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ORIGINAL PAPER

Vulnerability and adaptive capacity of community food systems in the Peruvian Amazon: a case study from Panaillo

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Abstract Rainfall variability and related hydrological disasters are serious threats to agricultural production in developing countries. Since projections of climate change indicate an increase in the frequency and intensity of climatic hazards such as flooding and droughts, it is important to understand communities' adaptive capacity to extreme hydrological events. This research uses a case study approach to characterize the current vulnerability and adaptive capacity of the food system to hydrological hazards in Panaillo, a flood-prone indigenous community in the Peruvian Amazon. Participatory methods were utilized to examine how biophysical and socioeconomic factors constrain or enable local adaptive capacity to climatic hazards over time. Seasonal flooding was shown to strongly influence agriculture and fishing cycles. Panaillo residents have developed several adaptive strategies to adjust to hydrological extremes, such as food-sharing and the cultivation of fast-growing crops on riverbeds. However, Panaillo residents generally lack the necessary human, physical, social, and natural resources to effectively employ their adaptive mechanisms as a result of major social and environmental changes in the area. Economic development, low institutional capacity, climate variability, and the assimilation social model in Peru all have profound effects on the food system and health by affecting the ways in which adaptive strategies and traditional livelihoods are practiced. Climate change

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has the potential to exacerbate these socioeconomic and biophysical drivers and further compromise community food systems in the Peruvian Amazon in the future.

Keywords Climate change · Adaptation · Vulnerability, flood · Food security · Peru · Amazon · Food system · Indigenous

1 Introduction

Peru had one of the highest rates of undernutrition in Latin America and the Caribbean in 2008, notwithstanding a significant reduction in overall malnutrition rates, dropping from 22.9 to 17.9 % between 2005 and 2010 (Acosta 2011). While some authors attribute this reduction to recent political efforts and social welfare programs, others assert that these social programs have been ineffective as a result of failing to consider local context and the drivers of malnutrition (Urke et al. 2014; Stifel and Alderman 2006; Aguiar et al. 2007; Yamada and Castro 2007). It is also important to note that Peru still experiences significant inequalities in nutritional status, with the malnutrition rate of rural populations almost three times higher than the malnutrition rate of urban populations (Acosta 2011). Amazonian and Andean regions, in particular, experience higher food insecurity in comparison with the national average (Urke et al. 2014).

Food security is intimately linked with health and climate in an Amazonian context, where livelihoods are often directly dependent on environmental resources (Kronik and Verner 2010; Takasaki et al. 2010). Agro-fishing livelihoods are widespread in the Peruvian Amazon. Fish and bushmeat are the primarily sources of protein for Amazonian inhabitants, and corn and cassava are considered to be the most important food sources for subsistence farmers in the area (Aguiar et al. 2007). Agro-fishing livelihoods and local ecosystems are strongly linked to the flood-pulse in the Amazon Basin, characterized by a terrestrial phase with low water levels and an aquatic phase with high water levels (Junk et al. 1989). The flood-pulse is crucial for triggering certain ecological processes (e.g., plant growth rates, and nutrient deposition) and influences the timing of socioeconomic activities for floodplain inhabitants (Marengo et al. 2012; Kvist and Nebel 2001). Flood peak levels vary year to year, with some years experiencing flood levels that are higher or lower than normal (Espinoza et al. 2009). Interannual variability in the flood-pulse can thus result in years with extreme flooding and/or droughts, which have been associated with El Niño Southern Oscillation (ENSO) events, as well as sea surface temperature (SST) anomalies (Marengo et al. 2012; Espinoza et al. 2012). While some interannual variability in the flood cycle is normal, Espinoza et al. (2012) assert that extreme hydrological events have increased in frequency in the Amazon Basin since the 1980s.

Extreme hydrological events, such as droughts and flooding, are projected to increase in frequency and severity in the Amazon as a result of climate change (Magrin et al. 2014). According to mid-range climate change scenarios, temperatures in the Amazon as a whole are expected to rise by 1.8 to 5.1 °C by 2100 (Malhi et al. 2008), with a recent study projecting that extreme El Niño episodes will double in the future as a result of warming (Cai et al. 2014). Transitions from extreme El Niño episodes to La Niña phases can also result in dramatic seasonal transitions, such as the 2010 drought, which was followed by the 2010–2011 floods (Espinoza et al. 2009). Studies have found important distinctions in how different parts of Amazonia will respond to climate change (Cook et al. 2012;

Cochrane and Barber 2009). For example, the Peruvian Amazon, located in the western part of the Amazon Basin, is expected to have a wetter rainy season in the future, whereas the southern Amazon and central Brazil are expected to experience a drier dry season, as well as a wetter rainy season (Cook et al. 2012). Temperatures are also expected to rise more in the western Amazon than in the east (Magrin et al. 2014). Langerwisch et al. (2013) calculated future flood duration and area in the Amazon Basin using 24 climate models from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. In 70 % of the 24 climate models, the area of flooding increased in the Amazon Basin by one-third. On average, flooding also lasted three months longer in the western Amazon and 1 month longer in the eastern Amazon. The lower river levels in the dry season and stronger currents and storms in the rainy season would severely impede transportation in the area (Santa Cruz et al. 2013; Pinho et al. 2014; Marengo et al. 2013). The impact of climate change in the Peruvian Amazon would have significant repercussions for the flora and fauna in the area, including impacts on food networks and competition, reproductive cycles, and plant phenology (Santa Cruz et al. 2013; Langerwisch et al. 2013; Davidson et al. 2012; Marengo et al. 2013). Davidson et al. (2012) highlight that Amazonian species are accustomed to seasonal variability, but that extreme hydrological events could overwhelm the ecosystem's resilience.

It is also important to note that agricultural expansion, deforestation, and recent growth in urban populations have been crucial factors in generating current regional climate changes in the Peruvian Amazon (Magrin et al. 2014; Malhi et al. 2008; Vegas de Cáceres 2010). Land-use changes in the region are largely driven by the expansion of agriculture and palm oil plantations, deforestation, the extraction of minerals, coca, and forest products, urbanization, and the construction of roads and infrastructure (Brondizio and Moran 2008; Vegas de Cáceres 2010; Santa Cruz et al. 2013; Magrin et al. 2014). These drivers have been stimulated by national and international demand and have been closely linked to Peru's rapid economic growth (Santa Cruz et al. 2013; Davidson et al. 2012; Pantigoso 2014).

Extreme climatic events, such as flooding and droughts, have occurred in the Amazon for thousands of years and communities have developed traditional adaptive mechanisms to negotiate this uncertainty and variability (Kronik and Verner 2010; Tomasella et al. 2013; Pinho et al. 2014). For example, in the Peruvian and Ecuadorian Amazon, swidden-agricultural practices and crop diversity have helped strengthen food production systems and maintained food security amidst climatic hazards (Perreault 2005; Gray et al. 2008; Kvist and Nebel 2001). Floodplain agriculture also sustains most of the rural population in the area due to enhanced fertility on floodplains (Kvist and Nebel 2001). However, due to a combination of economic structures, public policies, shifting social networks, and environmental changes, food systems in the Amazon are undergoing rapid transitions and may be unable to maintain food security amidst seasonal flooding events in the future (Pinho et al. 2014; Marengo et al. 2013; Hofmeijer et al. 2013; Gray et al. 2008; Goy and Waltner-Toews 2005). For instance, many indigenous Amazonian households are now practicing more intensive, commercial agriculture, which is inherently less resilient to a climatic hazard (Gray et al. 2008). Indigenous populations are particularly vulnerable to climate change impacts on food security due to their political marginalization, dependence on natural resources for food and livelihoods, rapid socioeconomic and cultural transitions, and health inequality (Ford 2012, 2006; Green 2009; Hofmeijer et al. 2013). It is thus increasingly important to understand communities' adaptive capacity to extreme hydrological events in order to address future health inequities and inform climate change policies.

