

## Research Article

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# Scoping adaptation needs for smallholders in the Brazilian Amazon: a municipal level case study

**Abstract:** Over the past decade, several climate extreme events have caused considerable economic damage and hardship in the Brazilian Amazon region, especially for small-scale producers. Based on household surveys and focus group interviews in the Municipality of Alenquer as well as secondary data analyses and a literature review at the regional level, this study seeks to assess rural small-scale producers' vulnerability to climate and non-climate related shocks and identify entry points for government action to support adaptation at the local level. In our case study area, small-scale producers with similar wealth, self-sufficiency, and resource use specialisation levels exhibited stark variation in levels of sensitivity and adaptive capacity to climate and non-climate related shocks. Our findings indicate that this variation is partly driven by cultural, historical, and environmental resource use specialisation strategies and partly by differences in local governance capacity and the level of social organisation. Emerging government-led initiatives to promote climate change adaptation in the region would benefit from taking these factors into account when designing local implementation strategies and priorities.

**Keywords:** climate change, risk, shocks, vulnerability, climate extremes

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## 1 Introduction

Climate extremes represent shocks for both human and natural systems. The severity of a shock depends on how vulnerable people and ecosystems are to extreme events and their vulnerability tends to vary considerably in space and time [1,2]. In developing countries, limited access to public services and high dependency on natural resources and agriculture often position rural communities as among the most vulnerable to climate change related risks [2-6]. Vulnerability is typically defined as a function of exposure, sensitivity, and adaptive capacity [2].

The impacts of climate extremes (i.e. extreme weather or climate events) are especially relevant for climate-sensitive sectors such as water, agriculture, forestry, health, and tourism [1]. Small-scale farmers depending strongly on rain-fed crops for securing their livelihoods tend to be particularly sensitive to these extreme events [7].

In addition to climate extreme events, changes in temperature, CO<sub>2</sub> levels and precipitation affect human systems by altering crop yields, livestock productivity, and fisheries as well as animal health [8]. Consequently, climate change ultimately affects food security [9,10]. In the forestry sector, climate change is expected to increase production risk, especially in tropical areas and may also affect the distribution of forest vegetation types in the long term [11,12].

Excessive rainfall and droughts can lead to a higher incidence of crop disease or loss as well as changes in fishing and residency patterns. Indirectly, climate change impacts can result in adverse effects on human health affecting labour availability for agriculture and other activities [8].

Climate change can result in alterations in the incidence, length, timing, intensity, and spatial extent of extreme climate and weather events [1]. For example, the recorded frequency of climate related disasters has more than doubled in Latin America since 1970, including two extreme El Niño Southern Oscillations

(ENSO), floods and droughts [13,14]. Record droughts in 2005 and 2010, in addition to a record flood in 2009, have caused significant economic losses for thousands of smallholders across the Amazon region [15,16]. However, given the lack of sufficient historical climate data, climate change scenarios for the Amazon region are subject to large uncertainties.

Combined with climate change, it has been suggested that deforestation in the region will eventually lead to large scale forest dieback and partial transformation to a savanna state [9,17]. Apart from the implications for ecosystem service provision, a forest vegetation dieback would also have severe consequences for small-scale farmers as well as traditional and indigenous populations who predominantly depend on extensive slash-and-burn agriculture and non-timber forest products (NTFP).

The Brazilian Amazon is the world's largest remaining continuous tropical rainforest and is in risk of anthropogenic and climate change impacts on the natural ecosystem and its services [18,19]. Despite comparatively low population densities human impact on forest cover and biodiversity has been particularly devastating in the past. Within the Brazilian Amazon region, small-scale or family farms can be up to 400 hectares according to official definitions [20]. Between 2001 and 2010 the 813,853 farms in the Brazilian Amazon deforested an average of two hectares each per year [21,22]. As a result, an individual farmer's land use decisions tends to have a much larger effect on global ecosystem service provision in the Amazon than elsewhere in the developing world.

Moreover, relative resource abundance does not necessarily imply that smallholders in the region are less vulnerable to climate related and other sources of risk. The traditional staple crop cassava (*Manihot esculenta*), a key subsistence and income source for the majority of the rural population, is particularly vulnerable to excess rain and occasional droughts [23].

Climate change research in the Amazon region has so far primarily focused on the ecological implications of climate change. Yet, very little research exists on the vulnerability of small-scale producers and their production systems to climate related and other risks in the region. A study by Brondizio and Moran suggests that considerable differences in adaptive capacity exist between small-scale producer groups in the Brazilian Amazon depending on migration patterns and socio-cultural traditions [24]. Clearly, more research is needed to understand how small-scale producers' vulnerability is linked to key production systems and related value chains in order to devise effective strategies in the face of environmental and economic change.

Based on a case study of a typical smallholder production system in the Northern Brazilian Amazon, this paper (1) assesses the relevance of climate related and other risks currently affecting typical smallholder's livelihood strategies, (2) describes local adaptation strategies and related bottlenecks, and (3) identifies priorities for public action at the municipal/local level in the context of the Brazilian Amazon.

## 2 Conceptual framework for the assessment of smallholders' vulnerability

As defined above, vulnerability is the degree to which a specific system is susceptible to external shocks and can be characterised in terms of exposure, sensitivity, and adaptive capacity. In the context of climate change, exposure comprises the character, magnitude, and rate of change as well as the variation to which a system is exposed to [2]. Sensitivity refers to the positive or negative extent to which a system is affected by climate-related stimuli. Effects can be direct, e.g. a change in crop yields resulting from a change in temperature, or indirect, e.g. in the case of damages due to increased frequency of floods caused by sea level rise [25]. A system's adaptive capacity to current or expected climate change describes its ability to deal with climate change induced damages and consequences, or benefit from climate change related opportunities [25,26].

