ASSESSING VULNERABILITY TO DROUGHT IN CEARÁ, NORTHEAST BRAZIL

by

Simone Brant

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Thesis Committee:
Associate Professor Maria Carmen Lemos, Chair
Professor Don Scavia

Abstract

This paper seeks to contribute to the understanding of the current vulnerability to variability in rainfall of small farmers in the State of Ceará in Northeast Brazil by identifying factors that affect a household's vulnerability and its ability to prepare for, or respond to, droughts. Understanding these factors can help to identify the households most in need of assistance during a drought and provide a target for programs that build capacity to adapt. Assistance programs currently use criteria to identify eligible programs. This analysis could also help inform an assessment of whether those criteria are appropriate for assisting the most vulnerable families.

While, overall, we would expect that vulnerability would be tied to poverty, for this study, I make the assumption that within comparable levels of poverty, there are factors that may increase the resilience of some households to drought. Hence, although all households surveyed for this study would be considered poor, I assume that specific factors—such as land ownership, irrigation or pension income—may make a family more resilient to drought. Both qualitative and quantitative data and methods are used in this analysis. The qualitative section describes the information acquired in interviews with Brazilian experts. These responses were used to inform the selection of variables in the quantitative portion of the analysis. The quantitative piece uses data from a survey of small farmers in two areas of Ceará. Participation in a work front, a state-run temporary employment program available only during droughts, is used as a proxy for vulnerability to drought since historically work fronts have been used only as a last resort strategy when families have lost all other alternatives of income. A probit analysis is used to identify economic and demographic variables that are linked with increased probability of participation in the work front. A factor analysis is then used to identify components that explain a significant portion of the variance in the data set and to group households into similar groups. These results are then compared with the outcome of work front participation.

Overall, the combination of probit and factor analyses proved successful in identifying households that were likely to have joined the work front in the past. The similarity of results from the probit and factor analysis supported the results. Additionally, variables identified as important determinants of vulnerability to droughts in interviews and the literature proved to be significant statistically. These key variables include on-farm production, non-farm income, particularly pensions, irrigation and plot size.

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I: Introduction

In semiarid regions, limited water availability and climate variability (drought) greatly restrict natural resource productivity even under normal conditions (Krol and Bronstert, 2007). The Northeast of Brazil is a semiarid region marked by a history of severe droughts. For example, the 'Great Drought' of 1877-79 devastated much of Northeast Brazil, ravaging the region's two major income-generating sources, cotton and cattle, as well as its rain fed subsistence agriculture. Given their already precarious existence in good times, subsistence farmers were left with the option of starvation or migration during the drought. Many flooded the towns of the Northeast, left for major cities such as Rio de Janeiro or São Paulo, or migrated to tap rubber in the Amazon. However, despite this massive migration from the area, by the end of the drought, many people had starved or looked like 'walking skeletons' as they wandered from place to place in search of food and shelter (Greenfield, 1992).

Many people in Northeast Brazil and similar semiarid regions are constantly vulnerable to hunger, famine, displacement and material loss. This vulnerability is not caused by climate variability alone. Local people are aware of the history of extreme climate events and shape their lives around preparing for them. However, while expected, these events remain highly unpredictable and residents of the semiarid lands of the developing world where drought and poverty intersect remain at high risk (Ribot et al., 1996).

These hardships are expected to worsen under a climate change regime. While predictions of the effects of climate change on water availability in Northeast Brazil remain uncertain, recent modeling efforts indicate that river flow, water storage and crop production are likely to be greatly affected (Krol and Bronstert, 2007). In addition, it is likely that recurring droughts will continue if not worsen. Any analysis of future impacts of global climate change on vulnerability of populations requires an understanding of current vulnerability. Knowledge of the current situation allows for inference of lessons for coping with future impacts from climate change (Bohle et al., 1994).

This paper seeks to contribute to the understanding of the current vulnerability to variability in rainfall of small farmers in the State of Ceará in Northeast Brazil by identifying factors that affect a household's vulnerability and its ability to prepare for, or respond to, droughts. Understanding these factors can help to identify the households most in need of assistance during a drought and provide a target for programs that build capacity to adapt. Assistance programs currently use criteria to identify eligible programs. This analysis could also help inform an assessment of whether those criteria are appropriate for assisting the most vulnerable families.

While, overall, we would expect that vulnerability would be tied to poverty, for this study, I make the assumption that within comparable levels of poverty, there are factors that may increase the resilience of some households to drought. Hence, although all households surveyed for this study would be considered poor, I assume that specific factors—such as land ownership, irrigation or pension income—may make a family more resilient to drought. Both qualitative and quantitative data and methods are used in this analysis. The qualitative section describes the information acquired in interviews with Brazilian experts. These responses were used to inform the selection of variables in the quantitative portion of the analysis. The quantitative piece uses data from a survey of small farmers in two areas of Ceará. Participation in a work front, a state-run temporary employment program available only during droughts, is used as a proxy for vulnerability to drought since historically work fronts have been used only as a last resort strategy when families have lost all other alternatives of income. A probit analysis is used to identify economic and demographic variables that are linked with increased probability of participation in the work front. A factor analysis is then used to identify components that explain a significant portion of the variance in the data set and to group households into similar groups. These results are then compared with the outcome of work front participation.

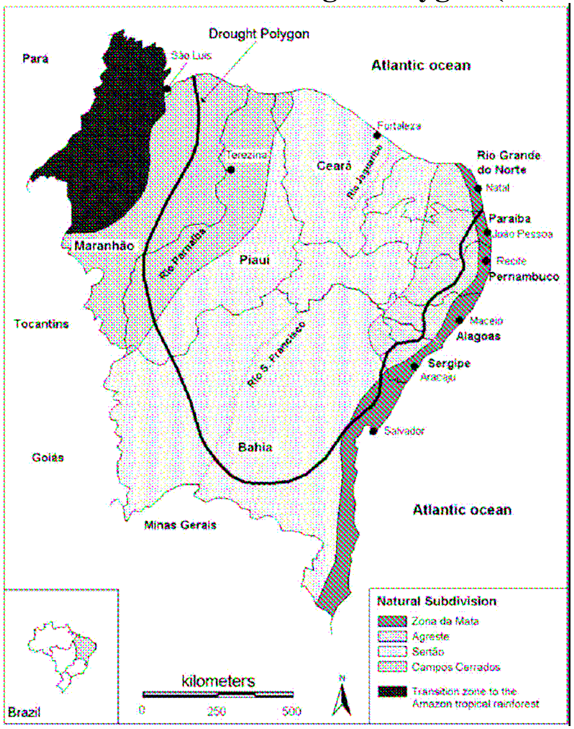
Section II describes the demographics and history of drought in Ceará and Northeast Brazil. Section III reviews the literature on vulnerability analysis. Results of interviews with experts in smallholder agriculture and climate in Ceará are presented in Section IV. Section V reports results of the quantitative analysis of a survey of small farmers in Ceará and Section VI provides conclusion.

II: Background

The northeast of Brazil, including the state of Ceará, is a semiarid region. Precipitation is the most important climatological variable in this area. Changes in the level of precipitation have widespread impacts that influence water availability, vegetation, water management, agriculture, industry and society as a whole (Werner and Gerstengarbe, 2003). Most of Ceará is within the "drought polygon," or the semiarid sertão, where smallholder crop production and livestock farming are prevalent activities among the vulnerable rural population. The sertão faces highly uncertain rainfall and droughts are common (Seitz et al., 2006) (Figure 1).

In the drought polygon, potential evaporation far exceeds annual rainfall. Mean annual rainfall for the region is 900 mm while 3000 hours of annual sunshine and mean annual temperatures of 19 to 29ºC result in real evapotranspiration of about 700 mm. This leaves only 22% of rainfall for runoff (120 mm) and percolation (80 mm). On top of this low average water availability, rainfall is extremely irregular in time and space in this region. There can be considerable variation even within the same town. These low levels of precipitation and high levels of evaporation mean that all rivers in Ceará are naturally intermittent (Frischkorn et al., 2003).

Figure 1: Map of Northeast Brazil Indicating Regional Vegetation Types and the Boundaries of the Drought Polygon (Source: (Seitz et al., 2006))



Societies in semiarid regions in developing countries are typically highly vulnerable to variability of climate and water availability due to low consistency of water availability under average climate conditions. Northeast Brazil is typical of these regions in that it is already regularly affected by severe droughts, many of which have led to major famines in the past. Additionally, increasing population and land-use changes are already putting stress on the natural resources of the area. As a result of this natural climate variability, local populations' economic and social well-being has been negatively impacted (Gaiser et al., 2003).

Ceará has a long history of major droughts. In fact, Northeast Brazil is the largest area in Latin America with marked vulnerability to climate variability (Zhao et al., 2005). Droughts have historically been associated with occurrences of El Niño. Extreme droughts occurred in Northeast Brazil during the strong ENSO years of 1911-1912, 1925-1926, 1982-1983, and 1997-1998 (IPCC, 2001). It has been suggested that under climate change, more El Niño-like conditions will be experienced, which in turn may indicate that Northeast Brazil will experience more frequent droughts in the future. Over the next 100 years even with no change in El Niño strength, greater extremes on drying and heavy rainfall and higher risk of droughts and floods are expected (IPCC, 2001). Additionally, Northeast Brazil is considered to be a hotspot for desertification.

Given the scarcity of water in both rivers and groundwater reserves, the only way to have water available during the dry season with some amount of confidence is to store the excess rainfall during the rainy season. Historically, this strategy has been a priority for many Northeast Brazil government administrations. Since 1885, dams have been constructed to collect water. Currently there are over 7,000 dams in the State of Ceará alone (Frischkorn et al., 2003). However, rainfall is rarely enough to fill reservoirs to their capacity of 12,500 m^3. At the end of the rainy season reservoirs are generally 50-70% full and in a dry year such as 2001 capacity can get to less than 40%, about the amount usually left at the end of the dry season (Frischkorn et al., 2003).

