

# HUMAN STRATEGIES FOR COPING WITH EL NIÑO RELATED DROUGHT IN AMAZÔNIA

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**Abstract.** This article reports on findings of a research project examining farmers' coping strategies in the Brazilian Amazon in response to El Niño related weather events. We examine the extent of vulnerability of small and large farmers to these events in a tropical rainforest environment. Little attention has been given to the impact of ENSO events in Amazônia, despite evidence for devastating fires during ENSOs. Although we found a range of locally developed forecasting techniques and coping mechanisms, farmers have sustained significant losses, and we suggest that increased access to scientific forecasts would greatly enhance the ability of the farmers in our study area to cope with El Niño related weather events.

In Amazônia the El Niño phase of the El Niño-Southern Oscillation (ENSO) climate pattern leads to an extended period of reduced rainfall (Hobbs et al., 1998). This period of reduced rainfall can result in significant agricultural losses for farmers and ranchers in the area and in increased forest flammability. We have found that the majority of our study population uses several methods of forecasting, coping with, and adapting to drought events – and they recognize the economic losses they can experience and the loss of forests through the accidental spread of fire. The poorest farmers in our study area experience El Niño related drought events as a serious threat to their livelihoods. Their vulnerability is heightened during extreme climate events and our observations revealed that all of the farmers in our study would benefit from increased availability of improved forecast information relevant to their locality and their current farming strategies. This paper examines the availability and use of forecasts, the occurrence of accidental fires and techniques to prevent fire related losses, and the coping mechanisms for dealing with El Niño related drought in the agricultural regions surrounding the cities of Altamira and Santarém, in Pará State, Brazil. Distribution of an El Niño Prediction Kit at the end of the study and a series of workshops may lead to better local information on rainfall variability and create a farmer-maintained grid of collecting stations to sensitize farmers to the variability of precipitation in the region, and on their property.

## 1. Introduction

ENSO-related fires exacerbate the already heavy impact that deforestation is having on Amazonian tropical rain forests. Though we might have expected that the

devastating forest fires in Borneo and Kalimantan in 1982–1983 (which resulted in more than 400,000 ha being destroyed) would have sounded a global alarm, during the early stages of the 1997–1998 ENSO over 5 million ha burned in Rondônia State alone in the Brazilian Amazon (Stern and Easterling, 1999: 47), and estimates are that an area cumulatively at least that large burned in the rest of the Amazon Basin. Although charcoal remains suggest that fire has been a natural disturbance in Amazônia for thousands of years, the frequency of large natural fires is thought to have been rare (i.e. once in hundreds or thousands of years) (Sanford et al., 1985; Saldarriaga et al., 1988; Meggers, 1994). Frequencies are now intra-decadal with measurable ENSO events in 1972–1973, 1977–1978, 1982–1983, 1986–1987, 1991–1993, 1997–1998, and 2002–2003.

The public, as well as the scholarly community, tends to associate ENSO events with either floods along the Peruvian Coast, or drought in Northeast Brazil – but not with impacts in the Amazon. This is a major oversight, since ENSO conditions have also been historically associated with dry conditions over most of northern South America (NOAA, 1999: 81). During the 1982–1983 ENSO, all 60 weather stations in Amazônia reported rainfall at least 70% below normal during January – February (Nobre and Renno, 1985; Molion, 1990). Rainfall at the Balbina hydroelectric climate station was 6.8 mm during January 1983, versus 200 to 300 mm, and it was only 94 mm in February as compared with the 250 to 350 mm typically expected (Meggers, 1994: 329). During the 1997–1998 ENSO, the impacts were even more severe, with fires destroying more than 6 million hectares of forest. The February to May 1998 forecast for Northern South America predicted a 45 to 50% below normal rainfall for the Amazon region, and it proved much lower than that in many regions, including our study areas (NOAA, 1999: 82). By the end of the 1998 ENSO drought, 1.5 million square kilometers of the Amazonian forests had less than 250 mm of water moisture in the top 10 m of soil, and thus were prime candidates for catching fire (Wuethrich, 2000).

This topic deserves increasing attention because of the growing evidence that unintended fires resulting from the greater flammability of the forest now account for more of the destruction of forests than intentional deforestation to convert forest to agropastoral uses (Alencar et al., 1997). This is not a result of drying from climate alone, but from the combined effects of selective logging that leads to in drier conditions in the remaining forest. The climatic drying associated with ENSO events make the conditions for large fires very likely. Not only are vast areas of forest destroyed, but so are plant and animal biodiversity, and a large amount of carbon is emitted from these areas (Cochrane and Schulze, 1998). Alencar et al. (2004) note that 91% of the forests that caught fire in their study area near Paragominas caught fire during ENSO events, once again highlighting the importance of this climate event to the survival of Amazonian forests. A special issue of the journal *Theoretical and Applied Climatology* was dedicated to Amazonian climate (V. 78, No. 1–3, 2004: pp. 1–193), a reflection that climatic information is being gathered and disseminated.

## 2. El Niño and its Amazonian Manifestations

Building upon advances in climate prediction gained from the Tropical Oceans and Global Atmosphere (TOGA) Observing System, the Coupled Ocean-Atmosphere Response Experiment (COARE) explored aspects of tropical atmosphere-ocean coupling that were poorly understood (National Research Council, 1996). These projects focused their attention on developing an accurate model of the inter-annual cycle of ocean warming and climate events that were associated with the El Niño phenomenon. El Niño cycles are associated with higher than normal sea surface temperatures in the tropical Pacific, while La Niña cycles are associated with lower than normal sea surface temperatures in the tropical Pacific (National Research Council, 1996). The 1997–1998 El Niño was thought to be the most severe in more than 100 years and gained worldwide media attention that resulted in an awareness of the potential of the El Niño phase of the ENSO cycle to impact people's lives (Changnon and Bell, 2000). While attention in Brazil has focused on the impact of these climate events on the drought-prone Northeast region (for instance Gaiser et al., 2003; Nelson and Finan, 2000), these climate events also impact the Amazon Basin.

