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The limits of poverty reduction in support of climate change adaptation

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Abstract

The relationship between poverty and climate change vulnerability is complex and though not commensurate, the distinctions between the two are often blurred. There is widespread recognition of the need to better understand poverty-vulnerability dynamics in order to improve risk management and poverty reduction investments. This is challenging due to the latent nature of adaptive capacities, frequent lack of baseline data, and the need for high-resolution studies. Here we respond to these challenges by analyzing household-level data in Northeast Brazil to compare drought events 14 years apart. In the period between droughts, the government implemented an aggressive anti-poverty program that includes financial and human capital investments. Poverty declined significantly, but the expected reduction in vulnerability did not occur, in part because the households were not investing in risk management strategies. Our findings complement other research that shows that households make rational decisions that may not correspond with policymaker expectations. We emphasize the need for complementary investments to help channel increased household wealth into risk reduction, and to ensure that the public sector itself continues to prioritize the public functions of risk management, especially in areas where the social cost of climatic risk is high.

Introduction

Within both scholarly and development policy circles, a critical and challenging question is the extent to which poverty reduction also reduces climate vulnerability. The relationship between poverty and vulnerability is well established in the literature, particularly regarding the disproportionate way that poor individuals are likely to be affected. However, the nature of this relationship is complex: poor people are not all equally vulnerable and vulnerable people may not be poor [1]. Although climate vulnerability and poverty are conceptually distinct concepts [1, 2], these distinctions are often blurred. While decision-makers may infer that a reduction in poverty automatically leads to a reduction in vulnerability, the conflation of poverty and vulnerability can lead to the assumption that all forms of assets are equivalent and thus interchangeable in their contribution to vulnerability reduction. However, depending on socioeconomic conditions, structural factors and the specific threats an individual or household faces, different assets are likely to have different implications for vulnerability. Furthermore, between levels of wealth, combinations of assets may yield varied outcomes, both positive and negative [3, 4].

Improving the effectiveness of both risk management and poverty reduction investments requires a focus on differential vulnerabilities and capacities across levels of wealth rather than just targeting the most poor [2, 5–8]. Building adaptive capacity not only includes creating and consolidating the preconditions (assets) necessary to overcome climate and other stressors but also the ability to mobilize these assets effectively [9]. Hence, identifying pathways towards sustainable adaptation [4, 10] requires analytical focus on the dynamic relationships that link vulnerability and adaptation with development and poverty [6].

Here, we analyze poverty-vulnerability dynamics in drought-prone Northeast Brazil by comparing vulnerability across two drought events, 14 years apart, in the state of Ceará. In the period between droughts, the Brazilian government implemented an aggressive anti-poverty program that includes financial and human capital investments. Our analysis differentiates assets into two forms of capacities: generic and specific [3]. We analyze how these two forms of capacity influence levels of food security in farming households, within and between two drought years. Generic capacities are those more directly related to human development, often associated with a households' increasing ability to respond to multiple stressors, whether economic, political, social or environmental. Examples include livelihood capitals such as financial and human assets, social networks, and access to institutional programs to alleviate poverty [11]. Specific capacities concern the ability of households to respond to particular climate-related hazards such as drought or flooding. These may include early warning systems, adoption of technologies such as crop varieties, or use of climate information [3].

To disentangle the poverty-vulnerability relationship and better understand the roles that different types of capacities play in decreasing climate impact risk, we report on data collected from approximately 480 households in 1998 and 2012. We use a measure of food security from consumption-based coping strategies as concrete evidence of household vulnerability [12] and analyze changes in food security in relation to changes in generic and specific capacities.

Many empirical studies explore aggregated, national level relationships between adaptive capacity indicators and hazard outcomes to define the range of adaptive capacity determinants [13] and their relative strengths [14–16]. Our research furthers these and similar studies by (1) increasing the resolution of the unit of analysis from national to the município (a legal jurisdiction in Brazil that encompasses a town and its rural areas) and (2) analyzing how changes in adaptive capacities over time manifest in changes in drought vulnerability. Our research addresses three common challenges to measuring adaptive capacity [13, 16, 17]: the latent nature of capacities—in the sense that capacities can only be adequately measured when mobilized and evaluated against an actual threat or hazard; the lack of baseline data and inadequate metrics for many theorized determinants; and the local and place based nature of adaptive capacity, which makes generalization challenging. In the next sections, we present the results of our empirical analysis of poverty and vulnerability relationships for small-scale farmers in Ceará, Brazil.