Despite this water storage capacity, reserves in many small dams will not last through a drought. Large and medium-sized dams are designed to last for droughts of up to two years. These dams allow several rivers in the state to flow year round. However, water trucks are still necessary to provide drinking water to small towns and rural areas during frequent droughts (Frischkorn et al., 2003).

The Northeast is also an area of high poverty. Despite a thirteen percent increase in per capita income for rural residents of Northeast Brazil between 1991 and 2000, 77% of the rural population in the region remained in poverty and 51% of the rural population in extreme poverty in 2000[1] (OECD, 2005). These values are the highest of any region in Brazil. While poverty fell ten percent, gains were due in large part to a major increase in social security payments, which increased by 186% during this period. While agricultural earned income decreased by 28%, non-agricultural income increased only slightly (10%) during the same period (OECD, 2005).

The history of poverty and drought in Northeast Brazil has resulted in a legacy of migration from the area. Beginning with the Great Drought of 1877-9, there has been significant migration from the semiarid Northeast to the Amazon and other parts of Brazil, especially São Paulo. Other industrial centers of the Southeast were also a major destination for immigrants. Migration has continued in recent years both as a normal livelihood strategy and as a coping strategy in the face of severe drought. However, as access to other regions has become easier, families have began to use seasonal migration as a way to get through lean times rather than leaving permanently. Still, limited opportunities in the rural Northeast result in many young people migrating to urban centers around the country (Nelson, 2005).

Between 1991 and 2000, the population of Northeast Brazil increased 12.3%, from 42.5 million to 47.7 million. This population growth rate was the lowest of any region in Brazil during this period and well below the national growth rate of 15.6% from a population of 146.8 to 169.8 million. While the overall population within the Northeast region grew during this period, the rural population fell 11.7% from 16.7 million to 14.8 million. This was similar to the national average for decrease in rural population of 11.1% from 35.8 to 31.8 million (OECD, 2005).

Municipal level data indicate that municipalities with greater out-migration had larger reductions in rural poverty due to both higher per capita income growth and smaller increases in income inequality. This suggests that migration occurs disproportionately from the poorest households. The reduction in poverty from migration may result from a

[1] Poverty is defined as income up to 50% of the minimum wage; extreme poverty is income up to 25% of the minimum wage.

variety of factors including removal of poorer individuals and surplus laborers and a flow of remittances from migrants to their families who remain in rural areas (OECD, 2005).

Despite this trend, however, agriculture remains a major employer in Northeast Brazil. The decrease in agricultural employment between 1992-3 and 2001-2 in Northeast Brazil was 5.6%. This was the smallest decline for any region in Brazil. Additionally, while the number of people engaged in non-remunerated family labor fell significantly during this period, the number of subsistence farmers actually increased 12.2% indicating a shift from non-remunerated labor to subsistence farming (OECD, 2005).

For those who remain in the rural agricultural sector, livelihood options remain extremely limited due to issues of access, poverty and marginalization. Approximately 50% of farmers in Ceará are landless and many more own parcels too small to form a viable production unit. Additionally, most people have little political voice and historically political focus has been on emergency measures rather than creating environments that promote increased livelihood options (Nelson, 2005).

Historically, there has been widespread acceptance of the government role in addressing drought in Ceará. Initially, there was a focus on technological responses to drought. The first solution implemented was water storage. The first dam in Ceará was built between 1881 and 1906. A drought-fighting agency, the *Inspetoria de Obras Contra as Secas* (Inspector for Works Against Drought) (later renamed DNOCS or the *Departamento Nacional de Obras Contra as Secas* (National Department for Works Against Drought)) was formed in 1909. Throughout the 1900's, the focus of DNOCS was to increase water storage infrastructure. In the 1940's there was also an effort to develop drought resistant crops and an effort to encourage farmers to plant hardier crops (Finan and Nelson, 2001). In the post-war era, the problem of drought was addressed within the larger context of economic development. A variety of programs have sought to address the problem of recurrent droughts. These have included reduction of the population through resettlement in the Amazon, and integrated rural development programs that provided access to water resources, credit, education, and health care and promoted non-agricultural income. Currently, there remains a debate about how to address the problem of vulnerability to drought in Ceará. Some argue that rain fed agriculture is not a viable option in the semiarid environment and a shift towards export-oriented irrigated agriculture is the only option. Meanwhile, others contend that measures such as land reform and the building of human and social capital can increase the feasibility of rain fed agriculture (Finan and Nelson, 2001). In this context, a better understanding of the nature of vulnerability of poor subsistence agriculture households can be invaluable to inform policymaking to respond to climate variability and change.

III: Literature Review

Vulnerability Analysis

The concept of vulnerability has been used in a range of fields within the natural and social sciences. Current theories of vulnerability are generally derived from two major fields relating to human use of environmental resources and related environmental risks. These research traditions looked at vulnerability either as lack of entitlements or vulnerability to natural hazards (Adger, 2006).

The theory of entitlements derives from the work of Amartya Sen focusing on the causes of famine. It characterizes famine as the state of not having enough food, which in turn may be caused by lack of assets such as land and money, necessary to provide or acquire food. Since, in a market economy, people can exchange what they own for other commodities, those at risk of starvation are the ones who do not have enough assets to have a feasible commodity bundle that includes sufficient food (Sen, 1981). Overall, the entitlement approach of analyzing the causes of famines often discounted the importance of ecological or physical risk. However, it did highlight the link between social differentiation and vulnerability (Adger, 2006).

The natural hazards tradition comes from research on management of floods and other natural disasters. It demonstrates that the impacts of a natural disaster vary greatly depending on the social status of those affected. The vulnerability of a human population varies depending on where it is located, how the community uses its natural resources, and the resources the people have to cope with a negative impact (Adger, 2006). The political ecology tradition also looked at natural hazards but focused on the social and structural causes of vulnerability to hazards rather than the engineering focus of the natural hazards tradition. Political ecologists tried to explain the reasons that the poor and marginalized were more vulnerable to hazards by, for example, focusing on political acts such as civil strife that leave populations vulnerable to the effects of natural hazards. In these cases, technical solutions would not adequately address the vulnerability of the population.

Blaikie bridged these two traditions by creating a social model in which environmental fluctuations and changes are located among other material and social conditions shaping and being shaped by household well-being. For example, when considering soil erosion, Blaikie views the principal question to be the extent that farmers are able to compensate for soil degradation through use of fertilizers, improved seeds and conservation methods. Poor farmers living in marginal areas would be less likely to compensate on their own and to have the power to motivate government or research institutions to respond. Technical solutions are also often not suitable or are inaccessible to poor farmers (Blaikie, 1985). Therefore, according to Blaikie, both the technical problem of soil erosion and structural inequalities within society affect the vulnerability of farmers to land degradation. As a result, both technical and political interventions could have positive effects and should be considered as options for improving soil quality.

Entitlement and natural hazards research have contributed to recent examinations of vulnerability. For example, Bohle, Downing and Watts (1994) defined three factors that contributed to vulnerability: entitlements, human ecology and political economy. In this view, Sen’s definition of the necessary feasible consumption bundle, as well as the need for necessary empowerment to obtain those entitlements, feed into the entitlement portion of vulnerability. A society's dependence on and use of natural resources including its sustainability and the risk of negative impacts, such as droughts, contributes to the human ecology portion of vulnerability, while social and political processes, particularly class structure define the political economy portion (Bohle et al., 1994). Therefore, both economic and natural assets are considered as well as the political and social structures that govern use and exchange of those assets.

Definition of Vulnerability

The study of vulnerability of human and natural systems to climate change and variability is a relatively new field. The concept of vulnerability has been an important tool in describing the risk of negative impacts of both physical and social systems and has a variety of definitions depending on the research tradition from which it is being used. Definitions from the climate change literature tend to fall into two categories. Vulnerability is seen either in terms of the potential damage that could be caused by a particular climate-related event or as a state that exists within a system before a particular event is encountered. The first definition focuses on the biophysical vulnerability of a system such as the likelihood of a particular event to occur and the human exposure to that hazard while the second describes vulnerability as a state present in society independent of actual exposure. However, in current definitions of social vulnerability, exposure is included since it depends on where a population lives and how it constructs its settlements, communities and livelihoods (Brooks, 2003).

Since social vulnerability has been used most often for projects concerned with identifying the most vulnerable members of society, I will use Adger's (2006) definition of vulnerability as "the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt." According to his survey of the literature, the components most often included in definitions of vulnerability are exposure to perturbations or external stresses, sensitivity to perturbation, and the capacity to adapt (Adger, 2006).

The socio-ecological system has increasingly been used as the unit of analysis for vulnerability analysis due to the recognition that both the human and biological aspects of a system affect its vulnerability, adaptive capacity and resilience and must therefore be considered (Gallopín, 2006).

The terms vulnerability, adaptive capacity and resilience are closely related and all have been used in a variety of ways in discussions of a socio-ecological system's ability to withstand climate-related stresses such as droughts and floods. Both vulnerability and resilience are generally examined in relation to a shock. Vulnerability can be thought of as susceptibility to harm or change in the face of a perturbation while resilience can be seen as the potential for the system to recover from a stress (Gallopín, 2006).

Adaptive capacity, or the ability of a system to cope with a stress, is generally thought of as actions that can be taken to reduce future vulnerability by adjusting to current or future stresses. Often these adaptations are shaped and constrained by social, political and economic constraints (Smit and Wandel, 2006). Constraints on adaptive capacity include; wealth, technology, education, information, skills, infrastructure, access to resources and stability and management capabilities (IPCC, 2001). While I refer to vulnerability in this study, the concept could also be described as a lack of resilience or adaptive capacity. I view all of these terms as equally applicable to this analysis.