Drought events are part of a feedback cycle that leads to decreased forest cover in the Amazon Basin. Deforestation in the Amazon Basin is a matter of persistent international concern because of its impact on biodiversity, climate change and emission of greenhouse gases (Gash et al., 1996). In a region where farmers still use fire as a part of a fallow-cycle farming technique, the control of fire under drought conditions becomes less reliable and the potential for accidental fires is increased. Reports of the spread of fires into forests have steadily grown in the Amazonian literature (Uhl and Kaufman, 1990; Holdsworth and Uhl, 1997; Lefevre and Stone, 1994; Nepstad et al., 1999). In areas that have been heavily logged in southern Pará State, it has been estimated that standing forest affected by fire now exceeds new deforestation by more than three-fold (Alencar et al., 1997). Logged forests reach combustible conditions after only six continuous rainless days, and secondary forests or fallows do so after only ten days (Uhl et al., 1990). In our study areas, especially Santarém, there can be 30 days without rain during ENSO events. Forests experiencing one fire are estimated to lose 10% of live biomass and, more importantly, they are more prone to a recurrence of fire – with the second and third events destroying up to 80% of living biomass (Cochrane and Schulze, 1998). In the Amazon El Niño years result in reduced rainfall. Feedback cycles are exacerbated by reduced rainfall during El Niño, accelerating forest loss (Figure 1, adapted from Nepstad et al., 1999). If one accounted for accidental fires in the region, the overall deforestation estimates in some regions would increase by as much as 129% (Cochrane et al., 2004). As the Amazon continues to be deforested and occupied with farmers and ranchers, and with increased logging activities, we can expect that ENSO events will continue to result in major devastating fires with both economic and biodiversity consequences.

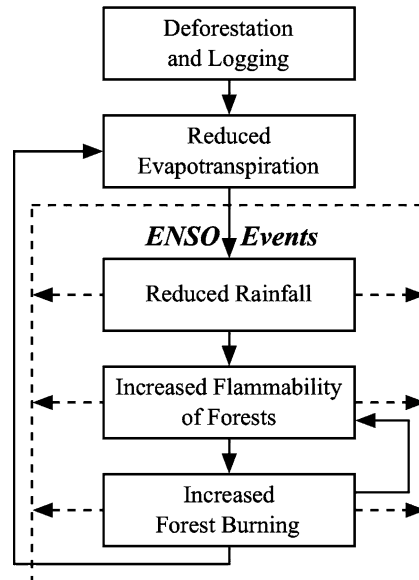


Figure 1. ENSO feedback cycle (adapted from Nepstad et al., 1999a).

Mega-Niño events in Amazônia appear to have occurred at ca. 400, 700, 1000, and 1500 BP, and were severe enough to have caused widespread fire, water shortages, and dispersal of indigenous populations (Meggers, 1994). Newspaper stories reported on the severity of El Niño in 1997–1998, the destruction of some areas of forest, and of the low level of the hydroelectric reservoir that resulted in regular blackouts for the urban population due to lack of generating capacity resulting from low water in the dam area (Alexander, 2002). Interestingly, a survey conducted in Santarém, one of the two sites investigated in the present study, showed that in early 1997, local newspapers reported higher than normal rainfalls and localized floods. This exceptional rainfall may have provided some protection during the early stages of the impending ENSO, masking the impact of the drought during the early months. However, in the latter stages it was regularly reported that the fire department had to be called to quench fires on properties near Santarém, as accidental fires became more common. During the 1997–1998 El Niño an extensive fire near the community of São Jorge, southwest of Santarém, burned an area of approximately 450 km<sup>2</sup> and was still well remembered by the community in 2001. The time-series satellite images below (Figure 2) show the impact of the 1997–1998 El Niño fire in São Jorge. The first image shows the highly vegetated pre-fire area in 1986; the second image shows the degraded vegetation, as well as patches of bare soil (red) caused by the 1998 fire; and the third image shows the extensive secondary succession (light green) in 2001.



Figure 2. Community of São Jorge – example of fire scarring (Landsat TM images are of July 29, 1986; August 10, 1999; and July 30, 2001 – path 227, row 62).

### 3. Vulnerability

While the vulnerability of forests to climate events has been well documented, the vulnerability of the populations to these same climate events is not as well known. This research focuses on the vulnerability of human populations in the Amazon to El Niño induced drought. Following Ribot et al. (1996) we define social vulnerability to climate events as a susceptibility to a reduction in the ability of affected populations to produce, reproduce, and develop due to the interaction between the features of the weather event and the social position of the population. Vulnerability to climate events varies based upon both characteristics of the climate event and the social and economic standing of the affected population. Ribot et al. (1996) describe the nature of this relationship:

“Vulnerability is shaped by ongoing processes of social differentiation and marginalization, within a specific social history of access to productive resources, formal and informal social security arrangements, state development policies, conflicts, etc. The resulting distribution of material stocks and access to income opportunities, land and other material resources, as well as access to formal and informal social security arrangements, spells out the material and social conditions circumscribing vulnerability for some households and security for others.” (pg. 8)

In the Amazon, this vulnerability is related to the reliance of the farming population upon adequate rainfall for the attainment of good harvests given the local agricultural cycle. Figure 3 shows the agricultural cycle in the Amazon region. The

