Climate variability, agricultural livelihoods and food security in Semiarid Brazil

Variabilidad climática, medios de vida agrícolas y seguridad alimentaria en la región semiárida de Brasil

Variabilidade climática, modos de vida agrícola e segurança alimentar no Semiárido brasileiro

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ABSTRACT

Climate change and variability are among the main threats to socio-ecological sustainability in many semi-arid regions of the world and are of special concern to resource-poor family farmers. In the Brazilian semi-arid region, high levels of social vulnerability in addition to predicted climate events can adversely affect subsistence crops and other cultivated areas with serious consequences for rural food security. An extreme drought that started in 2010 left 174 (of 184) municipalities in the northeastern state of Ceará, Brazil, in a state of emergency in 2012. During the period of drought, we studied household production characteristics, sources of water for domestic consumption, perception of temperature change and the relationship of those variables with perceived food security. Food security was associated with the presence of piped water and with the diversity of livestock owned by the household. In addition to the importance of observing the role of those variables in public policies related to food security and regional development in the semi-arid region of Brazil, we also highlight the need of understanding the local context where those policies are implemented and the types of local adaptations taking place during periods of shock, which will be recurrent in a scenario of climate change.

Keywords: Droughts, Climate change, Food Security, Vulnerability, Brazil.

RESUMEN

La variabilidad y el cambio climático son algunas de las principales amenazas a la sostenibilidad del medio ambiente en muchas áreas semiáridas del mundo, y son de particular interés para los pequeños agricultores con recursos limitados. En la región semiárida de Brasil, los altos niveles de vulnerabilidad social, junto con los eventos climáticos previstos, pueden afectar negativamente a los cultivos de subsistencia y a zonas de cultivo con graves consecuencias para la seguridad alimentaria rural. Una sequía extrema, que comenzó en 2010, dejó 174 (184) municipios en el estado de Ceará, Brasil, en estado de emergencia en 2012. Durante la sequía, se estudiaron las características productivas de los hogares, fuentes de agua para el consumo doméstico, percepción de los cambios de temperatura y la relación de estas variables con la percepción de seguridad alimentaria y la nutricional. La seguridad alimentaria se asoció con la presencia de agua corriente y la variedad de animales existentes por hogar. Además de la importancia de observar el papel de estas variables en las políticas públicas relacionadas con la seguridad alimentaria y el desarrollo regional en zonas semiáridas de Brasil, se plantea la importancia de comprender el contexto local donde se implementan estas políticas y los tipos de medidas de adaptación utilizadas durante los períodos eventos extremos, ya que serán más comunes en un escenario de cambio climático.

Palabras clave: *Sequía. Cambio climático. Seguridad Alimentaria. Vulnerabilidad. Brasil*

RESUMO

A variabilidade e as mudanças no clima estão entre as principais ameaças para a sustentabilidade socioambiental em muitas áreas semiáridas do mundo, e são de especial preocupação para agricultores familiares com limitação de recursos. Na região semiárida do Brasil, os altos níveis de vulnerabilidade social, em conjunto com os previstos eventos climáticos, podem afetar adversamente culturas de subsistência e áreas de cultivo com consequências sérias sobre a segurança alimentar rural. Uma seca extrema, que iniciou em 2010, deixou 174 (de 184) municípios no estado do Ceará, Brasil, em estado de emergência em 2012. Durante o período de seca, foram estudadas características produtivas do domicílio, fontes de água para consumo doméstico, percepção de mudanças de temperatura e a relação de tais variáveis com a percepção de segurança alimentar e nutricional. A segurança alimentar foi associada com a presença de água encanada e a variedade de animais existentes por domicílio. Além da importância em observar o papel dessas variáveis em políticas públicas relacionadas com segurança alimentar e desenvolvimento regional em locais semiáridos do Brasil, é levantada a importância de se entender o contexto local onde tais políticas são implementadas e os tipos de medidas de adaptação utilizadas durante períodos de eventos extremos, uma vez que serão mais recorrentes em um cenário de mudanças climáticas.