The social and economic context

The dryland farming system in the state of Ceará, Brazil demonstrates persistent vulnerability of human systems to climate variability and change [18]. Farmers derive livelihoods from a mix of strategies, including subsistence and market-oriented agriculture, livestock production, small business, off-farm employment, a federal retirement program and more recently, conditional cash transfers under the *Bolsa Família* (Family Voucher) program. Agricultural technology is primarily manual. Maize and beans, which were household staples in this region prior to European colonization, remain the dominant subsistence crops. Historically, cattle production was a symbol of wealth and prestige, although over the last two decades livestock production shifted towards small ruminants, including goats and sheep. Off-farm income opportunities are limited, in terms of availability and wage levels. The federal retirement program (providing rural pensions) remains an economic anchor in the rural areas; for example, 35% of the households in our 2012 sample receive pensions.

The prevalence of irrigation is low, and was reported by only 23% of households in 2012. The government has invested in irrigation projects in the state, but these are limited in space and scope and have a history of failure, particularly for small-scale farmers [19]. For most farmers, irrigation is a farm-level investment. Economic constraints of drilling are compounded by the geology of the region and potable water is not always accessible. Since the early 1990s the state meteorological service provides an annual seasonal climate forecast for the upcoming agricultural campaign. The probabilistic forecasts are intended to help farmers make informed planting decisions by providing information on the likelihood of a wet, normal, or dry season. Although the forecasts are technically sound, they have had limited impact on farmer behavior due to miscommunication, mistrust, and lack of alternatives for farmers in years when droughts are likely. As a result, over 98% of the farmers in our sample report that they make planting decisions based on environmental observations rather than the state-sponsored forecasts [20]. For most, the trigger for planting is soil that is moist to a depth of 20 cm.

Since the early 2000s Brazil has invested heavily in conditional cash transfers as a way to reduce poverty, including the internationally replicated *Bolsa Família*, for which poor and extremely poor families qualify, provided their minor children are regularly vaccinated and attend school [21]. These investments are associated with greatly reduced regional poverty levels, as evident in household income and human capital, and in increased access to basic public services [22]. For example, between 2000 and 2010 the level of extreme poverty at the national level fell from 12.5% to 6.6%; poverty fell from 27.9% to 15.2%; and the percentage of adults over 18 years of age with at least eight years of schooling increased from 30.1 to 39.8 [23]. In parallel, the

Table 1. Three month standard precipitation index (February, March, April).

Município	SPI values[a]							
	1998				2012			
	JFM	FMA	MAM	AMJ	JFM	FMA	MAM	AMJ
Boa Viagem	0.118	0.221	−0.214	0.118	−0.622	−2.100	−1.517	−0.622
Guaraciaba	−0.351	−0.309	−0.523	−0.351	−1.000	−1.962	−1.902	−1.000
Itarema	0.454	0.397	0.166	0.454	−0.426	−1.516	−0.948	−0.426
Parambu	−0.071	−0.018	−0.364	−0.072	−0.787	−2.044	−1.235	−0.787
Limoeiro do Norte	−0.168	−0.671	−0.960	−0.168	−0.855	−1.857	−0.964	−0.855
Barbalha	0.496	0.627	−0.270	0.496	0.389	−0.120	−0.502	0.389

[a] Source: Grupo de Gerenciamento do Risco Climático e Sustentabilidade Hídrica/Universidade Federal do Ceará. Unpublished.

government also substantially modified its approach to drought management and response. Historically, government responses to drought in Ceará included distribution of food baskets (to address food insecurity) and enrollment in a cash-for-work program (to generate income), yet these policies were associated with clientelism and corruption [18, 24]. The new suite of policies focuses on small-scale insurance and extension (seed and animal feed distribution) and increasing capacity for household water storage, in effect transferring responsibility for responding to drought from the state to the individual households. This shift represents not only a significant change in the rationale of drought response but also suggests an assumption, evident in our interviews with policy makers that changes in development investments, aiming to increase income and improve generic capacities (education, health, pension), would result in reduced drought vulnerability.

