CLIMATE CHANGE AND ADAPTIVE STRATEGIES IN AGRICULTURE: ASSESSING THE IMPACTS ON SMALL FARMERS IN THE BRAZILIAN SERTÃO

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Abstract

The Brazilian Sertão is the most populous semiarid region in the world, and faces the highest rates of poverty and food insecurity in Brazil. Irregular rainfall and climate variability make these social constraints even more difficult to be solved in the short term, since basic economic activities in the region, as dairy farming and subsistence agriculture, tend to be mainly affected by recurrent and prolonged droughts. This study analyzes the impacts of climate conditions on the agricultural production and how adaptative strategies may alleviate such effects. First, it analyzes the dynamics of climate variables between 1974 and 2013 in the semi-arid region of the State of Bahia, the largest and most populous State of Sertão. Secondly, based on a panel with climatic and production data, it assesses the ex-poste impacts of these climate variables on the agricultural production of the municipalities in the region. Thirdly, it estimates the relation between several adaptive strategies and the agricultural family farmers' production, based on microdata of the Brazilian Agricultural Census for small farmers in the region. The study evaluates four main agricultural productions: milk, cattle, goat, sheep and corn. The final and general aim of this study is to discuss the effectiveness of strategies for small farmers which would create climate resilience and attenuate the negative impacts of climate change on agricultural production of this vulnerable region.

Keywords: natural resource economics, environmental policy, rural development, caatinga

JEL: Q18, Q51, Q54

1. Introduction

With a population estimated in more than 22 million people in 2010, the Brazilian Sertão is the most populous semiarid region in the world. Despite recent improvements, the region still presents the highest rates of poverty and food insecurity in Brazil. Irregular rainfall and climate variability make these social constraints even more difficult to be solved in the short run, since basic economic activities in the region, as dairy farming and subsistence agriculture, tend to be mainly affected by the recurrence of prolonged droughts. Studies suggest that the average temperature in *Sertão* increased by approximately 2°C over the past 40 years, while the average precipitation fell between 300 and 450 mm, which corresponds to a reduction of 30% (Burney et al. 2014).

The practice of extensive livestock farming prevails in the region and exposes the animals directly to the natural environmental conditions and, hence, to the impacts of climate cahnges. Studies suggest that the loss in milk production in the region may vary from 3 to 7 kg/day, depending on the extent of climate changes (Silva et al. 2010). Moreover, according to the most pessimistic forecasts, an increase of almost 6° C in average temperature would induce a drop in the land availability and provoke negative effects on the regional GDP, which could decrease nearly 14% (Domingues, Magalhaes, and Ruiz 2011; Krol et al. 2001). The agricultural activities would suffer a significant decline, with a reduction of nearly 20% in all states of the region.

In such relevant environmental, social and economic context, this study has three main objectives. First, it analyzes the dynamics of climate variables between 1974 and 2013 in the semi-arid region of the State of Bahia, the largest and most populous State of Sertão. Secondly, based on a panel with climatic and production data, it assesses the ex-poste impacts of these climate variables on the agricultural production of the municipalities in the region. Thirdly, it estimates the relation between several adaptive strategies and the agricultural family farmers' production, based on microdata of the Brazilian Agricultural Census for small farmers in the region. The study evaluates four main agricultural productions: milk, cattle, goat, sheep and corn. The final and general aim of this study is to discuss the effectiveness of strategies for small farmers which would create climate resilience and attenuate the negative impacts of climate change on agricultural production of this vulnerable region.

2. Material and Methods

2.1. Data source

Minimum comparable areas

The impact of climate change on agricultural production is analyzed using the smaller territorial units available in Brazil. Although socio-economic data for 266 municipalities of Bahia semi-arid region were available, many of these municipalities emancipated in the period. This means that the total number of municipalities at the beginning of the period of analysis (1974) does not correspond to the end period (2013), as well as their regional boundaries. Thus, in order to consider the changes implemented in the Brazilian Territorial Division between 1974 and 2013, the 266 municipalities of Bahia's semiarid region were aggregated into 206 Minimum Comparable Areas (MCAs) according to the methodology proposed by the Brazilian Institute of Geography and Statistics (IBGE) and the Institute of Applied Economic Research (IPEA) (Reis et al. 2011). Each MCA consists of one or more municipalities historically comparable, i.e., integrated areas of the territory before emancipations realized during the analysis period.

Climate data

Climatic data were obtained from conventional weather stations of the National Meteorological Institute (INMET). These data refer to historical series of climatic variables for the 26 weather stations in Bahia and 4 stations located in the northern region of Minas Gerais, all them inserted in semi-arid regions. Variables comprise daily data of maximum temperature, minimum temperature, average temperature and total precipitation between the years 1974 and 2013. However, information for the years 1981-1985 and 1989-1991 were not available.

Daily data were interpolated through the 206 MCAs located in the semiarid region of Bahia. The interpolation was performed by the method of Inverse Distance Weighted (IDW) using the package *gstat* of geostatistical analysis developed by (Pebesma 2004) for the statistical program R. The IDW method is based on the weighted linear combination of the data collected in each meteorological station, using the inverse of the distance as weighting factor (Amorin et al. 2011). After interpolation, the average daily values of climate variables were estimated for each of the MCAs in the region.

The description and average values of the climate variables used in the analyzes are shown in Table 1. Overall, results highlight the high levels of average temperatures and the low levels of rainfall, measured by the number of days per year without rain. The average annual temperature varied between 23 °C and 24 °C, while the number of days per year with precipitation lower than 1mm varied between 232 and 272.

Agricultural production

Information of agricultural production and population in the semiarid of Bahia were obtained from the IBGE System of Automatic Recovery (SIDRA) and refer to the following surveys: i) Municipal Livestock Survey (PPM); ii) Demographic Census. This information was originally available to municipalities, and were aggregated into the 206 MCAs. Table 1 describes the variables used in analyzes, which were largely limited to the availability of annual information for all semiarid locations. Five types of production and productivity were considered: productivity of milk (variable *pmilk*), cattle (*catle*), goats (*goat*), sheep (*sheep*) and production of corn (*corn*). Information on milk productivity refer to the period 1974 to 2013. Information on livestock production, goat and sheep refer to the period 1974 to 2012. In turn, information on corn production were available exclusively for the period 2003-2013. Information on rural population (*prural*) were only available for the census years: 1970, 1980, 1991, 2000 and 2010. Values between the census years were estimated based on the average growth rates for each MCA.

Despite the persistence of rural exodus in last decades, the semiarid of Bahia still has a significant rural population, with 2.6 million residents in 2014. The productivity of milk, one of the main agricultural products in the region, is low: 499 liters per cow in 2013, value that is substantially below the national average, which was 1492 liters per cow in the same year. The cattle farming prevails in the region (nearly 6 million heads in 2013), although the number of goats and sheep are also significant: 2.3 and 2.6 million heads, respectively. The corn production in the semiarid Bahia (631 thousand tons in 2013) is mainly used for animal feed, and represented 29% of the total state production (less than 1% of the total national production).