Palavras-chave: *Seca. Mudanças Climáticas. Segurança Alimentar. Vulnerabilidade. Brasil.*

INTRODUCTION

Climate change is predicted to impact urban and rural areas around the world and to increase the challenges associated with economic development, socioeconomic inequality and alleviation of poverty in vulnerable areas and developing countries (IPCC 2014). The availability, access, utilization and stability of food, i.e. food security, will be also strongly affected by those impacts on natural resources and infrastructure related to production, post-processing, distribution and food preparation (PORTER *et al.*, 2014). Especially for small-scale rain-fed farm systems, extreme events may significantly impact farmer vulnerability to food and nutritional insecurity due to modifications of the amount, diversity, quality and nutritional value of production, and limitation on the ability of stocking safe food in a sanitary manner (EBI *et al.*, 2010).

In Brazil, climate change is expected to affect farmers in many different ways, including extreme events of extended drought (e.g.: in the semi-arid areas) and intense rains associated with flooding (in almost the whole country) (PBMC, 2013). Thus, aiming for long-term food security in face of climate change, a deeper understanding of the factors that contribute to the livelihood and resilience of farmers in rural areas is necessary. According to the latest national Census of Agriculture (IBGE, 2006), family farmers produce much of the food consumed in the country, and this ability to supply both household subsistence needs and regional markets is directly linked to their capacity to persist in those areas. Poverty, challenges related to the production and marketing of food, and health and nutritional issues are all involved in this relationship and make people more vulnerable to socioeconomic and climatic shocks that can drive migration to urban centers. Therefore, a better understanding of the current vulnerabilities within the family farming sector is essential for more efficient public policies and programs in this field.

In the Northeast of Brazil, family farmers are highly vulnerable to the impacts of climate change (CONFALONIERI *et al.*, 2014). This region is considered the most susceptible to the impacts of climate change due to the high levels of social vulnerability, and the predicted consequences of drought, high temperatures and changes in precipitation on agro-ecological systems will cause a loss of subsistence crops and degradation of agricultural areas (IBGE, 2006; PBMC, 2013). Increased migration from rural to urban zones is also foreseen for this region due to failing agricultural systems and lack of water in the countryside (CEDEPLAR- FIOCRUZ, 2008).

Within this region, the state of Ceará is one of the most vulnerable to climatic impacts. For the period of 2010-2050, studies have estimated a possible loss of 79.6% in agro-productive areas, and an increase in health issues (such as dengue fever) with further consequences for the regional socio-economic situation (CEDEPLAR-FIOCRUZ, 2008). In Ceará, the semi-arid zone occupies approximately 86.8% of the area and about 4.5 million inhabitants have their lives influenced by climate variability (RIBEIRO; SILVA, 2010). A dominance of climate-sensitive production systems, low development rates and weak institutional capacity conferred to farmers in those areas a low level of adaptive capacity (BURNEY *et al.*, 2014) and a great vulnerability to droughts and other extreme events over the years.

Even though droughts are part of the cyclic environmental conditions of these regions, years 2010 through 2013 were marked for their periods of long and severe lack of precipitation, affecting millions of people mainly through the loss of agricultural production, limited water for animals and domestic consumption, and death of cattle (BURNEY *et al.*, 2014; GUTIÉRREZ *et al.*, 2014). Among 184 municipalities in the state of Ceará, 174 were declared to be in a state of emergency, with government interventions including water resupply trucks provided by the army and other compensatory measures, such as cash transfers for those affected by drought (Bolsa Estiagem), drought insurance payments (Garantia Safra), and sale of grains (maize) at below-market prices (Venda em Balcão - CONAB). Even if Brazil has a long history of drought preparedness and measures for adaptation to drought in the semi-arid, which include several other emergency programs, there is still much to be done for the development of a drought policy that would effectively improve preparation for future drought events and to adapt to ongoing climate change (GUTIÉRREZ *et al.*, 2014). The use of more comprehensive strategies taking into consideration the current types and levels of vulnerability could at the same time address socioeconomic problems while also increasing resilience to future impacts.

Drawing on this scenario, this article analyses agricultural production and water availability profiles, farmer perception of changes in temperature and food security status in a semi-arid area of Ceará during the last three months of 2012. Using this region and the drought situation as a case study to discuss the vulnerability to food insecurity in the face of climate change, we identify opportunities to improve the socio-economic profile of the most vulnerable populations. The discussion highlights some of the observed characteristics related to the household that can be better addressed by public policies to prevent people falling into more food insecurity and vulnerability, with the potential to be instructive to other semi-arid regions.