Situated in this context, this paper characterizes the current vulnerability and adaptive capacity of the food system to hydrological events in Panaillo, a flood-prone indigenous community in the Peruvian Amazon. Specifically, the paper aims to characterize the biophysical and socioeconomic drivers of the food system at the household and community level and examines how socioeconomic and biophysical factors enable or hinder local adaptive capacity to climatic hazards over time. In doing so, we examine how the food system operates under normal climate conditions and characterize how climatic and non-climatic stresses and change propagate through the food system. Given the importance of social factors in determining vulnerability (Watts and Bohle 1993; Smit et al. 2000), this paper focuses on the *relative* impact that flooding and climatic stressors have on the food system in comparison with other non-climatic factors, as well as how flooding exacerbates or alleviates those non-climatic drivers.

2 Methodology

2.1 Conceptual approach

This paper adopts a "contextual" vulnerability approach and seeks to understand how climatic hazards interact with socioeconomic, cultural, and political conditions to make some individuals, households, groups, and communities more vulnerable to climatic hazards than others (O'Brien et al. 2007; Smit and Wandel 2006; Ford et al. 2010). Vulnerability is a dynamic concept that describes a system's "capacity to be wounded" (Ford et al. 2010) and is both an outcome and a process, reflecting the potential for loss or the susceptibility to harm of a system in response to change or stimuli (Smit et al. 2000; Smit and Wandel 2006). Vulnerability is a function of sensitivity, exposure, and adaptive capacity (Smit et al. 2000). Exposure refers to the nature of the stimuli (e.g., flood) and its characteristics (e.g., magnitude, spatial extent, frequency, duration). Sensitivity refers to the traits of the socio-ecological system itself, which determine how the exposure will manifest (e.g., livelihood activities and how they take place in the context of the exposure, biodiversity). Adaptive capacity addresses how the system manages, addresses, and adjusts to the conditions that result from this exposure sensitivity, including the ability to take advantage of new opportunities (Ford and Smit 2004; Smit and Wandel 2006). Sensitivity, exposure, and adaptive capacity thus illustrate how vulnerability results from a combination of internal and external processes, including the system's underlying susceptibility and defenselessness, as well as external risks, shocks, and stresses (Bohle et al. 1994). Resources are often differentially distributed within a system, which can constrain or enable the accessibility and implementation of certain adaptive strategies (Bohle et al. 1994; Kelly and Adger 2000). Accordingly, "contextual" vulnerability research focuses on building adaptive capacity in order to address multiple underlying drivers of vulnerability, not just climate-related risks (Kelly and Adger 2000; Ribot et al. 2005). Vulnerability thus depends upon multiple stressors interacting at multiple spatial and temporal scales (Smit and Wandel 2006).

In order to acquire a multi-scalar, holistic understanding of food security, this research referred to the "food systems" approach to vulnerability (see Ford 2012; Ingram et al. 2010). Food security is often defined in terms of the availability, accessibility, and utilization of food (FAO 2008). A food system approach examines these food security components, as well as the wide range of activities that are responsible for food production, processing, packaging, distribution, retailing, and consumption (Ingram et al. 2010). Our research thus focuses on traditional food security outcomes, as well as the social and environmental conditions that influence and result from food system activities (e.g., market dynamics, river navigability, extractive industries, and social networks). Food system vulnerability thus results when food security outcomes are not achieved (e.g., insufficient food quantity), social welfare is diminished (e.g., disruption of social networks), and/or environmental damage is incurred (e.g., biodiversity loss) (Eriksen 2008).

Ford (2012) notes that the exposure sensitivity of a food system to climate change reflects (1) the nature of the climatic conditions (e.g., magnitude, duration, speed of onset, and timing; discussed in Sect. 3.2.1) and (2) the characteristics of the food system (e.g., livelihood diversification, poverty, and social relations). Accordingly, this research examines how the specific characteristics of a given climatic hazard (e.g., flood timing, intensity, and duration) affect food security, as well as the socioeconomic and cultural factors that pre-condition the food system to be vulnerable or resilient to a climatic hazard (e.g., income inequality, market dynamics, and institutional arrangements). Flooding may not be a driver of food insecurity if there are sufficient deployable resources before, during, and after the event to effectively cope with the post-hazard aftermath (Eriksen and Silva 2009; Sherman and Ford 2013). Although some authors distinguish "adaptive" strategies from "coping" strategies (e.g., Campbell and Beckford 2009), this paper will exclusively refer to "adaptive" strategies when describing how an entity copes with or manages a particular stress, consistent with other studies (see Smit and Wandel 2006).

2.2 Study site

A case study approach is valuable in vulnerability research to provide an in-depth, contextualized understanding that can be difficult to attain using other research methods (Ford et al. 2010). The Shipibo-Konibo community of Panaillo served as the case study for this research. Panaillo was selected as a case study given the community's similar socioeconomic characteristics to other indigenous communities in the area (Hofmeijer et al. 2013) as well as the community's current and historical experiences with seasonal flooding. Similar to many Amazonian communities in this region, the history of Panaillo also illustrates the community's precarious location on a shifting riverbed. Since it was founded in the late nineteenth century, the community has had to relocate several times due to shifts in river flow (Bergman 1980). In 2004, the village was forced to temporarily relocate to the nearby urban centers of Pucallpa and Yarinacocha due to extreme flooding and erosion from a shift in river flow. Many households assumed permanent residence in Pucallpa at this time, while others re-established the community of Panaillo in its current location (Sherman 2014). Panaillo currently has a population of 220 people, representing 22 households. Whereas the community's former location was only inundated during exceptionally high flooding, occurring every 5 years at most, Panaillo's current location floods with .75–1.5 m of water each rainy season. The intensity and frequency of this flooding is thus relatively new for Panaillo, making Panaillo a useful case study to explore the vulnerability and adaptive capacity of communities in the Peruvian Amazon amidst a shifting flood regime.

Panaillo is located in the Peruvian Amazon on a riverbank where the Panaillo tributary and the Ucayali River meet (see Fig. 1). Panaillo floods each year during the rainy season, which is typically from January to April (Carranza 2013). Due to seasonal flooding, houses are elevated on stilts so that the floor is between one and 1.5 m from the ground. It is Shipibo-Konibo custom to have settlements on the banks of rivers and lakes in the

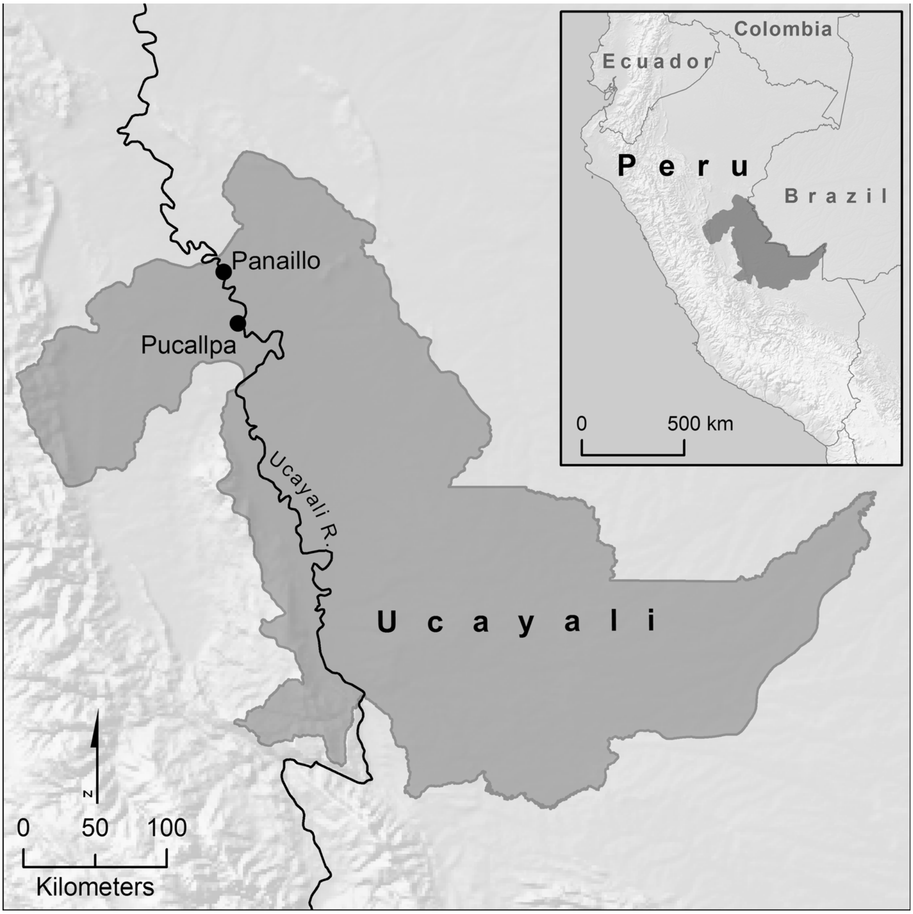

Fig. 1 Study site of Panaillo. *Source*: Adam Bonnycastle

floodplains since these locations have easy access to aquatic life and fertile soils (Bergman 1980). Detailed information on seasonal flooding is provided in Sect. 3.2.1.