According to the literature on shock or risk coping and adaptation, we distinguish two types of climate and non-climate related shocks: *covariate* and *idiosyncratic* [27]. *Covariate shocks* tend to affect most members of a community or region, e.g. excess rainfall or sudden drops in prices on local markets. Traditional risk sharing mechanisms are often ineffective in response to *covariate shocks*. *Idiosyncratic shocks*, e.g. accidents or non-epidemic diseases, usually affect individuals and more often than *covariate shocks*, are effectively insured against in social safety nets [27].

The degree of vulnerability of small-scale producers often results from environmental and socio-economic conditions. These varying local conditions include: land cover and use of natural resources, rainfall distribution and seasonal patterns, infrastructure, welfare system, access to markets, diversification of income sources and social networks, access to supporting services as well as memories of past events and their current application [24,28].

Adaptation, in general terms, results from the interaction of several climatic and non-climatic factors

[1]. For the assessment of vulnerability, the most relevant features of climate change are those linked to variability and extremes and not just altered average conditions [29]. Most regions and communities are able to adapt to changes in average conditions, in particular when they are gradual. But, they are less able to adapt to changes in the frequency and/or extent of other than average conditions, especially climate extremes [29].

Adaptation can be responsive, e.g. after changes in natural or social systems or preemptive and planned in anticipation of such changes [2,29]. However, adaptive capacity does not automatically result in actions to reduce vulnerability and can be limited by technological, financial, behavioural, cognitive, and socio-cultural factors [30]. Clearly, the constraints and costs of adaptation are highly context specific [1,2].

The objectives of public action to adapt to climate change are often to: (i) improve robustness of and access to infrastructure; (ii) enhance the awareness and preparedness of society, and (iii) implement new and strengthen existing safety nets [31]. Both public and private action that reduces vulnerability may or may not be devised directly in response to climate extremes. Creating a farmer cooperative, for example, increases commercialisation opportunities, but can come with additional safety net functions as a positive side effect. Both formal and informal social networks tend to incorporate traditional knowledge that allows social groups to evaluate and choose among adaptation strategies. This ensures that the adopted strategy is consistent with community values, yet can also delay decision making, particularly during periods of rapid change (e.g. climate extremes). However, overall, communities with dense social networks were found to be at an advantage when it comes to collective adaptive action [24].

What specific lessons do we expect to learn from studying small-scale producer vulnerability in a tropical forest environment, such as the Amazon region? First, recent research suggests that not all smallholders benefit equally from forest use and the “safety net” function associated to forests. The role of forests as safety nets largely depends on appropriate knowledge and specialisation in their use, which is often related to specific resource access conditions. Second, in a resource abundant setting, very distinct livelihood strategies develop, including niche strategies with a high degree of specialisation, but also diversified livelihood strategies based on farming, processing, and commercialisation. Therefore, we expect resource

access conditions and specialisation patterns to play a key role in determining vulnerability outcomes in our study area. Policy actions aiming to reduce the vulnerability of smallholder agriculture to climate change is likely to be more effective if these patterns are taken into account.

### 3 Study area, data collection and methods

#### 3.1 Regional context and study area

According to its formal definition, the Brazilian Legal Amazon region comprises over 5 million square kilometres of mostly dense tropical rainforest [32]. This area was established as an administrative unit by Federal Law No. 5173/1966 and includes the federal states of Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, Tocantins, Maranhão, and Mato Grosso.

During the 1990s and until 2005, the region boasted the world’s highest absolute forest loss of up to 27 thousand square kilometres per year [33]. Small-scale producers are thought to be responsible for about 30% of annual forest loss on average [34]. Since 2004, Brazil has implemented far reaching environmental policy measures to combat deforestation and since 2009, annual forest loss has been consistently low at around 5 thousand square kilometres per year [35].

Agriculture represents the region’s most important economic sector, followed by forestry and fisheries (see Table 3.1). Small-scale or family agriculture is the main income source for the rural population and contributes with 54% to the total value of agricultural production [22]. Although cattle pastures are the most important land use type in the region area wise, most smallholders rely predominantly on annual crops, such as cassava, that are cultivated in a traditional slash-and-burn production system. More recently, however, smallholders have increasingly invested in cattle production [36].

Two different ecological zones in the region are relevant to this study: the *Terra Firme* (TF), upland forest which is not inundated seasonally and *Várzea* (VA), floodplain forest which is subject to 5-6 months annual river inundation [37,38]. The TF host a great variety of plant species, including the Brazil nut tree (*Bertholletia excelsa*). After the states of Amazonas and Acre, Pará has the highest share of Brazil nut tree production and gross value of production in Brazil, representing 23% and 16% in 2009, respectively [39]. The VA area, which has a vast

extension in the lower Amazon, is more humid and palm trees and herbaceous vegetation are common. The *várzea* is one of the most important environments for fresh water fishing in the world and fish is the main source of protein for the communities living there [40].

Amazon River fisheries are affected by the seasonality of river flows that determine size and location of fish stocks. Traditional fishing requires little investment and fishers tend to also engage in other rural economic activities. Besides fishing and agriculture, wages complement the income of small-scale fishers in the Lower Amazon region with 18% and 10% respectively [41]. The federal government supports traditional fisheries by providing an income subsidy (*Seguro Defeso*) during the “off season”, between October and February, wherein it is prohibited to fish threatened high value species [42]. This is equivalent to the minimum monthly salary in the region [42].

Our case study covers the municipality of Alenquer in the state of Pará. The Municipality of Alenquer belongs to the micro-region of Santarém, at the northern bank of

the Amazonas River (Figure 1) and covers an area of 23,645 km<sup>2</sup> in the Lower Amazon Region [39, 43]. Other regions in the Brazilian Amazon are likely to find similar patterns of smallholder production to the Alenquer context, including forest, agriculture, and fishing based production systems both in TF and VA zones (see Table 3.1).