The next section will provide context about the study-area, the research methods and statistical analysis employed. We then describe the main findings and discuss the main variables associated with presence of food security, and point to possible characteristics to be more closely observed by policies and programs in the field of social protection, rural development and food security.

STUDY AREA AND METHODS

The semi-arid region of Brazil is home to more than 22 million people and extends through an area of 980.133 km2 (INSA, 2013). Approximately 38% of the semi-arid population live in rural areas, comprising about 8 million rural inhabitants (IBGE, 2006). For these families, food production is closely linked to annual cycles of precipitation (300-800mm/yr) and temperature. The landscape is composed mostly of shallow soil over crystalline rock formation and presence of xerophilous vegetation (MAGALHÃES, 1993). Major annual variations in the amount of precipitation and the start/end period and distribution of rains have been documented, with many years characterized by extreme drought, crop failure, and subsequent social impacts (Tavares *et al.* 1998). There is extensive historical documentation of extreme hunger and malnutrition, high mortality rates due to increased susceptibility to diseases (e.g. smallpox), adoption of coping strategies that include migration to different regions, consumption of wild plants and animals, and looting (CASTRO 1984; LIVINGSTONE; ASSUNÇÃO, 1989). The drought period which started in 2010 and has continued through 2013 has been considered one of the most significant droughts of Northeastern Brazil in the last 50 years (WMO, 2014).

For the study, the state of Ceará was chosen to represent a semi-arid area that faces productive and food security challenges due to high vulnerability (low development rates and large percentage of people in the countryside) and a high incidence of climate variability and change (LEMOS, 2007; CEDEPLAR-FIOCRUZ, 2008). Within southern Ceará, the Cariri is a semi-arid region comprised of 28 municipalities in an area of 16.350 Km2 (Figure 1). This location is characterized by irregular temporal and spatial distribution of rain, with average annual precipitation reaching 1,000 mm mainly from January to April (MDA, 2010).

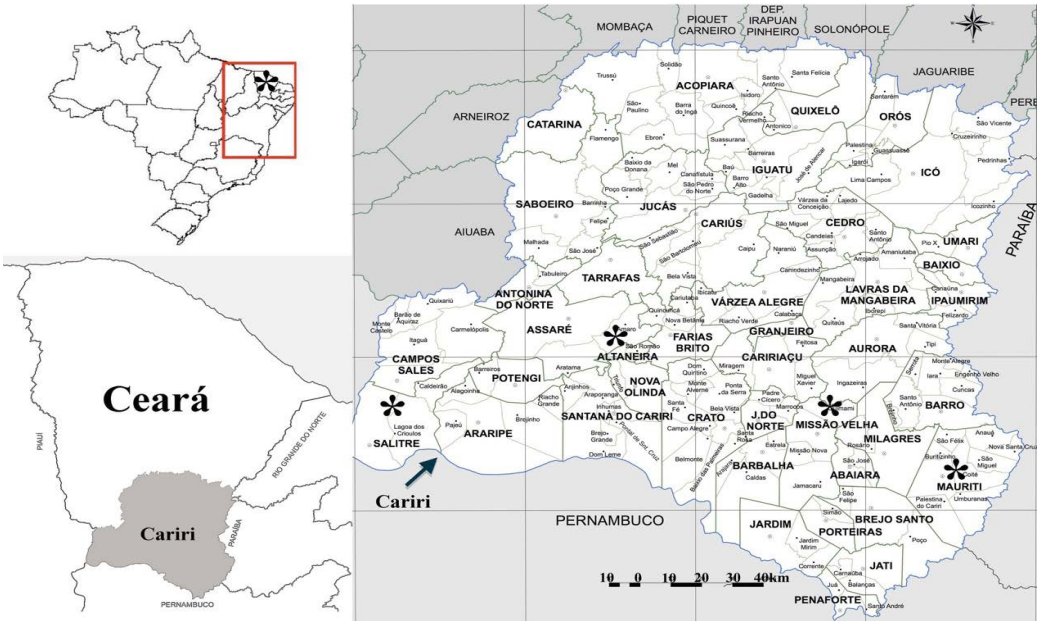

Figure 1: Representation of the study area (* represents studied locations).

Source: adapted from IPECE-IBGE (2010).