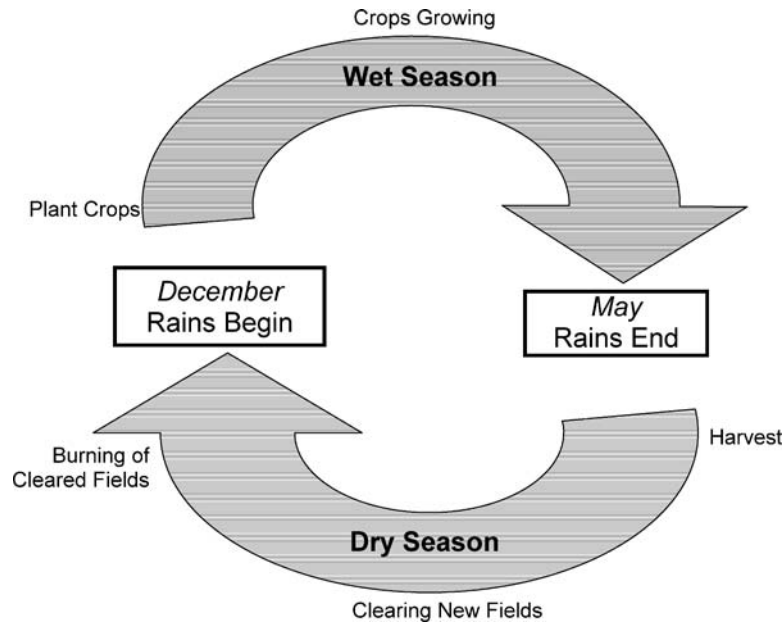


Figure 3. Agricultural cycle.

harvest is collected at the beginning of the dry season in May, which is followed by a period of field cleaning and preparation. At the onset of the wet season, the fields are burned and crops planted. The burning phase of the cycle is particularly critical since a good burn is necessary for good crop productivity. However, burning is a dangerous activity given the possibility of the fire getting out of control, especially if the vegetation is too dry.

The regional settlement process has resulted in differently endowed farmers at our two study sites, which influences the vulnerability that they experience due to El Niño related drought. Vulnerability is reduced by increasing the amount of information available to those with limited resources (Katz and Murphy, 1997). Accurate, useful forecasts of climate extremes could serve as one tool for vulnerability reduction (Stern and Easterling, 1999). The advances in our understanding of impacts of ENSO events allow better forecasts of weather events associated with this climate cycle, thereby providing tools to reduce vulnerability. However, the usefulness of a weather forecast is dependent on the accuracy and suitability of the forecast in relation to the coping strategies of users and their perceived needs (Stern and Easterling, 1999). We have sought to understand the ways in which farmers in the Brazilian Amazon make use of forecasting information, and what type of forecasting information would be welcomed in order to facilitate reduced vulnerability. Our study examines the local forecasting techniques and social vulnerability to El Niño related drought effects at two sites in Pará State, Brazil.

#### 4. Study Areas

Both Altamira and Santarém were incorporated into the national highway system in the early 1970s as part of a federally funded effort to enhance economic growth throughout the Amazon basin and integrate the region into the national economy. These efforts opened large tracts of land to planned colonization and spontaneous invasion. Previous to this time, both cities contained largely extractive economies concentrated near rivers and they depended largely on water transportation – Santarém being located at the confluence of the Amazon and Tapajós Rivers, Altamira on the Lower Xingu River. Santarém and Altamira are located in the same region and represent a similar historical, socio-economic, and colonization process, but contrasts exist between the cities in terms of current economic and biophysical conditions. The median farm size is larger in Altamira, while in Santarém the landholdings are not as evenly distributed, with both much smaller and much larger properties. The colonization of Altamira farmsteads was directed by the National Institute of Colonization and Agrarian Reform (INCRA), which selected farmers, brought them to the Amazon, and assigned 100 ha lots and house sites (Moran, 1981)<sup>1</sup>. While the settlement system was altered by the colonists, the landscape remains a model of the “fishbone” land use pattern, and farm sizes and geometry are very homogeneous, especially in comparison to the Santarém area. Farmers in Altamira have a higher average standard of living, and are located in an area with large patches of fertile “terra roxa eutrófica” soil or alfisols of high fertility in the U.S. Soil Classification System (Moran, 1981; Moran et al., 2002).

The Santarém agricultural region is much more heterogeneous than in Altamira, containing a greater concentration of both large-scale landownership and small-scale subsistence farming than Altamira. While INCRA was also active in Santarém, much of the upland farming area in Santarém was settled through land claims following the penetration of roads into the surrounding forests, in a more organic settlement process that resulted in smaller farms with less certain land tenure compared to Altamira. The Santarém study area does not contain the same high quality “terra roxa” soils and the water table is low making water access through well construction both difficult and costly throughout much of the upland area.

#### 5. Methodology

This paper is based on findings from a research project funded by the National Oceanic and Atmospheric Administration (NOAA) Program on Human Dimensions of Climate Change, involving a detailed survey of 442 households (171 in Altamira and 271 in Santarém) ranging in topic from demographic household structure to land use histories to forecasting methods. Fieldwork was carried out with teams of interviewers conducting separate interviews with the male and female heads of household. To accurately locate each household on the satellite images,

GPS units were utilized to collect spatially explicit information for each household. In addition, farm fields were visited to assist in the cross validation of land cover and land use as understood via the interviews and classified satellite imagery. Rainfall data, including hourly rainfall, temperature and humidity records from climate stations in both study areas, were collected. Members of the research team conducted interviews with personnel at radio stations, TV stations, and government agencies. Archival data related to past weather events, forecasting information, and government policy were collected. Research team members also participated in meetings with scholars, associations, and organizations operating in both study areas.