The Shipibo-Konibo are an ethnic group in the Peruvian Amazon that mainly resides along the Ucayali River and its tributaries (Behrens 1986). Shipibo-Konibo culture is a product of the fusion of three communities: the Shipibo, the Konibo, and the Xetebo all of which belong to the Panoan linguistic group (Tournon 2002). The Shipibo-Konibo have a matriarchal social organization, and women play an active part in community organization and resource management, although male heads of larger families have the most influence (Heise 1999). According to common practice and traditional custom, Shipibo-Konibo communities are relatively egalitarian (Tournon 2002). The Shipibo-Konibo residents of Panaillo have maintained strong traditional beliefs and customs, including the use of the indigenous language and the value placed on kinship and reciprocity (Sherman 2014). However, Panaillo and many other communities in the area are currently experiencing major environmental and social changes, including more extreme flooding and increased market integration. Following the construction of a road, Panaillo is now accessible in the dry season by traveling 2–4 h by road from Yarinacocha. However, the road is often closed due to poor conditions, and residents must frequently rely on boat travel in the rainy season and much of the dry season to reach Yarinacocha (approximately 5–7 h, depending on river level) (Sherman 2014).

The community has two schoolhouses and four schoolteachers who teach kindergarten and primary school. Given the distance and cost of transport (approximately 10 USD round-trip) to travel between Pucallpa and Panaillo, community members must temporarily move to the city in order to attend secondary schools, typically staying with extended family members. The community also has one Level 1 health post where community members can receive basic medical treatment. However, the health post is operated by a single nurse technician, who frequently travels to Pucallpa. Since the health post is frequently closed, community members with boat access often travel to the health center in the neighboring *mestizo* (non-indigenous) community of Tacshitea.

Traditional livelihoods largely include agriculture and fishing, which is the predominant source of food and income for Panaillo households. Household income has become increasingly important to purchase foods, especially in times of food scarcity, such as the offseason (Sherman 2014). At the time of fieldwork, six residents also sold timber, five residents sold fish, four residents were recently employed by logging or oil companies, and all Panaillo households sold agricultural products. Six Panaillo respondents and two migrant respondents also reported working on large agricultural plantations as temporary wage laborers. Households purchase food from two local family stores in Panaillo, the market in Tacshitea, and the regional market in Pucallpa (Hofmeijer et al. 2013). In half of households, one or more family members reported working outside of the community in the past year in low wage, temporary labor positions (e.g., commercial agriculture, oil/logging operations, and small businesses), and over 75 % of households report migrating seasonally to live in Pucallpa and the surrounding area during the rainy season (Sherman 2014).

2.3 Methods

The study was carried out in accordance with the principles of community-based participatory research (CBPR) and guided by an ethical framework developed prior to the research being undertaken (Sherman et al. 2012). In this research, community members work in partnership with the researchers and are actively involved throughout the research process and the research is built on a foundation of respect, trust, co-learning, and empowerment (Sherman et al. 2012). Accordingly, a variety of participatory rural appraisal (PRA) qualitative methods were employed. PRA describes a family of qualitative field research methods that are designed to be culturally appropriate and accessible to rural populations with low levels of education, for example, by utilizing local materials and visuals in the research activities (Chambers 1994). PRA methods have been successfully employed in other studies examining community adaptive mechanisms to climatic hazards in Latin America and Africa (Kronik and Verner 2010; Eriksen et al. 2005; Tschakert et al. 2010; Hofmeijer et al. 2013).

Semi-structured interviews were conducted with 27 Panaillo residents (12 men, 15 women). Interviews were carried out with at least one member of each household ($n = 18$), thus representing a census of all households present in the community during fieldwork. Snowball sampling was also used to interview an additional 15 migrants (six men, nine women) who formerly lived in Panaillo and now permanently live in the outskirts of Pucallpa. Interviews were also conducted with 32 employees of local, regional, and national institutions, including governmental and non-governmental organizations working in health, disaster risk management, agriculture, education, indigenous issues, and research (For a list of interviewees and their institutions, see Online Resource 1). Interviews lasted between 45 and 120 min and were conducted in Spanish or Shipibo-Konibo with the assistance of a local research assistant.

Interview guides were utilized for the community and institutional interviews (see Online Resource 2). The interview guides were pretested for content and context by academics, local research collaborators, and community members. Seventy percent of participants gave permission for interviews to be audio-recorded ($n = 52$). Recorded interviews were transcribed verbatim and manually checked for transcription error. When participants preferred to be interviewed without audio-recording ($n = 22$), detailed notes were written for each interview. Community members were asked questions regarding their traditional livelihoods, history in the community, food sources and preferences, food security questions adapted from the Latin American and Caribbean Household Food Security Scale (ELCSA) (Pérez-Escamilla et al. 2007), as well as climate change perceptions and experiences with flooding and droughts. Interviews with institutional employees were asked questions regarding their institutions and experiences with flooding and food security. It is indicated in the results section when a given question was not asked to all interview respondents. However, food security questions were asked to every Panaillo resident and migrant who were interviewed.

Participant observation was also performed by the field researcher in order to gain a more in-depth understanding of the study area and research topic. The field researcher was able to build rapport with community members through home stays, cultural exchange, and participation in local customs and practices during extended field visits that first began in 2013 and have continued since project completion.

Three types of *participatory rural appraisal focus groups* were also carried out in Panaillo. Eight to thirteen individuals participated in each focus group. Each focus group was carried out twice, once with a group of men and once with a group of women, in order to examine the different perspectives that exist in the community and to comply with local cultural norms and power structures (Davis 2001; Mayoux 2005; Kesby 2000). The field researcher also separated the participants into smaller groups and monitored the participation of each individual. In accordance with cultural norms, all community members were invited to participate in the research at a communal assembly. The field researcher also worked in partnership with research assistants, local authority figures, and other community members to ensure that diverse and alternate voices were represented in the research. The historical timeline activity was carried out first, followed by the seasonal food security calendar, and then the risk ranking exercise. Each focus group session lasted between 1 and 3 h.

The first focus group aimed to gain a better understanding of community context and history through a *historical timeline* activity (see Fig. 2; Online Resource 3). Participants were asked to chart the community's history in relation to food security from a point in the past to the present by recalling the important social and environmental events in their lives or in the popular memory of the community (Mayoux 2005; Davis 2001). Discussion centered on the significant socioeconomic, cultural, and climatic events in the community's history, the adaptive strategies used in response to these events, as well as the evolution of food practices and resource availability in the community.

The second focus group centered on the creation of a *seasonal food security calendar* in order to characterize the impact of normal seasonality on food security and livelihoods, as well as to examine how extreme climatic events impact the food system (FAO 2011).

