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Linking development to climate adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil

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ABSTRACT

To respond to climate impact, poor agricultural households in less developed regions rely on different types of assets that define their overall adaptive capacity (AC). However not all assets build capacity equally. In this study we argue that building AC requires a combination of interventions that address not only climate-related risks (specific capacity) but also the structural deficits (e.g., lack of income, education, health, political power) (generic capacity) that shape vulnerability. Focusing on rainfed agriculture in NE Brazil, we investigate how households leverage and combine generic and specific capacities to reduce vulnerability. Particularly we explore: 1) the relative importance of different kinds of capacity in shaping vulnerability on these households and 2) how the level of generic capacities (particularly as a result of Brazil's anti-poverty program *Bolsa Família*) influences the adoption of specific ones. We find that both kinds of capacity matter, as relatively higher levels of generic capacity (in terms of income in general, and climate-neutral income specifically) are associated with higher levels of specific capacity (irrigation). In addition we find that while *Bolsa Família* has been positive in increasing income, it has not been sufficient to manage the risk of food insecurity during drought events, suggesting a 'poverty trap' in which families are constantly coping with drought but failing to overcome the conditions that make them vulnerable. Our findings indicate that in order to decrease climate vulnerability of poor agricultural households, development interventions, such as anti-poverty programs, have to go beyond cash transfer and should incorporate risk management policies that enhance synergies between generic and specific capacities.

1. Introduction

In order to effectively respond to increasingly severe climatic hazards and other stressors, social systems will have to significantly increase their capacity to prepare and recover, that is, they will have to build their adaptive capacity (AC). In practice, especially in less developed regions, developing and building AC requires a combination of interventions that addresses not only climate-related risks but also the structural deficits (e.g. lack of income, education, health, political power) that shape vulnerability (Eriksen and O'Brien, 2007; Burch and Robinson, 2007; Lemos et al., 2007). Yet, despite much attention paid to climate vulnerability and poverty (Olsson et al., 2014), the relationship between building AC, development policy (especially anti-poverty programs) and climate risk management has remained critically under-theorized and studied (Denton et al., 2014). One problem is the difficulty that scholars encounter in accounting for AC, which is at the same time challenging to assess and only truly defined post-impact (Engle, 2011).

Early on, the AC literature highlighted the role of different kinds of *determinants* (e.g. financial, human, social, technological, political resources) for increasing the ability of different groups exposed to climate-related impact to prepare, respond and recover

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(Smit and Wandel, 2006). But the high level of generality of these determinants rendered them virtually useless for defining specific policies to increase AC to climate impacts (Eakin and Lemos, 2006). One way to start addressing this issue is to think of how different types of capacities influence the management of risk at different scales. While recognizing that AC is a dynamic concept, influenced by decisions made in the past with respect to future risk and uncertainty (Eakin and Bojorquez-Tapia, 2008; Vincent, 2007), for analytical purposes, we define specific capacities as manifestations of the ability to respond to and manage an identified climate hazard (e.g., drought emergency response plans, hurricane warning systems, climate forecasting, design and construction of protective infrastructure such as irrigation and public works such as reservoirs). In contrast, generic capacities refer to the ability to respond to more general social, economic, political and ecological stressors (e.g., income, access to education and health, physical assets, social capital). Elsewhere we have argued that there is an explicit relationship between generic and specific capacities that needs to be explored empirically (Eakin et al., 2014). We proposed a two-way relationship in which, on the one hand, a minimum of generic capacity might be necessary to support risk management (specific capacity), and on the other, if levels of generic capacity were too low, systems could be trapped in a vicious cycle of exposure, sensitivity and coping (Lemos et al., 2013).

In this article we investigate how these two kinds of adaptive capacity—generic and specific, influence the overall vulnerability of subsistence rainfed agriculture households in NE Brazil. Specifically, we seek to understand: 1) the relative importance of different kinds of capacity in shaping vulnerability on these households and 2) how the level of generic capacities influences the building and deployment of specific capacities. To explore these questions, we surveyed 476 households in 2012, a year of severe drought, in six municípios in the state of Ceará to query both about their different livelihood capitals and access to risk management resources. We then categorized these data into generic and specific capacities at the household level and regressed them against food security as a proxy for vulnerability under conditions of drought. In the next sections we describe our research methods, study sites and policy background to our study. Then we present our statistical analysis and explore our findings, paying special attention to the synergies and potential trade-offs of different combinations of generic and specific capacities in the context of drought impact.

2. Adaptive capacity, livelihoods and poverty

Policy aiming to reduce vulnerability must be based on a solid understanding of what motivates and constrains human capacity for adaptation (Adger et al., 2009; Ford et al., 2008); livelihood analysis provides a pragmatic approach to assessing capacities. Drawing from Sen's (1981) entitlement theory, sustainable livelihood research (Scoones, 1998; Carney et al., 1999) addresses the relationships among a household's resource base (assets), its entitlements (the institutional context affecting rights and access to resources), and the result of these activities for aggregate household welfare (outcomes). Poor households can be conceived as those with limited assets and constrained access to the entitlements that can enable them to mobilize what assets they have to enhance their welfare through, for example, market transactions or social interactions. Poverty alleviation programs are thus often designed to enhance and protect the asset base of the poor (through, for example, wealth transfer programs, nutrition programs and other safety nets) as well as to improve their capacity to mobilize assets by conditioning wealth transfers on household investments in education and health (Craig and Porter, 2005; Green and Hulme, 2005; Caldés et al., 2005).