Characteristics of small farms

The associations between characteristics of small farmers and agricultural production are analyzed using data of the Agricultural Census 2006 of IBGE. The Agricultural Census allows us to consider a wide range of socioeconomic characteristics of farms as determinants of the agricultural production. Thus, it allows to establish the relationship between the production and characteristics of farms and the production system, such as the use of strategies to mitigate the impacts of climate change on agricultural production. It also allows a specific analysis for the production of small family farms, since this classification is available in the Agricultural Census. So, despite the fact that the Census allows only a static comparison of farms production under different climatic conditions (only the impacts in 2006), it allows us to evaluate the potential impacts of adaptive measures on agricultural production, such as use of mechanical technology, technical guidance and treatment of soil.

The Agricultural Census contains data for the total population of farms in Brazil. In this analysis, we used the information of family farms in the semiarid of Bahia, which represented 509,775 establishments in 2006. Family farms were classified according to the variable "*Family Farm*-Law 11326 of 07/24/2006." In addition to information on the value of production, analyses also consider characteristics of the farmer, such as education and the membership in a cooperative or agricultural association, and the production system, such as the use of technologies, soil treatment and technical guidance. The list of variables associated with the characteristics of the farms, farmers and the production systems are described in Table 2 and Table 3. All variables refer to the harvest 2005-2006.

In the same to the analysis of the municipal production, five types of production were considered in these analyses, identified by the variables *milk*, *catle*, *goat*, *sheep* and *corn*. Among the small family farmers also prevails cattle and sheep farming, practiced with very low level of intensification. The average number of head of cattle per farm was 6.6, and the average number of head per hectare of pasture was only 0.8. Similar results are found for sheep and goat, with an average number of head per farm respectively equal to 2.9 and 3.6 and average number of head per hectare equal to 0.4 in both cases. The average milk yield per family farm is 123 liters per year, which amounts an average yield of 1045 liters per cow (123 liters / 0.12 cows = 1045 liters / cow). This milk yield is higher than that estimated for the whole territory (Table 1), which considers all types of farms and is based on estimates for the municipal production, but it is still significantly below the national average per family farm (1556 liters / cow). In turn, the average corn production per family farm is 1.4 tons.

The farm size (*atotal*) controls the physical capital. In the case of production of cattle, sheep, goats and milk, five types of land use are considered: natural pasture area (*anatpast*), degraded pasture area (*adegpast*), not degraded pasture area (*andegpast*) planted area of forage (*aforage*) and area of forest (*aforest*). The planted area of corn (*acorn*) is used in the corn production. The average farm size is 14 hectares, which is used predominantly for livestock farming. The pasture areas represent more than half the farm size: on average 3.4 hectares of non-degraded pasture, 0.9 of degraded pasture and 3.6 of natural pasture. Areas of forage (especially palm) adds 0.4

hectare, on average, and forests (savanna) more 4.5 hectares. The average planted area with corn is 1.4 hectares.

The labor force is controlled by the variable *lf*, which corresponds to the sum of family labor (including managers) and hired labor. Proxies for social capital are: membership in cooperative (*coop*); or membership in farm association (*assoc*). Farms have, on average, roughly 2 workers, and only 1% of them are member of cooperatives. Participation in farm associations is more usual, 42%.

Human capital and social relations are analyzed by variables related to gender (*female*), age (*age*29, *age*30_39, *age*40_49, *age*50_59, *age*60) and education: no education (reference of analysis); can read and write (*school*01); adult literacy (*school*02); incomplete primary education (*school*10); complete primary education (*school*11); complete technical or secondary education (*school*21); and complete college education (*school*31). Results highlight that farmers are relatively elderly for the Brazilian standards, since 34% of farmers have 60 years or more, and they present very low levels of education, since 40% of the farmers have no formal education.

The use of technologies is analyzed by the variables *atraction* (if the farm uses animal traction) and *mtraction* (if the farm uses mechanical traction). The variable *guidance* indicates whether the farm received technical assistance by qualified professionals. The use of good agricultural practices considers: the fertilization of pastures and crops (*fertilizep* and *fertilizec*); the use of lime or other corrective of soil ph (*soilcor*); the use of fallows, rest or crop to recover pastures (*fallow*); and the use of pasture rotation (*rotation*). The use of animal traction or mechanical is low among family farms in the semiarid of Bahia: 39% used animal and 27% used mechanical traction. The percentage of farms that received some technical guidance in agricultural production is also remarkably low, only 5% in 2006. Technics of soil treatment are also rare: 3% applied lime or other corrective of soil pH, 2% fertilized their pasture and 20% fertilized their crops. The rest of pasture is practiced by only 14% and rotation by only 19% of family farms.

The use of adaptive strategies to droughts in the farm is analyzed by the existence of cisterns (*cistern*), wells (*well*), natural lake or weir (*weir*); and control of diseases or parasites in animals (*diseasec*). The construction of cisterns has been the main policy to fight droughts in the Brazilian semiarid region. A quarter of family farms in the region had cisterns in 2006. Weirs (or natural lakes) are also relatively frequent, 15%. And the control of diseases or parasites in animals is practiced by almost half of family farms.

Two variables defined by the FAO (Food and Agricultural Organization) and INCRA (National Institute of Colonization and Agrarian Reform) (Guanziroli 2001), helped to characterize the production system: the degree of specialization and the degree of market integration. The degree of specialization, which is measured by the ratio between the production value of the main product and the total production value, is analyzed by 3 categories: highly specialized (*specialized*1), with degree of specialization equal to 1; specialized (*specialized*2), with degree of specialization lower than 1 and greater than 0.65; diversified (*specialized*3), with degree of specialization lower than 0.65. Almost half of farms did not have a specific specialization in agricultural production. In other words, the value of the main product of these family farms did not represent more than 65% of total production value.

In turn, the degree of market integration, which is measured by the ratio between the total revenue from agricultural activity and the total value of agricultural production was analyzed by the 3 categories: highly integrated (*integrated*1), with a degree of integration higher than 0.9;

integrated (*integrated*2), with a degree of integration between 0.5 and 0.9; poorly integrated (*integrated*3), with degree of integration between zero and 0.). More than half of the family farms were poorly integrated, i.e., their revenues from agricultural products represented less than 50% of total agricultural production, which reflects the prevalence of self-subsistence agriculture in the region.

Finally, the access to credit is analyzed by the binary variable *credit*, which identifies whether the family farm obtained funding from PRONAF (National Program to Strengthen Family Farming), which is the main public funding program for small family farms in Brazil. Although the percentage of farms receiving PRONAF in 2006 was substantially low (7%), it must be considered that this value refers only to loans contracted in 2006. Since the period of payment is up to 10 years, with up to 3-year grace period, the percentage of family farms assisted by PRONAF is probably much higher.

2.2.Statistical analyses

Climate clusters

In order to facilitate analysis and consider nonlinear relationships between climate and agricultural production, this study defined climatic clusters in the semiarid of Bahia. The variables used in these analyses are those presented in Table 1: average annual temperature (*avgtemp*), maximum temperature (*maxtemp*), minimum temperature (*mintemp*), relative humidity (*humidity*), annual precipitation (*precip*), total number of days in the year with preciption lower than 1 mm (*norain*). Each climatic cluster corresponds to a set of MCAs with relatively homogeneous values for the selected variables. The groups consider climate for the MCAs in each year of analysis (1974-2013). This means that there were 206 (MCAs) observations for each year of analysis, summing 6,592 observations in 32 years with valid observations in the period. Thus, a MCA may belong to a specific cluster in one year and to other cluster in other year.