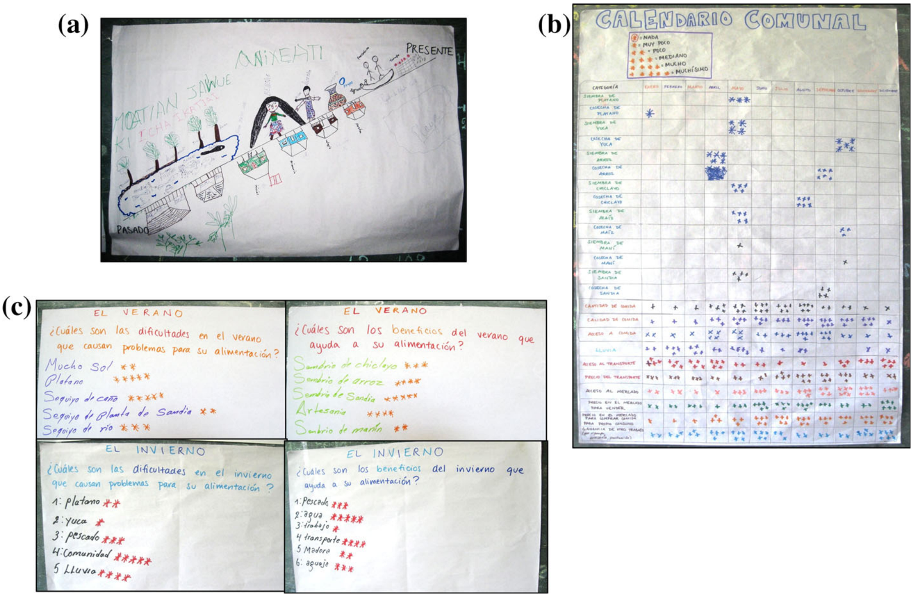

Fig. 2 Posters from participatory rapid appraisal focus group activities, including, **a** historical timeline, **b** seasonal food security calendar, and **c** risk ranking

Participants were provided a blank calendar with categories related to household food security (e.g., food quantity, food quality, and access to food), local food markets (e.g., access to the market, market prices for buying/selling agro-fishing products), livelihoods outside of agriculture and fishing (e.g., traditional handicrafts, timber production), precipitation, transportation (e.g., price, accessibility), and planting and harvest activities of the main crops (e.g., plantain, cassava, rice, cowpea, corn, peanut, and watermelon) (see Fig. 2). Each category was evaluated based on if the abundance or availability in a given month was very high, high, moderate, low, very low, or nonexistent.[1] Participants were in agreement for the majority of scores given to a given category and dissonance for a particular score was resolved through deliberation. After the completion of the calendar for a year with "normal" flooding, the group was asked to identify a year with "extreme" flooding. All groups chose to discuss the extreme flooding that occurred in 2010–2011. The groups then discussed the similarities and differences between the "normal" flood year and the "extreme" 2010–2011 flood year for each category of the original seasonal calendar. Participants also discussed the various adaptive strategies that have been used in the community in response to climatic extremes and explained how these strategies have changed over time.

Risk ranking activities were employed in the final focus group in order to examine the perceptions of vulnerability drivers and adaptive strategies among community members. In this focus group, participants listed and ranked what they considered to be the principal

[1] For example, the scores for the category regarding prices for buying food in the market were highest in the rainy season (November to January) and lowest at the end of the harvest season (August to October). Since the markets in this area are driven by supply and demand, the community perceptions of price fluctuations, in this case, are coherent with what would be expected for markets in the area.

challenges and opportunities of maintaining household food security during the rainy season. The ranking activity was then repeated for the dry season (see Fig. 2). Discussion centered on the availability of and preferences for particular adaptive strategies for climatic events and also examined the persistent effect of certain drivers of risk (e.g., if food security in the dry season is still affected by flooding from the rainy season). This activity also illustrated the relative perceived risk of flooding and droughts for food security in comparison with other non-climatic risks.

All interviews, participant observation notes, and focus groups were transcribed and analyzed using the Mayring approach to qualitative analysis (Mayring 2004). Accordingly, a codebook was created based on the vulnerability framework (e.g., Ford and Smit 2004; Smit and Wandel 2006) and applied to the transcripts. The prominent themes that emerged through this preliminary analysis (e.g., low institutional memory) were then included in the codebook and applied deductively to the transcripts for final analysis. The results are thus presented according to the prominent themes that emerged in the inductive category development, although the vulnerability framework provided the conceptual foundation for the work. Multiple sources of data (i.e., community interviews, institutional interviews, focus group discussions, participant observation, peer-reviewed literature, and gray literature) were also triangulated in the analysis for this study. Frequency counts and percentages were sometimes used to describe the data, such as food security questions (e.g., "in the past year, did you ever eat less than you felt you should because there wasn't enough food?").

3 Results

3.1 Household food insecurity among current and former Panaillo residents

The traditional Shipibo-Konibo diet is largely based around fish, which is complemented by a carbohydrate, such as plantain, cassava or rice. Households also consume chicken, beans, vegetables [e.g., regional sweet pepper (*Capsicum chinense*), tomato, and fruit (e.g., camu camu (*Myrciaria dubia*), mango]. Whereas households are typically able to produce sufficient cassava, rice, and cowpea in Panaillo, they will often need to travel to Pucallpa or Yarinacocha to purchase plantain, chicken, vegetables, and fruit. However, when asked about the level of household consumption of vegetables, 93 % of Panaillo residents ($n = 25$) and all migrants indicated that a lack of financial resources made it difficult to incorporate vegetables into their diet. Current and former Panaillo residents also reported significant challenges with household food quantity, quality, and stability (Table 1). Eighty-five percent of Panaillo respondents ($n = 23$) and all migrant respondents interviewed reported reducing food consumption as a result of not having enough food, and inadequate quality of food was reported in the majority (89 %) of interviews with Panaillo and migrant households. All current and former Panaillo residents ($n = 42$) interviewed reported being worried about their household's food security, especially for children in the family. Over three-quarters of current and former Panaillo respondents reported feeling hungry, skipping meals, and eating less than they felt they should at various points in the last year. In 2012, Panaillo had the highest rates of malnutrition and anemia out of the 33 communities participating in a provincial nutrition supplementation program for children under the age of 5 (Programa Articulado Nutricional, Ucayali, interview 2013).[2] A worker

[2] Official documentation is currently unavailable.

Table 1 Overview of food insecurity among current and former Panaillo Respondents

Dimension of food insecurity	Panaillo respondents ($n = 27$)	Migrant respondents ($n = 15$)	Average ($n = 42$)
Insufficient food quantities	100 % ($n = 27$)	100 % ($n = 15$)	100 % ($n = 42$)
Insufficient food quantities leading to reduced food consumption	85 % ($n = 23$)	100 % ($n = 15$)	93 % ($n = 39$)
Poor food quality	89 % ($n = 24$)	100 % ($n = 15$)	93 % ($n = 39$)
Skipping 1–2 meals	77 % ($n = 21$)	87 % ($n = 13$)	81 % ($n = 34$)
Eating less than know should	77 % ($n = 21$)	100 % ($n = 15$)	86 % ($n = 36$)
Feeling hungry	85 % ($n = 23$)	80 % ($n = 12$)	83 % ($n = 35$)

from this nutrition program commented that: "When the children are over 6 months old, the mothers just teach them how to endure the hunger" (Interview #47, 5/17/2013).

When asked why the household had insufficient household food, 85 % of Panaillo interviews ($n = 22$) attributed this to the male household head not going fishing as a result of illness, injury, flood conditions, and/or being occupied with other income-generating livelihoods, such as working outside of the community for logging companies, commercial plantations, and construction (see Table 2). Almost half of Panaillo respondents with reduced food consumption ($n = 11$) discussed how the household suffered from insufficient food when alternative ways of acquiring food were unavailable, such as sharing food ($n = 4$), consumption of agricultural products ($n = 3$), and using money to purchase food ($n = 4$). Since fishing is a male-dominated activity, women must rely on a male family member going fishing and/or depend on agricultural production, other sources of household income, and food-sharing to provide food for themselves and their families. Whereas only one Panaillo respondent exclusively discussed low financial resources when asked what was responsible for insufficient household food levels, all migrants discussed money as the sole reason for insufficient food quantities.