Because the rural poor are also populations that tend to be dependent on natural resources for their livelihoods, they are particularly sensitive to climatic shocks and stress affecting the productivity of those resources (Bebbington, 1999). Given these constraints, the poor are widely perceived to be relatively more sensitive to climate change: the resources on which they depend are particularly sensitive, and their constrained asset base and lack of entitlements limit their capacity to adapt (Eakin et al., 2014; Olsson et al., 2014; Siegel and Alwang, 1999). Thus it would seem logical that investments in poverty alleviation may well directly or indirectly enhance adaptive capacity in the face of climatic shocks and stress (Huq et al., 2005; Agrawal and Lemos, 2015).

Rural household capacity attributes can be categorized into five classes of livelihood capital: human capital (education, health, attitudes, belief systems); natural capital (soil quality, water endowments); physical capital (equipment, transport); social capital (connectivity in social-political networks); and financial capital/production (monetary savings, income composition) (Bebbington, 1999). In principle, these capitals form the basis of households' ability to manage risk, respond to economic opportunities and adapt to multiple forms of stress, including those associated with climate variability and change (Bebbington, 1999; Yohe and Tol, 2002; Brooks et al., 2005). Nevertheless, the relationship among forms of assets held by households and the contribution of these assets to a households' ability to manage poverty and climate stress is still poorly defined, in part because these relationships are likely to be geographically and temporally specific (Lemos et al., 2013). For example, climate change adaptation recommendations for rural areas have tended to focus on technological improvements such as irrigation or improved seed varieties as means of managing climatic risk (e.g., Reilly and Schimmelpfennig, 1999) and recently technological packages promise "climate smart" results (see FAO, 2013). Moreover, engaging in such strategies typically requires "lumpy" investments with significant capital outlay (Dercon, 1998), thus presupposing the existence of some level of assets and entitlements that enable the management of the specific threat of climatic risk. Without a degree of stability and security in, for example, natural or financial capital, an asset-poor household may view the potential losses associated with a failed adaptation as greater than the more familiar loss associated with *not* adapting (Eakin, 2006, 2005). And although impoverished and vulnerable households may effectively cope with some level of climatic and other kinds of resource variability autonomously – through, for example, risk pooling strategies or income diversification – these strategies can come at the expense of investing in their future through human capital formation (education), or material and financial capital accumulation (infrastructure and savings) (Eakin et al., 2014). As a result, such households may not have the ability to transform their circumstances in response to unprecedented socioenvironmental change, falling into a virtual 'trap' of stress and coping from which it is very hard to get out (Maru et al., 2012; Barrett and Swallow, 2006).

In this analysis we focus on the tension between the forms of assets and entitlements that enable households to invest constructively in their future well-being and welfare, irrespective of the nature of the future challenges they face (generic capacities) and the forms of assets and entitlements that specifically address climatic risk (specific capacities). We argue that building adaptive capacity is a dialectic, two-tiered process in which climatic risk management (affecting specific AC) and deeper level socioeconomic and political reform (affecting generic AC) iterate to shape overall vulnerability (Lemos et al., 2013). On the one hand, the development of specific adaptive capacities alone will have limited success in reducing overall vulnerability, and concurrent investment needs to be made in more general adaptive capacities to promote more successful adaptations. On the other hand, by increasing households' overall adaptive capacity, anti-poverty programs (especially those that couple with education programs) may positively influence their ability to better take advantage of risk management mechanisms (e.g. access to social programs and insurance, identification of effective drought response). Yet, research focusing on anti-poverty (especially cash transfers) programs shows that in order for these interventions to have longer-term impact they need to be carefully designed and include specific actions to maximize results. For example, a recent study using a longitudinal experimental design with a sample of over 10,000 poor households in six countries by Banerjee et al. (2015) robustly shows that anti-poverty programs are significantly more effective if deployed with training and support, including life skills coaching, cash consumption support, access to savings and health information and services.

Empirically, the distinction between generic and specific adaptive capacities has received little attention despite widespread recognition of its critical implications for policy design and choice. At its root, the policy conundrum is whether building specific capacities to manage climatic risk should be prioritized over other investments designed to tackle the generic conditions of underdevelopment, inequality and poverty (Lemos and Boyd, 2009). Some scholars, for example, argue that the concept of generic adaptive capacity can only take us so far as some variables are not generalizable between different stresses and systems (Adger et al., 2005); others suggest that the prospect of adaptive capacity across a range of stresses is essentially a myth (Tol and Yohe, 2007).

3. Data and methods

We collected survey data in six *municípios*, sampled as part of a broader longitudinal study comparing drought vulnerability and responses during two drought events (1998 and 2012) in the state of Ceará. The sites were selected to represent each of the six agroclimatic zones in the state defined by the Ceará State Meteorology Agency (FUNCEME) through a combination of temperature, elevation, quantity and timing of the onset of rains, and soil characteristics. Fig. 1 shows the map of the state of Ceará with the sampled *municípios*. Fig. 2 illustrates our sites drought conditions by showing the rainfall deficit across our *municípios* in 2012 relative to each region's mean historical rainfall from 1912 to 2012. We used IBM SPSS 22 to organize and analyze the data.