The selection of sampled municipalities was based on a regional report concerning the spatial-temporal distribution of precipitation between 1910-2010 in the Cariri region of Ceará (FETTER *et al.*, 2012). Briefly, the authors identified thirteen climatic areas based on precipitation variability and for our study four of those climatic areas were selected. The areas ranged from areas of low to high precipitation variability and the municipalities of Salitre, Missão Velha, Altaneira and Mauriti were sampled to represent the Cariri area as a region. Even though the Cariri is comprised of a vast area spread over a heterogeneous landscape, we believe the selected municipalities and the sample design allow a generalization of the findings across the region. The selected municipalities covered approximately 9,000 rural households (IBGE, 2006).

In November 2012, the research group completed a preliminary field campaign to assess the regional context. A subsequent field campaign was executed over 7 days in January 2013 with a result of 233 valid family farmer interviews (margin of error of 6.3% at 95% confidence level). For the interviews, a team of 15 graduate students was trained for the application of socio-economic questionnaires. The questionnaires included semi-structured questions related to the agricultural production practices (e.g. use of inputs, types of livestock and crops) and also household perceptions regarding temperature changes and main challenges in relation to agricultural production and food security. In addition to the semi-structured questions, the Brazilian Scale of Food Insecurity (EBIA) was used to measure the perception of food insecurity of family farmers (SEGALL-CORREA *et al.*, 2003). The EBIA is composed of 15 closed questions about dietary history during the three previous months, resulting in a household classification as food secure, mildly food insecure, moderately food insecure, and severely food insecure. This scale has been validated by various studies, both in urban and rural regions in Brazil and no differences have been observed concerning the gender interviewed (HACKETT *et al.*, 2008).

The resulting data was analyzed through thematic analysis of open-ended questions and descriptive and quantitative statistics using statistical analysis software (SPSS). For the statistical analysis, some variables were transformed in binary (presence/absence – P/A) while some were kept in the numeric format. The dependent variable FS (food security) derived from the EBIA analysis was transformed to presence and absence of FS as a way to simplify the interpretation of such a vast dataset. The variables selected from all dataset for further analysis using logistic regression with P/A of food security as dependent variable are described in table 1.

Table 1: List of selected variables used in the logistic regression and relationship with the variable food security (FS) (+ and – demonstrate the expected relationship with FS).

Variable	Rationale for choosing variable in relation to FS	Reference
Landownership P/A	+: tenure related to more investment in land and production	Maxweel and Wiebe, 1999
Pesticide Use P/A	+/- : increase in production but various adverse affects.	Carvalho 2006
Fertilizer Use P/A	+: increase in production	Yengoh 2012
Agriculture and Livestock P/A; Livestock P/A; Livestock types N (number of varieties);	+: diversification of farm activities and varieties related to more resilience to shocks	WFP 2010
Piped Water and Cistern P/A; Only Cistern P/A; Only Piped Water P/A;	+ : available domestic water related to quality and amount of water for cooking/drinking	HLPE 2015
Irrigation P/A;	+ : irrigation systems related to more capacity to produce	Tesfaye et al. 2008
Perception of Temperature Changes P/A	+ : perception of changes driving adaptation and investment in productive systems	Di Falco et al. 2011

RESULTS

According to the results of the EBIA questionnaire, 103 households (44.21%) reported having experienced food insecurity during the period of October to December 2012. From those, 73 were classified as mildly food insecure, 27 were classified as moderately food insecure and 3 were severely food insecure (Table 2).

Table 2: Food security status of households: total, with and without dependents younger than 20 years old in household (HH)*.

Category	Total % (n)	With dependents in HH (n)	No dependents in HH (n)
	(n= 233)	*66.95% (156)*	*33.05% (77)*
Food secure	55.79% (130)	42.31%	83.12%
Mildly food insecure	31.33% (73)	39.10%	15.58%
Moderately food insecure	11.59% (27)	17.31%	0.00%
Severely food insecure	1.29% (3)	1.28%	1.30%

Source: Household surveys. * The cutoff for presence of dependents in a household (20 years old) was defined according to the used version of EBIA scale.