Evaluating Vulnerability

Vulnerability is not something that can be directly observed or quantified on its own. Rather, it is a relative term comprised of many dimensions. As a result, it is necessary to identify proxy variables or indicators that can be used to assess vulnerability. Ideally these indicators will simplify complex phenomena and the transform them into a usable form. The idea is to identify a small yet comprehensive set of indicators that can be tracked over time and disaggregated to the relevant social unit (Brenkert and Malone, 2005).

Several previous attempts have been made to create a quantitative index of vulnerability. These indices seek to provide scores that describe the relative vulnerability of countries, regions or communities. The scale of these assessments can vary from the individual or household to a single stressor such as drought or flood, to the vulnerability of a community to multiple stressors, or even to the global vulnerability of humans or ecosystems. They can also vary by timescale and whether social, economic or biological systems are considered (Smit and Wandel, 2006). Often these studies assess the vulnerability of a system to create a starting point for evaluating potential adaptations.

Examples of this type of index include O'Brien et. al. (2004), Moss, Brenkert and Malone (2001, 2005) and Vincent (2004). O'Brien et. al. build maps of agricultural vulnerability to climate change and globalization in India by creating indices of adaptive capacity, climate sensitivity, climate change vulnerability and import-sensitivity by district. These indices are comprised of biophysical, socioeconomic and technological factors that affect agricultural production such as soil conditions, ground water availability, levels of human and social capital, presence of alternative economic activities, literacy rates and gender equity (O'Brien et al., 2004). These maps can then be used to characterize relative vulnerability of the districts by overlaying vulnerability to climate and other societal changes.

Moss, Brenkert and Malone (2001) identify eight key sectors that they see as indicators of a society's ability to recover from extreme events and adapt to long-term changes in climate: settlement/infrastructure sensitivity, food security, ecosystem sensitivity, human health sensitivity, water resource sensitivity, economic capacity, human and civic resources and environmental capacity. These indicators are proposed to assess a country's sensitivity to changes in climate and its coping or adaptive capacity. They then use proxy variables for these indicators to assess a country's vulnerability to climate change and create an index of countries' vulnerability relative to the world average and the United States. They also break down the overall vulnerability into the relative contribution from each variable. Overall, they find that this is a technically sound means for creating a first approximation of vulnerability to begin to consider adaptive actions (Moss et al., 2001). Brenkert and Malone also scale down their model to the state level in India (Brenkert and Malone, 2005).

Vincent compares vulnerability of African countries to climate change by creating indices of economic well-being and stability, demographic structure, demographic structure, institutional stability and strength of public infrastructure, global interconnectivity and dependence on natural resources. These subindices are then used to create a weighted combined index of social vulnerability. In creating this index, Vincent uses a theory-driven approach to select indicators of vulnerability to climate change induced changes in water availability (Vincent, 2004).

While the above approaches use indices to compare levels of vulnerability at the national level, they can also be used at the local level. For example, a study focusing on Nebraska, assesses vulnerability to drought based on several key factors affecting agricultural production. This study used several environmental factors such as climate data, crop production statistics and soil type, as well as the way the land was being used and whether it was irrigated to assess vulnerability to drought. This was done by using a weighted combination of data on probability of moisture deficiency, capacity of the soil to hold water, land use and irrigated cropland with the classes within each factor being assigned a vulnerability ranking. The results indicated that non-irrigated cropland and rangeland on sandy soils in areas with high probability of moisture deficiency were most vulnerable to agricultural drought (Wilhelmi and Wilhite, 2002).

Creation of indices has been the most common method used in attempts to quantify vulnerability to climate variability and change. While this approach is valuable for monitoring trends and exploring conceptual frameworks, indices are limited by the subjectivity of variable selection and weighting, availability of data and the difficulty of validating methods (Luers et al., 2003). For example, it is unlikely that the sixteen variables selected by Moss, Brenkert and Malone could fully capture the extent that climate change would affect or harm a country.

In order to compensate for these limitations, Luers et. al. (2003) propose that rather than creation of indices, attempts to quantify vulnerability should focus on assessing the vulnerability of selected variables of concern to specific sets of stressors. This could be done through measurements of the variability of selected variables, or calculation of the probability that levels would cross a specified threshold. They do this for wheat yields of the Yaqui Valley in Mexico, demonstrating that both soil type and management systems affect vulnerability (Luers et al., 2003). While this approach solves the problem of overgeneralization encountered with the indices, it perhaps goes too far in specificity since a household's well-being may be influenced by many factors besides wheat yields.

Several other approaches have been taken to address household vulnerability. For example, Seitz et. al. (2006) use a modeling approach to study the livelihood strategies of small farmers in Northeast Brazil. In this study, farms are divided into four states based on crop yields and resource quality, where production is either increasing or decreasing and resource quality is either improving or deteriorating (Seitz et al., 2006). While not explicitly a study of vulnerability, the most vulnerable households are clearly those whose yield is decreasing while damage to resources such as soil, water and vegetation mounts. This scenario is often the case in Northeast Brazil where unequal land distribution and limited access to productive lands result in production on lands with low carrying capacity and high risk of degradation. Often this leads to increasing allocation of labor to off-farm activities and out-migration from rural areas (Seitz et al., 2006).

Outcome variables can also be used to assess local level decisions. For example, Fuhr uses household survey data to assess a household's likelihood of migration from two rural communities in Northeast Brazil. His model of migration consists of population, family income, education and health infrastructure. These are used to predict likelihood of migration and are compared with survey results and migration statistics (Fuhr, 2003). Once again, this is not explicitly a measure of vulnerability. However, factors characterized as affecting quality of life are similar to those theoretically linked to vulnerability.

Several of the examples above attempt to integrate the social and environmental components of vulnerability. Often this is done through creation of a composite index that combines rankings of both social and environmental variables on a national scale. Little has been done to adapt this methodology to a local scale. Local studies tend to focus on specific sectors such as those by Wilhelmi and Luers et. al. or at strategies employed at the household level. Household studies such as those taken by Seitz and Fuhr look at livelihood strategies of households given their social and environmental constraints. These choices and the factors affecting them can be used to identify households that are particularly vulnerable.

This study employs a household-level analysis. Similar to the Fuhr study, it uses an outcome variable as a proxy for vulnerability. In this case, the outcome is participation in a work front as an indicator of vulnerability to drought. This outcome is analyzed as a function of household income, assets and demographic data. This approach has the advantage of going beyond a purely theoretical measure of vulnerability to one with an observable outcome. This allows for identification of statistically significant variables at the household level. It also encompasses a variety of livelihood strategies, since assets can be derived from multiple sources rather than only one sector such as wheat in the case of Luers et. al. However, the analysis is only as complete as the data available. In this case, only social and economic data were available. Ideally, environmental variables such as farm-level rainfall and soil data would have been included as well.

IV: Qualitative Analysis

During August 2006, I conducted interviews with experts on vulnerability and agriculture in two areas of Brazil, the state of Ceará in the Northeast and the state of Pará in the

Amazon[2]. These experts came from a variety of fields including state and local government, farmer's cooperatives, NGOs and academia. Many worked directly with small farmers in the region through rural extension or assistance programs. The interviewees were asked questions about rainfall, local agriculture, drought and vulnerability in their locality with the aim of understanding the issues deemed to be most important concerning the vulnerability of small farmers to drought and groups of farmers considered to be the most vulnerable. These interviews were used to inform variable selection in the quantitative portion of the analysis. The interview questions are presented in Appendix I.

While farmers in the two regions experience very different environmental conditions, they face a similar set of environmental, technological, social and political challenges. In order to have a successful production system, you need to have these various factors working together. According to one interviewee, several factors are necessary for a farm to be successful. "You need good soil. You need a competent producer. There have to be appropriate inputs at the right time supporting that producer and there has to be research to find solutions for problems that appear." In this paper, I will focus on responses from and concerning Ceará. However, responses from Pará that apply generally to all small farmers are included where appropriate.

The descriptions that follow attempt to synthesize the general perceptions of the interviewees as related in their interviews. While interviewees did not agree on the relative importance of all factors, there was broad general agreement in their descriptions of the situation.

Rainfall

In a land marked by recurrent drought, the amount of rainfall clearly impacts a farmer's success. When considering the vulnerability of farmers, "the climate is first," according to a state official. In a normal year, the rainy season lasts three to four months, from January to April. Therefore, eight dry months are expected and do not present a major threat. However, if there is little rainfall for ten or twelve months, serious problems emerge as reserves are exhausted. In Ceará, where there is a drought every three and a half years on average, risk of major droughts is persistent. However, most of the time, average rainfall is above that necessary for crop production.

Variability in the distribution and timing of rainfall on a local level is as much of a threat as lack of rainfall. Even in years with adequate average rainfall, some areas may receive very little rain. As one official described it, in Ceará rainfall varies "not just each year but in each locality. It's very diverse in time and space. Sometimes it rains here, but ten kilometers away it is not raining. It is very irregular." "What people say about the irregularity of rainfall is that even when climate is considered "normal," you can be certain that some *município* in the northeast region is suffering from drought." Within

[2] Interviews were conducted in these two areas since the research was originally designed to compare vulnerability of farmers in the two regions. While this proved impractical, several interviews conducted in Pará were general enough to provide information that could inform the analysis as currently constructed.

one *município* there can be five different rainfall situations. This leaves those dependent on rain fed agriculture very vulnerable to the unpredictability of rainfall in any particular location.

This extreme variation means that planting at the correct time is a challenge. Ideally, farmers will prepare their fields and plant when the rainy season begins. However, the irregularity of the beginning and length of the rainy season make this difficult to carry out in practice. A few days without rain during the rainy season is manageable, but if there is no or little rain for twenty days then there will be widespread crop losses. A period of extreme rainfall can also cause major problems. "Every year is a bet" since there is no guarantee of when, where, or how much rain there will be.