The sample was stratified by biophysical characteristics in order to capture the range of rainfall variation in the state, which in our research design serves as the indicator of the natural event to which individuals are vulnerable. A randomized sample of the rural population in each *município* (~80 households per *município* for a total of 476 households) was identified and surveyed, face-to-face, in Portuguese, in the summer of 2012. Data were collected during the months of June and July, directly following the harvest season for subsistence crops. In addition to the household surveys, we carried out key informant interviews with policy-makers responsible for drought response and anti-poverty programs in different sectors in each *município*. Although unplanned, the field data collection coincided with a severe drought event and the research team witnessed first hand the devastation and level of response of many of the sampled households.

4. NE Brazil, *Bolsa Família* and responding to drought

NE Brazil encompasses 18% of the national territory and one-third of the country's population. It is divided into nine states that constitute the vast majority of the infamous "drought polygon," a particularly vulnerable region that has recorded periodic climate-related crises ever since the arrival of Europeans 500 hundred years ago (Aguiar, 1983). In this study we focus in the state of Ceará, one of the poorest in the region and whose territory mostly (94%) sits in a semi-arid region. The combination of highly variable rainfall patterns, scarce groundwater, historical lack of perennial rivers, and high evapotranspiration rates make the pursuit of rainfed agriculture difficult. Although the state has experienced significant urbanization during the last 40 years, over two million people still live in rural areas. Despite the well-documented difficulty of practicing rainfed agriculture in the region (Nelson,

Fig. 1. Map of Ceará with the sampled *municípios*.

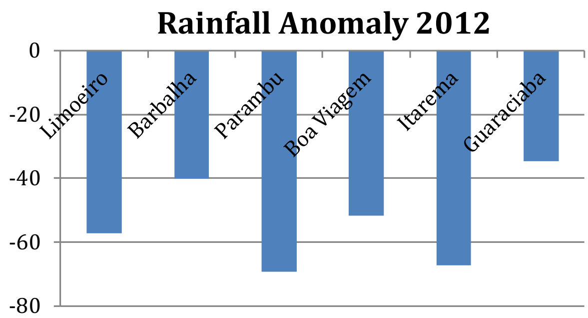

Fig. 2. 2012 Rainfall Anomaly Relative to Mean Rainfall (1912–2012).

2005; Lindoso et al., 2014 Lindoso et al., 2014), a large (and mostly poor) portion of the population still depends on subsistence agriculture. One indicator of the precarious and marginal nature of the agricultural system is that while agriculture represents only 5% of the state's GDP, nearly 30% of the economically active population still depends on farming for their livelihoods (Araujo and Falcão, 2004). Climate projections for the region suggest increased aridity as a result of increasing temperatures and, as a result, higher levels of evapotranspiration (Ambrizzi et al., 2007; Marengo, 2007). According to several climate change scenarios in which El Niño-like mean conditions are expected, NE Brazil will become drier and likely more exposed to extreme events with potential negative outcomes to food production and poverty (Barbieri et al., 2010; PBMC, 2014). In addition, models predict a relationship between changes in precipitation and availability of water resources, with some scenarios (dry) projecting river runoff decreases by twice the level of precipitation change (Krol and Bronstert, 2007).

4.1. Developing specific adaptive capacities

The history of responding to drought in NE Brazil had many phases but in all of them there has been the common belief among decision-makers that it was possible to develop specific capacities to respond to drought. Until the late 1980s the main focus of drought policy was the construction of public works (water canals and reservoirs) to move, capture and store water (for a detailed description see Magalhães and Neto, 1991). A second area of public policy revolved around mitigating the human impacts of drought events. Responses included distribution of food baskets, the provision of drinking water to communities, and the creation of public cash-for-work programs. While these activities alleviated immediate hardship, they also contributed to the perpetuation of a cycle of clientelistic politics that characterizes the history of drought response in the state (Nelson and Finan, 2007; Lemos and Tompkins, 2008). More recently the government has created a series of programs to increase the specific capacity of subsistence agriculture farmers to prepare and respond to drought and aiming to replace more traditional subsidies such as cash-for-work programs and food basket distribution (Eakin et al., 2014; Lemos and Tompkins, 2008). These include a seed distribution program, micro insurance and subsidized feed for livestock.

For our households two risk management strategies (specific capacities) are the most relevant in mediating their risk. The first strategy is a state-sponsored micro insurance program (*Garantia Safra)* that is available for farming households with monthly income of less than or equal to 1.5 minimum wage (around US$370 in 2015). Farmers must buy into the system through purchase of a small monthly premium (around 1–2% of the value of the insurance). The total amount each household can receive per year is R$816 (around US$270 in 2015). In the models presented below, this program is represented by the variable "insurance". The second strategy is access to irrigation. The scale and dependability of the irrigation options varies considerably among the households in our sample. A majority of the households take advantage of nearby surface water, such as reservoirs, which are spaced irregularly across the region. These systems are not capital intensive and less dependable in terms of water availability because water levels diminish rapidly following the rainy season even in years of normal rainfall. Wells, the most dependable source of irrigation outside a government established irrigation perimeter, are capital intensive and are only feasible in certain areas because much of the region's groundwater is too saline for crop production. Table 1 displays the frequency of each type of irrigation per *município* in the sampled households.