Methods

Our aim in this study is to evaluate the implications of changes in levels and composition of adaptive capacities for managing drought vulnerability. Our analysis is based on two representative samples of rural households from six municípios. Each município represented one of six agroclimatic zones as defined at the time by the Ceará Meteorological and Water Resources Foundation (FUNCEME), which captured the spatial variability of the region's climate. In 1998, 484 face-to-face interviews were carried out with farmers whose names were randomly selected from lists provided by the local Rural Workers Unions. Because the Federal government considers membership in rural labor unions as proof of agricultural occupation—which is necessary in order to apply for a rural pension—membership rolls consistently represent the number of farmers in a region. In 2012, 480 surveys were conducted in the same six municípios, following the same procedures. In both years, semi-structured interviews were conducted with individuals related to policy development, drought responses, or public administration. Individuals included: mayors, extension workers, bank representatives, local policy makers involved with drought response and anti-poverty programs, agricultural workers, and union representatives.

Both 1997–1998 and 2011–2012 were severe drought years in the region. Table 1 provides the standard precipitation index (SPI) values for each of the six municípios, for four sets of overlapping three month periods. Unlike many parts of the world, where planting windows are narrow, planting dates in the six municípios can vary up to nearly four months (late December–March) depending on the quality of the rains [25]. The SPI values for JFM and FMA represent planting conditions and the remaining two columns, MAM and AMJ, represent later growing cycle up through harvest. Indicative of a semi-arid climate, the SPI demonstrates high spatial and temporal variability. According to meteorological measures, the drought conditions were more severe in 2012 in all six of the municípios.

We use a food security indicator as our dependent variable to measure the realization of adaptive capacity at the household level, assuming that higher or increased capacities in the face of drought would likely result in lower or decreased food insecurity. Food insecurity has been demonstrated to be a pivotal driver of extreme and undesirable forms of household response to drought events (e.g. stress migration, abandonment of household) [24, 26]. In addition, because of their responsiveness to livelihood shocks [27, 28], food-related coping strategies offer a sensitive measure of drought vulnerability. We derived our independent variable from households' descriptions of their change in food access in response to drought. These data were based on locally relevant coping strategies, and are consistent with internationally validated methods for measuring food insecurity [29]. For our analysis, coping strategies include reduced consumption either through fewer meals or smaller servings; reduced quality of the diet (e.g. stop eating meat); or the need to rely on public or private assistance to meet food needs. We considered food insecure those households that reported at least one of these coping strategies.

To test the relationship between adaptive capacity and food insecurity we applied a logistic generalized linear model, using continuous and categorical predictors that include generic and specific capacities. In the models, we test our independent variables after controlling Year (1998/2012) and Município as fixed effects to control for unobserved heterogeneity that correlated to the observed independent variables. Because the SPI values are measured at the município level, there are only six value points of SPI variable, which therefore is not included in the regression model to avoid the violation of linearity assumption. We identified 21 independent variables (13 generic capacities and eight specific capacities) to control in the models. The bivariate correlations between independent variables and dependent variable for each group are in supplement 1.

Variables were selected based on their theoretical and empirical effects on food insecurity. Households that have access to more land than they cultivated, for example, have a choice about where they are going to plant and can make decisions that incorporate soil characteristics and anticipated climate conditions. Per capita annual income variables (including rural pension, Bolsa Família, climate neutral and climate sensitive incomes, and agricultural sales) were adjusted for inflation. The inflation adjustment factor of 1.964 for 1998–2012 was based on consumer price index values from the Brazilian Geography and Statistics Institute [30]. Agriculturalists are eligible for pensions at age 55 (women) and 60 (men). The household asset index is a measure of the ownership of durable goods, such as refrigerators, radios, and various forms of transportation, along with productive agricultural assets such as cultivators and plows, and represents a wealth proxy. The index was created using weights calculated from a pairwise comparison of the relative value of each type of asset [31]. Per capita livestock assets were calculated using tropical livestock units [32] in order to normalize herd investment for comparison across time.