Regarding agricultural and livelihood practices, only 54.5% of households owned their land while the remaining used land in tenancy/partnership schemes, shared land with family members, and other tenure arrangements. 229 of the 233 households were classified as family farmers as their primary livelihood strategy. Of these, 43% did not report management of livestock (3). Livestock production ranged from management of poultry (n= 81) and swine (n= 43) farming as a primary household activity, while as a whole many households mentioned the possession of at least a small number of chickens (n=138) and swine (n= 72). There was a lower predominance of cattle (n= 52), sheep (n= 20) and/or goats (n= 16) among the sampled households.

As observed in 3, the interviewees mostly engaged in the cultivation of a small diversity of rain-fed cultivated items, including beans, maize, cassava and fava beans. Only 25% of households reported using fertilizer (organic and purchased), while 82% of the households reported the use of pesticides/herbicides. The most prevalent factors identified by households as challenges to agricultural production were water shortage (n= 86) and climate (in terms of variability and uncertainty) (n= 69) (Table 4). The perception of changes in temperature indicated that most (n= 219) perceived the temperature changing to warmer levels (n= 207).

Table 3: Land ownership and productive profile. Number of mentioned times (Nm – more than one option).

Land Ownership	N households	**Rainfed Cultivation**	Nm	**Chemical inputs**	Fertilizer N	Pesticide N
Yes	127 (54.5%)	Beans	218	Yes	59	192
No	101 (43.3%)	Maize	197	*Organic*	*37*	*6*
Family land	*24*	Cassava	70	*Industrial*	*13*	*185*
Tenancy/Partnership	*59*	Fava Beans	31	*Both*	*9*	*1*
Occupied land	*3*	Upland Rice	4	No	158	37
Government Settlement	*3*	Banana	5	NR	16	4
Under bailment	*6*	Castor beans	5			
Other	*6*	Grass	11			
NR	5	Herb garden	3			
		Nopal cactus	3			
Productive Activity	Nm	**Presence of Livestock**	Nm	**Variety of Livestock**	N	
Agriculture	229	*Chicken*	*138*	0	54	
Strictly	*94*	*Swine*	*72*	1	*89*	
Livestock presence	135	*Cattle*	*52*	*2*	*58*	
Chicken raising	81	*Sheep*	*20*	*3*	*22*	
Cattle raising	49	*Goat*	*16*	*4*	5	
Swine raising	43	*Bees*	*5*	5	2	
Sheep/Goat raising	34	*Horse/Mule*	4	6	*1*	
Apiculture	7			NR	2	
Flour mill	1					
NR	3					

Source: Study data

Table 4: Perception of changes in temperature over the course of the years (from 15 or 20 years previous to the interview) and main challenges for production (n = 233). N_yes = number of people among the ones that answered yes in "Perception of Temperature Changes" and Nm = Number of mentioned times - more than one option)

Perception of Temperature Changes	**N**	**Challenges for production**	***Nm***
Yes	*219*	*Yes - 222*	
No	*12*	*Water shortage*	86
NR	*2*	*Climate*	69
		Pests/Disease	51
	N_yes	*Financial resources*	*36*
Warmer	*207*	*Labor*	*30*
Cooler	*2*	*Degraded/Poor land*	27
No difference	*3*	*Lack of Technical assistance*	11
NR	*7*	*Energy, Roads, Market, etc*	15

Source: Study data

Only 12 out of the 229 households engaged in agricultural production at the time of the interview were utilizing an irrigation system. For domestic water consumption, 56% (n= 111) of the valid interviews had exclusively piped water available, while others had exclusively cisterns in their property for catching rainwater (n=50), or to be filled by water trucks provided by the army (n= 32) or/and by private water trucks (n= 15). Tube wells were installed in 63 households, while the use of artesian wells, reservoirs, and dams were not as common (Table 5).

Table 5: Water profile of households (n=233). Numbers of piped water and cistern indicate the presence of exclusively piped water (and no cistern) and exclusively cistern (no piped water) at the household.