4.2. Developing generic adaptive capacities—anti-poverty programs

For the past ten years, Brazil has implemented a rapid expansion of social spending under a cash transfer program called *Bolsa Família*. The primary component of this policy is a series of conditional cash transfers (CCTs) that distribute funds to households that meet certain criteria (being below a certain income level and having school-age children) and meet a few conditions (carrying out child vaccination and prenatal care and documenting school attendance). Overall, the program benefits families in extreme and moderate poverty (with monthly incomes below R $77 and R$154–respectively, around US$ 23 and US$45 in 2015), with monthly cash transfers between R$35 and R$77 (around US $10 and US$23 in 2015) (MDS, 2014) with most families receiving an average of R$167 (US$50 in 2015) (MDS, 2014). In December 2008, almost 900,000 families in Ceará (44%) received income through the program, with a total value of R$77 M (US$44 M) per month (Barros et al., 2010). This cash transfer accounts for 25% of household income in Ceará, which is the fourth highest percentage among all Brazilian states (Barros et al., 2010; IPECE, 2013). By investing in education, health and income, *Bolsa Família* builds poor household' level of generic capacity.

A second cash based program, rural pension, has been developed by the Brazilian government in the early 1990s. All rural workers are eligible for pension when they reach 60 (for males) and 55 (for females) provided they can show they have worked as a rural laborer for 15 years and are associated with a

Table 1
Frequency of different types of Irrigation per *município*.

	Limoeiro do Norte n (%)	Barbalha n (%)	Parambu n (%)	Boa Viagem n (%)	Itarema n (%)	Guaraciaba do Norte n (%)	Total n (%)
No Irrigation	23 (4.9)	59 (12.6)	78 (16.7)	71 (15.2)	72 (15.4)	53 (11.3)	356 (76.1)
Surface water	21 (4.2)	11 (2.4)	1 (0.2)	4 (0.9)	4 (0.9)	19 (4.1)	60 (12.8)
Wells	30 (6.4)	10 (2.1)	0 (0)	4 (0.9)	3 (0.6)	5 (1.1)	52 (11.1)
Total n (%)	74 (15.8)	80 (17.1)	79 (16.9)	79 (16.9)	79 (16.9)	77 (16.5)	468 (100)

rural labor union or association, irrespective of having contributed to the social security system before. The program benefits both those who worked as wage laborers and those who worked in their own land. Households that receive rural pension do not qualify to receive *Bolsa Família*; all households qualify for small crop insurance, provided they do not exceed a certain income and property size.

Although both programs transfer funds and seek to address abject poverty overall, they are fundamentally distinct regarding their target beneficiaries and transformational goals. While the pension program is a safety-net for individuals at retirement age and beyond, *Bolsa Família* is designed to meet short term income needs and promote transformational change by focusing on both the education and health of young Brazilians with the goal of eliminating hunger and extreme poverty over the long run. In the past few years, both programs have been lauded for their role in decreasing poverty rates and increasing the level of human development of poor households (PNUD, 2014); yet there is relatively little evidence of how these changes, and the government programs that produced them, might have affected recipients' vulnerability to climate-driven events.

In Ceará, both *Bolsa Família* and rural pension have broad implications for rural agricultural households vulnerable to climatic shocks and fluctuating income stream since monthly cash transfers may provide fungible income that can supplement farm income, buffer against crop failures, and smooth household consumption. In the case of *Bolsa Família*, while this additional income may have immediate effects, the investment in human capital (especially through education) may also have an impact on future vulnerability and rural demographics.

4.3. Household livelihoods

The farm households in our sample build livelihoods and develop strategies within relatively constrained social, economic, and environmental opportunities. While it is true that the recent anti-poverty programs significantly improved indicators for generic capacity, including those such as education, health and extreme poverty, the Northeast region continues to demonstrate marked differences in development achievements compared with Southern and Southeastern Brazil. In the sample, rates of high school graduation, even for the recent cohorts that benefited from *Bolsa Família*, remain under 40%. Fewer than half the households reported non-agricultural off-farm employment income, and for those that did, 75% earned less than R$6000 per year (around US $1764 in 2015) from this source. Federal social protection programs, including *Bolsa Família* and the pension program, were the largest sources of cash income for the sample population and contributed 48% of total reported income for the 12 months preceding the survey. The pension program is the backbone of the rural economy and recipients draw a pension equal in value to the minimum monthly salary, a value of R$622 (US$183 in 2015). Forty-four percent of all households include at least one pensioner, and more than half of these include two or more pensioners. Fifty-five percent of the sample received *Bolsa Família*, though the monetary value is significantly less (mean value is R$130 or US$38 per month in 2015) than that of a pension.

Smallholder agriculture remains a fundamental component of livelihoods in the region. Although agricultural sales in 2012 represented only 13% of total reported income, households also consume production, primarily beans and maize. Most farmers plant a range of selected cultivars that will produce in both dry and wet conditions and similarly diversify their crop choices. Farmers in the region grow a range of regional staples including manioc, cotton, perennial and annual fruits, horticultural products, and other cash crops. Where possible, farmers plant in different physical locations to take advantage of variation in slope and soil characteristics. Only 112 out of 476 households (under 24%) of the sample irrigate some or all of their production.

4.4. Understanding differential capacities and food security

We focus on the contributions of generic and specific capacities in ameliorating food insecurity associated with drought conditions as a proxy measure of household vulnerability. While we focus on household responses in a particular moment in time, these responses can be interpreted as temporal manifestations of accumulated capacities. Specifically, food security is a fundamental livelihood outcome and a household's ability to realize food security at any moment is largely a function of "stores" of generic and specific capacities. Research suggests that some of the first coping strategies that households implement are food related. Reductions in food intake and dietary diversity are indications that a household is unable to deal with ongoing or punctuated stress. Due to this sensitivity to livelihood stress, food security indicators are thus strong proxies for high vulnerability and low levels of adaptive capacity. For many years, indicators estimated caloric intake, though research shows that they are not always predictive of food security outcomes (Coates et al., 2003). Other approaches to assess food security have focused on its cultural and experiential aspects to understand its relationships to vulnerability (Webb et al., 2006).