Due to large and mostly uninhabited forest reserves in its northern part, the population density in Alenquer is much lower than in the Legal Amazon as a whole. However 93% of farms in Alenquer are considered small-scale (family agriculture) compared to 90% of the average value for the Amazon.

The average municipal GDP per capita in the Brazilian Amazon is USD 4,980 compared to USD 1,334 in the municipality of Alenquer in 2008 [44]. A comparison of annual gross value of production per municipality across productive activities (Table 3.1) reveals that agriculture clearly leads the field with USD 3,841,920 at the regional level and USD 5,557,880 in Alenquer. Revenue from livestock production (which is not typically for smallholders) is the second most important with USD 900,778 at the regional

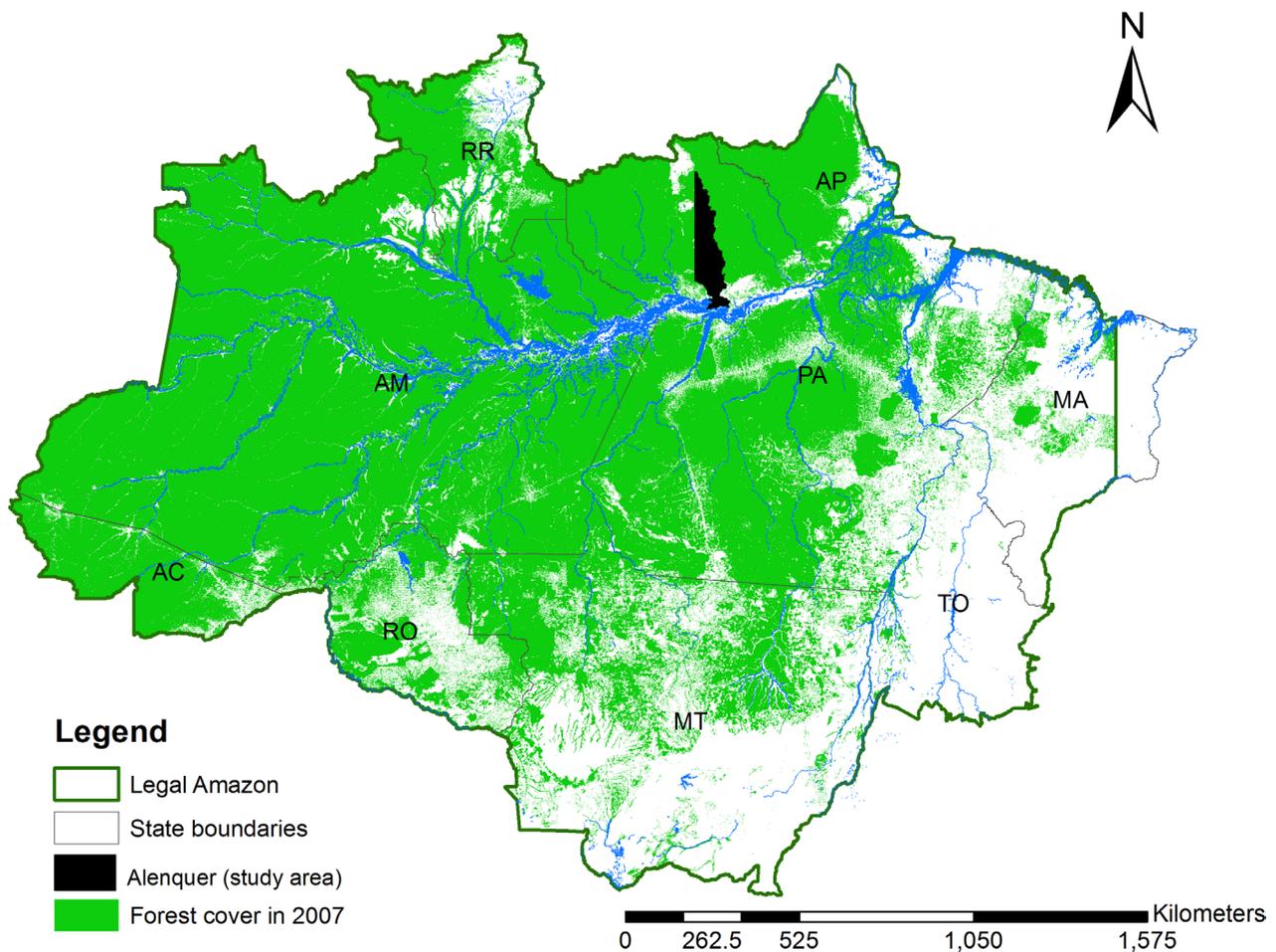


Figure 1: Study area within the Legal Amazon including forest cover [21]

**Table 3.1:** Selected variables for the Brazilian Amazon in comparison to the municipality of Alenquer

Geographical area		Legal Amazon		Alenquer
General characteristics	Unit	Municipal average	Total value	
Population <sup>[39]</sup>	inhabitants	31,609.9	24,371,265.0	52,626.0
Area extension <sup>[39]</sup>	km <sup>2</sup>	6,530.3	5,034,847.8	23,645.5
Population density	inhabitants.km <sup>-2</sup>	4.8	4.8	2.2
Rural population <sup>[39]</sup>	%	71.8		47.3
GDP per capita in 2012 <sup>[44]*</sup>	USD	4,980.2		1,334.0
<b>Land use</b>				
Farms with family agriculture <sup>[22]</sup>	%	89.7		93.5
Area with family agriculture <sup>[22]</sup>	%	29.7		74.30
Total area under farms <sup>[22]</sup>	km <sup>2</sup>	1,500.1	1,156,609.1	1,264.3
Total pasture area within farms <sup>[22]</sup>	km <sup>2</sup>	354.5	543,849.9	528.8
Share of forest area 2012 <sup>[21]</sup>	%	72.9		75.6
<b>Annual gross value for the most important sectors<sup>†</sup></b>				
NTFP <sup>[22]</sup>	USD*	475,278	278,037,727	191,363
Timber <sup>[22]</sup>		222,474	124,485,909	1,818
Fisheries <sup>[45,48]</sup>		248,459	191,562,000	173,154
Cattle farming and other animals <sup>[22]</sup>		900,778	3,433,120,000	1,122,670
Agriculture <sup>[22]</sup>		3,841,920	7,265,040,000	5,557,880