	Piped Water	Rain-fed Cistern	Reservoir	Water dam	Water truck - Army
Yes	111	50	2	6	32
No	82	143	187	185	157
NR	40	40	44	42	44
	Private water truck	**Artesian well**	**Tube well**	**Water gallon**	**Other sources**
Yes	15	31	63	1	28
No	176	160	130	188	166
NR	42	42	40	44	39

Source: Study data

Evaluation of statistical tests

Initially, the Omnibus Test of Model Coefficients in each of the steps estimated a G^2 of 15.742 and a p-value smaller than 0.0001%, signaling that at least one variable in the model had the potential to predict the dependent variable food security. Even though the Cox and Snell R^2 of 0.078 and the Nagelkerke R^2 of 0.105 did not present a compelling statistic, the Hosmer and Lemeshow Test (Chi-square of 1.163 and p-value of 0.948) indicated the model adjusts to the dataset, meaning that all estimated values present a good compliance to the observed ones. Regarding the classification of households in the two groups within the dependent variable, there was an increase in the efficiency of the estimated logistic model (classification rate of 61.1%) in relation to the casual classification (of 46.1%). Finally, the Wald test highlights the variables Livestock types (N) and Only Piped Water (P/A) as significant at the 1% level in the logistic model (Table 6).

Table 6: Summary of the statistical analysis with the two significant variables.

Variables	B	S.E	Wald	df	Sig.	Exp(B)
Livestock types (N)	0.412	0.148	7.768	1	0.005	1.510
Only Piped Water (P/A)	0.804	0.304	6.992	1	0.008	2.235
Constant	-0.850	0.304	7.837	1	0.005	0.427

Source: Study data

Based on the estimated model parameters, it is possible to infer that the chance of a household to be considered food secure (according to their own perception), in ceteris paribus conditions, augments 51% with the increase in variety of raised animals, in comparison to a household under a condition of food insecurity. Moreover, households that have access to piped water had 2.2 times more chance of being food secure (in conditions ceteris paribus) in comparisson to the group of food insecure.

The area under the ROC curve (Receiver Operating Characteristic) had a value of 0.657, superior to 0.5 (p-value < 0.001), being possible to conclude that the model presents a good discrimination power to

classify households in relation to the perceived sense of food security and insecurity (the two groups within the dependent variable). The guarantee of a constant access to piped water and an increase in variety of animals caused an effect towards the presence of food security in the households included in this research. An augment in the variety of animals from about 1 to 2 is predicted to cause an increase of 6.2% in the probability of being food secure, while for 3 varieties the likelihood would reach 14.4%. If a household does not possess access to piped water and animals, the chances of being food secure would be 29.9%, below the cutline thus signaling the condition of perceived food insecurity. Below we will discuss the major findings related to the two variables (variety of livestock and presence of piped water) that had a significant relationship with the dependent variable food security.

DISCUSSION

Climate change is predicted to impact many characteristics of small-scale agro-ecological systems with further consequences over the vulnerability to food insecurity of those most in need. In the studied sample, more than half (55.79%) of households were food secure, falling within the regional average from the last national food security survey (IBGE, 2010). Compared to other regions, and to the national average of 69.8% of food security, the Northeast appeared as the most food insecure region in Brazil. The main concern of participants in our study were related to not having food in hand or the means to acquire it, either from producing or purchasing, which could be related to historical events of hunger, entrenched in the mind of people in food insecure areas. For family farmers that depend on household production for subsistence or on income acquired from agricultural activities utilized for the purchase of food, it can be expected that both socioeconomic challenges and the pressures over productive systems from climate variability can increase their vulnerability to food insecurity.

Access to water has been considered, together with land access, the most prominent challenge to the food issues around the world (HANJRA; QURESHI, 2010). First of all, related to food security, there are two main “compartments” to be considered: water for production and water for domestic consumption. Water for production, through the use in irrigation, can ignite production in drought-prone areas and boost diversity and yield. Deficient irrigation can make people more vulnerable to drought events (LIVERMAN; 1999) and to crashes in production. Meanwhile, the availability of safe water for consumption and preparation of food, and proper sanitation, has been related in various levels to the food and nutritional security and health status of vulnerable populations. The access to clean drinking water is a major variable related to decreases in infant mortality (FAO; 2009), diseases and chemical contamination of food (HLPE; 2015). For participants in our study, limitations in water availability, along with climate variability and uncertainty were identified as the two major challenges for production in the studied households. Even though the variable irrigation was not significant in the logistic regression, a variable related to access to water for domestic use (presence of piped water) had a positive significant relationship to presence of food security. Supporting our findings, an analysis with data from the Brazilian census and FS survey of 2004 found that the presence of piped water was the main variable related to presence and to the various levels of FS countrywide (HOFFMAN, 2008). Additionally, Rocha and Soares (2012) observed that water scarcity has been linked to higher infant mortality, lower birth weight and shorter pregnancy periods in a semi-arid region in Brazil. Thus, especially in face of climate change, proper attention should be given to the availability of domestic water since the access to clean, safe and constant water supply is directly linked to FS and health. Higher temperatures associated to climate change are predicted to increase many climate-sensitive food-borne diseases (HPLE, 2015; WHO; WMO, 2012).