3.2 Distal drivers of Panaillo food system vulnerability

Climate variability, economic development, low institutional capacity, and the assimilation social model in Peru have profound effects on the food system and health by affecting the ways in which livelihoods and adaptive strategies are practiced (Fig. 3). These four drivers reflect the prominent themes that emerged in the Mayring qualitative analysis. Each driver will be described in the context of this study in the following sections.

3.2.1 Climatic events and variability

The Panaillo River begins to rise with the onset of the rainy season in November. Flooding typically begins in January in the same lower areas of Panaillo each year and was reported by most Panaillo respondents (78 %, $n = 21$) to become completely flooded within one week. Flooding typically lasts 2–3 months, with peak flood levels in February or March. Earlier rains can result in earlier flood onset, as seen in 2012–2013 (Carranza 2013). The flood in 2012–2013 also had a later peak than usual due to less intense rains, which led to a slower progressive rise of the Ucayali River (Carranza 2013). Hydrological station data are

Table 2 Respondent-attributed reasons for household food insecurity dimensions

Reason reported for household food insecurity	Dimension of food insecurity reported to affect	Panaillo respondents attributing reason to dimension of food insecurity	Migrant respondents attributing reason to dimension of food insecurity
Male family member does not go fishing	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	96 % ($n = 22$)	0 % ($n = 0$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	86 % ($n = 18$)	0 % ($n = 0$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	86 % ($n = 18$)	0 % ($n = 0$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	87 % ($n = 20$)	0 % ($n = 0$)
Male family member away working	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	22 % ($n = 5$)	7 % ($n = 1$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	19 % ($n = 4$)	0 % ($n = 0$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	19 % ($n = 4$)	7 % ($n = 1$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	17 % ($n = 4$)	8 % ($n = 1$)
Male family member occupied with local work (e.g., agriculture, commercial fishing)	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	17 % ($n = 4$)	0 % ($n = 0$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	10 % ($n = 2$)	0 % ($n = 0$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	5 % ($n = 1$)	0 % ($n = 0$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	9 % ($n = 2$)	0 % ($n = 0$)
Low financial resources	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	26 % ($n = 6$)	100 % ($n = 15$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	29 % ($n = 6$)	100 % ($n = 15$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	43 % ($n = 9$)	100 % ($n = 15$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	43 % ($n = 10$)	100 % ($n = 12$)

Table 2 continued

Reason reported for household food insecurity	Dimension of food insecurity reported to affect	Panaillo respondents attributing reason to dimension of food insecurity	Migrant respondents attributing reason to dimension of food insecurity
Lack of harvest foods	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	13 % ($n = 3$)	0 % ($n = 0$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	14 % ($n = 3$)	0 % ($n = 0$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	19 % ($n = 4$)	0 % ($n = 0$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	17 % ($n = 4$)	0 % ($n = 0$)
Flood conditions explicitly mentioned	Insufficient food quantities resulting in reduced food consumption ($n = 23$ Panaillo; 15 migrant)	9 % ($n = 2$)	0 % ($n = 0$)
	Skipping 1–2 meals ($n = 21$ Panaillo, 13 migrant)	10 % ($n = 2$)	0 % ($n = 0$)
	Eating less than know should ($n = 21$ Panaillo, 15 migrant)	19 % ($n = 4$)	7 % ($n = 1$)
	Feeling hungry ($n = 23$ Panaillo, 12 migrant)	22 % ($n = 5$)	8 % ($n = 1$)

not available for Panaillo specifically, although local meteorological data from the nearby city of Pucallpa indicate that 2004, 2008, 2011, and 2012 were years with particularly severe flooding (General Direction of Aquatic Transport, personal communication 2013). When asked to describe extreme flooding, community members stated that extreme flooding rises faster (48 %, $n = 20$), lasts longer (79 % $n = 33$), and rises higher (88 %, $n = 37$). Twenty-one percent of community members ($n = 9$) also commented the flood duration was the most important distinguishing feature of an extreme flood in comparison with normal floods. Additionally, over 80 % of community members ($n = 35$) described extreme flood years by the relatively greater damage it incurred. The most frequently mentioned characteristic of extreme flooding in community interviews was that floodwaters cover the house floor ($n = 32$). Whereas community members discussed extreme flooding events in the historical timeline activity, they did not discuss droughts or extreme dry conditions. Although droughts have been documented in the area (Espinoza et al. 2012), community members did not identify a particular year with extreme drought conditions in any of the interviews or focus groups and instead exclusively described the conditions that normally occur in the dry season. The focus placed on flooding likely reflects the recent memory of two extreme flooding years (2010–2011 and 2011–2012), which took place prior to fieldwork in 2013 and led to the Ucayali region declaring a state of emergency in order to receive national support for flood relief (SENAMHI 2014).

The interaction between the rainy and dry season was shown in this research to strongly influence agro-fishing livelihoods in Panaillo. The majority of interview respondents and

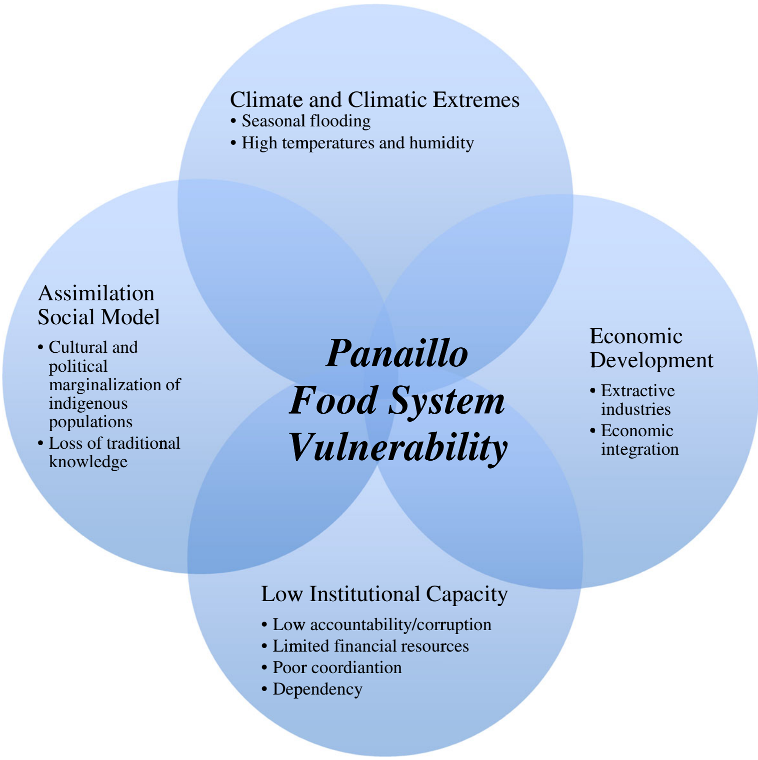

Fig. 3 Distal drivers of Panaillo's food system vulnerability

focus group participants discussed how flooding inhibits year-long agricultural production and Panaillo residents can only cultivate fast-growing crops that can reach maturation in 3–4 months (e.g., cowpea, rice, watermelon, and peanuts). However, Panaillo residents also take advantage of the vast nutrient-rich floodplains that emerge when the water levels lowers in the dry season. Many households will construct temporary shelters on the sandbar in August in order to harvest more efficiently. Since the sandbar in Panaillo is closer to the neighboring town of Tacshitea, Panaillo residents also have greater access to the Tacshitea market to buy and sell in the dry season. Floodplain agriculture is responsible for the majority of harvest foods used for household consumption and sale. With regards to fishing livelihoods, the high volume of water and strong currents associated with flooding make fishing difficult in the rainy season. Equally, flooding was also described by the majority of community members to replenish local fish stocks since the high water levels enable fish to leave their lake habitats and migrate downstream, which is consistent with observations elsewhere (e.g., Goulding 1980). As a result, community members experience more productive fishing during the *mijano*, which is the period of fish abundance when the flood waters recede and fish become trapped in new lakes (Junk et al. 1989; Santa Cruz et al. 2013; Kvist and Nebel 2001). The abundance and variety of fish during the *mijano* were discussed in over 30 % of community interviews ($n = 13$), as well as the seasonal food security focus group.