\*All currency values are converted from BRL to USD with OANDA (<http://www.oanda.com/currency/converter/>), where 1 USD = 2.2 BRL. †All values are obtained from the last official agricultural census data in 2006 with the exception of fisheries, for which data are available only for 2007.

level and USD 1,122,670 in Alenquer, followed by NTFP, fisheries, and timber.

In agriculture, cassava stands out as the dominant product for smallholders, followed by corn, rice, beans, and others [22]. Among perennial crops banana, orange, and cocoa stand out. NTFP production is dominated by Brazil nut along with Cumaru (*Dipteryx odorata*) a product that is increasingly entering local markets [22].

For fisheries, in Alenquer gross value is lower (USD 173,154) than the average municipal value in the Amazon (USD 248,459). However, the first value considers only fish landed at the Alenquer port with estimates based on fish volume (kg) of the main fish species and their average price in that year. These estimates were less than 1% of the monitored production by ProVarzea in 2007 [45].

Official data on small-scale fisheries generally underestimate total production in the Brazilian Amazon

because locally consumed fish is not accounted for. Case studies suggest, nonetheless, that this local consumption represents a major share in total production value [46]. In Alenquer, fisheries are exclusively small-scale and “low tech”, and VA areas comprise 5,473 inhabitants over 1,620 square kilometres [46]. Fishing occurs mainly in this region during the dry season wherein big fish are caught easily in the river floodplain, while in flood period fish prefer the lakes in the VA [40]. Agriculture in the VA is mostly seasonal and carried out during the dry season.

### 3.2 Data collection and methods

Semi-structured interviews, focus group discussions, and participant observation in urban and rural environments were our main data collection strategies. A list of main

climate extreme events including droughts, floods, and fires potentially related to climate change was constructed in a public consultation. Participants included local government authorities, producer representatives, teachers, and journalists.

Interviews in the rural areas covered communities specialised in agriculture, fisheries, and NTFP extraction. In a participatory mapping exercise with relevant local institutions<sup>1</sup>, communities that were representative of one of these three rural economic sectors were identified.

After mapping the communities, three zones were set, with one zone located in the VA (Salvação), representing the fisheries sector, and the other two located in the TF (Camburão and Pedra Redonda) representing the agricultural and extraction sectors, respectively. This zoning was based on the stratification by the Amazon Environmental Research Institute (IPAM), where areas of subsistence agriculture, cattle production, and fisheries were delimited for the whole region [43]. The total universe of 33 communities with 1,050 families was set up, which included those communities located in the part of the Municipality for which official statistical information by the Brazilian Institute of Geography and Statistics (IBGE) were available. Subsequently, a sample size that guaranteed representative data collection within the municipality was defined based on official statistics from EMATER containing communities and their respective number of families [47]. Finally, we carried out a random selection of communities. This process resulted in a total of 59 households belonging to 12 communities in TF and VA zones (39 and 20 respectively).

Interviews covered individual perceptions of past climate and non-climate related shocks and their economic impact, existing and potential adaptation practices, information on income sources and their relative importance, self-sufficiency levels for key production activities, and production constraints, such as labour force availability and infrastructure quality. Interactive visualisations were used in order to obtain better quality data on risk perception. Risks or shocks frequently mentioned by farmers in an explorative field visit were structured in terms of the following categories: sudden price drops, unexpected transport problems (e.g. bus line interruptions after heavy rains), storage loss, land tenure associated risks, changes in government policies, labour shortages (e.g. during peak seasons), diseases and

death in the family, accidents, excess rain, prolonged droughts, floods, accidental fires, pest or animal diseases, and others. All farmers in our sample were asked to report and rank these risks according to their own perception.

We analysed household perceptions regarding shock/risk incidence as a proxy for exposure and priority rating as a proxy for sensitivity in the TF and VA areas of Alenquer. All prior mentioned categories of risks were re-classified in *covariate* and *idiosyncratic shocks*. *Covariate weather shocks* included rainfall, floods, and droughts. *Covariate other shocks* comprised unexpected changes in prices, transport conditions, labour shortages, accidental fires, and policy induced shocks. *Idiosyncratic shocks* included non-epidemic diseases including loss of family members and accidents.

Key secondary data sources were the Brazilian Institute of Geography and Statistics (IBGE), Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), National Institute for Space Research (INPE), Amazon Institute of People and Environment (IMAZON) in 2012 and the project on Management of Natural Resources of Várzea (ProVárzea) [21,22,39,44,45,48].

## 4 Results

### 4.1 Exposure and sensitivity to shocks in the Municipality of Alenquer

In the decade before our field research in the Municipality of Alenquer, the region was struck by several severe climate related shocks. Table 4.1 lists the major events based on data from the local Civil Defence Committee (COMDEC) and focus group interviews.