Related to the overall water management in the semi-arid regions of Brazil, a variety of policy strategies have been historically recorded since the major drought event in 1877 (MAGALHÃES, 1993; GUTIÉRREZ *et al.*, 2014). Construction of dams and small reservoirs (first in 1906), and later more incentives for irrigation were the two major actions employed by policy-makers to battle the water deficit (LIVINGSTONE; ASSUNÇÃO, 1989). However, most of those actions had little impact, and while other emergency measures were also developed (e.g. work brigades), the ultimate economic benefit related to the mitigation of drought was for the benefit of the most powerful in the region (BURSZTYN, 1984; LIVINGSTONE; ASSUNÇÃO, 1989). A more recent (since 2003) and successful public policy measure has

been the construction of cisterns, which herein was explored as one of the main variables related to FS ("One million Cisterns", later "Water for all, 2011). The implementation of cisterns has been related to increased household water availability, decreased diseases and increased time availability for women and kids (CONSEA, 2010). Also, since the construction of cisterns involves local community participation, it also aligns with the principle of increasing population participation in initiatives aimed to mitigate the impacts of drought as raised by the United Nations Convention to Combat Desertification (UNCCD, 1994).

Thus, herein we raise a few hypotheses that may explain why only the presence of piped water was associated with FS while cisterns, which also provide water for domestic use, did not appear to have a direct effect on food security outcomes. First, the effect of water being available directly to the households might be more direct than the presence of cisterns, which depends on an external source of water (rainwater or emergency water supply). The convenience of having water directly deployed to the house for cooking could have an influence in the perceived notion of FS, facilitating the preparation of food. Moreover, households that entirely depend on cisterns can be directly impacted by extended periods of drought, since cisterns accumulate rainwater (16,000 liters) that only lasts up to 6-8 months (in a household of 5 people – for cooking and drinking). In years of limited rainwater supply for extended periods (such as the studied period), governmental emergency measures (water-tank truck program) are used to supply water to those cisterns. The distribution of water from this program can be unreliable concerning the frequency and amount of water received, according to some study participants. Thus, the relationship of availability of piped water for cooking and drinking and FS, and the benefits of extending the public water distribution system to areas solely attended by the cistern program should be of even more concern in a scenario of climate change. If vulnerable people have the means of acquiring food from their own rain fed production systems or from markets, and have a limited or unsafe quality of water for cooking and drinking during regular and periods of shock, the benefits from adapting productive systems to the changes in climate would be insufficient to have a direct impact on the vulnerability to food insecurity and persistence in rural areas.

Concerning the findings related to livestock, the benefits associated with this activity and the relationship with presence of FS have also been debated elsewhere (WFP, 2001; BASHIR *et al.*, 2013). Overall, livestock is a central asset in rural regions since they can provide a saving opportunity to be used during distress sales, in addition to being used for household consumption and farm activities, depending on the size and structure of animals. In our study, we observed only a few households with cattle, which can be related to the difficulty of raising large animals in such an environment with limited and distant sources of water during dry periods.

During the 2012 drought, the lack of fodder due to the shortage of hay required some producers to divert financial assets to the purchase of cattle feed. For some eligible farmers, the government subsidized the purchase of maize, through the program "*Venda em Balcão* – CONAB". In November 2012, the local office allowed the monthly purchase of 15 kg of maize per beef cattle (or 60 kg per dairy cattle) with the maximum amount of 900 kg per owner, per month. Even though the program officially allowed more purchase for some farmers, this regional office had to reduce the amount to be able to cover more producers. Despite the fact that this emergency measure probably alleviated the loss of assets for securing cattle feed, many owners lost their animals due to the extreme climate and lack of water in the Cariri region.