All of the benefits and difficulties listed in the risk ranking focus group for the dry and rainy seasons were directly or indirectly related to hydrological conditions. For example, participants in the risk ranking focus group and the food security calendar focus group described lacking access to safe drinking water in the dry season. Since the water wells are not functional in Panaillo, drinking water comes from backswamps and the Panaillo tributary, which become stagnant and turbid amidst low river levels. Easy access to water for cooking and bathing was listed as benefit of the rainy season in all risk ranking focus groups. Participants in the risk ranking focus group also described how employment opportunities are often limited in the rainy season since many local industries, such as commercial agriculture, are unable to operate fully in the rainy season, whereas employment opportunities was considered to be a benefit of the dry season. Accordingly, the hydrological conditions in Panaillo bring both opportunities and challenges to the food system. However, community members generally lack the resources needed to fully take advantage of the opportunities presented by the rainy season and dry season for reasons discussed in the following sections, including constraints related to economic development, low institutional capacity, and the assimilation social model.

3.2.2 Economic development

Recent economic growth has dramatically changed the landscape and livelihoods of the Peruvian Amazon. Extractive industries, including mining, logging, and oil exploration, have significantly contributed to Peru's rapid economic growth (Pantigoso 2014). The recent Law 20230, which was passed by the Peruvian Congress in July 2014, is expected to further expand these extractive industries. The law aims to promote investment in Peru by simplifying the procedures and permits as well as establishing favorable tax measures for investments, specifically mining projects. Since Panaillo residents depend on both financial and natural resources for their food, the resource extraction and market integration that have resulted from Peru's economic development have important implications for the food system. Community members also directly participate in extractive industries through temporary employment ($n = 4$).

Panaillo residents have also become increasingly dependent on financial resources to meet household needs, yet community members struggle to effectively participate in the market economy. All Panaillo respondents reported lacking access to a stable, fairly priced market. Financial resources are needed to sell and purchase foods, as well as to engage in traditional agro-fishing livelihoods. For example, a fisherman needs a boat, gasoline, traps, ice, and an ice chest in order to profitably sell fish. One Panaillo resident explained: "You need money in order to work" (Interview #36, 7/13/2013). Financial need was stated by the majority of Panaillo respondents ($n = 25$, 93 %) as the reason for selling their agricultural crop immediately after the harvest. Since the markets in Ucayali are entirely driven by supply and demand, this means that the vast majority of Panaillo respondents sell their crops at a time when market prices are lowest. Panaillo residents also have limited access to fair prices due to their lack of market contacts. The majority of Panaillo residents reported needing to sell their products to intermediaries, which reduces profit.

3.2.3 Low institutional capacity

This research documented a variety of challenges for institutions at the community, district, provincial, and national levels, including low institutional resources, poor budget management, limited preventative action, and dependency on international organizations (for further discussion see Sherman 2014). Institutional capacity in this area was also weakened by the high rates of turnover in leadership positions. For example, the Civil Defense is responsible for disaster management at the local and regional levels and is led by the mayor at the district level and the president of the region at the regional level. These positions change every 4 years, and the former leader is not required to leave any information or documents in the office for the newly elected official. Furthermore, the mayor and president of the region receive no explicit training in disaster management and also have many other responsibilities. One respondent commented that: "Because of high turnover, [the mayor] doesn't know what to do when there's a disaster" (Interview #65, 7/8/2013). When asked to describe what is needed to manage and respond to annual flooding, two institutional interviewees considered the lack of institutional memory to be the greatest weakness of the disaster management system in Peru.

Inaccurate institutional information as a result of weak information systems in many government institutions further constrains the delivery of government services. For example, Panaillo's electoral district changed 5 years ago from Callería to Yarinacocha and Panaillo should currently benefit from services and programs designated for communities in the Yarinacocha district. However, two respondents from the Yarinacocha branch of a program at the Ministry of Agriculture were unaware that Panaillo was part of their district's jurisdiction and that Panaillo should thus be included in program activities. As a result of this misunderstanding, Panaillo cannot consistently rely on Yarinacocha services and the community is not taken into consideration in the planning of Yarinacocha programs.

Issues of accountability and corruption were prominent themes that emerged in this research's qualitative analysis and have been documented elsewhere. For example, corruption was estimated to cost Peru approximately 3.6 billion dollars annually (Comisión de alto nivel anticorrupción 2013). It is also estimated that the poorest Peruvians spend 5 % of their income for payments to officials in order to receive services (World Bank Peru 2013). In this research, one-fourth of institutional interviewees ($n = 8$) discussed how political favors and the politicization of services have become increasingly common. Consequently, citizens often leverage their political power around elections in order to receive services. One respondent from the National Civil Defense Institute (INDECI) described the need for increased vigilance over mayoral allocation of resources. The respondent explained that: "Many times a mayor might be friends with a particular community, invent a disaster, and give money that ultimately goes to a party. Other times, the funds stay in the mayor's office and never make it to the community" (Interview #63, 6/17/2013). Five interviewees also discussed how political affiliations stifle effective collaboration between government offices. Corruption of this nature significantly constrains government services and programs that could otherwise benefit Panaillo's food system and increase its adaptive capacity to seasonal flooding.

3.2.4 Assimilation social model

Whereas climatic events, economic development, and low institutional capacity are relevant for all communities in the area (indigenous and non-indigenous), indigenous communities such as Panaillo must also contend with a social model in Peru that ultimately promotes cultural assimilation. Over the past few decades, Peru began to advocate for *interculturalidad*, an idea based on cultural exchange and communication between distinct groups with different customs (Coronel Cáceres et al. 2008). However, many authors note the continued use of a social model that systematically promotes assimilation (described in this study as an "assimilation social model") (Valdivia et al. 2007; Carmona and Cristóbal 2009). In particular, Valdivia et al. (2007) asserts that the state's policy toward indigenous peoples is ultimately based on acculturation and assimilation. In this research, institutional interview respondents similarly listed the dominance of the western system ($n = 6$), the creation of dependency within social programming ($n = 5$), and the State's lack of recognition of the indigenous system ($n = 6$) as obstructions to *interculturalidad* in Peru. According to semi-structured interviews, the indigenous system is described here as the belief system, political system, ethical values, educational system, and social norms that reflect indigenous principles, which are often distinct from the western system associated with European influence. According to six institutional interview respondents, the Peruvian State has not provided the conditions needed for a genuine exchange between the western and indigenous worlds and has favored the western system. One institutional interview respondent explained that,

> Our approach is still very western… [The Peruvian government] isn't saying that 'I'll give you support for your model, your culture, your perspective, your life plan.' No. Instead, they say 'I won't include your system and I'll include you under the image of welfare' (Interview #72, 8/1/2013).

Peru's assimilation social model was further illustrated by the high levels of discrimination and political marginalization that were documented in this research. Panaillo participants in the historical timeline focus group reported personal experiences of cultural discrimination and political marginalization in health posts, schools, and government institutions. Six institutional respondents noted how government programs related to indigenous issues do not receive the appropriate amount of funding. Ten interview respondents and participants in the historical timeline focus group explicitly discussed how discrimination and marginalization have contributed to the loss of traditional knowledge and practices. Consequently, Panaillo residents, especially younger community members, can no longer depend on the traditional strategies used to cope with flooding (Table 3). For example, one of the youngest interviewees could not answer any question related to traditional agricultural knowledge (e.g., How do you know to plant your seeds in the sandbar? What sort of soil do you plant on for different crops?), whereas all of the other community respondents were able to answer these questions in interviews. Similarly, Behrens (1989) observed that Shipibo-Konibo communities increasingly ignored traditional agricultural knowledge when they began cash cropping rice.