We operationalized our dependent variable as food insecurity outcomes associated with drought by using responses to a series of nine questions adapted from the Household Food Insecurity Access Scale (HFIAS) from the US Agency for International Development (USAID). This scale was designed to measure food insecurity in multiple cultural contexts and has been previously tested and calibrated for use in Brazil (Segall Corrêa et al., 2003). Each question queries whether or not a household member experienced a particular manifestation of food insecurity, such as reduced dietary diversity. We assigned a value of 1 for each positive response and used a sum of the scores to measure the presence and relative magnitude of food insecurity. The scale ranges from 0 (food secure) to 9 (most food insecure).

To understand the relative role of generic and specific capacities in the vulnerability of our households we divided our variables across these two broad categories of capacity. To measure specific capacity, we asked households whether they had an irrigation system in their farms (either from natural or well sources) and whether they participated in the small crop insurance program. For specific capacity, we considered four combinations: 1) households with no insurance and no irrigation; 2) households with irrigation only; 3) households with insurance only; and 4) households with insurance and irrigation. We then assessed food insecurity (Fig. 3) and total household annual income (Fig. 4) across these four combinations of specific capacities, both for all households and for those households that do not receive pension. Dividing our sample this way enabled us to evaluate specific and generic capacities in relation to two very different baseline levels of income with potentially different impact in terms of future generations. Pension-receiving households have substantially more income than those who do not receive pensions; *Bolsa Família*, as an anti-poverty program, is oriented to low income households (who generally do not have access to pension income) and is expected to have transformational impacts on poor livelihoods.

Next, to examine the relative role of different capacities in influencing vulnerability we regressed different types of generic and specific capacities against households' food insecurity (Table 3 below). In this step of the analysis, we focused exclusively on the poorest households: those without pension income (248 households across the whole sample). This focus allowed us to

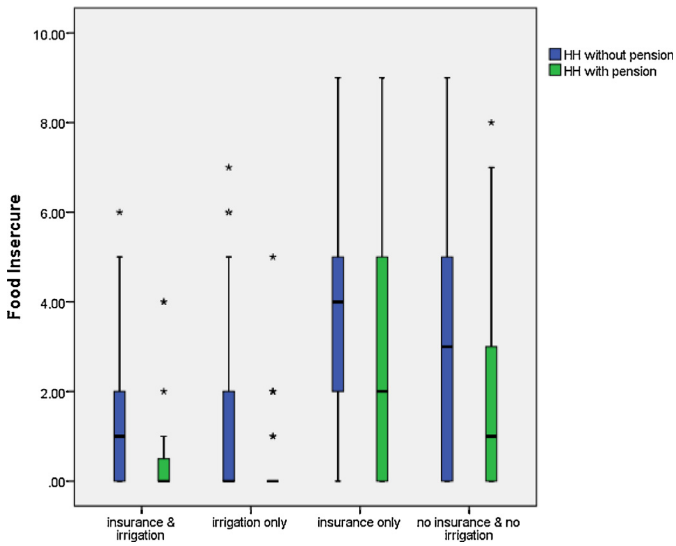

Fig. 3. Boxplots of food insecurity for households with and without pension by specific capacity combinations.

understand the relative role of generic and specific capacities for the most impoverished households. For generic capacity we used several variables including level of education of head of household, indices of farm equipment ownership and use of agricultural technology, and soil quality of their farmland. Household annual income variables (climate sensitive agricultural labor, climate neutral salary work, non-agricultural labor, and *Bolsa família* income) were other indicators of generic capacity. The dummy variables of irrigation and insurance as indicators of specific capacity were also included in the model.

Our analysis explored two hypotheses:

H1. Different combinations of generic and specific capacities may lead to differential outcomes in terms of vulnerability to drought, as measured through food security.

H2. There is a positive relationship between generic and specific capacities in reducing vulnerability in that households need some level of generic capacity to be able to manage drought risk.

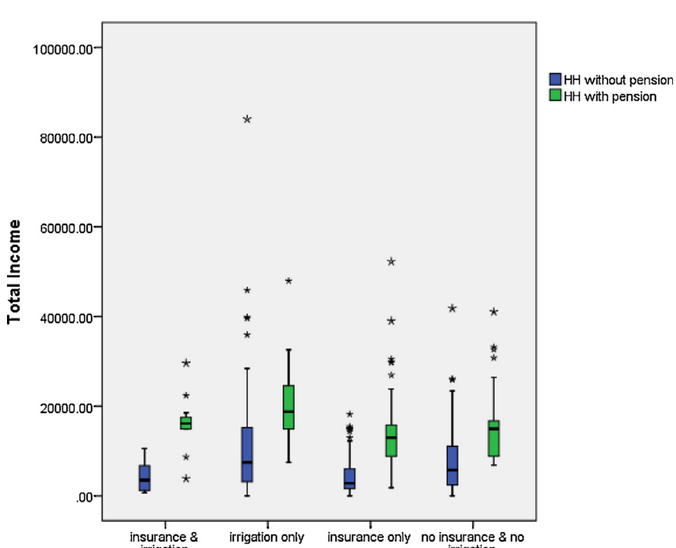

Fig. 4. Boxplots of total income for households with and without pension by specific capacity combinations (income data in Brazilian Real).