The classification of municipal observations in cluster was defined with the technique of Cluster Analysis (CA). The CA defines hierarchical groups of observations within a data set. There are several methods that can be employed in this process, but all are based on the same principle of hierarchical clustering. Initially, each observation is a cluster. The two closest clusters are joined to form a new cluster, and so on, until the method forms a maximum number of clusters that is predetermined by the researcher. The difference between the methods is basically the way the distance (or dissimilarity) between the clusters is calculated. The clustering method used in this study is the Ward method, an aggregation strategy based on the analysis of variance within and between the groups formed. The aim of this method is to create hierarchical groups in such a way that the variance within the groups is minimal and the variances between the groups is maximal (Crivisqui 1999). The aggregation criterion consists in finding the next group which minimizes the variability within the new formed group. To facilitate the understanding of the variability within the groups, they are usually divided by the total variance to represent a ratio of the maximum achieved variability (R^2 semipartial).

Panel data analysis of the municipal production

The relationship between the dynamics of climate clusters and the agricultural production of MCAs was analyzed using panel data models. The analysis of panel data allows to evaluate more accurately the cause and effect relations between the dependent variables (*Y*) and independent (*X*), since it controls unobserved factors associated with MCAs (c_i) which are constant in time. The dependent variable of each model is represented by the natural logarithm of the types of agricultural production. The logarithmic transformation aims to approximate to linearity the relationship between the dependent variable and covariates *X*. It also allows to analyze the relative variation (%) in the type of production due to marginal variations in *X*. The relationship is given by:

$$\ln Y_{it} = \alpha + \sum_{j=1}^{k} \beta_j X_{j_{it}} + \delta t + c_i + \varepsilon_{it} \qquad (1)$$

Where ln Y_{ij} is the natural logarithm of the dependent variable (*pmilk*, *cattle*, *goat*, *sheep* and *corn*) and X_j is the *j*-th regressor of interest. Covariates were represented by the rural population in the MCA (*prural*) and binary variables discriminating the climate clusters obtained in the previous analysis. The coefficient α is the intercept and β_j is net impact of X_j on ln *Y*. The coefficient δ refers to the time trend of the dependent variable and represents for example, factors associated with technological advances and other unobserved factors that are constant between the MCAs in time. The factor c_i refers to unobserved factors that are associated to MCAs (human and social capital, or soil quality, for example). The variable ε is the idiosyncratic error, uncontrolled factors that are not associated with municipalities and/or time.

Although the factor c_i is not be observed, it can be controlled by the fixed effects approach (Wooldridge 2002). The fixed effects approach considers that the c_i factor represents a population parameter, which can be controlled through binary variables (binary variables estimator) or through algebraic transformations (*within* estimators). In this work, we adopted the transformation *within* which, thought algebraic transformations, excludes the factor c_i from the original specification (equation 1), preserving the relationship stablished for the other parameters of interest (α, β_j and δ). Estimators were obtained using the trig command from Stata 12.0.

Cross section analysis of the small farm production

The potential impacts of the characteristics of farms and adaptive strategies on the production of family farming in semiarid of Bahia is based on cross-sectional models using microdata of the Agricultural Census 2006, sponsored by IBGE. The relationship between the variables is given by:

$$\ln Y_i = \alpha + \sum_{j=1}^{k} \beta_j X_{j_i} + \varepsilon_i \qquad (2)$$

Where ln Y_i is the natural logarithm of the production of family farming. The subscript *i* refers to the *i*-th family farm. The set of dependent and independent variables (X_j) is presented in Table 2 and Table 3. Coefficients were estimated by the method of Ordinary Least Squares (OLS) using PROC REG procedure of SAS statistical package 9.4. Standard error estimators are robust to heteroscedasticity. These robust estimators were obtained using ACOV option of PROC REG.

A model was adjusted for each type of production, which dependent variables are very similar to those used in previous analyses of panel data models: (i) total liters of milk (variable *milk*); (ii) head of cattle (*catle*); (iii) head of sheep (*sheep*); (iv) head of goat (*goat*); and (v) tons of corn per year (*corn*). The main difference in relation to the previous analysis refers to the dependent variable associated with milk production, which now refers to the total production in liters rather than the yield per cow. This modification is due to the fact that this model showed a greater explanatory power and have produced more consistent estimates for the coefficients. In any case, the analysis of production efficiency, measured by the milk yield (liters/cow) is not compromised because the number of cows (*cow*) is used as a control variable. In other words, the coefficients of this model indicate a greater or lesser production of milk holding constant the number of cows, thus giving a measure of production efficiency.

3. Results

3.1. Climate Clusters

The CA was applied to identify groups of MCAs in each year with relatively homogeneous values for the variables: average temperature (*avgtemp*), maximum temperature (*maxtemp*), minimum temperature (*mintemp*), relative humidity (*humidity*), annual precipitation (*precip*) days in the year with the precipitation lower than 1 mm (*norain*). Six clusters were initially selected, and the differences between the mean values of these clusters accounted for 91% of the total variability (R^2 semipartial) observed between the annual values of MCAs. Since one of the clusters represented a rare climatic condition, observed for a low number of observations (462), it was incorporated into the cluster with closer characteristics to permit a more significant analysis. Thus, analyses were based on 5 climatic clusters, with average characteristics presented in Table 4.

From the 1st to the 5th cluster, the climate conditions tend to be better off, with lower average temperatures, and greater rainfall and humidity. Clusters 1 and 2 have the higher temperatures, lower relative humidity and precipitation and larger numbers of days with a precipitation lower than 1 mm. Cluster 1 presents more extreme conditions compared to cluster 2 with respect to precipitation, humidity and days without rain. Clusters 3 and 4 represent intermediate climate conditions in the region and the cluster 5 presents the best climate indicators. For example, the average temperature in cluster 5 is 1.5 °C lower than in the cluster 1 and the annual precipitation is almost 3 times higher.

3.2. The impacts on agricultural production

The analysis of the relationship between the dynamics of climate clusters and the agricultural production in the MCAs is based on the estimates of panel data models (Equation 1). The variables contain information for the 206 MCAs of semiarid of Bahia between 1974 and 2013, which were previously described. However, there was no information available for the whole period, i.e., analysis is based on an unbalanced panel. The aim of this analysis is to understand how the climate clusters positively or negatively affect each type of agricultural production in the MCAs. Five models were adjusted, one for each type of agricultural production (i) liters of milk per cow (*pmilk*); (ii) head of cattle (*cattle*); (iii) head of goats (*goat*); (iv) head of sheep (*sheep*); (iv) tons of corn (*corn*).

Among the independent variables X_j of the multiple regression model (equation 1), four binary variables were used to assess the impacts of climate clusters on agricultural production. For example, the binary variable *cluster*1 assumes 1 when the MCA *i* belongs to the climate cluster 1 in year *t*. The same is true for binary *cluster*2, *cluster*3 and *cluster*4. Cluster 5, which represents the best climate condition in the region, is used as reference of analysis. Thus, the coefficient β_j indicates the average difference between the climate cluster *j* and the Cluster 5 (reference). The expression $e^{\beta_j} - 1$ obtains the average relative difference (percentage) between the clusters (Halvorsen and Palmquist 1980).