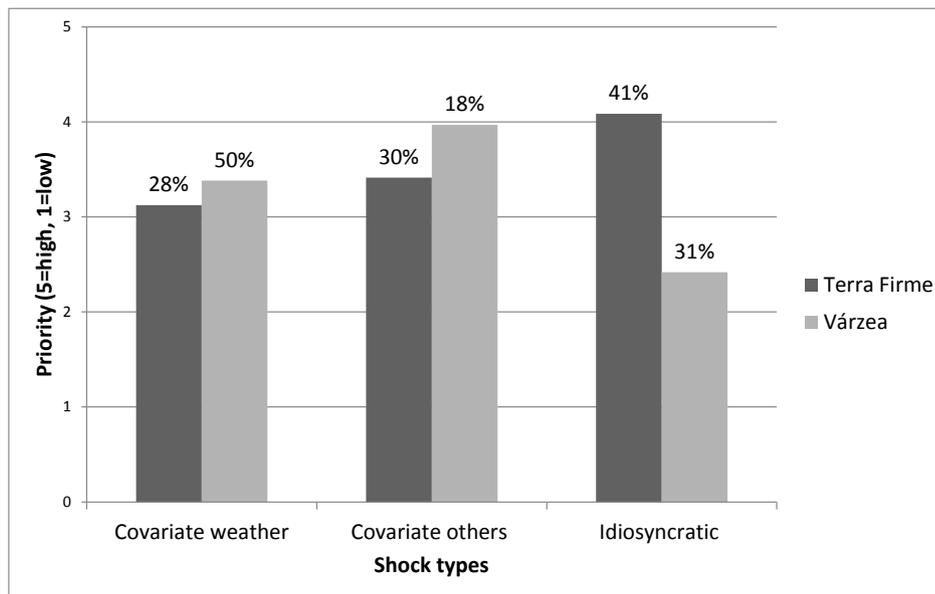
Extreme floods in combination with excess rainfall events in 2009 and 2011 especially caused considerable economic damage to both the rural and the urban populations in Alenquer. Among the rural population, VA inhabitants are the most exposed and sensitive to floods even though these so called *ribeirinhos* are traditionally well adapted to seasonally highly variable river levels, e.g. most people live in stilt houses. But, the sedimentation gradually lifts up the riverbed, meaning the stilts of older houses are pushed further into the ground, lowering the house in relation to river levels and thus, older houses are more vulnerable to high floods than new ones.

Rainy seasons with above average rainfall also increase production risks for farmers in TF regions, e.g. in the form of the cassava root rot disease. Analysing historical precipitation data from weather stations in and around Alenquer, Barreto found a weak but positive trend

<sup>1</sup> The Rural Workers Union, the Association of Small Rural Producers Involved in Extractivism and Artisanal Fishing (ASPROEXPA), and the Rural Extension and Technical Assistance Agency of the Pará State (EMATER)

**Table 4.1:** Specific shocks affecting alenquer.

Shock type	Type of damage	Source
2011 extreme flood	A total of 6,805 affected persons living in rural communities along the riverbank of Curuá River, who depend on access to the bridge on the river along highway PA 254. 13 houses were damaged, 6 completely destroyed Registered damages on the water and energy supply system, as well as the transport system for the affected population	[49]
2009 extreme flood	254 houses in 32 communities were affected, of which 26 houses were completely destroyed and 11 were considerably damaged in the community of Salvação (part of the study area). The damage was estimated at BRL 4 million (USD 1,747,430). Other directly observed impacts included reduced water quality resulting in a higher frequency of diseases (especially for children), and asset losses including financial and physical capital, e.g. cattle. Drinking water shortage, energy breakdown, household food insecurity, damage to dwellings, evacuation of families living in VA areas. Crop loss: particularly cassava plantations due to excessive rain increasing the incidence of root rot disease. Local markets reportedly react strongly to cassava shortages after major crop loss events, thus increasing food costs for the urban population. Honey production loss Dying of turtle population Appearance of a weed that kills cattle, higher incidence of snakes attacking livestock Increase sediment transport in river bank	[50, 51][focus group interviews]
Droughts in 1982, 1992, 2005, 2006	Crop and livestock loss (drought stress and dehydration) Reduced fish stocks (overfishing and death of fish in dried out lakes)	[51][focus group interviews]

**Figure 2:** Prioritisation of shocks by TF and VA dwellers. Percentages on top of bars represent the share of respondents that reported shocks in each of 15 categories

for both extremely rainy and extremely dry sequences of days for the period from 1976 to 2009 [52].

Figure 2 summarises our analysis of household perceptions regarding shock incidence (proxy for exposure) and priority rating (proxy for sensitivity) in the TF and VA areas of Alenquer.

Confirming the notion conveyed by focus group

interview participants, we find that weather and climate related *covariate shocks* are considerably more common among the VA population (50%) than among TF dwellers (28%). The VA population also attaches a slightly higher importance to these types of shocks than TF dwellers. *Other covariate shocks* are also rated of higher importance in the VA zone, albeit by a much smaller share of respondents

than in the TF zone. This result is influenced by fishers who reported extremely high and often unpredictable variations in fish prices in local markets. *Idiosyncratic shocks* are perceived as much more harmful among the TF population where they were also reported at the highest frequency. This result is, however, probably influenced by a flood event that occurred during the survey period which affected most of the VA respondents. According to interviews with community health agents, fishing accidents, and diseases are rather common in VA areas due to poor sanitary conditions.

In the VA, fishers reported that lakes –important fishing grounds– can dry out during prolonged drought periods leading to substantial production losses.

Excess rain is particularly harmful for cassava production in TF zones and reportedly resulted in 100% losses for some farmers. Cassava flour is an important staple crop and if a household's production is insufficient, purchases on far away markets and at high prices can result in considerable economic hardship.

