilience to rainfall instability, as well as the respective coefficients of variation.

4 Results and Discussion

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4.1 Average and Extreme Values of Food Crops and Rainfall Precipitation in the Sertão dos Inhamuns between 1977 and 2013.

In Table 1 are presented the historical averages and extreme values of rainfall, harvested areas, yield and GVA for corn and bean crops with their respective coefficients of variations and with the identification of the best and worst performances in the macro-region of Sertão dos Inhamuns and the State of Ceará in the period between 1977 and 2013. It is observed, in this study, that among the 14 indicators, the year 1983 appears six times (42.8%) being that this year presented the lowest precipitation index in the study period. When checking the column with the maximum values, it is observed that the year 2011 prevails as one of the best years for agriculture, appearing four times (28.5%) with the highest indexes. Despite not having the highest precipitation index, the year 2011, however, was a year with rainfall well above average for the region (969.2mm).

The rainfall range for the study region was 1260.3 mm and the average 701 mm, while for the State of Ceará, the range was 1470.3 mm and the average 904 mm. It can be stated, then, that the study region, although presenting less amplitude in rainfall, the severity of water shortage is greater than for the state as a whole. The Coefficient of Variation (CV) for this variable was 38%, showing to be high. From this information about the rainfall variable, it can be inferred that the Sertão dos Inhamuns macro-region presents high climatic instability associated with low rainfall rates. This information also extends to the state, because although the state presents data that show a lower climatic severity than the study region, when the coefficient of variation is observed (34%), it can be seen that the irregularity of the rainy season is frequent.

Table 1. Summary of the evolutions of harvested areas, yield and VBP of corn and beans, as well as rainfall between the years 1977 and 2013 in the macro-region of Sertão dos Inhamuns and the State of Ceará.

Macro-region of the Inhamuns				
VARIABLES	Minimum	Maximum	Mean	CV(%)

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	Year	Value	Year	Value		
Rainfall (mm)	1983	266.1	1985	1526.4	701	38
Area with beans(ha)	1983	24984	1991	118934	71061	34
Bean yield(kg/ha)	2012	53	2011	456	229	52
VBP beans(R$)	2013	6735	1986	117444	46718	64
Area with corn	1993	17687	2003	123268	81544	36
Corn yield	1993	47.5	2011	1138.4	456	67
VBP corn(R$)	1992	13.4	1994	461010	70960	123
Ceará State						
Rainfall (mm)	1983	418.1	1985	1888.4	904	34
Area with beans	1983	166,559	1994	765654	479970	29
Income from beans	2012	117	2006	463	269	34
VBP beans(R$)	2013	123,465	1979	681,490	367969	42
Area with corn	1981	120,000	2011	726,777	510047	31
Corn yield	1983	120	2011	1254	569	52
VBP corn(R$)	1983	36165.7	2011	599918	262666	55

Fuente: Dados da pesquisa.

All variables studied presented high CV, but the Sertão dos Inhamuns stands out when compared to the state as a whole for presenting higher instability. The CV for the region of the study varies between 34% for the area with beans and 123% for the GVA of corn, while this difference in the CV, when analyzing the state of Ceará, is between 29% for the area with beans and 55% for the GVA of corn, that is, the state presents more coherent differences among the CVs, while the region of the study presents high discrepancy that denounces the instability and fragility of the productive and economic conditions in agriculture.

Among the variables studied, corn proved to be the most vulnerable crop to environmental and economic effects, this is probably due not only to the physiological characteristics of the crop that presents a relatively high water requirement, but also to the economic vulnerability of the agricultural sector in the study region. Analyzing only the Sertão dos Inhamuns, the area planted with this crop varied between 17,687 ha in 1993 and 123,268 ha in 2003, the CV was 36%. The yield of the crop showed a CV of 67%,

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varying the productivity between 47.5 kg/ha in the year 1993 and 456 kg in the year 2011. The corn GVA variable was the most unstable, with a CV of 123%. What is really striking in this variable is that the most critical year was 1992, while the year with the highest Gross Value of Production (GVP) was 1994, with a difference of only two years between the maximum and minimum values for the same culture. In a deeper analysis, the fragility and dependence on environmental factors of the agricultural system in the region becomes evident when we observe an accentuated discrepancy with a very small chronological difference.