Many people consider climate forecasts or traditional methods such as rain prophets when deciding when to plant. However, the unpredictability of rainfall on a local scale means that crops will often fail. Those with adequate resources will clean their fields and replant, but small farmers often lack those resources and must take their chances with their one opportunity to plant. As an official from the agriculture ministry summarized it, "Agriculture is a risky activity in the Brazilian Northeast, in semiarid Brazil…A risky activity where whatever the rainfall will be, like a lottery, they gamble. Because the climatic variability is very large, often people plant, but climate conditions result in drought. The probability of success is very low. When it rains, they plant because it is the tradition in the region not to wait until winter is guaranteed. The tradition is that they must plant when it rains because the only alternative they have is to plant. They have no other choice. If they live only on agriculture and it rains, they feel obligated to plant. Otherwise they lose the opportunity. Therefore, when it rains they have to plant immediately." If they do not plant at all, they are guaranteed not to produce anything so for them it is worth a chance no matter how unlikely a successful crop is that year. As one farmer surveyed explained, when the field is wet we plant. "It is a game we play. Win or lose."

Other Environmental Challenges

Aside from the primary challenge of low and unpredictable levels of rainfall, several other environmental challenges affect the productivity of the land. According to an agriculture official, the land is overstressed. Currently there are 1.2 million people living on agriculture in the semiarid regions of Ceará, while the land is only capable of supporting 500,000[s1]. This overworking of the land is increasing levels of land degradation and erosion that ultimately lead to desertification and reduced production capacity. The state's crystalline soils have a naturally low capacity to hold water and low levels of organic material. This is compounded by rapid evaporation. The sun is out 2,500 hours per year, resulting in high soil temperatures that increase rates of evaporation. When it rains, much of the water quickly evaporates leaving little water available for crops. The combination of relatively delicate soils and intensive farming causes erosion and rapid loss of productive capacity.

In addition to these concerns, the directors of irrigated farmer's cooperatives cited additional challenges. Even if irrigation and larger plots made these farmers less vulnerable to climate fluctuations, they are still vulnerable to pests, particularly rats, and have trouble accessing markets.

Technology

There are many technologies available that can reduce a farmer's vulnerability to drought. These include water capture, storage and irrigation as well as improved techniques for soil preparation and management and improved crop planting, planning and production methods. Additionally, there are more resistant strains of seeds available and animals selected for increased production of eggs, meat and honey. All of these technologies allow for greatly reduced vulnerability. They can produce results like those from "another climate." In particular, water storage has allowed for improved access to drinking water and irrigation of crops.

The existence of these technologies is not enough. There also needs to be a means of accessing them and knowledge of their use. In order to benefit from technologies, "You have to know how and when you should use these technologies and tools. For example, for a small producer who does not have access to credit, how can he introduce tools to prepare the soil and capture water?"

The assumption that small producers do not have the tools to make the best management choices for their farms underlies the *Hora de Plantar* program. This program provides high quality seeds to farmers in exchange for grain harvested the previous year on credit to be paid the following year. Many subsistence farmers depend on this program especially in years of uneven rainfall when a first crop fails and needs to be replanted or after a long period of drought when seed reserves have been exhausted. However, seeds are made available only when government technocrats determine that it is the correct 'time to plant' based on climate and soil models. Many farmers resent the imposition of this strict planting calendar over their best judgment. The planting window can be very small given the unpredictability of rainfall and it can be very damaging if it rains before farmers have received any seeds (Lemos, 2003).

For this reason, technical assistance is very important. According to one expert, "My understanding is that the greatest vulnerability is lack of technical assistance...If you only give money and not ongoing technical assistance it doesn't improve anything and if you give money and technical assistance but not technology it doesn't improve anything. Therefore, technical assistance is the most difficult. Often, the extension agent goes to the farmer's property one time, which is very little, and then the farmer isn't supported when they have a need."

Poverty

The most vulnerable farmers are generally the poorest. 90 percent of small farmers (about 1.2 million people) in Ceará do not have sources of income outside of their farms. "Since they are supported only by agriculture their life is very fragile meaning that they don't have land and don't have any guarantee of work." Landowners at least have guaranteed access to their plots. Those without land are dependent on being hired or having the funds to rent land. They are also unlikely to have access to irrigation or other technologies.

"Rain fed agriculture really is what we call 'survival agriculture.' This type of agriculture is only about survival. It doesn't consider the future." This population is highly dependent on government assistance. Programs such as *Bolsa Familia*, *Bolsa Escola* and old age pensions provide income that helps keep the farmer afloat, but "are not fruits of their labor, of planting crops."[3] According to one farmer, crops last about five months. For four or five months, a family lives by selling milk from their cows, selling cattle and "anything else they can do to survive day to day" supplemented by pension income.

The educational system and school attendance in Ceará have improved greatly in recent years. Currently primary school attendance is close to 100%. However, poverty levels remain high. According to one official, the next step in alleviating poverty is to focus on local conditions and how to "better survive in the climatic conditions that we have." Incorporation of knowledge of the semiarid environment and appropriate technologies would directly assist the rural population in the state.

Government Agricultural Assistance

In addition to government funds available through pension and poverty alleviation programs such as *Bolsa Familia*, there are also government assistance programs specifically for agriculture. Respondents indicated that there were many types of assistance available to farmers. These included programs to distribute seeds, improve infrastructure and provide incentives for irrigated food production. During a drought, emergency assistance is available. Three types of assistance fall under the Ceará Emergency Drought-Relief program. The first are work fronts. They provide temporary employment such as road or reservoir building during severe droughts. Second, water and food is distributed in drought-stricken areas, and third, federal and state funds can be made available when an emergency is declared.

Historically assistance programs have been plagued by clientalism and corruption with distribution contracts and work front projects benefiting powerful interests. However, recent reforms have helped direct assistance to the neediest families rather than those with political connections. This has been achieved through the democratization of decision-making power from solely *prefeitos*, local elites such as heads of government agencies, directors of schools and large-scale landowners to local committees where the *prefeito* is just one of the twelve committee members. The State also imposed new rules on who could be enrolled in the program and the types of projects that could be

[3] Everyone over the age of 60 receives a pension as long as they can demonstrate 20 years in the labor force. *Bolsa Familia* and its predicesor *Bolsa Escola* are part of President Luiz Inácio Lula da Silva's *Fome Zero* (Zero Hunger) program. Families below the poverty level receive a stipend for each child as long as their children attend school and are vaccinated.

undertaken using federal relief money to limit the amount of autonomy of individuals at the *município* level. (Lemos, 2003; Nelson, 2005).

There was disagreement among those interviewed regarding the effectiveness of this assistance. A state official said he thought that "today almost all of the states of the Northeast are planning and thinking about the major problem of increasing development and income distribution in the *municípios*." He cited investments in water infrastructure, improvements in education including learning focused on semiarid environments, and improvements in coordination across the various levels of government as having significantly reduced farmers' vulnerability over the past twenty years. Another government official cited programs to promote new crops such as fruit trees and other export crops as well as programs for development of additional sources of income such as mineral exploitation, tourism and craft sales. "Principally, we are working on the question of contextualized education of the population so that they have capacity and understanding of the limitations of living in this region."

Many of these programs were seen as building general capacity, but not necessarily effective in improving resilience during a drought. For example, a rural extension agent claimed that while he "[saw] no specific action on the part of the municipal, state or federal government to try to reduce or diminish the vulnerability of family agriculture," there were many programs that did not specifically target drought that could, when well implemented and accompanied by technical assistance, help to build capacity to withstand difficult periods. However, one local official from a drought-prone *município* replied that "there is government assistance only to satiate hunger and thirst, but not for the person to progress in life. They continue to receive only the minimum that allows them to survive." He complained that "there is no prevention policy. There is only a policy to treat, not to prevent."

Outcomes of Qualitative Analysis

Given the regular recurrence of droughts and the extreme variability of rainfall even in years with adequate rainfall, water availability and access is the primary factor identified as affecting vulnerability of farmers in Ceará. Technologies that reduce the risk of crop failure, in particular those that allow for regular access to water such as water storage, capture and irrigation greatly reduce vulnerability of farmers.

Even with these technologies, however, the risk of crop failure remains. For this reason, alternative sources of income are also important. The better educated may have off-farm sources of income. However, the majority of small farmers do not. For them, government assistance is a very important source of income. In particular many families depend on the old-age pensions provided for those over 60 years of age. Poverty alleviation programs also provide additional income and incentives for school attendance.

Not surprisingly, according to these interviews, the farmers with the highest vulnerability are those with fewer resources. They have low levels of education, little income and do not have access to technologies that could improve production. In many cases, they also do not own their land, meaning that they must pay rent to landowners or, in the case of hired labor, could be laid off in bad times. These people have few options besides trying to produce what they can on their small plots of land. Even when they know that there is unlikely to be adequate rainfall, they take the chance and plant since there are no viable alternatives available to them (Lemos et al., 2002; Nelson, 2005).

To succeed, local agriculture -- including family farms -- need research, technical assistance, infrastructure and markets. While progress has been made in many of these areas in recent years in Ceará, benefits have not reached the majority of small farmers in the state. An integrated program is necessary to meet the needs of these farmers. “It is important to create a specific policy for the semiarid region to develop a family agriculture program with credit, technology, [and] technical assistance”
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V: Survey Analysis

Ceará Survey

This section uses survey data collected by a team of researchers from the University of Arizona, Federal University of Ceará and FUNCEME (the Ceará Foundation for Meteorology and Water Resources) in the spring of 2000 as part of two project grants funded by the National Oceanic and Atmospheric Administration Office of Global Programs. This survey was a follow-on to a larger survey conducted in January and February 1998, where 484 households in six different *municípios* (Limoeiro do Norte, Barbalha, Boa Viagem, Parambu, Guaraciaba do Norte, Itarema) were interviewed. The state was stratified into six climatic zones. Each *município* was then selected as a representative of one of the zones to look at possible differences in vulnerability, risk management, and use of climate forecasts based on agriculture or ecological factors. Within each *município,* approximately 80 families were selected to be interviewed from lists of members of farmers associations. Almost all farmers are members of these associations since they provide access to government programs such as credit and development assistance (Nelson, 2005).