The model description is:

$$
\begin{aligned}
\text{Log}\left[\frac{P(\text{Being Vulnerable})}{1 - P(\text{Being Vulnerable})}\right]
&= \beta_0 + \alpha_1\text{Panel} + \alpha_2\text{Municipio} \\
&\quad + \beta_1 \text{ Household Size} \\
&\quad + \beta_2 \text{ Per Capita Pension Income} \\
&\quad + \beta_3 \text{ Per Capita Neutral Income} \\
&\quad + \beta_4 \text{ Per Capita Climate Sensitive Income} \\
&\quad + \beta_5 \text{ Receive Remittances} \\
&\quad + \beta_6 \text{ Number of Household Income Sources} \\
&\quad + \beta_7 \text{\% Adults with High School Education} \\
&\quad + \beta_8 \text{ Education Level of Household Head} \\
&\quad + \beta_9 \text{ Own Car or Motorcycle} \\
&\quad + \beta_{10} \text{ Household Asset Index} \\
&\quad + \beta_{11} \text{ Per Capita Livestock Assets} \\
&\quad + \beta_{12} \text{ Landowners} \\
&\quad + \beta_{13} \text{ Productive Asset Index} \\
&\quad + \beta_{14} \text{ Sold Agricultural Production} \\
&\quad + \beta_{15} \text{ Cultivate less land than own/access} \\
&\quad + \beta_{16} \text{ Had Irrigation} + \beta_{17} \text{ Use Tractor} \\
&\quad + \beta_{18} \text{ Crop Diversification} \\
&\quad + \beta_{19} \text{ Total Land Cultivated} \\
&\quad + \beta_{20} \text{ Total Crop loss} \\
&\quad + \beta_{21} \text{ Manioc Production} + \varepsilon
\end{aligned}
$$

where $\varepsilon \sim N(0, \sigma)$.

Results

To confirm a change in poverty levels between 1998 and 2012 in our sampled households, we carried out a series of t-tests to identify statistically significant independent variables (table 2), including income, wealth and human capital measures. The analysis shows that annual income (adjusted for inflation and including all wage labor, other off-farm sources of income, and government transfer programs) and the consumer goods index (which represents income and purchasing power) both increased. Transportation ownership, primarily motorcycles, also increased as did the percentage of adults with a high school level education. The only variable that did not increase from 1998 to 2012 was the measure of livestock assets. Key informant interviews in all six of the municípios suggest that decrease in livestock assets is less a question of income constraints than a response to the levels of theft of livestock that occur as better roads increase access to once remote herds. Finally, although income has increased substantially, the distribution of income within the sample population remains similar between years. Table 3 shows that the proportion of total income for each of the quintiles has changed minimally. The percentage value of the increase in income for the lowest quintile is relatively larger than for the other groups, which is an expected outcome of the poverty reduction programs.

Contrary to expectations, food insecurity for the entire sample was considerably higher in 2012 (35%) than 1998 (22%). The strongest predictors of vulnerability are the asset index ($B = -2.542$, p-value $= 0.007$), which is a proxy for wealth, and access to irrigation, which increased from 17% in 1998 to 24% in 2012 ($B = -0.755$, p-value $= 0.026$) (table 4). Surprisingly, neither of the two education variables (% of adults with high school education and level of education of household head) was statistically significant. The additional generic capacities of per capita livestock assets and percent of household income from the government pension are both negatively correlated with vulnerability. The significant specific capacities include the amount of land cultivated, whether a household had access to more land than was being cultivated, and whether households were planting manioc, a highly drought-tolerant staple, in addition to other crops. The percentage of households planting manioc increased from 15% to 43% in 2012. To test the specific role of irrigation in reducing vulnerability, we introduced an interaction term (year*irrigation) in the model; we find that the association between use of irrigation and drought vulnerability in 1998 and 2012 are different significantly

Table 2. Changes in poverty-related adaptive capacities.