NTFP extractivists did not report any particular *climate related shocks*. For this group, *other covariate shocks* posed a higher risk, such as price fluctuations. When prices for Brazil nut fall below a profitable level,

it is common for people in this sector to abandon extractivism and focus on agriculture. Exceptions exist, for example, among households in a traditional *quilombola* community (Brazil nut extractivists, who are of African descent), respondents were less concerned about Brazil nut price fluctuations. Despite its high dependence on extractivism this particular *quilombola* community maintains stronger horizontal business relations in the NTFP value chain than the general rural population, which has reportedly helped to stabilise income during low price periods.

Given poor quality and/or limited access to public health services in the rural areas, *idiosyncratic shocks*, such as serious diseases and accidents are perceived as particularly severe among both the TF and the VA populations.

In summary, we find systematic differences in exposure and perceived sensitivity to both climate and non-climate related shocks between VA and TF zones. These differences are clearly influenced by resource use specialisation strategies, but also depend on a host of contextual factors including rural-urban linkages and the cultural background of communities and individual households.

**Table 4.2:** Covariate and idiosyncratic shocks affecting the Brazilian Amazon.

Shock type	Type of damage	Source
<b>Covariate</b>		
Increased frequency of fires in 1997, 1998 and 2003 in the Northern Amazon (Roraima)		[53]
2005 drought "...one of the most intense droughts of the last hundred years ..." (September) with an air temperature increase of 3–5°C than normal. Reported extremely low river levels	Livelihood activities related to fishing, agriculture and cattle ranching were directly affected Dry out of small rivers ( <i>igarapés</i> ) and partial preclusion of the transport of goods Communities distant from markets and roads that rely on rivers to transport their crops and NTFP, lost substantial amounts of production.	[15] [54]
2009 flood Amazon River in Óbidos (Baixo Amazonas) surpassed previous maximum levels registered. In March to June levels of water kept increasing reaching 8.4 m in June, considering a level of 7.7 m for this river as of "flood alert".	Significant asset and production losses	[50,55]
Diseases* Negative effects on human health by extreme events	Malaria transmission followed by deaths can increase with floods Observed increase of epidemics' occurrence (malaria, hantavirus pulmonary syndrome, several forms of leishmaniasis, and leptospirosis)	[56] [13]
<b>Idiosyncratic</b>		
Accidents	Brazil nut gatherers " <i>castanheiros</i> " killed by falling shells " <i>ourichos</i> " (head injuries)	[56]

\*In this case epidemic like malaria has a covariate nature

## 4.2 Exposure and sensitivity to shocks at the regional level

The historical flood and drought events in the decade leading up to 2010 affected not only the Municipality of Alenquer, but the whole region (Table 4.2).

In Table 4.2 we report the effects of documented climate extremes, such as fires, droughts and floods on the rural population of the Amazon during the last decade. Drought increases forest flammability and the break out of accidental fires [57]. Degraded forests are generally more vulnerable to fire than intact forest [58].

Across the Brazilian Amazon, the extreme weather and climate events affected VA and TF dwellers in much the same way as the rural population in Alenquer, albeit with different degrees of intensity depending on location, elevation patterns, river size, and other factors. The systematic differences in exposure and sensitivity observed between people that specialise in different livelihood strategies in Alenquer (here fishing versus farming and extractivism) are very likely found in other regions of the Brazilian Amazon.

## 4.3 Adaptive capacity in Alenquer

After the 2009 flood, in particular, civil society organisations and the local and state level administrations engaged in measures to alleviate the burden on the affected population groups. For example, the fishers' association Z-28 invested a total of USD 2,522 to buy construction materials and emergency food supplies for flood victims. The Civil Defence Committee (COMDEC) distributed local, state, and federal basic support items, such as blankets, towels, mosquito nets, mattresses, and medicine. COMDEC in Alenquer recorded 2,154 families in VA areas, who received 11,500 kg of food and 10,800 clothing items donated by schools, organisations, and individuals. Additionally, in 2009 a USD 1,713,888 budget was allocated by the State Coordinator of Civil Defence (CEDEC) from Pará in collaboration with their Municipal Department from Alenquer in order to cover remaining expenses with registering and relocating homeless victims of the above mentioned flood [52].

In response to the 2009 flood, the state government of Pará approved the decrees 2992/2009 and 2996/2009 of emergency situation in Alenquer. The former consists of an emergency plan for responses to disasters and a call for volunteers to support affected populations, both under the coordination of COMDEC in Alenquer and the state government of Pará.

In general, it appears as if the local administration is relatively well prepared to deal with the effects of the

known seasonal variation of river levels in the flood prone areas. However, extreme river levels still represent a serious challenge to local risk management even though river levels tend to increase slowly over the course of several months and unusually high river levels before peak months indicate upcoming flood risks at least in this part of the region. Adaption practices against shocks are therefore merely responsive rather than preemptive and to date there are no longer-term strategies to increase adaptive capacity to extreme flood events at the municipal or state levels.

For most other types of shocks, such as extreme price variation, droughts, and diseases neither responsive nor preemptive specific publicly supported adaptation practices could be identified. If affected by these kinds of shocks, most small-scale producers have to rely either on basic public services, such as health centres and agricultural extension agencies, or organise their own social safety nets.

A popular coping strategy, especially among fishers is organisation in associations (in Alenquer Z-28), whereas many TF dwellers are organised either in rural worker unions or associations and cooperatives that evolve around specific production activities, for example, honey production, such as the Association of Small Rural Producers Involved in Extractivism and Artisanal Fishing (ASPROEXPA). Eighty three percent of surveyed households belong to some kind of profession-related civil society organisation. In normal times, these organisations act as political interest group, support members in administrative matters, such as applications for public pensions, or negotiate better prices for specific products with retailers in and outside the Municipality. However, in times of larger scale *covariate shocks* or even individual economic hardship, these organisations do, as reported above, also provide safety net functions. Consequently, the network of civil society organisations may be considered part of a non-specific risk coping strategy that can contribute considerably to increasing adaptive capacity of some rural population groups.