Two other binary variables, *cluster*1_2 and *cluster*2_2, where also considered among the independent variables in order to evaluate the impacts of the recurrence of extreme climate events. These binary assume the value 1 if the climate groups with the most extreme conditions, clusters 1 and 2, occur repeatedly in two consecutive years. For example, if the MCA is classified in the climate cluster 1 for two consecutive years (t and $t-1$), the variable *cluster*1_1 assumes 1 in the year t. Thus, suppose that β_1 is the coefficient associated with the binary *cluster*1 and β_{1_2} the coefficient associated with the binary *cluster*1_2. The mean difference of *Y* between clusters 1 and 5 will be equal to $\beta_1 + \beta_{1\_2}$ when the MCA is classified in the cluster 1 for two consecutive years. That is, the relative difference between the mean values of the *Y* between clusters 1 and 5 will be given by $e^{\beta_1+\beta_{1\_2}} - 1$. Similar analysis can be derived using the binary variable *cluster*2_2, which takes 1 when the MCA is classified in cluster 2 for two consecutive years.

The recurrence of clusters 1 and 2 for more than two consecutive years was tested, but results were insignificant and the variables were disregarded. Similarly, the recurrence of other climate groups (3 and 4) was also tested, but their effects were largely insignificant, and the variables were dropped to facilitate analysis. It should be noted that the inclusion of lagged values of covariates (X_{t-1}) tends to generate multicollinearity, increasing the standard errors of the estimators.

The logarithm of the rural population was included among the independent variable as a proxy for labor supply in agriculture. A time trend was also incorporated in the model, which was controlled by the variable *t* with values ranging between 0 (for 1974) and 39 (for the year 2013). This variable identifies a common linear trend in the local production, which would be associated, for example, with technological or socio-economic development in the region.

Table 5 exhibits the fixed effects estimates for the coefficients of equation (1). Each column refers to one of the vie dependent variables. Estimates of coefficients appear in the first line of each regressor. The p values consider standard errors robust to the presence of heteroscedasticity and autocorrelation. Table 5 also contains in its final lines statistics of goodness of fit. The total number of observations used in each estimation (n) differs between the models, since there is distinct availability of data for each type of production. The statistics R^2 indicate that adjustments have explanatory powers ranging between 3% and 12%. These coefficients refer exclusively to variability within the MCAs, i.e., they do not consider the variability between MCAs. Although the values are relatively low, it must be highlighted the relatively low number of covariates used to explain a long history of extremely heterogeneous variations of municipal agricultural production. Several factors that affect production are not been considered, such as access to infrastructure, credit, human and social capital, since these variables are not available for the whole period of analysis. Anyway, all models showed significant statistics *F*, i.e., the models add significant contributions to explain each type of agricultural production.

The estimates for the coefficients associated with the rural population highlights the cattle raising is the most sensitive to the population size. The expected number of head of cattle increase by 0.28% for each 1% increase in the rural population. The other productions showed no significant relationship with the rural population, suggesting that cattle farming are the most labor intensive production in the semiarid of Bahia, although with a low elasticity.

The coefficients associated with each climate cluster indicate the relative differences between the mean production during the years in which the MCA is classified in a respective climate cluster and the years in which the same MCA is classified in the reference group (cluster 5). For example, the estimate for the coefficient associated with the cluster 1 (variable *cluster*1) for the milk yield suggests that holding constant other factors, the milk yield in the years in which the MCA is classified in the cluster 1 is on average 8.1% lower ($e^{-0,084}-1$) that that observed in the years in which the MCA is classified in cluster 5. The occurrence of climate conditions similar to that of clusters 2 and 3 also negatively impacts the milk yield in MCA, when compared to the yield in the climate cluster 5. The mean yield in cluster 2 is 3.1% lower ($e^{-0,031}-1$) than in cluster 5 and it is 3.0% lower ($e^{-0,031}-1$) in cluster 3.

Although the impact of the second most extreme climate event (cluster 2) is lower than that of the most extreme event (cluster 1), the effects of cluster 2 are boosted in the years the MCA is classified for two consecutive years in cluster 2. In these years (MCA classified in cluster 2 for two consecutive years), the mean milk yield is 6.7% lower ($e^{-0,031-0,038}-1$) that that in the years in which the MCA is classified in cluster 5. Thus, while the main impact of more extreme climate event (cluster 1) in milk yield is of short-term, the impact of cluster 2 is of medium-term, i.e., with the recurrence of the climate phenomenon for two consecutive years in the same locality.

The most significant impact of climate change on the number of head of cattle occurs with the recurrence of extreme events, particularly the classification of the MCA in the climate cluster 1 for two consecutive years. In such years, the number of head of cattle is on average 10.2% lower ($e^{0,000-0,108}-1$) than in cluster 5. The recurrence of extreme weather events also tends to cause significant impacts on the head of sheep and goats. When the MCA is classified in cluster 2 for two consecutive years, the number of head of goats is on average 7.7% lower ($e^{0,007-0,088}-1$) than that of the years in which this same locality is classified in the climate cluster 5. The value is 7.9% lower ($e^{0,015-0,097}-1$) for the number of head of sheep.

Among the types of agricultural production analyzed, the corn production is undoubtedly the most affected by climate change in the semiarid of Bahia. In years when the MCA is classified in the 3 hottest and driest climatic clusters (clusters 1, 2 and 3), the average corn production is substantially lower than in the years when the same locality is classified in cluster 5. For example, compared to the years in which the MCA is classified in cluster 5, corn production is on average 72.7% lower ($e^{-1,298}-1$) when the climate conditions in the MCA is equivalent to the cluster 1; 46.6% lower ($e^{-0,627}-1$) when such conditions are equivalent to that of cluster 2; and 21.6% lower ($e^{-0,243}-1$) when the MCA is classified in cluster 3. The impacts in corn production are of short- term, i.e., it occurs in the same year of the climate event, since the recurrence of the most extreme events (clusters 1 and 2) has shown insignificant impact on corn production.

Finally, the coefficients associated with the variable *t* indicate trends for each type of production in time, assuming constant the climate conditions and the dynamics of the rural population (control variables). The trends for the milk yield and the cattle farming are not relevant. In turn, the trends for sheep and especially goats present the most substantial growth: 1.1% per year ($e^{0,010}-1$) for sheep and 2.4% per year ($e^{0,024}-1$) for goats. In turn, corn production fell in the period, with a negative trend of 4.9% per year ($e^{-0,050}-1$).

3.3. Adaptative strategies for small farms production

The potential impacts of farms' characteristics on the production of family farming in semiarid of Bahias are now analyzed, indicating potential factors that could be considered as of climate resilience strategies. The analyzes are based on estimates of the multiple linear regression models for the 2006 Agricultural Census data (equation 2).

A model for each production type was adjusted, with some adaptations in the dependent variable compared to the previous analyses: (I) total liters of milk (variable *milk*); (ii) cattle herd (*cattle*); (iii) sheep herd (*sheep*); (iv) goats (*goat*); and (v) corn production (*corn*). The natural logarithm was also applied to all the dependent variables to obtain a linear relationship between the variables. The main difference from the previous analysis refers to the dependent variable associated with milk production, which refers now to the total milk production in liters (and not to the production per cow). The reason is that this model has shown a greater explanatory power of the dependent variable and presented more accurate estimates for the model coefficients, besides a greater explanatory power. In any case, the analysis of productive efficiency, measured by the milk productivity (liters / cow) is not compromised because the number of cows (*cows*) was used as control variable. In other words, the coefficients of this model indicate a higher or lower impact on milk production while keeping constant the number of cows, thus giving a measure of production efficiency.