## 6. Discussion of Findings

We found that weather forecasts available from television, radio, and other media sources are reported at a basin-wide scale (an area the size of the continental U.S.A.), and is therefore of little local significance (i.e. “today it will be rainy in the Amazon region”). Our study population displayed a considerable lack of trust in these official forecasts, which is not surprising given its lack of local relevance. They understood that it would rain somewhere in the Amazon that day, but did not know from that forecast whether it would rain in their particular area of the Amazon. When farmers were asked about the sources of weather forecasts, most of them answered that they receive this information from the generalized media forecast, largely the Jornal Nacional forecast at 8 pm. (see Figure 4). The local TV stations reported that they simply repeated the national forecast as that was all the information available to them. However, when these same farmers were asked about the source of information for actual dry years remembered, the overwhelming response was

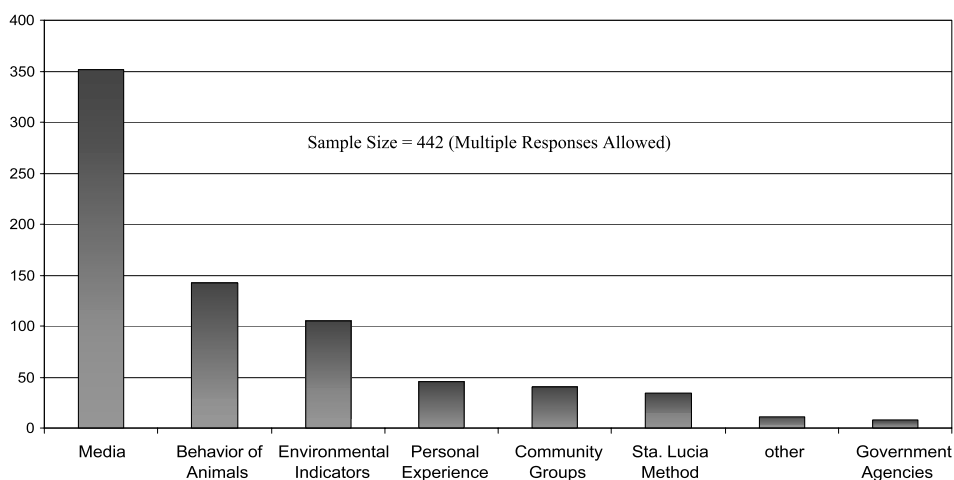


Figure 4. Sources of weather information in general.

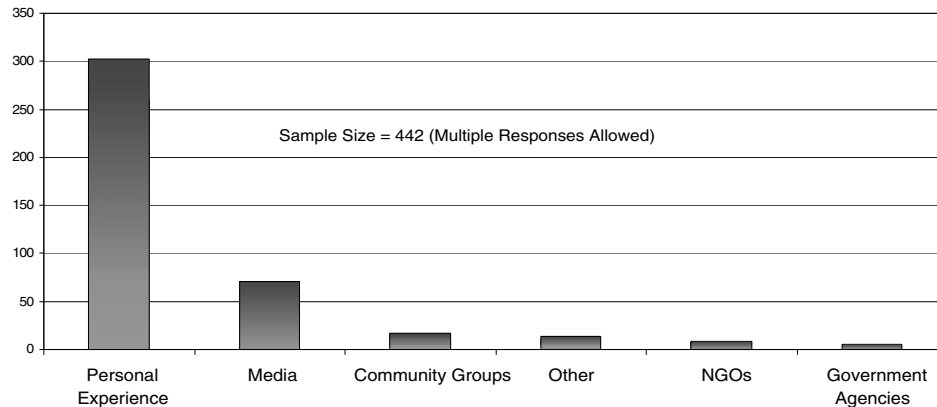


Figure 5. Sources of weather information for driest year remembered.

that the farmers relied on their own experience. This confirms the limitations of current weather information available from media sources and its irrelevance for reducing farmers' vulnerability to climate change. It is somewhat striking, how few farmers received information on a potentially catastrophic climatic event, like El Niño, from organizations that should be supporting them, like government agencies, NGOs, community groups, and the media (see Figure 5). The 2002–2003 ENSO was not reported at all during that period, as it was judged too mild. However, farmers during our study period noted that the early months of this ENSO event were comparably dry to the 1997–1998 event.

Farmers accurately recalled El Niño years, and they remembered the 1997–1998 El Niño with particular clarity, consistent with the risk perception and memory literature (Johnson, 1993). Figure 6 shows the correspondence between rainfall in the Amazon region.<sup>2</sup> El Niño years, and the local dry years as reported by interviewees. The strong memory of the 1997–1998 El Niño may be due to the intensity of the weather event (Changnon and Bell, 2000), its more recent occurrence, the loss of electrical power and water supply for parts of the Santarém site (Alexander, 2002), the effects of drought on the farmers' production, or perhaps due to the spread of accidental fires during this drought event.

Memories of dry years correspond to the recency of the event, rather than to any correlation or salience associated with their arrival time. In Figure 7 each cohort corresponds to the population that arrived between El Niño years. According to the literature 1997–1998 El Niño should be most strongly remembered, and this is confirmed by this research, and the declining memory of earlier dry events as a function of time. While the memories of farmers generally corresponded well to El Niño years, a remarkable number of farmers could not remember any particular dry year. This may indicate that occasional dry years are not unexpected and do not serve as a memorable event, or that at the time of the interviews in 2001 and 2002, the areas of study had experienced two years in a row of unusually heavy rains.