Although intercultural healthcare and multilingual education have been actively promoted in Peru, several recently studies have similarly criticized these systems and their implementation. The Peruvian healthcare system has been criticized by several authors for the lack of recognition and validity given to traditional health systems, particularly in rural and Amazonian regions (Goy and Waltner-Toews 2005; Francke 2013; Defensoría del Pueblo 2008). Other authors highlight how intercultural bilingual education in Peru exists in less than half of rural schools, teachers do not receive sufficient technical and financial support and curricula often lack cultural and sociopolitical content (Cueto et al. 2012; Sumida Huaman 2014; Maurial and Suxo 2011). Aikman (2012) describes how intercultural schooling in the Peruvian Amazon can further marginalize indigenous communities by reinforcing the "otherness" of indigenous people and labeling the community as "indigenous," which is a term that still connotes backwardness and inferiority in many parts of Peru. According to Aikman, what is needed is "a political and transformative response to the intercultural lives they lead, not a technical adaptation of the educational status quo" (2012: 248).

Table 3 Common traditional adaptive strategies for flooding in Panaillo

Traditional adaptive strategy	Description of strategy
Cultivation of fast-growing crops on fertile sandbars	Fast-growing crops are cultivated on sandbars in the dry season. Community members cultivate rice, cowpea, corn, peanut, watermelon, as well as a fast-growing cultivar of cassava that reaches maturity within 4 months. All households sell agricultural products to the local markets. Since the flooding changes the timing and soil conditions for agriculture each year, children are taught by parents and family members how to plant, maintain, and harvest these crops amidst variable conditions
Food-sharing	It is a strong Shipibo-Konibo custom to share foods with extended family and neighbors. Behrens (1992) reported that sharing food helps to smooth food consumption during food shortages and to avoid spoilage
Seed storage	After the harvest, seeds are stored in plastic containers (e.g., plastic bottles). Community members use these seeds for planting material, as well as an food source during food shortages in the rainy season
Campeón and *sapo* plantain	Community members cultivate and consume more flood-resistant plantain plants throughout the year. Normal plantain species cannot survive multiple days submerged in floodwaters. These species can withstand up to 1 week in water due to the plant's strong roots. These plantain species have not been formally classified
Fariña	Fariña is a dried and preserved form of cassava that is prepared prior to the rainy season each year. Fariña is used as a carbohydrate source when plantain is unavailable. Children are taught by parents and family members how to prepare the fariña
Breadfruit (*Artocarpus altilis*)	The fruit from breadfruit trees are consumed as a carbohydrate source when other carbohydrates are unavailable. Breadfruit trees grow wild in the surrounding area of Panaillo, although community members reported that the number of wild breadfruit trees has declined over the past 5 years, potentially due to over-extraction

3.3 Proximal drivers of Panaillo food system vulnerability

The interaction of climate variability, economic development, low institutional capacity, and an assimilation social model has important consequences for Panaillo's food system vulnerability (Fig. 4). The following sections will describe how these distal factors translate on the ground to influence Panaillo's vulnerability.

3.3.1 Resource degradation and ecosystem changes

The growth of extractive industries in the Peruvian Amazon amidst low institutional capacity has contributed to widespread resource degradation throughout the area, as found in this research as well as other literature (Goy and Waltner-Toews 2005; Finer and Orta-Martínez 2010). Deforestation from agricultural expansion, road paving, logging, and other land-use changes in the Amazon basin alters the energy and water balance in the local and regional ecosystem, as well as accelerates the erosion that naturally occurs in these meandering river systems (Davidson et al. 2012). In the Pucallpa area, most logging is done through illegal concessions, in which local residents sell timber directly to companies (Cossío et al. 2014). In Panaillo, such practices have resulted in increased scarcity of high-

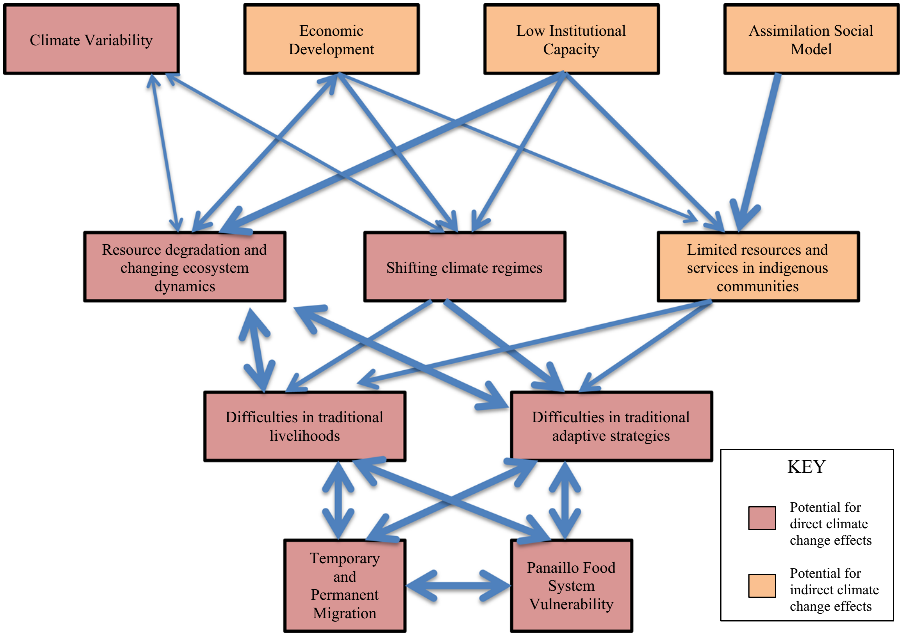

Fig. 4 Interaction of major drivers of Panaillo's food system vulnerability

quality timber that can be sold in the market (historical timeline focus group), and three community respondents reported being unable to engage in timber extraction this year as a result. Seven interview respondents also attributed declines in fish and animal populations to deforestation, since logging has introduced debris and toxins into the water, directly destroyed the habitats of many animals, and used loud machinery that causes animals to flee the area. Over the past few decades, the indigenous and non-indigenous populations in Ucayali region have also grown rapidly, which also increases pressure on aquatic and terrestrial resources (Goy and Waltner-Toews 2005).

Fish populations are also threatened by illegal fishing practices and over-extraction, as mentioned in 10 community interviews and seven institutional interviews. The historical timeline focus group also described how traditional fishing methods (e.g., spears) did not capture as many fish and that large nets and poisons have been increasingly used in the past decade. Barbasco is derived from the roots of the plant *Lonchocarpus nicou* and is widely used in the Peruvian Amazon as a poison for fishing. The roots are macerated and placed into the water and the poison stuns the fish, allowing for the capture of a large quantity of fish at varying maturity levels (Smith 2001; Sirén 2006). According to a higher-level official in the provincial Civil Defense office, the laws to sanction such practices are ineffective, since minor infractions frequently go unsanctioned, especially when committed by small-scale fishermen (Interview #53; 5/30/2013). Another expert on the Ucayali fishing sector noted the lack of control mechanisms to effectively monitor the area, stating that,

> A million laws can be passed, but the problem is in the implementation… The law comes out-the rules, the size restrictions-but the institutions don't have the logistics and the ability to enforce or control it… It's a dead law (Interview #70, 7/22/2013).

Accordingly, 45 % of community interviewees ($n = 19$) and over one-third of institutional respondents ($n = 11$) discussed changes in fish and animal populations in the recent past. The decline in fish populations has severe repercussions for the Shipibo-Konibo cultural identity, which is strongly linked to fish. Several studies have similarly attributed changes in ecosystem dynamics in the Amazon Basin to agricultural expansion, deforestation, mining and oil exploration, overfishing, urbanization, and, to a lesser extent, human-induced climate change (Santa Cruz et al. 2013; Davidson et al. 2012; Vegas de Cáceres 2010; Kvist and Nebel 2001; UNDP and BCPR 2013; Futemma and Brondízio 2003; Finer and Orta-Martínez 2010).