The set of independent variables used as determinant and control of production are presented in Table 6 (producers' and farms' characteristics) and Table 7 (production systems' characteristics). The climate conditions were controlled by four binary representing the MCAs classification in 2006, according to the methodology explained in Part 2: *cluster*1, *cluster*2, *cluster*3, *cluster*4. The climate cluster 5 is used as reference for the analysis. Differently from previous analyzes with panel data (Equation 1), the analysis of the equation 2 do not establish a cause and effect relationship between the independent variables and the agricultural production. This is because climate clusters tend to be correlated with unobserved factors in the territory, which also determine the production, such as the adaptability of the producer to regional conditions. Nevertheless, the most important result of these cross-sectional models is to allow the assessment of the marginal relations (single effects) of socioeconomic characteristics and the adaptation measures in agricultural production, which may indicate potential impacts on agricultural production. However, as with the associations of climate groups with production, these analyzes should be performed with caution because an isolated association relationship does not necessarily mean an impact of the variable on production.

The estimates of models for each type of production are presented in Tables Table 6 (characteristics of the farms and of the chiefs) and Table 7 (characteristics of the production system). All the adjustments were significant, that is, with at least one estimative of the angular coefficient statistically different from zero (*F* statistics). The coefficients of determination of the adjusted models (R^2) vary between 21% (sheep) and 88% (corn), highlighting the quality of the adjustments obtained to explain the variability of the dependent variables.

As expected, the farm area, used as proxy of physical capital, tends to significant and positive association with the production. The marginal effect tends to be larger to the area with forage cultivation. For example, for each 1% increase of the forage cultivation in the total farm's area, one expects an increase of 0.13% in the milk production, keeping constant the other variables. Cattle is particularly influenced by the area with non-degraded grazing (elasticity of 0.16%), while goats and sheeps are less influenced by the grazing areas, probably because of their ease to adapt to different environmental conditions. These livestock appear to depend mostly on forage areas. In turn, corn is extremely elastic to the cultivation: for each 1% variation in the area, one is expected a variation of 2.1% in the production. It is an expected result since this production is strongly correlated with the extent of cultivation with low technology adoption.

On the other hand, the total workers in the agricultural activity have little impact on production since other factors are controlled. For example, for each additional worker, it is expected a variation of only 1.6% in the cattle production, keeping constant the other production factors. These results should be analyzed with caution, though they initially suggest that the production of family farming in the semi-arid of Bahia is inelastic to the use of labor in the establishment. This fact that would be associated with small-scale production.

The association of cooperatives with livestock production is positive and significant, but insignificant with the cultivation of corn and negative with milk production. The average production of the cooperative family farms is 6.9% higher ($e^{0.066}-1$) than that of non-cooperative to cattle production, 5.1% ($e^{0.049}-1$) to the sheep production and 3.0% superior ($e^{0.029}-1$) to the goat production, *ceteris paribus*. The negative association of cooperatives with the milk production would probably related to lower scale of the familiar agricultural production associated to the local cooperatives. The most productive milk producers tend to be those associated to the agriculture association membership: production is in average 8.9% superior ($e^{0.086}-1$) than those of non-associated. Similarly, sheep and goat production also tends to be higher for producers associated with the agriculture association membership: 3.3% ($e^{0.033}-1$) and 5.5% ($e^{0.054}-1$), respectively.

Farms run by women present expected livestock production lower than men's due to the need of heavy manual work. Such lower average production value may be also associated, for example, to the absence of a partner to share the livestock activities, which usually demand intense physical effort. The production comes to be 14,1% inferior ($e^{-0.152}-1$) in the cattle. In the corn production, farms managed by women tend to present a bigger production (7,4% higher on average), which probably would be associated to a greater allocation to agricultural practice.

The milk and cattle production tend to be greater for those farms managed by older people. For example, the number of cattle in the farm managed by more than 60-year old people are on average 27% higher ($e^{0,2391}-1$) than that of those farms managed by people up to 29 years old. The acquisition of cattle, particularly of selected species, requires capital accumulation that may be not be easily accessible to the younger. Farms run by younger people tend to be associated to the production of goat, sheep and especially corn, which require lower initial capital.

Education is another important factor to explain all types of production. The higher the educational level, the greater will be the production of cattle and lower the production of other agricultural activities (milk, goats, sheep and corn). Farmer that can only read and write (variable *escola*01) present, for example, a production of cattle that is 7.8% ($e^{0,075}-1$) higher than that of farmers with no education. Production grows more intensively if the farm has fundamental education or more (variables *escola*11, *escola*21 and *escola*31). For example, production is on average 23% higher ($e^{0,207}-1$) if the farmer has fineshed superior eductioan (compared to the production of those with no education). In turn, the strongest negative association was observed for the production of milk, suggesting a strong specialization of production among those more educated (cattle) and less educated (milk).

The use of animal traction is positively associated with milk and cattle production, while the use of mechanical traction is positively associated with milk and corn production. The mean production of milk, for example, is 21.8% ($e^{0,197}-1$) higher in farms with mechanical traction, holding constant other factors. In turn, the number of head of sheep and goats is negatively associated with the use of animal and mechanical traction, suggesting that these types of production prevail in less technified farms.

Family farms receiving technical guidance present production of goats and sheep that is expressively higher than others: 24.6% for goats ($e^{0,220}-1$) and 19.7% for sheep ($e^{0,225}-1$). This result may reflect the efforts of local agencies of agricultural extension in disseminating the raising of goats and sheep in the region, species that would be more adapted to the climate conditions of the semiarid. For other activities, the differences are negligible or insignificant.

The effect of fertilizer is positive and significant for most types of production, with the exception of cattle farming. For example, farmers that fertilize pastures present a mean milk production that is 27% ($e^{0,239}-1$) higher than others, independent of other control factors. Similar net effects are observed in the goat and sheep farming. The corn production is on average 37.2% higher ($e^{0,317}-1$) for producers using fertilization. In turn, the use of lime or other types of correction of soil pH is negatively associated with all types of agricultural production. These results indicate that the correction of soil pH would be more common in other agricultural activities in the state.

Pasture rotation is positively and significantly associated with milk production and cattle farming. Farmers who perform pasture rotation have men milk production 74.3% higher ($e^{0,556}-1$) than others, and a mean number of head of cattle 61.9% ($e^{0,482}-1$) higher. In turn, the fallow, resting or strategies to cultive crops for pasture recovery has positive association only with the cultivation of corn, a crop that may be being used in crop-livestock integration. Nonetheless, this result reflects only the short-term impacts on livestock. There is no information available to evaluate the impacts on the total value of production and or the sustainability of the system in long term.

Among the production techniques considered under analysis, the control of diseases and pests in animals is the one with the largest partial effects on livestock farming. Farmers who perform this type of control have a mean number of head of cattle that is more than 2 times higher than others ($e^{0,842}-1 = 132.2\%$). The impact is lower in the case of goat farming ($e^{0,211}-1$), suggesting that this specie is more resistant to diseases and parasites that occur in the region.