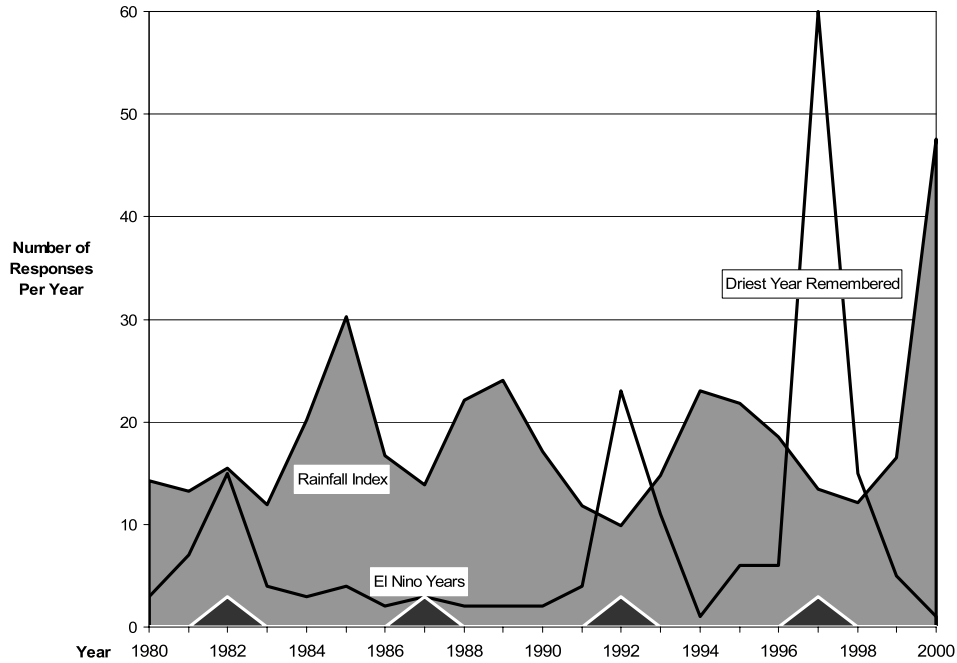


Figure 6. Memories of dry years vs. rainfall index of Amazon rainfall, local drought remembered, and El Niño occurrence (the rainfall index is given by total annual rainfall in mm. divided by 100, El Niño years from NOAA website, retrieved 2003).

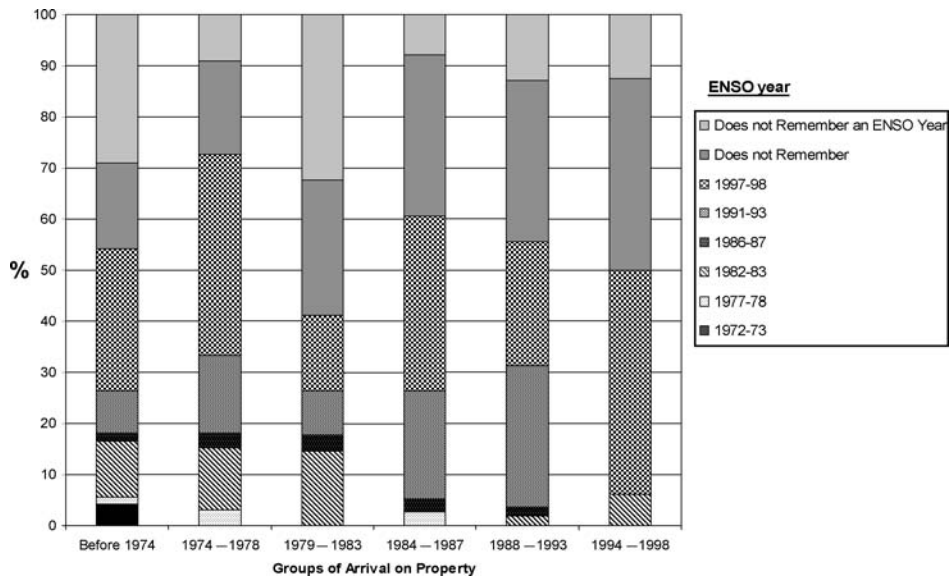


Figure 7. El Niño remembered as percentage of arrival group size.

Some interviewees focused on the very wet conditions of the last two years, rather than on earlier dry events, noting the difficulties created by excess rainfall.

Forecasts are perceived locally as irrelevant. This is due to a difference between the type of information provided by forecasters (daily national forecasts) and the type of information sought by farmers (beginning of the rainy season, end of the rainy season to facilitate harvesting), and to the intra-regional variability in rainfall intensity and timing. Figure 8 represents a three-month moving average of recorded precipitation in Santarém for the years 1980 to 1999, and in Altamira for the years