5. Results

5.1. Specific capacity and food insecurity

Across the whole sample (both pension-receiving households and non-pension households), irrigation was negatively and significantly associated with food insecurity. In other words, households with both insurance and irrigation, and households with irrigation alone, were comparatively more likely to be food secure than both households with no insurance and no irrigation and households with insurance alone (Fig. 3). Households with irrigation also tended to have higher incomes for both pension-receiving households and non-pension households (Fig. 4), suggesting higher levels of generic capacity. Overall we found that the mean values of food insecurity for pension-receiving households were substantially smaller than for those without pensions across all four specific capacity combinations (Fig. 3). Moreover, the average income values of pension-receiving households were all higher than non-pension households across the four specific capacity combinations (Fig. 4). Examination of the subset of households without pension income further confirms the observed relationships: even in these relatively poorer households, those with both insurance and irrigation and households with irrigation alone tended to be less food insecure than the other two categories of households (blue boxplots in Fig. 3).

To further explore the relationship between generic capacities and food insecurity, we categorized households' total annual income into eight ordinal categories and calculated the mean values of each category of food insecurity for each group (Fig. 5). On the one hand, the chart suggests that the income interval from R $20,000–25,000 (around US$6600–8300 in 2015) may represent a threshold in terms of a minimum necessary level of generic capacity among all households sampled as the overall level of food insecurity is relatively lower and the maximum level food insecurity value drops from 9 to 6. On the other hand, the mean value of food insecurity drops the most for the income interval between $10,000- US$15,000 (around US$3300- US$5000 in 2015), suggesting that to achieve food security goals, cash transfers that raise average incomes may do the most good to households below this income category.

To control for the effect of the pension on households' capacities, we then conducted an Analysis of Variance (ANOVA) on the subset of households without access to pension income. We evaluated differences in the values of generic capacity indicators and in food security outcomes across the four categories of households defined by their level of specific capacity (irrigation and insurance). The results are shown in Table 2. Consistent with the boxplots, households with both insurance and irrigation, and with irrigation only, had significantly lower values of food insecurity. Among the generic capacity variables, climate-neutral income was significantly less among those households with insurance only. Climate-sensitive income and *Bolsa Família* income

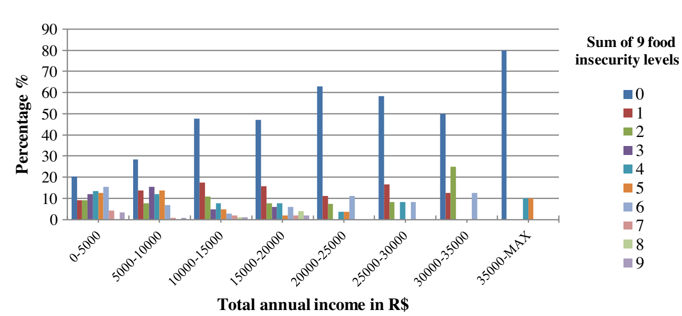

Fig. 5. Level of Food Insecurity by Income categories (income data in Brazilian Real).

Table 2
ANOVA.

Variable	No Insurance and No Irrigation (n = 75) Mean (SD)	Irrigation only (n = 29) Mean (SD)	Insurance only (n = 84) Mean (SD)	Insurance and Irrigation (n = 17) Mean (SD)	F-test (*p*-value)
Food Insecure	3.04 (2.40)	1.62 (2.14)	3.92 (2.28)	1.41 (1.77)	10.83 (<0.001)
Generic Capacity					
Climate Neutral Income	2826,25 (3228.22)	2934.34 (3290.02)	1267.16 (2305.06)	2013.28 (3289.27)	4.68 (0.004)
Climate Sensitive Income	584.47 (1354.75)	706.21 (1790.72)	604.09 (1475.90)	1029.71 (1926.95)	0.49 (0.687)
Bolsa Família Income	1288.24 (921.23)	1166.69 (853.67)	1458.72 (758.09)	1505.65 (1671.82)	1.01 (0.392)
Education[a]	2.51 (1.49)	3.17 (1.87)	2.19 (1.21)	2.59 (1.37)	3.43 (0.018)
Had Saving Account[b]	0.17 (0.38)	0.38 (0.49)	0.10 (0.30)	0.12 (0.33)	4.50 (0.004)
Farm Equipment[d]	0.28 (0.51)	0.59 (0.87)	0.54 (0.80)	0.88 (0.93)	3.98 (0.009)
Agricultural Technology[e]	1.36 (1.36)	2.17 (1.56)	1.71 (1.64)	2.47 (1.81)	3.52 (0.016)
Moisture holding capacity of soils[c]	1.83 (0.84)	2.86 (1.06)	1.57 (0.73)	2.18 (1.13)	16.89 (<0.001)

[a]Education: 1 = illiterate, 2 = literate, 3 = some grade school, 4 = complete grade school, 5 = some high school, 6 = complete high school to 7 = more than high school.
[b] Savings: 1 = have a saving account and 0 = have no saving account.
[c] Moisture holding capacity of soils: 1 = Very low, 2 = Low, 3 = High to 4 = Very high.
[d] Equipment 0 = no equipment owned, 1 = one equipment owned to 2 = more than 1 equipment owned.
[e] Agricultural Technology: Number of technology used from 1 to 6.

did not differ significantly across the four groups. Households with irrigation only had the most educated heads of household, and a higher percentage had savings accounts, as well as higher soil quality. Moreover, the households with both insurance and irrigation owned more pieces of farm equipment and used more pieces of agricultural technology.