Common adaptative strategies in the region, as the use of wells, tanks and cisterns have different effects on agricultural production. The partial effect of wells is higher in the cattle farming:

production 11.9% higher ($e^{0,112}-1$) for those with wells. The use of lakes and weirs is also positively associated to cattle farming - production that is 15.9% higher ($e^{0,147}-1$) - sheep farming - production 16,0% higher ($e^{0,149}-1$). In turn, the use of cisterns is more associated with goat and sheep farming: the production of goats is on average 23.2% higher ($e^{0,208}-1$) in farms with weirs and the sheep production is on average 31.8% higher ($e^{0,276}-1$).

The specialization in few agricultural products do not have a unidirectional effect on all types of activities. The high specialization has a positive effect only on cattle farming. Even so, the partial effect is not very substantial. Highly specialized farms, that is, where the value of the agricultural production comes almost exclusively from the cattle farming, present a production that is on average 5.5% ($e^{0,053}-1$) higher than diversified farmers, independent of other characteristics. In turn, the specialization in the production of milk, with some diversification into other agricultural activities, shows relevant positive results: the production is on average 28.3% higher ($e^{0,249}-1$) than diversified farmers. Moreover, the results of specialization, especially high specialization, is significantly negative for the production of goats, sheep and corn. For example, the average production of goats from highly specialized farmers is 9.5% lower ($e^{-0,099}-1$) than that of diversified farmers. These results may suggest that the integration of an agricultural crop with sheep and goat farming would have a positive impact on these activities.

In turn, the degree of integration with to the market, i.e., the share of the total agricultural production that is commercialized in the market, has a positive and significant impact on most types of production. The impacts of the high integration, in which virtually all agricultural production is sold in the market, is positive and significant, especially in the case of cattle and sheep farming. Highly integrated farms have a cattle production that is on average 21.5% higher ($e^{0,195}-1$) than poorly integrated farms, and a sheep production that is on average 22.9% higher ($e^{0,206}-1$). The effects are more relevant when there is more interaction between the production for sale and the production for self-consumption or animal feed. In integrated farms, where the ratio between the agricultural production and the revenue from agricultural production is between 0.5 and 0.9, the milk production, for example, is 24% higher ($e^{0,215}-1$) that that of highly integrated farms.

The access to agricultural credit (PRONAF) is positively related to milk production and cattle farming. For example, farmers who received PRONAF in 2006 showed an average milk production 16.2% higher ($e^{0,150}-1$) than those who did not. In turn, the access to PRONAF is negatively associated with the production of goats, sheep and corn, once other factors are controlled. These results would reflect the greater allocation of public credit resources to the livestock industry in the region.

Finally, climate variables identify associations between the climate conditions that farmers are submitted and their agricultural production. The most relevant trends indicate a positive association between the production of sheep and goats to the most extreme climate groups (clusters 1, 2 and 3), as well as a negative association between cattle farming and milk production with the hottest and driest groups. That is, farms would naturally shift from the cattle farming to raise goats and sheep once the climate conditions of the territory are getting worse.

4. Final considerations

The climate changes observed in the semiarid of Bahia in the last 40 years are relevant. The average temperature has grown at a rate of 0.27^{o}C per decade, and the maximum temperature shifted from an average of 28.7^{o}C in the 1970s to 30.2^{o}C in the 2010s. At the same time, the number of days without rain over the year has increased (from an average of 251 in the 1970s to 275 in the years 2010), and total precipitation has reduced (from 923 mm to 667 mm). Short cycles of more extreme conditions were also witnessed in the second half of the 1980s and the first half of the 1990s, as well as a longer cycle in the 2000s.

In parallel with these climate changes, there is an accelerated abandonment of the rural areas and major structural breaks in the agricultural production. Recent climate changes in the semiarid of Bahia, as the growth of average temperature and reduction of rainfall, are likely to cause significant adverse impacts on all types of production (milk, cattle, sheep, goats and corn). The impacts are more significant in the production of corn and these impacts are in short-term. The losses in milk production are also significant, and tend to worsen with the recurrence of extreme events. In the livestock farming, the impacts are greater with the recurrence of extreme events, after which most of the producers tend to sell their livestock.

It must be highlighted that these results are based on the estimates of average impacts of different climatic groups on the municipal farming production over the period of analysis. The climate groups used in this study to estimate these impacts only summarize the main climate patterns, and are not able to represent the complexity of climatic phenomena that occur in the region. Periods of exceptionally atypical conditions can cause even more substantial losses in production, as observed in 1995 and 1996. Moreover, extreme situations that are recurrent tend undoubtedly to aggravate the scenario of production losses. Although the impacts of two consecutive years of extreme events have been tested, it must be considered that the statistical analysis with many lagged values of climate variables tends to present insignificant estimates due to the strong relationship among the independent variables (multicollinearity).

Another limitation of this analysis is that it only considers the impact of climate change on the whole agricultural production of a spatial locality. Unfortunately, there is no historical information disaggregated for the different types of farmers. In other words, these estimates are probably conservative, which means they underestimate the real impact on family farming production. The impactc would probably be greater among smallholder farmers, since they are usually submitted to the most vulnerable socioeconomic and productive conditions. Unfortunatelly, this factor was not possible to be considered due to the unavailability of data.

Such scenario of production losses is extremely troublesome in places which already face extremely vulnerable productive and socioeconomic conditions. Besides the climate conditions, the characteristics of farms, farmers and their production systems reinforce the low agricultural productivity in the semiarid of Bahia. Family farmers are largely unable to read or write, have advanced age, do not participate in cooperatives and employ few technological resources. Governmental policies to promote agricultural activity had a very limited range in 2006, since the percentage of producers receiving technical guidance for the production or even credit-oriented to family farming was very low.

The production of milk and cattle requires high initial investment and tend to be larger in farms run by older people. There is also a strong specialization of production in cattle among those with higher education, and of production of milk among those with less education. The association with cooperatives tend to generate more positive effects on livestock production (cattle, goats and sheep), while the association with farming associations tend to be more positive for the milk production.

Agricultural production also depends substantially on the characteristics of the production system, such as mechanization, technical guidance, soil treatment, access to credit and integration with the consumer market. The animal traction is associated with higher milk and beef production, while the mechanical traction is associated with the highest production of milk and corn. Family farmers who receive technical guidance have a production of goats and sheep markedly superior to the others, which is probably associated with the efforts of local agencies of agricultural extension in disseminating these activities in the region. Fertilization tends to generate positive and significant results in virtually all types of activity, while the pasture rotation generates positive and substantial effects on milk production and cattle farming.

The control of diseases and parasites in animals also appears to be a key strategy for increasing livestock production. The rural credit in the region is strongly directed to the production of cattle and milk. Among the most widespread strategies of adaptation to drought in the region, cisterns can bring positive results to the sheep and goat farming, while the use of lakes and weir would be more positive for cattle and sheep farming.

The positive impacts of some characteristics on agricultural production provide important elements to address adaptive measures to the negative impacts of climate changes. Notwithstanding still limited in the region, institutional policies aimed to promote access to education, credit and technical guidance showed significant positive impacts on different types of production and should be prioritized, as well measures to increase the technification of production system or even the integration of family farmers in supply chains in the region.

In this sense, it is necessary that local, state and federal government institutions introduce new resilience measures that are economically efficient. Among the main strengthening links in climate resilience, it is suggested: (i) a productive climate resilience reference system; (Ii) credit oriented to the financing of that system; (Iii) technical assistance for its implementation; (Iv) strengthening of cooperative institutions; (V) agro-industrialization of products to add value, and (vi) improving access to markets.