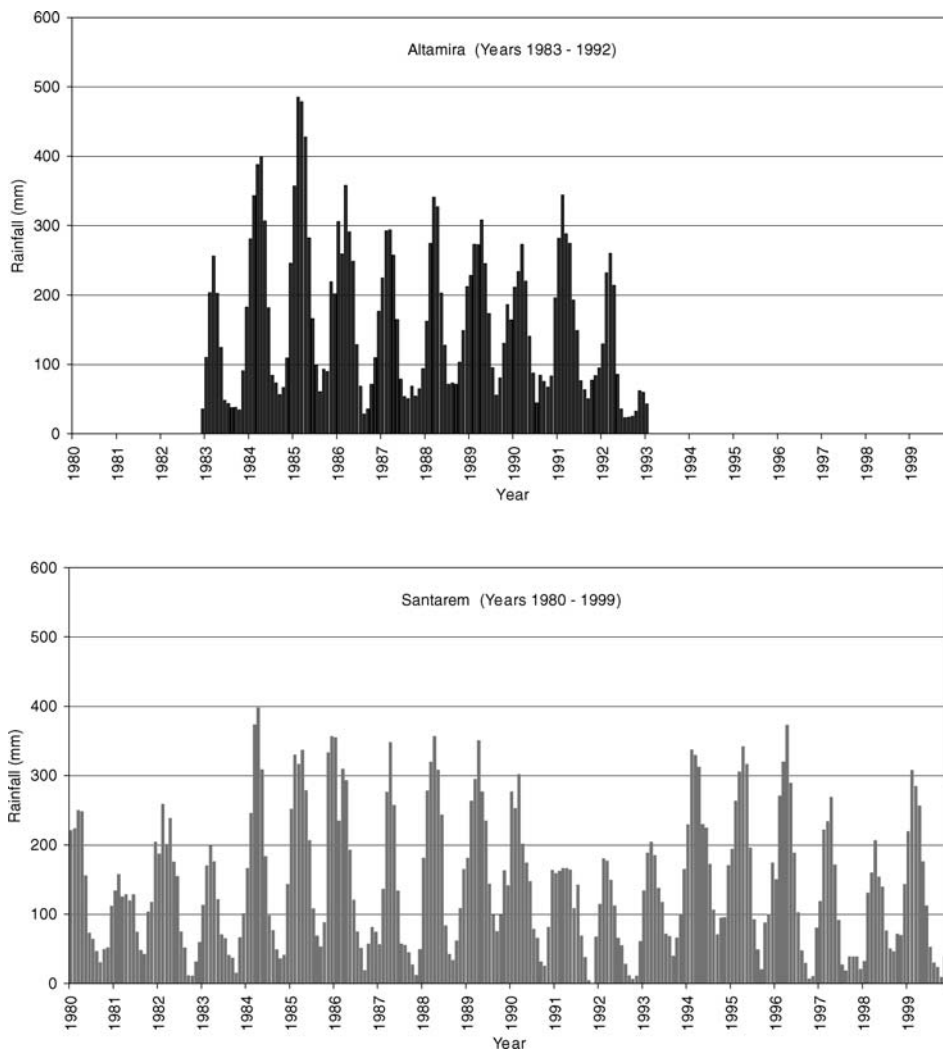


Figure 8. Rainfall in Santarém (Years 1980–1999) and Altamira (Years 1983–1992): 3 month moving average.

1983 to 1992.<sup>3</sup> Rainfall in Altamira is generally higher than in Santarém making the former area more resilient to dry periods. Soils in Altamira, in general, also have higher clay content, and thus greater moisture retention capacity, further buffering this area as compared to Santarém soils which have higher sand content. The rainfall data collected by EMBRAPA in the Santarém study area shows that during the 1997–1998 and 1992–1993 El Niño events the rains commenced with some irregularity and never reached the typical volumes during the peak of the rainy season. While the rainfall totals during these El Niños were significantly below average, local farmers placed greater emphasis on the timing of rainfall rather than the volume in a region marked by distinct dry and rainy seasons. The fear of drought ends with the beginning of the wet season, which usually delivers adequate rainfall once started. The timing of the beginning of the rains is essential for the most effective use of fire in the slash and burn agricultural system used in the region. The agricultural cycle (Figure 3) is aligned with the climate cycle of the region, rather than the calendar. In other words, the timing of burning and planting are timed to the first two or three rainfall events rather than to a given date. So, while burning may take place as early as October, it may also be delayed as late as January. If the fires are lit too early, the risk of accidental fires is increased, yet if the farmer waits until the rains start, then the abundant rainfall will lead to vegetation that will not be dry enough to burn efficiently. The ideal time to burn is just as the rains begin, because a fire lit too soon can result in accidental fire and extra work managing the aggressive regrowth of vegetation, while a fire lit too late will not burn efficiently due to wet fuel. During El Niño years, the drought conditions are manifest in the study region as a delayed start of the rainy season. This delay makes the calculation of the correct time to burn difficult, causes a decrease in the time available for crop production, and can devastate pastures. Figure 9 shows the effects of dry years as reported by the farmers in our sample. Most interviewees experienced negative effects related to their farming activity, such as delayed planting, diminished harvests, and dry pastures. These all have a direct impact on the overall level of production, increasing farmers' vulnerability. Dry pastures are of particular concern due to the widespread reliance on cattle as a form of savings and capital accumulation in the region (Moran, 1981; Moran et al., 2002). For farmers who specialize in the production of perennials, the increase in fire susceptibility is particularly important and is represented by both the fourth and fifth most commonly indicated effects of dry years in the region. These effects are real and can result in major losses.