In addition to the necessary adaptation for livestock farming under climate change, such as matching stocking with pasture production, infrastructure and changes in timing of grazing (TUBIELLO *et al.*, 2008; PORTER *et al.*, 2014), the composition of livestock should also be a factor to be considered, akin to the increased resilience provided to farm systems due to the diversification of plants. In this case, the reliance on smaller and diversified livestock should be observed, since those are more easily managed during times of emergency and also easily butchered for consumption. In our data, the most observed small animals were chicken and swine. The farming of sheep and goats were also mentioned as important livestock for some respondents and we raise the attention to goats due to their ability to adapt to drier climates. In general, goats possess a low metabolic rate that confers resistance to situations of limited water and food availability (SILANIKOVE, 2000). However, it has been documented

that many people in the semi-arid do not view this activity favorably, given that it does not carry the same social prestige as the raising of cattle (JUNIOR, 2011). Besides the benefits associated with their resilience to water-depleted environment, goats are animals that can contribute to the degradation of the vegetation and landscape if not well managed.

Only seven interviewees reported apiculture as an economic activity. However, bees will be also subjected to the effects of climate change. Giannini *et al.* (2012) found that in a warmer scenario, the least affected species will be *Centris sponsa*, a common species in Brazil's semi-arid region. Thus, the promotion of apiculture constitutes a promising opportunity to be further developed in this region as a means to improve current levels of social vulnerability. Another activity that should be investigated is the farming of pigeons for consumption and sale to local market. In one of the visited households, the farming of domestic pigeons (*Zenaida auriculata*) was mentioned as positive for the daily household consumption and also as a source of extra revenue.

As orientation for public policies we raise attention to programs that intend to strength livestock husbandry, especially smaller animals, and also diversify the production of family farmers. Some programs to be used as examples include the local Goat Allowance (since 2010) in Tejuçuoca (150Km from Salitre) and the federal Program for the Promotion of Productive Rural Activities (associated with the Brazil Without Poverty Plan). The first program selects participants in rural areas to receive goats, farm implements and a small allowance for farm investment (DUTRA, 2011). The second provides an allowance, associated with technical assistance and rural extension, for the promotion of farming of small animals and cattle, and small planting systems. At a later stage, participating farmers are included in the local markets and as providers to some of the local programs of food acquisition (MDS, 2015). In addition to more strategies improving livestock production and the access to water for domestic consumption, the process of diminishing vulnerability to food insecurity in face of climate change would benefit from more knowledge of traditional practices employed during extreme events and shocks. Background information for the development of strategies that would enhance development and reduce poverty, and at the same time strength livelihoods, are of great potential for long term effects over strengthening food security and other variables related to the persistence of farmers in productive rural areas.

CONCLUSIONS

There are more than 1 billion inhabitants in semi-arid areas around the world, with many facing similar challenges to the ones presented in Brazil. Vulnerability due to climate-sensitive productive systems, low socio-economic status and deficient institutions to support the most in need have to be improved so climate change does not drive more people into poverty and food insecurity. Our study indicated that among the studied variables, the presence of piped water and the variety of animals in the household were positively associated with food security, leading to discussions on the need of policies and programs that aim to improve food security in semi-arid areas of Brazil. More knowledge of local conditions to improve social programs, governance and management of natural resources, and to enhance the culture of planning and storage of food and water for periods subjected to shocks are deemed necessary. Additional understanding of the adaptation of policies and programs to the local context during extreme events, such as changes in amount of benefits (e.g. cattle feed) also seems to be required. It appears that climate extremes can drive modifications to already implemented programs, giving the opportunity for more policy-oriented research as a means to understand the decision process and the implications for food security and further adaptation in the local context. Understanding the situations that drive local vulnerability, and the inclinations and decision processes behind the adaptation of programs, would drive the development of more context-oriented policies, which would be both resilient to the impacts of climate change and be more efficient in the face of the multitude of realities encountered in semi-arid regions.

NOTES

[1] According to the EMG-UN (2011), semi-arid land is one of the four types of Dry Land Systems (DLS), which refer to areas with an aridity index of less than 0.65 - annual precipitation (P) smaller than 2/3 of potential evapotranspiration (PET). Based on the index, the four dry land categories are dry sub-humid (0.5-0.65), semiarid (0.2 -0.5), arid (0.05-0.2) and hyper-arid or true deserts (<0.05).

[2] Semiarid regions of the world are occupied by 14.4% of the global population (approximately 1.1 billion inhabitants as September, 2016), while Dry lands as a whole are occupied by 35.5% (2.6 billion) (UN-EMC, 2011).

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