References

Amorin, R. C., A. Ribeiro, Brauliro Leal, and G. C. Sediyama. 2011. "Desempenho Do Método Do Inverso Da Distância Pondera Na Interpolação de Dados Horários de Temperatura Do Ar." In *XVII Congresso de Agrometeorologia*. Guarapari.

Burney, Jennifer, Daniele Cesano, Jarrod Russell, Emilio L??vre La Rovere, Thais Corral, Nereide Segala Coelho, and Laise Santos. 2014. "Climate Change Adaptation Strategies for Smallholder Farmers in the Brazilian Sert??o." *Climatic Change* 126 (1-2): 45–59. doi:10.1007/s10584-014-1186-0.

Crivisqui, E. 1999. "Presentación de Los Métodos de Clasificación."

Domingues, E. P., A. S. Magalhaes, and R. M Ruiz. 2011. "Cenários de Mudanças Climáticas E Agricultura No Brasil: Impactos Econômicas Na Região Nordeste." *Documentos Técnicos Científicos - BNDES* 42 (2): 230–46.

Guanziroli, C. 2001. *Agricultura Familiar E Reforma Agrária No Século XXI*. Rio de Janeiro: Garamond.

Halvorsen, R., and R. Palmquist. 1980. "The Interpretation of Dummy Variables in Semilogarithmic Equations" 70 (3): 474–75.

Krol, M. S., A. Jaeger, A. Bronstert, and J. Krywkow. 2001. "The Semi-Arid Integrated Model (SIM), a Regional Integrated Model Assessing Water Availability, Vulnerability of Ecosystems and Society in NE-Brazil." *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere* 26 (7-8): 529–33. doi:10.1016/S1464-1909(01)00045-4.

Pebesma, Edzer J. 2004. "Multivariable Geostatistics in S: The Gstat Package." *Computers and Geosciences* 30 (7): 683–91. doi:10.1016/j.cageo.2004.03.012.

Reis, Eustáquio José, Márcia Pimentel, Ana Isabel Alvarenga, and Maria do Carmo Horácio dos Santos. 2011. "Áreas Mínimas Comparáveis Para Os Períodos Intercensitários." In *1o Simpósio Brasileiro de Cartografia Histórica*, 16. Paraty.

Silva, Thieres G. F. Da, Magna S. B. De Moura, Ivan I. S. Sá, Sérgio Zolnier, Sílvia H. N. Turco, and Luciana S. B. De Souza. 2010. "Cenários de Mudanças Climáticas E Seus Impactos Na Produção Leiteira Em Estados Nordestinos." *Revista Brasileira de Engenharia Agrícola E Ambiental* 14 (8): 863–70. doi:10.1590/S1415-43662010000800011.

Wooldridge, Jeffrey M. 2002. *Econometric Analysis of Cross Section and Panel Data*. *Booksgooglecom*. Vol. 58. MIT Press. doi:10.1515/humr.2003.021.

Tables and Figures

Table 1 – Climate and production variables for the MCA in the semiarid of Bahia

Variable	Description	1974	2013
Climate			
maxtemp	Annual average of the maximum daily temperatures (°C)	28.7	30.4
avgtemp	Annual average of the mean daily temperatures (°C)	22.8	24.3
mintemp	Annual average of the minimum daily temperatures (°C)	18.4	19.3
humidity	Average annual humidity (%)	73.6	68.6
precip	Total annual rainfall (mm)	1093	727
norain	Number of days in the year with rainfall lower than 1 mm (days)	232	272
Production and Population			
prural	Rural population (thousand persons)	3,025	2,684
Pmilk	Milk productivity (liters/cow per year)	388	499
Cattle(1)	Cattle production (thousand heads)	4,653	5,928
Goat(1)	Goat production (thousand heads)	1,646	2,341
Sheep(1)	Sheep production (thousand heads)	1,755	2,615
Corn(2)	Corn production (thousand tonnes)	320	631

Source: INMET and SIDRA (IBGE)

(1) Final data refer to 2012

(2) Initial data refer to 2003

Table 2 – Variables related to the characteristics of the fams and farmers in the semiarid of Bahia

Variable	**Description**	**2006**
Production and Population		
milk	Dairy production (thousand liters)	123
cattle	Cattle production (heads)	6.58
goat	Goat production (heads)	2.89
sheep	Sheep production (heads)	3.57
corn	Corn production (tonnes)	1.38
Area and inputs		
acorn	Corn area harvest (ha)	1.38
atotal	Total area (ha)	14.25
anatpast	Natural pasture area (ha)	3.44
adegpast	Degraded pasture area (ha)	0.90
andegpast	Not degraded pasture area (ha)	3.56
aforage	Forage area (ha)	0.41
aforest	Forest area (ha)	4.45
cow	Number of cows (heads)	0.12
lf	Total labor force (persons)	2.39
Associativism		
coop	1 if member of cooperativism (0,1)	0.01
assoc	1 if member of a farmer association (0,1)	0.42
Social characteristics		
female	1 if the farmer is a woman (0,1)	0.19
age29	1 if the farmer is 29 years or younger (reference of analysis)	0.07
age30_39	1 if the farmer is between 30 and 39 years (0,1)	0.16
age40_49	1 if the farmer is between 40 and 49 years (0,1)	0.21
age50_59	1 if the farmer is between 50 and 59 years (0,1)	0.22
age60	1 if the farmer is 60 years or older (0,1)	0.34
school00	1 if the farmer is illiterate (reference of analysis)	0.40
school01	1 if ther farmer can read and write (0,1)	0.18
school02	1 if the farmer has adult literacy (0,1)	0.06
school10	1 if the farmer has elementary education with no diploma (0,1)	0.28
school11	1 if the farmer has elementary education with diploma (0,1)	0.04
school21	1 if the farmer has secondary education with diploma (0,1)	0.04
school31	1 if the farmer has superior degree with diploma (0,1)	0.00

Source: Agricultural Census (IBGE)

Table 3 – Variables related to the characteristics of the system of production in the semiarid of Bahia

Variável	Descrição	2006
Technology and assistance		
atraction	1 if farm used animal traction (0,1)	0.386
mtraction	1 if farm used mechanical traction (0,1)	0.273
guidance	1 if farm received technical assistance (0,1)	0.053
Land management		
soilcor	1 if farm used limestone or soil pH correction (0,1)	0.027
fertilizep	1 if farm fertilezed pasture (0,1)	0.017
fertilizec	1 if farm fertilized crops (0,1)	0.190
fallow	1 if farm used fallow, crop or rest to recover pasture (0,1)	0.137
rotation	1 if farm realized pasture rotation (0,1)	0.191
Adaptative measures		
well	1 if farm had a water well (0,1)	0.083
weir	1 if farm had a weir (0,1)	0.152
cistern	1 if farm had a cistern (0,1)	0.247
diseasec	1 if the farm realized control of diseases or parasites in animals (0,1)	0.452
Market and credit		
specialized1	1 if the farm was highly specialized in one product (0,1)	0.203
specialized2	1 if the farm was specialized in one product (0,1)	0.309
specialized3	1 if the farm was not specialized in one product (reference of analysis)	0.488
integrated1	1 if the farm was highly integrated to the market (0,1)	0.190
integrated2	1 if the farm was integrated to the market (0,1)	0.205
integrated3	1 if the farm was not integrated to the market (reference of analysis)	0.605
credit	1 the farm received public credit (0,1)	0.069