Farmers in Amazônia find locally available ways to predict the beginning of the rainy season. These local sources include environmental signals, increased familiarity with the local weather gained from personal experience, ethnoecological forecasting methods, and information from community groups. Farmers monitor the behavior of the animals living on their farms, or wild animals living in the forests surrounding their farms; they learn to predict weather changes through monitoring cloud shapes, flowering or leaf dropping events in the local flora, and a variety of

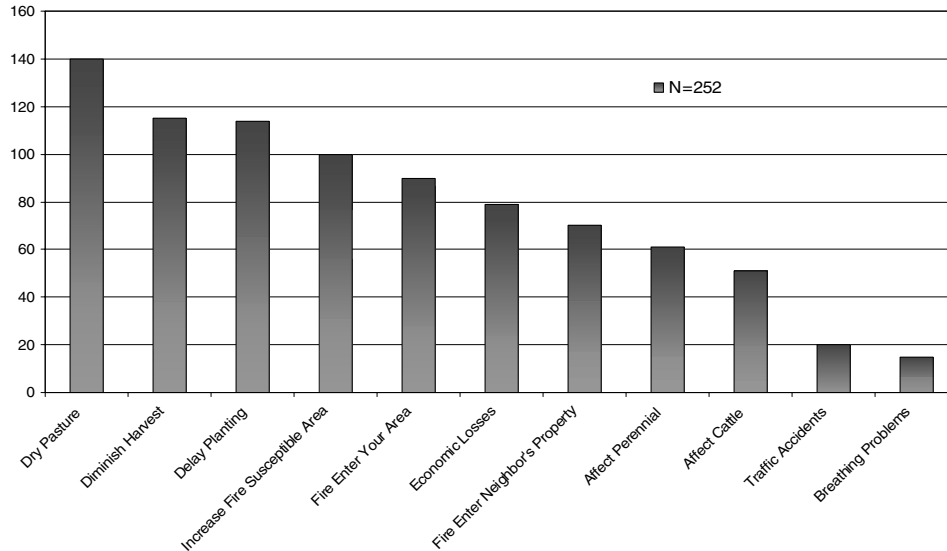


Figure 9. Effects of dry year.

other locally observable events that are reported as “personal experience” in our survey (see Figure 4). An interesting folk method of weather forecasting is related to the feast day of Santa Lucia. On her feast day, December 13th, families place five mounds of salt (for each of the five months of the rainy season) and these are laid out overnight on a table. The next day, the condition of the mounds predicts the months that will be rainy or not. Those mounds that remain intact represent drier than expected months, while those that break up due to moisture represent rainy months. This ethnoecological tradition appears to come from Northeast Brazil and is employed at both study sites, but mostly in Santarém where a larger set of migrants from Ceará, in Northeast Brazil is present. Farmers also indicate a willingness to turn to local agricultural extension agencies, NGO representatives, and churches for key information about the future local weather conditions.

Roncoli et al. (2002) suggest that local climate forecasting techniques may be just as accurate as available non-local/scientific forecasts. Orlove et al. (2000) reported on the remarkably accurate ethnoclimatological prediction system in the Andes in which farmers observe the apparent brightness of the Pleiades at the winter solstice in order to forecast interannual variations in summer rainfall, with remarkable accuracy in permitting adjustments in planting dates of potatoes, their most important crop. We suggest that until locally relevant forecast information is available, the use of folk criteria for forecasting may be no less accurate.

While many farmers in our study have developed reliable local forecasting methods for making agricultural decisions, they also welcome the possibility of gaining greater access to more scientific forecasting techniques. In support of this effort, our study reported on the results of the investigation after data collection and analysis,

and provided farmers with an ENSO Prediction Kit in a series of workshops held at both study areas. The Kit provided 60 farmers with rain gauges and a manual as a means to enable the collection of a daily rainfall record to be generated from a larger number of locations within this sub-region of the greater Amazon. The manual includes data for the past 20 to 30 years, and shows them how to record and diagram the information and how to recognize an ENSO pattern from the rainfall distribution. The goal is to establish a geo-referenced grid of farm-based collecting stations that will begin to provide a more detailed understanding of rainfall variability, and gradually result in better local forecasts. We hope to revisit each rain gauge every year to check on the success of the data collection effort, to discuss with farmers the pattern that they see in the data, and to collect the data from all the locations so that it can be fed into a database and used to generate spatially-explicit local forecasts that could inform the extension service and the farmers' union, both of which expressed interest in this information as an improvement over currently available records.

## **7. Vulnerability and Responses to Drought Events**

Farmers respond to the effects of El Niño related drought in a number of ways, reflecting their differing capacity to cope with these events. The use of firebreaks to prevent accidental fires is nearly universal. When the field is prepared, the vegetation is felled and left on the ground to dry. Before the vegetation is burned, the farmer clears the dried vegetation from a width of land on the edge of the field so that the firebreak contains no fuel for the fire near the edges of the intended burn area. Ninety-four percent of the farmers in our sample employ this strategy. Since the absence of this technique is locally considered to be irresponsible, we suspected that interviewees would over-report their use of the technique. However, 80% of farmers also report that their neighbors use this method, indicating the likelihood that a high percentage does in fact use firebreaks. It is possible that the use of these preventative methods is spreading due to the work of local officials and outreach programs such as that operated by Instituto de Pesquisa Ambiental da Amazônia (IPAM). The construction of a firebreak is not the only accidental fire prevention method. Many farmers (32%) warned their neighbors before burning, and a few farmers reported waiting for the right conditions to burn (8%) or maintaining a vigil over the burning field (7%). The labor requirements for these activities favor farmers with enough resources to pay for the firebreak to be constructed and those families with adequate household labor. The smaller-scale, older farmers face a labor allocation dilemma relative to decisions to clear more land, changing the timing of their burn, and time spent constructing firebreaks. The greater need for firebreaks during dry years in combination with less time available for crops to grow may lead to reduction in the areas to be cultivated for those without resources to pay for additional labor.

The farmers in our sample claimed a great willingness to change their behavior in response to drought. The strategies varied, but the primary ones reported by interviewees included the construction of a water reserve (20% Altamira/10% Santarém); investment of greater resources for accidental fire prevention (30% Altamira/9% Santarém); or the purchase of food supplies (9% Altamira/24% Santarém). Construction of a water reserve allows farmers to maintain their cattle herd during a period when cattle prices drop as farmers sell-off cattle to reduce pressure on their pastures. Those farmers who have adequate resources are thus able to choose a better time to sell their cattle, reducing their losses. Poorer farmers may be caught between rapidly degrading pastures and falling prices for cattle. Purchasing food supplies is a strategy employed most often by the poorest farmers, and cash reserves for this population can quickly be depleted, leaving them with few options if they should experience another crisis, such as a sickness in the family.