Apart from strategies that improve the quality of safety nets in times of shocks, preemptive measures that reduce exposure or sensitivity to these shocks can also be considered adaptation practices. One common strategy to reduce sensitivity to shocks is portfolio diversification [27]. Moreover, poor households facing price risk may also decide to become self-sufficient in essential staple crops to avoid having to reduce consumption in times of shocks.

In Alenquer, we find a relatively low degree of portfolio diversification with most households deriving more than half of their total income (including non-

commercialised production value) from not more than two income sources, especially in the VA region (see Table 4.3). In the TF region, farmers that were able to accumulate some wealth reportedly invested in cattle also as an insurance mechanism. Beef prices are relatively stable and, when needed, individual cattle units can usually be sold quickly and easily. The insurance function of cattle for smallholders has also been reported in other parts of the Amazon [59].

Most households are self-sufficient in the products they specialise in, such as fish (97% in VA) and permanent crops (~89%) or Brazil nut extraction (~80%) in the TF zone (see Table 4.3). However, households in TF and VA have lower self-sufficiency (34% and 11%) in temporary crops, which includes cassava flower, an essential staple.

Overall, there is little evidence that current resource specialisation patterns in Alenquer are strongly influenced by risk coping strategies. Instead, they represent resource-specific economic niches that have been occupied by different sociocultural groups in various stages of the region's colonisation process. For example, fishers are predominantly part of the traditional *ribeirinho* population, highly specialised Brazil nut extractivists (*quilombolas*), and many small-scale farmers in the TF zone are descendants of migrants from Brazil's Northeast or South that moved to the Amazon in later migration waves of the 20th century.

Yet, risk specific coping strategies have developed in some of these resource-specific economic niches. For example, cassava producers, who have access to well drained sandy soils, tend to switch to those as well as

**Table 4.3:** General farm characteristics, sources of income, and assets in Alenquer

	Terra Firme (TF) N = 39		Várzea (VA) N = 20	
	Mean	Std. Dev.	Mean	Std. Dev.
<b>General farm characteristics</b>				
Area size (ha)	45.1	59.9	11.6	25.6
Family size (number of members)	5.7	2.7	6.3	2.3
<b>Sources of income</b>				
Agriculture (%)	41.7	13.5	12.6	14.0
Cattle ranching (%)	11.9	15.9	4.9	9.5
NTFP (%)	9.8	10.6	0.0	0.0
Fishing (%)	4.4	6.4	58.5	17.3
Work outside the farm unit (%)	11.4	11.9	5.7	8.2
Others (%)	19.8	19.6	18.3	13.4
<b>Assets and other variables</b>				
Cooperative membership (%)	74.4		100.0	
Per capita asset value (USD)	9,005.4		3,542.9	
% with more than one plot	25.6		0.0	
% with possession of motorised vehicle	28.2		45.0	
% with land tenure title	28.2		30.0	
<b>Self-sufficiency (%)*</b>				
Permanent crops	88.7		83.3	
Temporary crops	34.4		11.1	
Animal products	45.2		60.0	
NTFP	79.7		0.0	
Fish	23.1		93.5	

\*Self-sufficiency is based on the degree of consumed products, which suffice household's consumption and require no need to buy or get these products elsewhere

to elevated terrains in order to avoid the negative effect of excess rain on cassava productivity. Farmers also experiment with a relatively large number of cassava varieties (15 as reported by local specialists in TF) including varieties that are particularly resistant to humid conditions or grow mature in shorter seasonal cycles [51].

For extractivists, who are heavily exposed to price fluctuations, a reported adaptation strategy is to seek employment or divert family labour into agricultural activities. Likewise, some farmers reported that they abandon cassava fields whenever Brazil nut prices soar or cassava flour prices are unexpectedly low. Hence, forests may sometimes serve as safety nets, but opportunistic behaviour can also eventually lead farmers to tradeoff medium-term food security for short-term forest income.

Adaptation practices for fishers are less diverse mainly because of limited alternatives to fishing in the VA zone. However, all fishers belong to a union, which supports them with some kind of insurance, functioning as a safety net in case of being affected by an extreme event such as a flood. The primary purpose of belonging to a union is not risk related. Union membership can also improve market and credit access conditions.

#### 4.4 Adaptive capacity at the regional level

Governmental institutions at all administrative levels have just started to join efforts for both preemptive and responsive actions to cope with large *covariate shocks*, especially floods, in the Amazon region. One example is the Brazilian National Plan on Climate Change launched in 2007 [60]. The main objectives of this plan include measures, such as strengthened inter-sector actions towards vulnerability reduction of the population, identification of environmental impacts derived from climate change, and scientific research towards low cost adaptation strategies [60].

Before the 2009 record flood in the Amazon region no regulatory mechanism for the location of residential areas was in place. As a result, residential areas were opened up in an uncoordinated way as urban centres encroached onto flood prone areas, such as VA zones. After 2009, a municipal level “code of conduct” was put in place to improve the urban planning process and raise the risk awareness among the population. The code includes plans to map high risk areas in which construction is supposed to be banned as well as the provision of safe and affordable residential areas [50].

At the federal or state scale, the decree 5376/2005, issued during the 2005 drought in the Amazon, promoted

the inclusion of Civil Defence principles in elementary and middle school curricula among other measures to deal with climate extremes.

At the community scale, training in construction techniques for teams that are responsible for constructing houses and participating in building up the infrastructure is promoted [50]. Additionally, in 2012 a monitoring and warning system for climate related risks was planned for the Legal Amazon, specifically for preventive actions of the Civil Defence in some basins: Araguaia-Tocantins, Xingú, Tapajós, Médio Amazonas [61]. A national programme “2040 Risk management and coping with disasters” with 10 key action points was recently launched, that include risk mapping and prevention of natural disasters with a focus on municipalities that are more susceptible to floods and droughts. The aim of this programme is to monitor and evaluate the use of federal resources to reduce the vulnerability of risk sensitive populations [61].