	Mean value		
Variable	1998	2012	p-value
Per capita annual income	R$668[a]	R$1501	0.000
Per capita livestock assets	3.9	3.5	0.563
Transportation ownership	24%	61%	0.000
Consumer goods index	0.02	0.24	0.000
Proportion adults with high school degree	4%	15%	0.000

[a] In June, 2012, the Brazilian Real was worth approximately .49 US dollars.

Table 3. Distribution of per capita adjusted income and total income by quintiles.

	1998		2012	
Quintile	% of sample income	Total income (R$)	% of sample income	Total income (R$)
1	1.1	2780	2.1	12 041
2	7.2	18 386	7.2	40 965
3	14.2	35 966	14.9	85 456
4	26.3	66 683	26.6	152 093
5	47.8	121 225	49.3	282 114

($B = 1.076$, p-value $= 0.035$). In 1998, the role of irrigation in explaining drought vulnerability was negligible. In 2012, however, households using irrigation were much less likely to be vulnerable than those not using irrigation. The município coefficients are in relation to the reference município of Guaraciaba do Norte. Barbalha and Limoeiro do Norte, which are less likely to be food insecure than Guaraciaba do Norte, are the two municípios with higher overall human development indicators and are closer to many public services, such as hospitals and institutes of higher education. They are also the two municípios with highest rates of irrigation due to the proximity of a perennial river in Limoeiro do Norte and natural springs and seepage in Barbalha.

Discussion

Drought vulnerability remains prevalent in the research area. Increases in income were not sufficient to offset the 2012 drought. Despite reductions of multiple poverty indicators, food insecurity for the entire sample was higher in response to the 2012 than the 1998 drought. The severity of drought in 2012 was greater than 1998, but the reductions in poverty measured by wealth, income, and education were significant and substantial. Our findings indicate that investments in poverty reduction alone had limited success in reducing vulnerability to drought. A universal challenge for social protection programs, such as poverty alleviation, is not only to reduce chronic poverty but also to protect populations from stochastic shocks (Slater and McCord 2007). This becomes particularly relevant if the government retreats from offering direct risk management programs and services and instead relies on anti-poverty interventions to reduce vulnerability.

Table 4. Logistic generalized linear model outputs[a].

Variable	Coefficient	Std. error	P-Value
Year			
1998	−1.609	0.3419	<0.001
2012	Ref		
Municípios			
Limoeiro do Norte	−0.970	0.3452	0.005*
Barbalha	−1.244	0.3007	0.000*
Parambu	−0.203	0.2855	0.477
Boa Viagem	0.541	0.2768	0.051**
Itarema	−0.497	0.2774	0.073**
Guaraciaba do Norte	Ref		
Generic capacities			
Per capita livestock assets	−0.041	0.0219	0.064**
Percent income from pension	−0.009	0.0022	<0.001*
Asset index	−2.542	0.9402	0.007*
Specific capacities			
Land cultivated (Ha)	−0.059	0.0300	0.049*
Cultivate less land than own/access	−0.388	0.1849	0.036*
Cultivate manioc	−0.362	0.1974	0.067**
Irrigation	−0.755	0.3392	0.026*
Interaction			
Year*Irrigation	1.076	0.5105	0.035*

*Significant at $p < 0.05$; **Significant at $p < 0.10$.

[a] Here we present only the final model. The full model includes all the variables listed in the bivariate correlation table in the supplementary material. None of the variables that we removed were statistically significant.

The fact that increases in wealth may not automatically result in comparable improvements in specific capacities is evident in our results: increased household income was not associated with evidence of similar increases in *household-level* investment in specific capacities for risk management. In other work, we demonstrate the positive correlation between irrigation and food security [33]. Despite this, access to irrigation increased from 17% to only 24% over 14 years. To address differential water availability across the state, a number of NGOs and state initiatives train farmers and offer irrigation with appropriate technology, but uptake is slow. There is also a decline in the average amount of land cultivated by a household (4.4 ha to 3.5 ha) and although more households now have access to more land than they cultivate (37% in 1998 and 53% in 2012) this appears to be offset by the reduced amount of land under cultivation. Even with increased and more stable income, many farmers in our sample appear to continue to cope with, rather than adapt to, climate extremes. Thus, rather than a natural outcome of higher income, adaptation may require that households make specific decisions to invest their additional wealth in risk reduction. Given the multiple and competing welfare needs of poor households, this process of translation and decision-making may not occur in the absence of institutional incentives and public sector support [8, 12].