Half of the farmers would alter their cropping patterns (timing, size, or crop type) in response to drought. Many of those who would not change indicate that they would maintain a system that is already quite flexible. The most prominent change in the cropping pattern is to alter the timing of planting. When questioned about response to a particularly dry year, 55% of farmers in Altamira would change the timing of their planting.<sup>4</sup> In Santarém, 50% would wait for the rain, and most of the remaining would use their "normal" timing, which according to the reported land use history of these farmers, appears to include waiting for the rain. For large-scale landowners, this strategy may be related to greater access to detailed crop information (such as private agricultural extension services). Seed varieties, timing and crop type could all be adjusted with accurate information on the time to harvest, input requirements and yield of the various options. The greater access to information would reduce the risks associated with these changes.

Compared to the Altamira site, a greater proportion of the Santarém population is extremely poor. This was observed throughout the fieldwork, and our survey confirms this relationship in terms of size of landholding, level of farming technology, and level of material wealth (ownership of a wide range of household items). Several of the poorer farmers elaborated on their responses to drought questions with indications of desperation, a few expressing fear of starvation if a strong drought were to occur. The ability of these farmers to increase the area planted or to change the type of crops is likely to be constrained by their inability to purchase agricultural inputs and foods to substitute for crops that perform poorly in dry years. The decision to delay planting is a particularly difficult choice under these circumstances, as an underproductive crop can have disastrous consequences.

Although our survey reports losses due to accidental fires, this rarely resulted in social conflict. Most farmers were committed to resolving disputes between themselves, instead of involving the police or the courts. In case of an accidental fire, two-thirds claimed that they would seek the neighbor or responsible party for a discussion about damages and compensation, but only one-fifth of respondents reported that they would seek the intervention of authorities.

The potential for an escalation of conflict related to losses sustained during accidental fires remains a concern in both study sites due to the proximity of distinct land uses and associated differences in socioeconomic status. In Altamira, large farmers with cocoa have given up the use of fire as a management strategy due to the danger of losing their significant capital and labor investment in their crop. In the time since our survey, Santarém has experienced an influx of large-scale mechanized grain farming (predominantly soybean) and these newly arrived farmers do not use fire to clear their fields. In both sites, those with a large number of cattle were likely to express greater concern with losses due to accidental fire, while those expressing the least concern in both sites are the subsistence farmers, who still burn as part of their land preparation strategies. The cost of accidental fires is potentially higher in areas dominated by greater capital investments such as cattle, cocoa, and soybean. In the future, the same type of neighborly resolutions to accidental fire losses may not be employed by larger-scale, better connected landowners, willing to use litigation to recoup their losses.

## 8. Conclusions

This research suggests that improved climate prediction and dissemination of information (i.e. forecasts and increased collaboration between stakeholders and extension agencies) would provide the necessary information to permit land users to take preventive steps to decrease crop and ranching losses and reduce the potential of fires running out of control. The climate information available to farmers in the Brazilian Amazon, however, is quite limited. Under these conditions, farmers turn to local environmental and ethnoecological sources of information about climate forecasting for farm management. To make decisions about likely weather conditions, they use signals such as the blossoming of particular trees, calls from particular birds, or most often some combination of signals learned through time, that they describe as “personal experience”. These strategies reduce vulnerability by enabling the farmers to make a variety of adaptations to climate change, such as adjusting the timing of their crop plantings, adjusting the proportion of their harvest that they hold over from year to year, investing in water retention for cattle, or changing the types of crops they plant. Despite these potential coping structures strategies, many of the poorest farmers still face the terrifying prospect of food shortage in the case of a strong drought. The distribution of an El Niño Prediction Kit at the end of the study, and a series of workshops explaining how to collect the rainfall in the rain gauges, and how to record and diagram the precipitation pattern, has begun to empower local people with an understanding of rainfall variability and provided them with a new set of tools to begin to improve their recognition of ENSO events at a local level.

### Acknowledgements

The authors wish to thank the National Oceanic and Atmospheric Administration (NOAA) for financial support of this research through their Office of Global Programs, Special Program on the Human Dimensions of Climate Change, and grant #NA06GP0344. They also wish to thank a very large number of collaborators who participated in the research and who will be authoring other papers related to this work, among them Cynthia Sorrensen, Eduardo Brondizio, Andrea Siqueira, Thomas Ludewigs, and Miguel Villarreal. We thank the Climatology Department at EMBRAPA/CPATU and Dra. Thereza Bastos for sharing the rainfall data. The comments from three reviewers were very useful in undertaking revisions. None of the above colleagues, nor our funding sources, should be held responsible for the views expressed here. They are the sole responsibility of the authors.

### Notes

<sup>1</sup>The lead author (Moran) has worked in Altamira for more than 30 years, and the research benefited from the availability of historical ethnographic and survey data for this site.

<sup>2</sup>(the rainfall index is given by total rainfall in mm divided by 100).

<sup>3</sup>The data set is not complete but is still the best representation of precipitation in the two study regions.

<sup>4</sup>25% of Altamira farmers would plant earlier (in Altamira another important concern is the early onset of the dry season, rather than a late start to the rainy season), while 30% would wait for the rain.

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(Received 24 August 2004; in revised form 13 December 2005)