At the household level, very little is known about adaptive capacity and risk specific coping strategies across the region. According to the IBGE agricultural census [22], over 61% of small-scale producers in the Brazilian Amazon derive more than 65% of their total production value from a single production activity. On average 38% of smallholders commercialise less than 50% of their total production value. The resource specialisation strategies identified in the Municipality of Alenquer thus exist in much the same way among small producers across the entire region.

Sub-regionally, considerable differences exist in terms of portfolio diversification. Case studies of eastern Amazonian smallholders, who are relatively well connected to urban markets, suggest a stronger tendency of portfolio diversification than among smallholders in remote and inaccessible regions [62,63]. At least in the Amazon region, diversification may thus still be driven much more by the availability of commercialisation opportunities than by risk aversion behaviour.

Severe climate and weather related shocks often tend to affect a relatively unprepared rural population and often lead to temporary or even permanent migration from rural to urban centres. Households with strong family ties in urban centres are therefore better off than households whose social networks are limited to the local community. But, as Brondizio and Moran [24] point out, even among isolated rural communities, considerable differences in social capital exists and may thus result in a heterogeneous distribution of potential for local collective action to cope with climate and non-climate related shocks.

## 5 Discussion

Based on a small household survey, focus group interviews, a literature review, and secondary data, this paper has characterised the core elements of vulnerability to climate and non-climate related risks among rural smallholder producers in the Municipality of Alenquer. This municipality is not considered representative for the whole Amazon region; however we show that similar environmental and socio-economic conditions exist in large parts of the region. Bottom-up studies of vulnerability in the Amazon are still rare. Our results, nonetheless, underline the importance of local contextual factors, such as natural resource availability and access, resource use specialisation (often affected by cultural traditions), the degree of social organisation, and local transportation as well as institutional infrastructure in determining the vulnerability of the major part of the rural population in the Brazilian Amazon to expected increases in climate extremes. Similar observations have been put forward by Brondizio and Moran [24] in a different social environment.

Our results suggest that expenditure-based poverty measures and indicators of resource specialisation may not necessarily be good indicators of vulnerability. Expenditure-based poverty measures can severely underestimate actual income for families that are self-sufficient in the rather high value stable crop cassava [64]. The same holds for families that are able to cover the most important share of their protein intake through fishing. Nevertheless, both natural resource characteristics and the associated supply chain structure can play important roles in determining how hard producers are hit by both economic and climate related shocks. Highly specialised fishers in the VA regions are clearly more vulnerable to climate related risks than highly specialised extractivists in the TF regions. This is not merely a result of higher seasonal variation – as opposed to Brazil nut collectors, fishers face downside risk in both the dry and the rainy season. Moreover, due to the dependence on inelastic local market prices and high storage costs, prices for fish tend to vary more on a daily and seasonal basis than prices for practically any other commercialised product in the region.

When it comes to vulnerability assessment, measures of natural resource use specialisation or diversification in the Amazon region thus require qualification with regard to resource type and actor-specific resource use strategies. Our case study shows that resource abundance and resource use strategies can vary considerably even at the lowest administrative unit – the Municipality.

Clearly, more quantitative and observational studies are needed to determine whether smallholders have

already adopted adaptive strategies in response to the rather frequent floods and droughts over the last decade. Our research indicates that pro-active behavioural change is still mostly driven by economic factors, such as changes in relative prices or improvements in transport infrastructure, among others. Although many producers reportedly consider environmental change as a potential threat, action is primarily expected to come from governments at the state and federal level. And indeed, for many smallholder families, for example in the VA zones, the investments necessary to reduce sensitivity to floods, e.g. regularly adjusting stilt house height, or maintaining a secondary household in the TF region may simply be unfeasibly high.

Better knowledge about potential climate change impacts at the local level as well as political awareness and institutional change will be needed to overcome the current barriers to adaptation.

## 6 Conclusions

Although the political discourse with regard to policies for small-scale producers in the Amazon region is still widely dominated by agricultural development and conservation agendas, climate change adaptation and disaster risk management are increasingly being recognised as important future agendas, especially at higher administrative levels. An important first step towards concrete action is to acknowledge that many of the most urgent adaptation measures represent no-regret options also in terms of rural development. Better public health and education services and improvements in the quality of transportation infrastructure will not only improve the rural population's capacity to cope with weather and climate related shocks, but also enhance small producers' productivity by reducing non-climate change related risks.

More actor specific government-led climate change adaptation measures, as suggested above, will require better targeting mechanisms to attend to spatially heterogeneous vulnerability patterns. Vulnerability assessments that are exclusively based on bio-physical and aggregated agronomic parameters can be misleading when local vulnerability is mainly driven by niche specialisation strategies or geographically determined by variations in access to markets and public services. Therefore, regional vulnerability assessments should draw more intensively on the widely underexploited information provided by agricultural and population censuses, which are increasingly made available at sub-municipal scale by the Brazilian Institution of Geography

and Statistics (IBGE). However, bottom-up studies contribute to better understanding and assessing local vulnerability and provide opportunities for increasing adaptation capacity at the local level.

In addition, a more systematic approach to the generation of case-study based evidence on the determinants of adaptive capacity in the Brazilian Amazon would clearly help to identify entry points for synergetic partnerships between local civil society organisations and government policies aimed at enhancing adaptive action at the local level. The research presented here suggests that -in addition to the conventional set of exposure related selection criteria- actor type, resource use specialisation strategy, and local governance indicators can be among key stratification variables to define case study locations to address smallholders' vulnerability to climate change.

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