For the second round of the survey, 60 formal interviews were conducted in each of the *municípios* of Boa Viagem and Limoeiro do Norte. These *municípios* were selected because they represented the best range of agricultural, climatic, and socio-economic indicators of the six original *municípios*. Limoeiro do Norte has one of the higher development indexes in the state and contains numerous irrigation projects. Boa Viagem, on the other hand, represents the *sertão*. The *município* is generally poor, has very little irrigation and is much larger than Limoeiro do Norte (Nelson, 2005). The questionnaire used for this survey is available (in Portuguese) in the appendix.

Table 1 demonstrates the differences in socio-economic indicators between Boa Viagem and Limoeiro do Norte. While average family sizes and plot areas are similar in the two *municípios*, access to irrigation, production of subsistence crops and per income is significantly greater in Limoeiro do Norte.

Table 1: Average Household Values by *Município* for 1999

	Limoeiro do Norte	Boa Viagem
Family size	4.88 (1.71)	4.70 (1.91)
Number of Pensioners	0.67 (0.88)	0.45 (0.79)
Number of Children Under Age 15	1.00 (0.92)	1.78 (1.61)
Total plot area (ha)	5.57 (5.69)	4.39 (6.88)
Percent with some Irrigation	57.6 (49.1)	3.3 (18.1)
Number of illiterate people over age 15	0.83 (1.09)	0.77 (0.91)
Percent with Permanent House	81.0 (39.5)	81.7 (39.0)
Percent with Electricity	72.4 (45.1)	68.3 (46.9)
Percent who own their Land	74.6 (43.9)	60.0 (49.4)
Per Capita Income (R$)	1521.03 (1765.96)	681.36 (775.78)
Production of Subsistence Crops (kg)	6,724.45 (16148.14)	838.43 (1787.45)

Standard deviations are in parentheses

Work Fronts

Most farmers in Ceará have few options for income outside of traditional subsistence agriculture. Therefore, in drought years, in many cases, the only alternative income source available to rain fed farmers aside from migration to urban areas was through government-sponsored 'work fronts' (*frentes de trabalho)* (Lemos et al., 2002). These work fronts have historically been one of the main resources available to relieve human suffering during droughts. They helped formerly self-sufficient producers buy needed food, but may also have allowed landowners to release laborers during unproductive periods thereby relieving them of the burden of supporting unproductive laborers while providing enough income to discourage permanent migration from the area (Hall, 1978). In particularly bad years the number of people employed on work fronts swelled. For example, in 1958, 536,000 of the 2.75 million people affected by drought were employed on the work fronts (Hall, 1978).

During droughts, as production falls, those who can no longer support themselves on their land have comprised the majority of work front recruits. This includes sharecroppers released from their land as well as small landowners. For example, in 1970, work front recruits were comprised of 42% sharecroppers and 31% landowners while these groups represented only 5 and 19% of the overall population respectively. Of these recruits, 85% worked on properties smaller than 10 hectares (Hall, 1978).

While work fronts have played an important role as a last means of survival for many poor families, they have also been marked by controversy. Historically, work fronts have been a powerful tool for local political bosses who trade places on the work front for electoral votes. They also have greatly benefited large landholders who are able to release their laborers to the work fronts during drought periods. This allows them to cut wages without risking permanent loss of employees to migration or other employment. Additionally, many of the work front projects such as building roads and water storage infrastructure directly benefited the elites (Hall, 1978; Lemos, 2003). While reforms of the 1990s, particularly the creation of local committees that identify the families that are most in need of drought relief, greatly reduced the clientalism that marked work front job allocation and have improved the equity of job allocation, the legacy of political interference remained. Additionally, the work fronts continued to address only the symptoms of vulnerability without affecting the underlying economic and social inequalities that leave certain groups vulnerable to drought (Lemos, 2003).

Work fronts provide an alternate source of income for those affected by drought. However, they also require heavy labor and living away from home. For these reasons they were generally a choice of last resort, accessed only by those most in need of supplemental income. In this way, participation on the work fronts can be viewed as an outcome that indicates vulnerability since members of only the most affected households will be the ones forced to join the fronts.

The reason that the second round of the survey was used for this analysis is that in Ceará, work fronts are formed only in drought years. There was not one in 1997, but there were work fronts in 1998 and 1999. This meant that data on work fronts was only available in the second Ceará survey.

Of the120 families in the survey, 34 percent (41 families) had a family member join a work front in 1998 while 31 percent (37 families) did in 1999. There was a high correlation between joining a work front in 1998 and doing so in 1999. Of the 41 families that participated in the work front in 1998 only seven did not do so in 1999. Meanwhile, only three families participated in 1999 and not in 1998.

A probit analysis was used to identify factors correlated with participation in a work front in 1998 and 1999 (Table 2). As would be expected, the larger the number of family members of working age, the more likely that someone in the family would participate. Participation increased with family size and decreased with the number of family members over age 50. Participation also increased with the number of income sources a family had, a variable also related to family size. Having a stable income source such as a government pension or civil service job had a small but significant effect on participation. Agricultural income and animal assets were also negatively correlated with work front participation.

There was a difference in likelihood of participation between the two *municípios*. This may be due to the drought being more severe in Limoeiro do Norte. In both 1998 and 1999, average rainfall in Limoeiro was farther below average levels than it was in Boa

Viagem. Average annual rainfall in Limoeiro do Norte is 745.4 mm while it is 668.4 in Boa Viagem. In 1998 average rainfalls were 313.0 mm and 394.9 mm respectively, while in 1999 they were 645.0 mm and 546.6 mm. The statistical difference in participation between the *municípios* may also be due to demographic and climate variation within the *municípios.* While Limoeiro do Norte is well known for its irrigated perimeter and small scale rice farmers and on average, is richer and receives more rain than Boa Viagem, there is a section of the *município* that is among the driest and poorest areas in the state (Nelson, 2007). It appears that nearly all work front participants came from this region of Limoeiro do Norte.

Finally, irrigation had a significant effect on probability of participation in the work front. The greater the number of irrigated hectares a family worked, the less likely they would participate. Also, having water in canals was negatively correlated with participation and highly significant in 1999. These canals are a method available only to farms located near reservoirs. They are able to use reservoir water to irrigate their crops by building canals. Perhaps by the second year of the drought this particular method of irrigation was still effective while others were not. Ceará has few permanent sources of surface water. Therefore, during a long dry period reservoirs will be the only source available for irrigation with surface water. The medium to large ones should have reserves available for at least two years.

Table 2: Probit Estimates of Work Front Participation for 1998 and 1999

Independent Variable	Coefficient - 1998	Coefficient - 1999
Number of Family Members over age 50	-0.536	-0.668*
	(0.331)	(0.376)
Family Size	0.225**	0.315**
	(0.109)	(0.125)
Agricultural Income	-0.0009	-0.005
	(0.0007)	(0.004)
Pension Income	-0.001**	-0.0006**
	(0.0006)	(0.0003)
Civil Servant Income	-0.002**	-0.001**
	(0.0006)	(0.0004)
Number of Income Sources	0.612**	0.393
	(0.248)	(0.243)
Cultivate Own Land	-1.081**	-0.235
	(0.464)	(0.452)
Hectares Irrigated	-0.291*	-0.762*
	(0.152)	(0.446)
Have Water in Canals	-0.405	-1.378**
	(0.534)	(0.703)
From Limoeiro	0.783*	1.154**
	(0.470)	(0.513)
Value of Animal Assets	-0.0001	-0.0003*
	(0.0001)	(0.0002)

** Significant at 95% confidence level.
* Significant at 90% confidence level.
Standard deviations are in parentheses.

Factor Analysis

Factor analysis is a statistical data reduction technique used to describe the variation among random variables in a data set by creating unobserved random variables that are linear combinations of the observed variables. This method is useful for identifying which variables are most important in indicating overall differences in observations across the data set.

A factor analysis was carried out for the 2000 Ceará survey. Variables used were similar to those used in the probit analysis for the 2000 survey except that binary variables had to be omitted since they cannot be used in this sort of analysis due to lack of a range of variance.

For the 2000 survey, variables used included income, family size, land area, irrigation, land ownership, production levels, and education (Table 3). These were combined into four major factors[4] that together explained 72.7% of the variance in the data set. Individually, these factors explained 27.6%, 17.3%, 15.1% and 12.6% of the overall variance (Table 4).

Factor 1 was primarily based on agricultural production and family income with important contributions from the variables for per capita income, total production of subsistence crops, total irrigated area and total irrigated land owned. The variables for non-irrigated land and non-irrigated land owned were most important in extraction of Factor 2. Factor 3 was related non-farm sources of income with important variables being number of sources of income, number of people with pensions, and some contribution from family size and the number of illiterate people over age 15. Meanwhile, Factor 4 was more directly based on family size and number of illiterate people over age 15 (Table 3).

[4] Components are considered major if they explain greater than ten percent of total variance in the data.

Table 3: Component Extraction Matrix

Component Matrix[a]

	Component			
	1	2	3	4
Per capita income	.776	.260	.152	-.300
Family size	-.111	-.111	.325	.764
Number of sources of income in household	.105	.002	.782	-.161
Total production of subsistence crops (corn, beans, flour, cassava, rice)	.801	.219	-.192	.216
Total irrigated area	.838	.153	-.186	.179
Total non-irrigated land cultivated	-.360	.901	.131	.110
Number of people with pensions	.241	-.041	.724	-.248
Total non-irrigated land owned	-.290	.930	.117	.063
Total irrigated land owned	.885	.129	-.008	.081
Number of illiterate people over age 15	.117	-.237	.509	.497
Income from help from children	.002	-.053	.182	-.530

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

Table 4: Total Variance Explained by Components

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.040	27.634	27.634	3.040	27.634	27.634
2	1.906	17.326	44.961	1.906	17.326	44.961
3	1.660	15.093	60.053	1.660	15.093	60.053
4	1.391	12.647	72.700	1.391	12.647	72.700
5	.905	8.223	80.923			
6	.767	6.977	87.900			
7	.491	4.462	92.362			
8	.353	3.214	95.576			
9	.252	2.287	97.863			
10	.190	1.728	99.591			
11	.045	.409	100.000			

Extraction Method: Principal Component Analysis.