For the state of Ceará, the CV for the corn crop was also high, however, these values were much lower in relation to Sertão dos Inhamuns, evidencing a greater stability of agriculture for the rest of the state. The highest CV was for the variable VBP being 55%. The worst year for this culture was 1983, corresponding to the year with the lowest rainfall and the best year was 2011, which was the year with one of the highest rainfall indices of the series shown in this study. These observations show how much agriculture in the state is dependent on climatic conditions.

Regarding the culture of beans, what draws attention is that in the Sertão dos Inhamuns, the best yield was in 2011 with 456 kg/ha and the worst yield was verified in the following year, with only 53 kg/ha. The CV for this variable was 52%, the second highest among the bean culture variables. The highest CV was for the GVP variable, being 64%. Just as for the corn crop, the bean crop in the Sertão dos Inhamuns presented more unstable variables when compared to the State of Ceará.

4.2 Results obtained in the estimation of the Resilience Index (INRES)

To estimate the Resilience Index (INRES), the indicators Yield Index (INREN), Area Index (INAREA) and GVA Index (INVBP) of the corn and bean crops were put in series. This procedure made the analysis of the Resilience Index have a total of 222 observations, that is, there were 111 observations per crop during 37 years. Thus, it was possible to increase the degrees of freedom to make the estimations, besides allowing the

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comparison of the results obtained between them, which would not be possible if the weights were different. The method used to estimate the weights was the decomposition of the observable variables into principal components, in which a factor was extracted with the characteristics shown in Table 2, which shows the weights estimated from the matrix estimated for the "factorial scores".

Table 2. Results obtained with principal component decomposition

MAIZE CROP			
INDICATORS	Component Matrix	Factor Score Matrix	Matrix of Estimated Weights
VBP index (INVBP)	0.804	0.359	0.31
Area index (INAREA)	0.884	0.394	0.34
Yield Index (INREN)	0.902	0.402	0.35
Total Estimated Variance	74.70		
BEAN CROPS			
VBP index (INVBP)	0.786	0.383	0.30
Area index (INAREA)	0.718	0.459	0.30
Yield index (INREN)	0.860	0.419	0.33
Total Estimated Variance	62.49		

Fuente: Dados da pesquisa.

From the items that make up the matrix estimated for the components, as well as the matrix of factorial scores, we obtain the weights for each of the indicators used in the construction of the INRES. Thus, it can be observed that the weights for the indicators are very close, varying between 0.31 for the BPNIC and 0.35 for the INREN in the corn crop, 0.30 for the BPNIC and INAREA and 0.33 for the INREN in the bean crop. This result reflects the high variability that the indices presented during the study period. The variance explained by the model for the corn crop was 74.7% and for the bean crop 62.49%. This high variance shows that more indicators were not included to measure more accurately, the resilience of the crops. This information was not included because data over long periods is not available. From this information, it can be stated that the weights obtained in this research, as well as the estimated patterns of resilience, can be interpreted as a trend.

All partial indices that make up the INRES are measured in percentages, based on the respective highest values equal to one hundred (100), as discussed in the methodology

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of the paper. Based on these weights presented in Table 2, the INRES equation for corn and bean crops, respectively, is defined as follows:

INRESTi (corn) = 0.31INVBPTi + 0.34INARETi + 0.35INRENTi (2)

INRESTi (bean) = 0.30INVBPTi + 0.30INARETi + 0.33INRENTi (3)

Based on equations 2 and 3, we estimate the trajectory of the resilience index for corn and beans between the years 1977 and 2013. This evidence is shown in Figure 2 for the resilience trajectory of the corn crop and in Figure 3 for the resilience trajectory of the bean crop. All figures show that the trajectories of crop resilience have a very similar configuration to those associated with rainfall, which are shown in index (highest rainfall = 100) for ease of visual comparison. This proves that there is a cause and effect relationship between the variables.

From equations 2 and 3, the maximum, average, and minimum resiliencies of corn and bean crops were estimated for the Sertão dos Inhamuns between the years 1977 and 2013. In Table 3, it can be seen that corn and beans showed the highest resilience index in the year 1994, the resilience being 84.24% and 83, 67%, respectively. In that year, the rainfall was 768 mm in the Sertão dos Inhamuns.

Table3. Estimativa da resiliência máxima das culturas no período de 1977-2013.