5.2. The relationship of generic and specific capacity to food insecurity

We developed a regression model to explore how the households' specific capacity (insurance and irrigation) and generic capacity (income, education, saving, farm equipment, agricultural technology and soil quality) affected their food security. We modeled the different *municípios* as a fixed effect to control for unobserved heterogeneity that correlated to the observed independent variables. The results are shown in Table 3. Households with irrigation and with higher climate-neutral income had statistically significant lower values of food insecurity after controlling all other variables. Based on the estimated coefficients, if a household had access to irrigation, it would be about one unit less likely to be food insecure than a household without irrigation. In monetary terms, to achieve a one unit decrease in food insecurity would require an annual increase of R$10,000 of their climate-neutral income. As an indication of the significance of this value, of the 43% of households reporting climate-neutral income, only 30% made more than R$10,000 (13% of entire sample). Also, households that had a savings account and owned more pieces of farm equipment had lower values of food insecurity, although the findings were marginally significant. All other variables were not significant. The model explained 24.8% (R-squared) of variance of food insecurity in the sample.

Table 3
Regression Model.

Independent Variables	Dependent Variable: Food Insecure		
	Coefficient	Standard Error	p-value
Intercept	3.424	0.711	<0.001
Generic Capacity			
Climate Neutral Income	−0.0001	5.897E-5	0.036
Climate Sensitive Income	5.392E-5	<0.0001	0.624
Bolsa Família Income	2.842E-5	<0.0001	0.871
Education	−0.127	0.113	0.261
Had Saving Account	−0.859	0.461	0.064
Farm Equipment	−0.545	0.305	0.076
Agricultural Technology	0.020	0.147	0.889
Soil Quality	−0.136	0.191	0.478
Specific Capacity			
Had Crop Insurance	0.448	0.359	0.214
Had Irrigation	−0.995	0.459	0.031
Município			
Limoeiro do Norte	0.367	0.618	0.554
Barbalha	0.812	0.608	0.183
Parambu	1.138	0.551	0.040
Boa Viagem	1.191	0.608	0.051
Itarema	1.075	0.588	0.069
Guaraciaba (ref.)			
			R-Squared = 0.248

6. Discussion: understanding differential capacities

The relationship between risk management (specific capacities) and income and livelihood capitals (generic capacities) is complex. Our findings confirm the assumption prevalent in most vulnerability literature: in general, relatively wealthier households are associated with less-severe household-level risk outcomes. In our sample, on average, pension-receiving households had 2.15 times the average income of non-pension receiving households, and 1.47 times lower levels of food insecurity than non-pension receiving households. The stark differences in food outcomes between these two groups are indicative of the importance of income for vulnerability. This finding echoes other research in risk and poverty that suggests that households with wealth were more likely to effectively invest in reducing future risk without drawing down on present welfare (e.g., Dercon, 2002). Moreover, our findings suggest that investments in generic capacity that enable a step-change in household wealth can be instrumental in giving households the flexibility for managing inter-annual volatility in climate and other shocks and stress.

But the importance of irrigation in modulating food insecurity points out that the ability to manage risk at different levels of income cannot be ignored. Adaptation, as an investment in the present to reduce future risk, requires capacity not only to allocate but also to combine resources for an uncertain future. In this sense, our analysis shows that both kinds of capacity (specific and generic) matter, as their different combinations are associated with different levels of food insecurity (H1) (Fig. 3). Our results indicate that relatively higher levels of generic capacity (in terms of income in general, and climate-neutral income specifically) are associated with relatively higher levels of specific capacity (irrigation), providing support for the hypothesis that these two forms of capacities interact synergistically in many cases (H2).

These findings suggest that over the long run, significantly improved income levels as well as enabling access to climate-neutral income sources in particular may have a substantial effect on household vulnerability. In the subsample analyzed (non-pension households) access to irrigation made a significant difference in vulnerability outcomes. Nevertheless, we found no differences in food insecurity outcomes between households with well irrigation and irrigation from natural sources, indicating that it is access to irrigation itself, irrespective of the capital investment required, that makes the difference for household vulnerability.

Interestingly, having income from *Bolsa Família* did not appear to have a substantial impact on food insecurity, notwithstanding its celebrated role in poverty reduction (Ibase, 2008). The program is targeted towards families of working age in order to 1) eliminate extreme poverty and 2) build human capital in younger generations. Immediate benefits are marginal, moving from extreme poverty to poverty. More significant long-term benefits are anticipated as the younger generations in the beneficiary households achieve higher income potential through enhanced education and health, but evidence supporting this outcome is not yet available and more research, especially in the context of environmental change, is needed.

The analysis of the households without pensions indicates that a one unit reduction in food insecurity would require the equivalent of an increase of R$10,000 in climate −neutral income; such an increase would entail doubling the income of most households in the sample. The results further suggest that the benefits of vulnerability reduction might be best realized if households invested additional income in specific capacity, namely, irrigation. While the synergistic benefits for vulnerability reduction between income growth and irrigation appear to be evident in our research, it is not clear how such synergies could be guaranteed.