The four components from the factor analysis were then used to separate the households into clusters based on mean values of the components. Of the 120 households that participated in the survey, three households were placed in Cluster 1, 84 in Cluster 2 and 32 in Cluster 3 while one household was excluded due to missing data (Table 5)

Table 5: Number of Cases in Each Cluster

Number of Cases in each Cluster

Cluster	1	3.000
	2	84.000
	3	32.000
Valid		119.000
Missing		1.000

The largest cluster, Cluster 2, had lower average values than did Cluster 3 for Factors 1 to 3 indicating lower income and agricultural production, less land, both irrigated and non-irrigated, and fewer alternate sources of income (Table 6). However, the higher value for Factor 4 indicated that families in Cluster 2 tended to be larger than those in Cluster 3.

Cluster 1, with only three families, contains the outliers. Mean values for Factors 2 and 4 are much higher than values for the other two clusters, while the mean value for Factor 1 is much lower. This combination of assets is unusual since it indicates families that lack irrigation but have high income and land holdings. These families stand out by having very large farms in relation to the other households surveyed. Their plots, which measure 26, 50 and 21 hectares, respectively and are owned by the family, were much larger than the sample average of 3.45 hectares. In fact, these were the three largest farms in the survey. As expected of a larger farm, production of subsistence crops and animal assets were relatively high on these three farms. Due to their large holdings these were also the only farms able to rent land. However, levels of irrigation on these farms were very low. While total average area of these farms was well above the overall average of 3.45 ha, total irrigated land was only 2.5 ha compared with an overall average of 1.5 ha.

While households in Cluster 1 stood out for their large land holdings, most households fell into Cluster 2 or 3. These results indicate that households in Cluster 2 will be more vulnerable to drought that those in Cluster 3 since average values are lower for factors 1 through 3. As indicated by these factor scores, total plot size, irrigated area and crop yield were smaller on average for members of Cluster 2. They were also less likely to own their own land and had fewer income sources. Income from skilled labor, pensions, assistance from children and total income are also higher for households in Cluster 3.

Table 6: Final Cluster Centers

Final Cluster Centers

	Cluster		
	1	2	3
Factor 1	-1.03835	-.14779	.48528
Factor 2	4.63306	-.19143	.06816
Factor 3	.11499	-.41230	1.07152
Factor 4	.62676	.23249	-.66906

Comparison of Cluster and Work Front Participation

In order to test for similarity of results between the probit analysis and the factor analysis, a crosstabulation between work front participation and cluster number was carried out. As expected, members of Cluster 2, were more likely to participate in the work front than were members of the other clusters (Table 7). None of the households in Cluster 1 participated in the work front while only two of the thirty in Cluster 2 did (6.7%). Meanwhile, 68 percent or 34 of the 50 households in Cluster 3 did join the work front.

This result indicates broad agreement between the cluster analysis and work front participation as an observed outcome of vulnerability. While placement in the high vulnerability cluster, Cluster 2, does not guarantee work front participation, nearly all of the households that participated in the work front were placed in this cluster.

Table 7: Crosstabulation of Work front Participation and Cluster Number

Crosstabulation of Workfront Participation and Cluster Number

Count

		Cluster Number of Case			Total
		1	2	3	
Workfront Participation	No	3	50	30	83
	Yes	0	34	2	36
Total		3	84	32	119

Scores for the individual factors were also compared based on work front participation. A significant difference was found between mean factor scores of the two groups for Factors 1, 2 and 4 (Table 8).

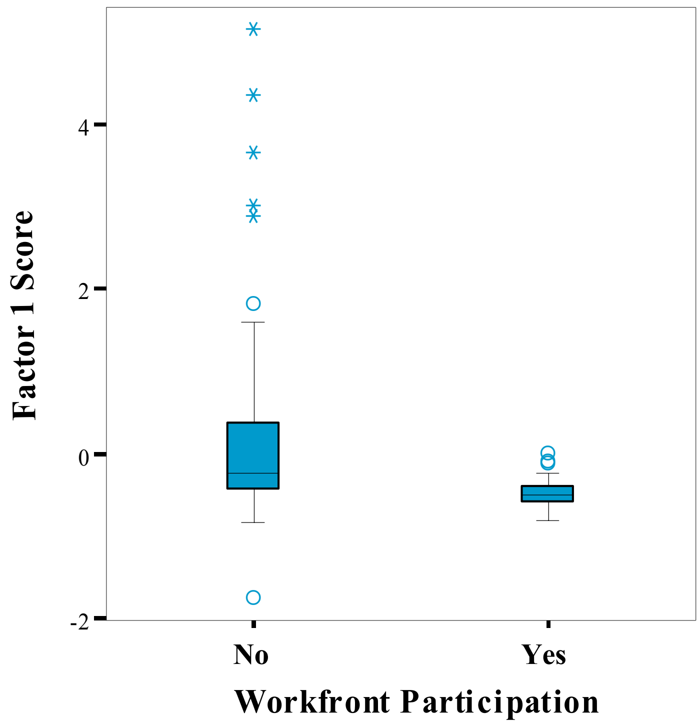
Table 8: Tests for Equality of Means between Families that Did and Did not Participate in the Work front

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Factor 1	Equal variances assumed	20.292	.000	3.549	117	.001	.67578453	.19042866	.29865055	1.05291852
	Equal variances not assumed			5.276	91.321	.000	.67578453	.12808597	.42136954	.93019953
Factor 2	Equal variances assumed	4.733	.032	1.859	117	.066	.36710884	.19752087	-.02407088	.75828857
	Equal variances not assumed			2.557	113.954	.012	.36710884	.14355001	.08273615	.65148153
Factor 3	Equal variances assumed	4.230	.042	.970	117	.334	.19364935	.19961425	-.20167622	.58897492
	Equal variances not assumed			1.068	84.240	.288	.19364935	.18124765	-.16676645	.55406515
Factor 4	Equal variances assumed	.104	.748	-3.452	117	.001	-.65900064	.19093075	-1.0371290	-.28087229
	Equal variances not assumed			-3.736	80.621	.000	-.65900064	.17641505	-1.0100363	-.30796503

For Factor 1, mean scores were significantly higher for those families that did not participate in the work front (Figure 2). The mean score for those who did not participate was 0.20 with a standard deviation of 1.13 while it was -0.47 with a standard deviation of 0.18 for those who did. Since Factor 1 was largely comprised of agricultural production, irrigation and family income data, it would be expected that individuals from families with higher means for this factor would be less likely to join the work front.

It is interesting to note the wide variance in scores for those who did not participate. It appears that while all families that did participate had a low score and all families with a high score did not participate there were many families with low scores that also did not participate. There is one case that is a clear outlier. It is visible in Figure 2 as the very low score in the no column. In fact, it is the lowest score of any family in the survey. However, on inspection of the data it appears that the particular combination of assets of this family led to a misleading factor score. It turns out that while this family does not have irrigation, they have very large non-irrigated landholdings compared to most other families. Despite this family's relatively high per capita income and subsistence production, the lack of irrigation and negative coefficient on non-irrigate land resulted in a very low score. Therefore, it is the unusual combination of assets, rather than extreme poverty that results in this very low score. In comparison, the family with the highest score for Factor 1 had only modest land holdings, but the entire plot was irrigated leading to high production and high per capita income.

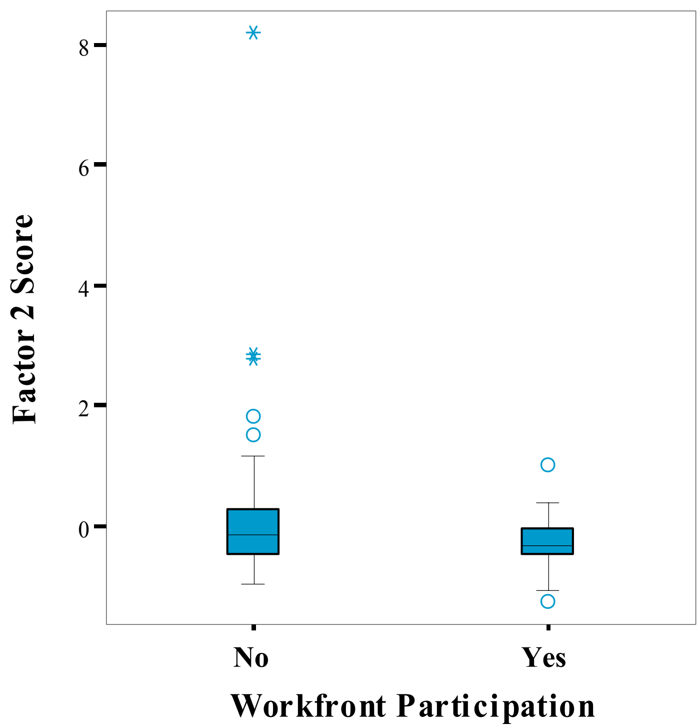
Figure 2: Box Plot of Factor 1 Scores by Work front Participation



For Factor 2 (Figure 3), families that did not participate had significantly higher mean scores. The mean score for those who did not participate was 0.11 with a standard deviation of 1.15 while it was -0.25 with a standard deviation of 0.41 for those who did. This would also be expected since Factor 2 was related to non-irrigated land holdings implying that those who did not participate had more land on average.