Source: Agricultural Census (IBGE)

Table 4 – Average values of climate variables by climate groups, Semiarid of Bahia

Climate Variable	**Climate Cluster**				
	1	**2**	**3**	**4**	**5**
Observations	849	1,340	1,382	1,657	1,332
maxtemp	30.2	30.2	29.6	29.3	28.7
avgtemp	24.1	24.1	23.7	23.5	23.1
mintemp	19.1	19.3	19.1	18.9	18.9
humidity	65.7	68.2	70.1	71.3	75.1
precip	406	603	743	882	1,141
norain	284	279	268	257	237

Source: Elaborated using data from INMET

Table 5 – Fixed effect estimates for the agricultural procution in the MCA, Semiarid of Bahia, 1974-2013

Regressors	Dependent Variable									
	ln(*pmilk*)		ln(*cattle*)		ln(*goat*)		ln(*sheep*)		ln(*corn*)	
Intercept	-0.995		7.231	***	8.213	***	8.548	***	9.186	
ln(*prural*)	0.002		0.283	***	-0.082		-0.039		-0.165	
*cluster*1	-0.084	***	0.000		-0.010		0.018		-1.298	***
*cluster*1_2	0.001		-0.108	+	-0.073		0.086		-0.722	
*cluster*2	-0.031	*	0.013		0.007		0.015		-0.627	***
*cluster*2_2	-0.038	+	-0.029		-0.088	+	-0.097	**	0.057	
*cluster*3	-0.031	+	0.033	*	0.061	+	0.039		-0.243	*
*cluster*4	0.000		0.046	***	0.095	**	0.083	**	0.052	
t	0.004	***	0.002		0.024	***	0.010	***	-0.050	***
n	5937		5732		5680		5565		2098	
F	5.117	***	5.217	***	9.544	***	6.947	***	29.717	***
R^2	0.026		0.022		0.147		0.062		0.114	

Source: Elaborated using data from SIDRA (IBGE)

*** Significant at 0.1%; ** Significant at 1%; * Significant at 5%; + Significant at 10%.

Table 6 – Ordinary least square estimates for the characteristics of the small fams and farmers with heteroscedasticity-consistent standard errors, Semiarid of Bahia, 2006

Regressors	Dependent Variable				
	ln(*milk*)	ln(*cattle*)	ln(*goat*)	ln(*sheep*)	ln(*corn*)
Intercept	0.419 *	0.906 **	0.272 **	0.249 **	5.314 **
cow	0.586 *	-	-	-	-
ln(*acorn*)	-	-	-	-	2.113 **
ln(*anatpast*)	0.012 **	0.080 ***	0.047 ***	0.047 ***	-
ln(*adegpast*)	0.027 **	0.112 **	-0.009 **	-0.004 **	-
ln(*andegpast*)	0.038 **	0.159 ***	-0.015 ***	0.005 ***	-
ln(*aforage*)	0.126 **	0.121 **	0.079 **	0.109 **	-
ln(*aforest*)	-0.003 **	0.056 ***	0.032 ***	0.010 ***	-
lf	0.014 **	0.016 ***	0.013 ***	0.017 ***	0.009 **
coop	-0.121 *	0.066 *	0.029 *	0.049 *	-0.020 *
assoc	0.086 **	-0.086 **	0.033 **	0.054 **	0.009 **
female	-0.115 **	-0.152 **	-0.027 **	-0.036 **	0.071 **
age30_39	0.025 **	0.047 **	-0.014 **	-0.011 **	-0.034 **
age40_49	0.0431 **	0.1004 **	-0.0241 **	-0.0148 **	-0.0761 **
age50_59	0.0680 *	0.1487 **	-0.0417 **	-0.0095 **	-0.0796 **
age60	0.0764 *	0.2391 **	-0.0519 **	-0.0236 **	-0.0789 **
*school*01	0.048 **	0.075 **	0.032 **	0.002 **	-0.039 **
*school*02	-0.023 *	0.146 **	0.038 **	0.038 **	-0.029 **
*school*10	0.008 **	0.099 **	-0.015 **	-0.037 **	-0.047 **
*school*11	-0.063 *	0.166 **	-0.025 **	-0.046 **	-0.084 **
*school*21	-0.185 *	0.177 **	-0.087 **	-0.103 **	-0.141 **
school31	-0.437 *	0.207 *	-0.083 *	-0.078 *	-0.222 *
n	509,775	505,136	505,136	505,136	505,136
F	14,656 ***	14,817 ***	4,120 ***	3,452 ***	112,700 ***
R^2	0.543	0.540	0.246	0.215	0.884

Source: Elaborated using microdata of the Demographic Census 2010.

*** Significant at 0.1%; ** Significant at 1%; * Significant at 5%; + Significant at 10%.

Table 7 – Ordinary least square estimates for the characteristics of the systema of production and adatative strategies with heteroscedasticity-consistent standard errors, Semiarid of Bahia, 2006

Regressors	Dependent Variable									
	ln(*milk*)		ln(*cattle*)		ln(*goat*)		ln(*sheep*)		ln(*corn*)	
atraction	0.197	**	0.0513	**	-0.004	**	-0.025	**	-0.025	**
mtraction	0.077	**	-0.022	**	-0.117	**	-0.022	**	0.085	**
guidance	-0.024	*	-0.042	**	0.220	**	0.225	**	-0.048	**
soilcor	-0.107	*	-0.140	**	-0.196	**	-0.161	**	-0.135	**
fertilizep	0.239	*	0.011	*	0.240	*	0.232	*	-	
fertilizec	-		-		-		-		0.317	**
fallow	0.002	**	-0.050	**	-0.046	**	-0.033	**	0.042	**
rotation	0.556	*	0.482	**	-0.122	**	0.001	**	-	
well	0.080	*	0.112	**	0.044	**	-0.010	**	-0.043	**
weir	0.064	**	0.147	**	0.050	**	0.149	**	-0.021	**
cistern	0.106	**	-0.032	**	0.208	**	0.276	**	0.080	**
diseasec	0.842	**	0.909	**	0.211	**	0.316	**	-	***
*specialized*1	-0.142	**	0.053	**	-0.099	**	-0.199	**	-0.254	**
*specialized*2	0.249	**	0.142	**	-0.065	**	-0.099	**	-0.014	**
*integrated*1	-0.165	**	0.195	**	0.053	**	0.206	**	-0.137	**
*integrated*2	0.215	**	0.131	**	0.107	**	0.238	**	0.014	**
credit	0.150	*	0.074	**	-0.081	**	-0.060	**	-0.015	**
*cluster*1	-0.331	*	-0.366	**	1.641	*	1.201	*	-0.348	**
*cluster*2	-0.317	*	-0.101	**	0.508	**	0.469	**	-0.104	**
*cluster*3	-0.141	**	-0.072	**	0.090	**	0.286	**	-0.006	**
*cluster*4	-0.084	**	-0.015	**	-0.028	**	-0.026	**	-0.150	**

Source: Elaborated using microdata of the Demographic Census 2010.

*** Significant at 0.1%; ** Significant at 1%; * Significant at 5%; + Significant at 10%.