In our study region, interviews with state and local policy makers indicate a shift in the locus of responsibility for managing climate risks. Previously, state interventions (work fronts and food baskets) mitigated the most severe drought impacts. After implementation of *Bolsa Familia* and other poverty reduction investments, these emergency programs were progressively phased out, and the *de facto* responsibility for managing drought risk has been largely transferred to the household. This shift in the nature of state support may help explain why households in 2012 experienced higher aggregate levels of vulnerability compared to 1998, despite the significant decrease in poverty. One plausible explanation for this unexpected outcome was that households did not have the support structure to make the investments in longer-term risk management strategies that might have at least partially compensated for the absence of explicit food distribution programs in 2012. This possibility is supported by research that indicates that social protection programs, such as *Bolsa Família*, are most successful in situations when they are accompanied by programs that enhance economic growth, which is not the case in rural Ceará [34]. Furthermore, lack of an accompanying change in social and political access, which are critical to poverty reduction efforts [35], may also mitigate the impacts of the social protection investments on drought vulnerability.

The data demonstrate a number of changes in household adaptive strategies between the two sample years. Indebtedness, for example, increased from 21% of households in 1998 to 44% in 2012. Although not a statistically significant factor in our modeling exercise, debt load does limit the resources available for risk reduction investments. The percentage of households with at least one member living elsewhere as a migrant dropped from 36% to 26% and prevalence of remittances from 26% to 16%. In 2012, 38% of the households were enrolled in the insurance plan. At the time of the survey, which was directly following the harvest, none of the farmers had yet received any insurance payout. One positive change was the substantial increase in the prevalence of manioc cultivation. Although this may indicate some level of purposeful change in adaptive investments, the low number of producers in 1997 was an aberration due to the local unavailability of woody cuttings for planting.

Our local-level analysis contributes to a growing exploration of the links between poverty and vulnerability and how these change over time. Unique to our study is the ability to look at the relationship of poverty and vulnerability within a given year and to analyze the ways in which changes in poverty are reflected in changes in vulnerability at different points in time. Within each of the years poverty is positively correlated with vulnerability. However, the substantial decreases in poverty between 1998 and 2012 are not sufficient to reduce the vulnerability of the population to drought. Our analysis offers the opportunity to look at capacities in relation to particular events and measure vulnerability in a more nuanced manner. We find that the most significant predictors of change in vulnerability are those that are specific to drought events including irrigation, land access, crop diversification, and the access to government pensions.

Conclusion

Our analysis robustly shows that the relative role of poverty reduction and specific capacity improvements in vulnerability reduction is dynamic. Which type of capacity is prioritized for intervention must be understood in relation to the initial conditions of the vulnerable population. Further insight is needed to enhance our understanding of the mechanisms by which changes in generic capacities and endowments, such as reduced poverty, are reflected in changes in risk management. Additional empirical research is needed to explore the possibility that there may be thresholds at which the synergistic effects of generic and specific capacity improvements are optimized.

These findings complement research in poverty studies that find that households make rational decisions that may not correspond with what policy-makers desire or expect—such as investments in long-term risk reduction [8, 36, 37]. In order to understand these results, we emphasize the conceptual separation of generic adaptive capacities, such as wealth and education, from those capacities specific to climate risk management. Linking household risk management to the institutional context for adaptation remains critical, especially as governments in less developed regions of the world mainstream adaptation policy in their development actions. Even as generic capacities improve, there is a need for complementary investments from the public sector to help channel increased household wealth into risk reduction and to ensure that the public sector itself continues to prioritize the public functions of risk management, especially in areas where the social cost of climatic risk is high.

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