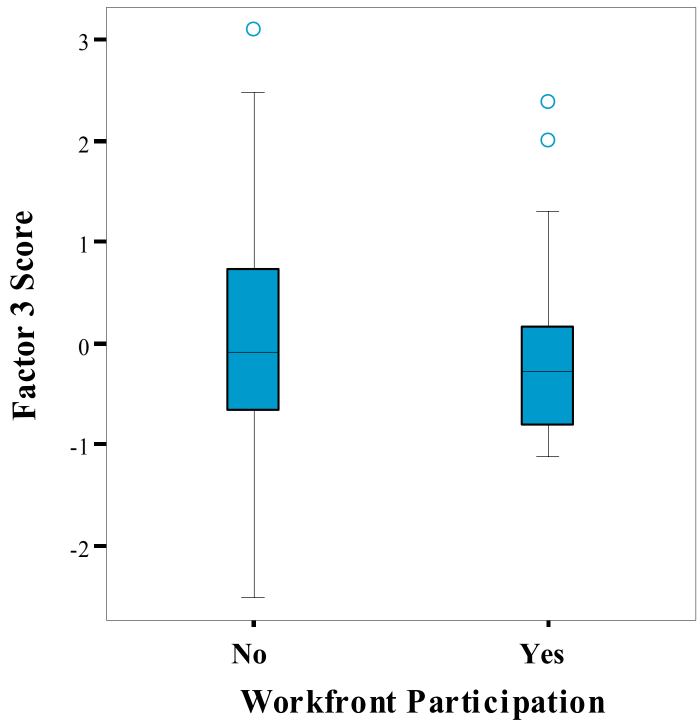
As in the case of Factor 1, there is a larger variation in values for those who did not join the work front. Interestingly, the same family that had an extremely low score for Factor 1 also had the highest value for Factor 2. This underscores the unusual combination of assets held by this family.

Figure 3: Box Plot of Factor 2 Scores by Work front Participation



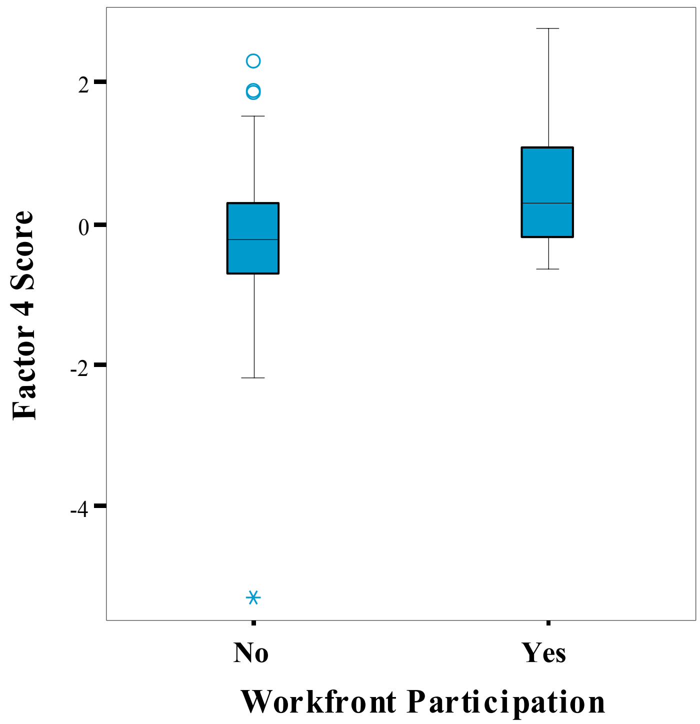
For Factor 3, there is no significant difference in means. The mean score for those who did not participate was 0.06 with a standard deviation of 1.06 while it was -0.14 with a standard deviation of 0.83 for those who did (Figure 4). This result is somewhat surprising since we might expect that families with more sources of income would be less likely to join the work front. However, these families also have more low skilled workers as indicated by the number of illiterate people over age 15 and in general, a bigger family would be expected to have more income sources. Therefore, perhaps it is not unexpected that overall, we would see significant difference in mean scores between the two groups. In general, this factor does not appear to be particularly useful since it is comprised of a rather unusual grouping of variables. Variables that would be expected to increase vulnerability such as the number of illiterate people and ones that would be expected to decrease vulnerability such as number of people with pensions both contribute to the factor score so it is not surprising that there is no difference in score between those who joined the work front and those who did not.

Figure 4: Box Plot of Factor 3 Scores by Work front Participation



Finally, for Factor 4 (Figure 5), mean scores are significantly higher for those that participated in the work front. The mean score for those who did not participate was -0.20 with a standard deviation of 1.01 while it was 0.46 with a standard deviation of 0.82 for those who did. Since Factor 4 is based primarily on family size and the number of illiterate family members, it would be expected that those with higher scores would be more likely to have a family member join the work front. Variance between the two groups is more similar in this case, though still slightly larger for families that did not join. As with Factors 1 and 2, there is one major outlier for this factor. On inspection of the data, it appears that the low score is due to this household being comprised of only an older couple, both of whom are pensioners. Their only income is from their pensions and help from their children. Since scores for Factor 4 are related to family size but discount those old enough to receive pensions, it results in an extremely low score for this household.

Figure 5: Box Plot of Factor 4 Scores by Work front Participation



Discussion

The probit and factor analyses produced results that are in broad agreement. Use of demographic and economic indicator variables enabled identification of factors correlated with an outcome that indicates vulnerability to drought, work front participation. As would be expected, households were less likely to have a member join the work front: 1) the greater their income from various other sources, 2) if they had access to irrigation, and 3) if they owned their own land. Steady streams of income such as pensions and civil service jobs were particularly important. Additionally, likelihood of participation increased with the number of family members of working age and was significantly higher in Limoeiro. This result is unexpected since the *município* of Limoeiro do Norte is better off economically than Boa Viagem on average. However, holding income and irrigation constant, residents of Limoeiro were more likely to join. In this case, though, it seems that the *município* average may not be an appropriate indicator given that Limoeiro do Norte contains one of the poorest and driest areas in the state as well as the irrigated agriculture for which it is known. While differences in political connections and a more severe drought may also have been factors in the higher participation rate in Limoeiro, it appears that there is no major discrepancy between families that would be considered vulnerable and those that joined the work front.

The factor analysis identifies patterns in the data by identifying correlations between variables and by creating new variables that are combinations of the originals rather than using an outcome variable as in the probit analysis. When households were divided based on the four key factor variables, they were separated into two main groups, a vulnerable majority and a second somewhat less vulnerable group. There was also a small group of three outliers. These groups were strongly correlated with the indicator variable used in the probit analysis, work front participation, since nearly all households that had a member join the work front came from the vulnerable group. This validates the cluster results. However, it is clear that membership in the vulnerable cluster indicates increased likelihood of work front participation but by no means guarantees it. Many members of the vulnerable cluster did not join the work front. In fact, nearly half of the households surveyed were placed in the vulnerable cluster but did not join the work front. Of course this cluster was much larger than the others.

Similarly, when each factor score was analyzed separately, there were significant differences between scores among households that did and did not participate in the work front. Interestingly, the variance in scores was greater for families with no participant. This once again indicates that a particular factor score indicates increased likelihood of the work front outcome but does not guarantee it. Overall, 84 households were grouped in the vulnerable cluster. Of those only 34 participated in the work front, meaning that many families were identified as being vulnerable but did not participate. However, it is important to remember that those that did comprised nearly all participants. The clustering method therefore proved useful for identifying increased probability of joining the work front.

While this analysis was limited by data availability and selection of variables, it has proven useful in identifying factors that are correlated with increased likelihood of joining a work front. Of course, the analysis is also highly dependent on the assumption that vulnerable families are more likely to join a work front. However, this assumption is generally supported by historical data. Having this outcome variable is an advantage since rather than having to predict future outcomes based on theory alone, there is an observable outcome that can be used. This allows identification of variables that are correlated with a household member joining the work front. Additionally, these variables can be used to predict those households likely to be vulnerable to future droughts.

VI: Conclusion

Vulnerability analysis is a relatively new field. Several methods have been developed to measure the vulnerability of populations. These include development of indexes of proxy variables such as those used by Moss, Brenkert and Malone (2001, 2005) and analysis of strategies or outcomes within a specific sector. All of these analyses are attempts to circumvent the inherent problem of vulnerability, in itself, not being an observable concept.

The approach used in the quantitative analysis for this paper is similar to that used by Fuhr (2003) in that it uses an observable outcome variable, in this case participation in the work front. This outcome has historically been tied to vulnerability and can therefore be seen as a reasonable proxy. Having this outcome variable enabled identification of factors that were correlated with a household member joining the work front.

The combination of probit and factor analyses proved reasonably successful in identifying households that were likely to have joined the work front in the past. The similarity of results from the probit and factor analysis supported the results. Additionally, variables identified as important determinants of vulnerability to droughts in interviews and the literature proved to be significant statistically. These key variables include on-farm production, non-farm income, particularly pensions, irrigation and plot size.

The analysis was limited by the fact that the Ceará survey was not designed for this purpose. Ideally questions would have been tailored specifically to questions of vulnerability to drought and reasons why family members may or may not have joined the work front. Additionally, the survey was conducted in 2000, meaning that it did not probe on more recent anti-poverty programs such as *Bolsa Familia*. Evaluations of *Bolsa Familia* indicate that it has been effective in addressing poverty. It would be interesting to look at whether these programs have also reduced vulnerability to drought in Northeast Brazil. Another option for future study would be to look at whether households that were identified as being more vulnerable are in fact more likely to have negative outcomes during future droughts.