As mentioned above, research focusing on the effects of cash transfer on the poor has shown that cash transfer alone (without training of how to best spend it) is not enough to produce longer term change in terms of well-being (Banerjee et al., 2015). Qualitative data and personal observations of our sample households suggest that the pattern of household investment in times of relative bonanza (non-drought years) has been diverse but rarely geared towards guaranteeing future food security – not the least because households capacity for savings is very low and the levels of indebtedness is relatively high in our sample (20.7% and 44.1%, respectively). Training focusing on spending and savings as part of cash transfer programs may help to improve long-term households' investments, but the extent to which households would likely invest in specific capacities is not clear. For one thing, positive synergies between investments in specific capacities and generic welfare goals might have to be observable both in good and bad years in order to be supported in the long run. Irrigation – as a specific capacity that not only mediates climatic risk, but also enhances incomes and productivity on farms – meets this criteria (Hussain and Hanjra, 2003). Nevertheless, for irrigation to have substantive impacts on poverty, attention to the institutional, economic and technological context is critical. For example, Burney and Naylor (2011) argue that whether or not any irrigation scheme is effective as a poverty reduction instrument is dependent on both the technological design of irrigation schemes and how the technology is supported institutionally. They also report that irrigation systems implemented with insufficient attention to such issues are often likely to be adopted and successfully utilized by wealthier farmers, reinforcing existing wealth differentials (Burney and Naylor (2011)).

In addition to the institutional and technological challenges, irrigation critically depends on water availability; to make water available to all vulnerable households in NE Brazil, massive public works programs would have to be built. Despite ongoing public works programs such as transposing the region's largest perennial river (*São Francisco River)* to provide interbasin transfers and guarantee water availability in reservoirs across NE Brazil, both the viability and long term environmental impact of such projects have been strenuously questioned (Mancuso, 2010). Nevertheless, the spatial extent of farmers with access to the water is limited and the supply concerns resulting from the current drought in the São Francisco Basin suggest that, as an adaptation option, large-scale irrigation may have limited viability (Eakin et al., 2014).

7. Conclusions

Better understanding of the role of development interventions for increasing adaptive capacity is critical both to further elucidate the relationship between poverty and vulnerability and to inform policy worldwide. However theorizing these relationships is complex because of the way different assets combine and/or tradeoff in shaping households' ability to respond to climate impacts. Our results support the widely assumed positive relationship between vulnerability reduction and income—particularly income that is climate-neutral. However, we also demonstrate that poverty alleviation is unlikely to be sufficient. Our findings suggest that in order to increase the ability of poor rainfed agriculture households to manage risk during drought events, government programs have to go beyond the current level of cash transfer, and should incorporate policies that enhance synergies between generic and specific capacities.

Significantly, there appears to be thresholds of wealth below which households may be unable to make the type of investments in specific capacities that would be necessary to effectively reduce future risks. Anti-poverty programs such as *Bolsa Família* have been positive in increasing income and providing households with choice in terms of consumption and investment, nevertheless, the observed improvements in income have not been sufficient to manage the risk of food insecurity during drought events. These findings suggest that many households may face a 'poverty trap' in which they find themselves constantly coping with drought, but unable to overcome the conditions that make them vulnerable.

In this sense, in order to increase overall capacities, policies that increase generic capitals should be coupled with programs that enhance specific capacities to address specific risks. What types, levels, and combinations of generic and specific capacities will be most likely to produce the desired risk reduction over time will necessarily be context specific. In some cases particular combinations of capacities may act synergistically, in other situations, the relationships could be antagonistic. While generic capacities by definition are intended to enhance abilities to manage a diversity of risks – and thus are proving their utility on an ongoing basis – specific capacities tend to come into play and prove their utility only in specific temporal moments of climatic stress. Ideally, in order to maintain political support for investments in both forms of capacities (generic and specific), the positive synergies among the forms of capacity should be observed in good years as well as bad. In this context, specific conditional programs and training on how best to manage risk both in years of normal rainfall and during drought could be desirable.

Moreover, understanding the long-term impact of human development interventions (i.e. those that combine, income, educational and health components) on future livelihoods is critical to assess the long-term sustainability of subsistence agriculture and the kinds of developmental interventions that would yield the best combination of generic and specific capacities. For example, if younger generations, better educated and healthier, rapidly migrate to other livelihoods and places, long-term investment in smallholder agriculture would be ill-advised.

As decision-makers strive to design "climate-smart" and "pro-poor" policy that addresses both climate and non-climate related stressors, it will be increasingly critical to evaluate the types of interventions that will be most likely to result in such "win-win" outcomes. Disaggregating adaptive capacity into those assets, entitlements and strategies that build generic capacities vs. those that address specific climatic stress is an essential first step. From there, it is possible to identify the different ways that improvements in generic capacity can reduce vulnerability synergistically with investments in specific capacity. Moreover, our findings indicate that the ways in which capacities interact will differ for households of different socioeconomic status; policy-makers may need to emphasize different suites of capacities to address the non-linear nature of generic and specific capacity interactions. Because specific capacities have value only in relation to particular types of events (e.g. drought, flood, landslide), a more comprehensive understanding of the relationships between generic and specific capacities requires additional research that focuses on different types of climate related stressors in other parts of the world. Nevertheless, our research provides initial evidence that investing in both forms of capacities is essential: while the relationship between poverty and climate vulnerability is complex, there is potential for significant synergies in climate adaptation and development investments. Identifying and catalyzing those synergies is an essential step in vulnerability reduction.

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