Crop	Year	Maximum Resilience	Rainfall (mm)
Corn	1994	84.24	768
Beans	1994	83.67	768

Fuente: Dados da Pesquisa.

Figure 2. Trajetórias da resiliência do cultivo do milho e da precipitação de chuvas no Sertão dos Inhamuns entre 1977 e 2013.

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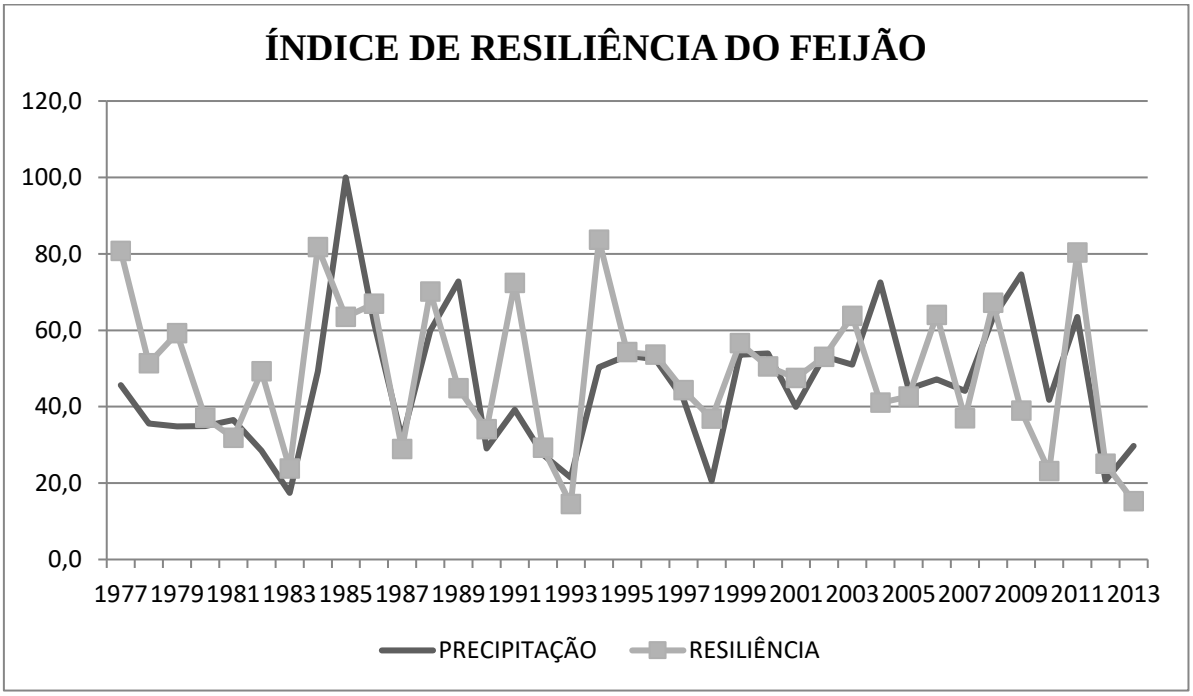
Fuente: Dados da pesquisa.

Figure 3. Trajectories of bean crop resilience and rainfall precipitation in the Sertão dos Inhamuns between 1977 and 2013.



Fuente: Dados da pesquisa.

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According to Table 4, it can be seen that the minimum resilience for corn and bean crops was in the year 1993, being 6.33% and 14.5%, respectively. The rainfall index in that year was only 327. When comparing the maximum and minimum resilience indexes for the Sertão dos Inhamus, it is verified that the chronological difference of these indexes is only one year, showing the fragility and dependence on the rain factor in agriculture in this region.

Table 4. Estimation of the minimum resilience of crops in the period 1977-2013.

Crop	Year	Maximum Resilience (%)	Rainfall (mm)
Milho	1993	6.33	327
Feijão	1993	14.5	327

Fonte: Dados da Pesquisa.

Table 5 shows the average resilience indices for the crops evaluated. These values are also low, being 41.27% for corn culture in the year 1978, in this year, the rainfall was 544 mm, and 49.11% for bean culture in the year 1982, the rainfall in this year was 435 mm. The coefficient of variation was very high, being 49.36% and 38.68% for corn and bean crops, respectively.

Table 5. Resiliência média das culturas no período de 1977-2013.