Unfortunately, a future analysis would not be able to use the work front outcome. The State of Ceará ended the work fronts beginning with the 2002-2003 agricultural campaign. Although reforms had made allocation of spaces on the work front more equitable, the program carried the burden of years of past abuse and continued to be viewed as a source of corruption (Nelson, 2005). In place of the work fronts the State initiated the program *Seguro Safra* (Guaranteed Harvest), a crop insurance scheme that makes payments to farmers who have lost their crops due to drought, floods or pests. This approach is a major change from the cash-for-work approach of the work fronts which attempts to both compensate farmers for crop losses and eliminate the clientalism of the past (Nelson, 2005). Therefore, a new outcome variable would have to be identified in order for this analysis to be updated.

Despite its limitations, however, this analysis has several benefits. Use of an observable outcome variable enabled the analysis to be grounded in the available data and made it easy to identify correlated variables. Using quite basic economic and demographic information, this analysis provided a grouping of households that would enable the creation of a list of households of concern. This could allow proactive targeted assistance to the most vulnerable households in years when a drought is predicted and would also allow the government to work to build adaptive capacity in areas of concentrated vulnerability.

Appendix I: Interview Questions

Demographic Info

1. What is your position here at …
2. What are your major responsibilities?
3. How long have you worked here?
4. What is your educational background?

Meteorological Info

5. Is there much variability in the timing/quantity of rainfall each year? Do you have data available on annual rainfall (at least for the last 20 years)?
6. Are there local weather forecasts/climate information available? How is the information distributed now? What are the plans for the future? What additional information would be helpful?

Farmers

7. What are the typical crops in this area?
8. Are crops mostly for local consumption?
9. What is the typical land tenure structure in this area?
10. How do farmers decide what and when to plant?
11. How easy is it for farmers to obtain credit?
12. Do many farmers have other sources of income besides their crops? Could you provide examples?
13. What are the major vulnerabilities of farmers in this area? For rain fed agriculture? For irrigated?
14. Are there particular strategies that help mitigate these vulnerabilities?
15. Are there particular subpopulations of farmers that are most at risk? Why is that?
16. What were the dry periods over the past 20 years? Can you think of any particularly bad year for farmers?
17. How did individual farmers prepare for the drought?
18. Were crop losses widespread?
19. How do people compensate for crop losses? What did they do in 19xx/20xx?
20. The percentage of people in agriculture has dropped significantly over the past 20 years. Is there a future for agriculture in Ceará?

Drought Response

21. Are drought (and fire) major political concerns in this area?
22. Is there government assistance available in the case of a disaster?
23. Given that droughts in this region are common, what measures are in place to assist those affected?
24. Are there any government efforts to reduce vulnerability of farmers?
25. Are there other government programs to assist farmers?
26. What do you consider the most important factor for preventing widespread hunger in the case of crop losses?

27. What has changed in the response to drought over the past 20 years? What was the most dramatic change? What change most affected the vulnerability of farmers (for better or worse)?
28. Are there preparations being made to respond to future impacts from climate change? Is the government thinking about this? Are farmers thinking about this?
29. Is there anything I haven't asked you about that you think is important for me to know about climate vulnerability in Ceará?

Appendix II: Survey Questionnaire

QUESTIONÁRIO Nº ___________________
TIPO I

Projeto NOAA/Universidade do Arizona/Universidade Federal do Ceará/Estado do Ceará

Município: ______________________________

Distrito: ___________________________

Associação: ____________________________

Nome do entrevistado: _____________________________________

Nome do entrevistador: ________________________________

Data: ___________________

Fez uma parte do primeiro estudo: _________ **Questionário Nº.** ___________

Fevereiro/Março 2000

I. CARACTERÍSTICAS DEMOGRÁFICAS

Nome da Pessoa	Relação ao Chefe da Família	Sexo	Idade	Educação (Anos Completos)	Trabalho 98 Remunerada	Trabalho 99 Remunerada	Emigração Passada
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							

Relação ao Chefe da Família:
1. Chefe
2. Esposa
3. Filho/a
4. Neto/a
5. Pai/Mãe

Educação:
1. Analfabeto
2. Alfabetizado
3. Primário incompleto
4. Primário completo
5. 1^0 incompleto
6. 1^0 completo
7. 2^0 incompleto
8. 2º completo
9. Superior

Trabalho:
1. Não trabalhou
2. Tempo parcial
3. Tempo integral
4. Aposentado oficial
5. Aposentado e trabalhou
6. Pensão

Emigração Passada:
1. Sim
2. Não

EMIGRAÇÃO- PASSADA

Nº. da Pessoa	Ano em que emigrou a primeira vez	Local	Tipo Trabalho	Frequência	Quanto Tempo	Assistência a Família

Local:
1. Outro local do município
2. Sede do município
3. Outro município
4. Outro estado
5. Fortaleza
6. Rio de Janeiro
7. São Paulo

Assistência a Família:
1. Não ajuda
2. Manda dinheiro
3. Manda bens de consumo
4. Vêm trabalhar na propriedade
5. Alguma combinação de 2,3,4

II. FAMILIARES NÃO RESIDENTES

Nome da Pessoa	Relação ao Chefe da Família	Idade	Sexo	Estado Civil	Local	Tipo Trabalho	Quando Saiu	Assistência à Família 1998		Assistência à Família 1999	
								Tipo	Frequência	Tipo	Frequência

1. Outro local do Município
2. Sede do município
3. Outro município
4. Outro Estado
5. Fortaleza
6. Rio de Janeiro
7. São Paulo

1. Não ajuda
2. Manda dinheiro
3. Manda bens de consumo
4. Vêm trabalhar na propriedade
5. Alguma combinação de 2,3,4

Alguem da família pretende sair? Sim Não
Para onde e por que?

III. ÁREA AGRÍCOLA

Propriedade/ Roça	Regime de Trabalh o	Área de Sequeiro			Área Irrigada			Culturas Principais	
		Cultiva da 98	Cultiva da 99	Unidad e	Cultivada		Font e de água	98	99
					98	99			

1- Proprietário
2- Morador
3- Cedida
4- Arrendatário
5- Associado/Coletivo
6- Arrendador

1- ha
2- tarefa
3- braça
4- m^2
5- pé
6- canteiro
7- leira
8- cova

1- Projeto
2- Açude
3- Poço/ Cacimbão
4- Poço Profundo
5- Rio
6- Nascente, Olha d'agua

IV. PRODUÇÃO AGRÍCOLA - 1998

Produto Agrícola	Produção			Vendas			
	Quantidade	Unidade	Ano Normal	Quantidade	Undidae	Preço Unitário	Valor Total

V. PRODUÇÃO AGRÍCOLA - 1999

Produto Agrícola	Produção		Vendas			
	Quantidade	Unidade	Quantidade	Unidade	Preço Unitário	Valor Total

VI. VENDA DE ANIMAIS 1998 VII. VENDA DE ANIMAIS 1999

Tipo	Número	Valor Total

Por que vendeu?:

Tipo	Número	Valor Total

Por que vendeu?:

1. Bovino
2. Caprino/Ovino
3. Suino
4. Equíneo
5. Aves

VIII. PECUÁRIA ATUAL

Bovino: __________ Caprinos e Ovinos:__________ Suinos:___________
Equíneos:_________ Aves:_________

IX. RENDA FAMILIAR RELATIVA AO ANO DE 1998

Nº da Pessoa	Atividades Renumeradas					
	Tipo	Período (Meses do ano)	Frequência	Renda (R$)	Unidade do Tempo	Renda Anual

X. RENDA FAMILIAR RELATIVA AO ANO DE 1999

Nº da Pessoa	Atividades Renumeradas					
	Tipo	Período (Meses do ano)	Frequência	Renda (R$)	Unidade do Tempo	Renda Anual

1. Mão de obra agrícola
2. Mão de obra não qualificada
3. Frente de trabalho
4. Mão de obra qualificada
5. Comerciante
6. Funcionário
7. Artesanato
8. Aposentado/Pensão

1. Por dia
2. Por Semana
3. Por Mes
4. Ano Total

XI. INFORMAÇÕES QUALITATIVAS:

1.0 <u>A quadra chuvosa</u>

1998	**1999**

2.0 O Plantio

1998	1999

3.1 Animais: Impactos e Respostas

1998	**1999**

4.1 Água (consumo humano): Impactos e Respostas

1998	1999

5.0 Saude

1998	1999

6.1 Consumo: Impactos e Respostas

1998	**1999**

6.2.1. Cesta Básica

1998	**1999**

6.2.2 Bolsão de Trabalho

1998	1999

6.2.3 Outras Atividades Remuneradas

1998	1999

6.2.4 Emigração e deslocamento

1998	1999

6.2.5 Ajuda de vizinhos e parentes

1998	1999

6. 2. 6 Crédito

1998	1999

6.2.6 Venda de benfeitorias

1998	1999

6.2.7 Venda de bens de consumo

1998	1999

BENS DE CASA

1 Televisor	( )	11 Moto	( )
2 Carro	( )	12 Geladeira	( )
3 Camioneta	( )	13 Maquina de costura	( )
4 Casa de alvenaria	( )	14 Fogão a gas	( )
5 Radio	( )	15 Cisterna	( )
6 Sistema do som	( )	16	( )
7 Energia dentro da casa	( )	17	( )
8 Água encanada	( )	18	( )
9 Parabólica	( )	19	( )
10 Bicicleta	( )	20	( )

XII. INFORMAÇÕES QUALITATIVAS: O ANO AGRÍCOLA DE 2000

1.0 <u>A quadra chuvosa</u>

2.0 <u>O Plantio</u>

XIII. FUNCEME

1.0 Acesso à informação

2.0 Compreensão das informações

3.0 Uso das informações

4.0 Como melhorar as informações

5.0 Tipo de medidas se houvesse informação perfeito:

Inverno chuvoso

Inverno fraco

XIV. OPINIÕES GERAIS

1.0 Se o governo/prefeitura atuou adequadamente durante os anos de 98/99 para mitigar os impactos dos invernos fracos.

2.0 Qual seria estratégia prioritária do governo/prefeitura para evitar as consequências duma crise futura?

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