Crop	Year	Average Resilience (%)	Coefficient of Variation (%)	Rainfall (mm)
Corn	1978	41.27	49.36	544
Beans	1982	49.11	38.68	435

Fonte: Dados da Pesquisa.

4.3 Relationship between Resilience of the Crops Studied and Rainfall in the Sertão dos Inhamuns

To estimate the relationship between the estimated indices of resilience in corn and bean crops, a simple linear regression model was used, in which the dependent variable is the Resilience Index of each crop (INRES), and the explanatory variable is the rainfall observed for the Sertão dos Inhamuns in the same period in which the resilience indices were estimated: 1977 to 2013. The rainfall precipitation was transformed into an

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index, based on the highest value that occurred in the studied series of 37 years. The other years were adjusted proportionally. This type of modeling facilitates the interpretation of the angular coefficient because its magnitude will signal the percentage of variation in the resilience index of the crop, resulting from a one percent variation in rainfall.

Table 6. Results obtained from regressions between resilience indices and rainfall between 1977 and 2013.

Dependent Variable INRES	Adjusted R^2	Linear Coefficient	Angular Coefficient	Significance (%)
Corn	0.281	12.209	0.633	0.0004
Beans	0.244	23.671	0.554	0.0011

Fuente: Dados da pesquisa.

The results in Table 6 show that there is a positive correlation between the resilience of corn and bean crops and rainfall precipitation in the Sertão dos Inhamuns between 1977 and 2013. The coefficients of determination proved to be low, being 0.281 for corn and 0.244 for beans. This makes it evident that there are other variables that affect the resilience of these crops not only in the study region, but in the semi-arid region as a whole. The values of the Adjusted R^2 infers that 28% in the case of corn resilience and 24% for bean resilience is justified by the rainfall index.

The estimated elasticities for the resilience indexes in response to rainfall variations in Ceará were 0.633 for the corn crop and 0.554 for the bean crop. This result shows that the corn crop is more sensitive to rainfall in the Sertão dos Inhamuns than the bean crop.

5 Final considerations

The research showed that the harvested area, yield and gross value of production, taking as a basis the two representative crops, which are corn and beans, in the Sertão dos Inhamuns present high instability when gauging their respective coefficients of variation, which were all above 29%. The rainfall regime in the region also presented high instability, with its coefficient of variation equal to 38%. However, the indicators related to

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crops, presented coefficients of variation greater than that estimated for the rainfall trajectory in the region between 1977 and 2013. This result shows that there are other factors, such as the low technological level and the fragility of the economy, that influence the variability of local agriculture. However, it was not possible to capture these indicators throughout the series due to the unavailability of these data in long historical series.

It was observed that the maximum and minimum values of harvested area, yield and gross value of production are directly linked to rainfall in the region. In the years with normal rainfall, agriculture reached its maximum values, the opposite happened in the years with low rainfall, when it was possible to verify that agriculture in the region reached its lowest values. The corn crop proved to be even more sensitive than the bean crop to variations in rainfall. The gross value of production was the variable that presented the greatest instability with an extremely high coefficient of variation of 123% for the corn crop.

The comparison of the maximum and minimum values of the variables studied between the Sertão dos Inhamuns and the State of Ceará as a whole showed that the study region has a more unstable agriculture, greater variability of the indexes, as well as a rainfall regime with an average lower than that of the state. This characterizes a greater fragility and vulnerability of agriculture in this region.

The resilience index that was estimated in the research to gauge the joint recovery capacity of the value of production, harvested area, and yield of each crop, showed that the bean crop presents the highest average magnitude. In relation to maximum resilience, to be obtained, it does not require very high rainfall levels, just being within the average. However, very low resilience rates were observed in the years with the lowest rainfall rates.

The regression analysis built to verify the relationship between the resilience of the crops studied and the rainfall in the Sertão dos Inhamuns, showed that there is a positive correlation between the two variables, but that there are other factors that influence resilience that could not be included in this work.

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The research allows us to conclude that the agriculture practiced by family farmers in the study region faces serious difficulties that are associated not only with environmental variations, but with other factors such as the lack of technical assistance, low technological level, and an unstable economy. The corn and bean crops presented high dependence on rainfall, however, the dependence of corn on rainfall is even more severe. With this study it was possible to infer that the Sertão dos Inhamuns presents a more fragile and vulnerable agriculture than the agriculture practiced in the rest of the state of Ceará.

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