3.3.2 Shifting climate regimes

In this research, over 30 % of community members ($n = 13$) and 38 % of institutional interview respondents ($n = 12$) reported observing changes in climate, including less predictable rains, hotter temperatures in the dry season, and more frequent and severe flooding events. These interview respondents noted how unpredictable rains have complicated agricultural production, and one community member commented that,

> It's been the dry season for two weeks here, but every afternoon it rains, rains, rains, and you can't work or cultivate or work around the house. There have only been three days in the summer without rain… Everything has changed (Interview #4, 5/10/2013).

Fourteen interview respondents also reported changes in river dynamics, including changes in river flow patterns ($n = 5$), more extreme flood events ($n = 8$), flooding in new areas ($n = 3$), and lower river levels overall ($n = 2$). A schoolteacher in Panaillo similarly commented that: "Now there's the fear that the river is dangerous and that it is eroding and Panaillo will disappear again" (Interview #57, 6/2/2013). Similar changes in climate have been perceived by other inhabitants of Ucayali, who reported experiencing a hotter climate, increased forest fires, and difficulty with transportation as a result of low river levels (Vegas de Cáceres 2010). Regional climate changes in the Amazon Basin have also been reported in recent publications, and have been associated with the types of land-use changes described in the previous section (Magrin et al. 2014; Marengo et al. 2012; Espinoza et al. 2009).

3.3.3 Limited resources and services reaching indigenous communities

Government support becomes crucial in this shifting environment (Pinho et al. 2014), yet this research highlights how low institutional capacity, the assimilation social model and economic development have resulted in the limited delivery of resources and services to indigenous populations in multiple government sectors. Eleven interview respondents reported that Panaillo and other indigenous communities lack access to consistent, culturally appropriate, quality health care. Goy and Waltner-Toews (2005) similarly report that health professionals in Ucayali often do not speak the Shipibo-Konibo language and do not have positive interactions with rural Shipibo-Konibo patients due to underlying ethnic tensions. Similarly, low-quality education in rural areas was reported in one-third of community interviews ($n = 14$) and 25 % of institutional interviews ($n = 8$). Government services were reported to be generally lacking in rural and/or indigenous areas, as discussed in all focus groups and over 30 % of interviews ($n = 23$). These respondents attributed the lack of services to the communities' physical isolation, low accessibility, discrimination, corruption, and/or the lack of economic incentive for governments to work with these communities. For example, one migrant respondent states: "They don't give Panaillo much importance. Sometimes they go when they want votes, but when they're already in their chair in the office, they forget about the communities" (Interview #32, 5/26/2013). Government employees that were interviewed acknowledged these issues, and ten respondents emphasized that current efforts are being made to improve the situation, such as creating contextualized capacity-building programs for artisanal livelihoods.

3.3.4 Difficulties in traditional livelihoods and adaptive strategies

The aforementioned biophysical and socioeconomic stresses have contributed to various challenges for traditional livelihoods and the adaptive strategies used for seasonal flooding (see also Sherman 2014). Over half of community members interviewed ($n = 24$) were not at maximum agricultural production for both climatic and non-climatic reasons. Lacking seeds was the most frequently reported constraint to planting, which was mentioned by 17 community members and seven institutional interviewees. Each year, the type of soil and size of the riverbeds varies, as does the timing of the riverbeds' emergence after the river level lowers. One-third of Panaillo respondents ($n = 9$) reported that this variability impedes agricultural production. For example, during fieldwork, households did not have sufficient seeds for cowpea (*Vigna unguiculata*) since the riverbed in the preceding year was most suitable for rice production and households saved mainly rice seeds. Community members also lacked seeds as a result of needing to eat their own seeds in the rainy season ($n = 5$), insufficient production in preceding years ($n = 1$), and poor storage of seeds ($n = 1$). Another major constraint to agricultural livelihoods discussed by community members was not having sufficient workers to plant all of their seeds in a timely manner ($n = 9$) and to harvest the entire crop ($n = 18$).

Traditional fishing livelihoods have also dramatically changed with the integration of fishing practices into the market economy. The participants in the historical timeline focus group discussed how younger generations no longer know how to make a canoe or use a harpoon for fishing. They instead rely on manufactured equipment or partake in other income-generating livelihoods. The seasonal food security focus groups also discussed how fish rot every year in the lakes because residents lack the equipment, labor, and time needed to extract and preserve all of the available fish.

The constraints of agro-fishing livelihoods have increased reliance on income-generating livelihoods, yet there are often limited opportunities to earn cash for Panaillo residents. For example, four community members reported being unable to extract timber for sale since they do not own a power saw. Community members with medical conditions also have limited alternative employment options since formal education is minimal and employers are increasingly conducting medical exams during job recruitment. Poor health and injury inhibited community members from engaging in agriculture, fishing, traditional handicrafts, and/or timber extraction in one-third ($n = 14$) of community interviews.

When income is low and the aforementioned food sources are limited, food-sharing is critical to maintain household food consumption. Extended families usually share one kitchen and eat together from a few common plates. Food may also be sent to other families, or families may be invited to eat with a host family (Behrens 1992). This arrangement is meant to smooth over temporary food shortages as well as avoid food spoilage (Behrens 1992). One Panaillo elder explained that: "Food tastes better when it is shared" (Interview #18, 5/23/2013). However, Behrens noted in 1992 that food-sharing practices were becoming less common in Shipibo-Konibo communities as a result of market integration. In this research, the risk ranking focus group and 13 interviews highlighted the continued existence of food-sharing networks in the community. However, according to Panaillo interview respondents, these food-sharing networks have been declining as a result of insufficient household food quantities ($n = 5$) and cultural changes ($n = 7$).

3.3.5 Migration

The biophysical and socioeconomic constraints on agro-fishing livelihoods and traditional adaptive strategies have coincided with increasing levels of migration. In this study, Panaillo residents most frequently discussed migration to nearby urban areas, such as Pucallpa. Migration to rural areas was also reported to occur as a result of marriage, social conflict, and/or flood damage. As discussed in Sherman (2014), employment and education were the most frequently mentioned motivators for permanent migration in this area. One-fourth of migrant interview respondents ($n = 4$) reported migrating to avoid the flood conditions in Panaillo. In all cases, permanent migration occurred in households that had a history of temporary migration. The principal motivation for temporary migration among current Panaillo residents was to pursue income-generating livelihoods (44 %; $n = 12$) (e.g., employment, selling artisanal handicrafts or agricultural products) and/or to avoid flood conditions (41 %; $n = 11$).

However, institutional respondents generally believed that the quality of life in the city is not better than life in rural areas. One institutional respondent explained that: “Migration doesn’t improve their lives. Migration promotes poverty belts” (Interview #73, 8/1/2013). Unemployment and job exploitation is common among migrants from indigenous communities, as mentioned in six interviews. When asked to describe his work on a tomato plantation, a male Panaillo respondent explained that: “Where they do the tomato harvest, they pay the cow 100 soles [~USD $30] per day, but they only pay us four or six soles [~USD $1.40–2.15] per day” (Interview #12, 5/21/2013).

As a result of limited financial resources, the permanent migrants interviewed in this research experienced greater difficulties with food security than Panaillo residents interviewed (Table 1). When asked whether the individual preferred living in Panaillo or the city, all of these migrant respondents emphasized the advantage of being able to produce their own food in Panaillo, for example, stating: “There you just had to grab your harpoon, hunt your fish, and soon you’d be eating. Here you can’t do that. Here there’s no harpoon; everything is just with money. It’s a tremendous shock” (Interview #5, 5/13/2013). Accordingly, 10 community members reported consuming more chicken in the city, due to the expensive nature of fish, the more preferable and traditional Shipibo-Konibo food. Panaillo respondents stated that money ($n = 13$) and/or family connections ($n = 16$) were needed in order to successfully migrate.

The separation of families that results from migration also has important implications for Panaillo’s food system and community structure. The majority of community members with higher education and skills have permanently migrated to the city. As one migrant explains, “It’s one of the problems of Panaillo-that it’s the professionals that have left there” (Interview #32, 5/26/2013). Elderly residents in Panaillo are particularly impacted by migration ($n = 3$), since many of their children have migrated to the city and are unable to provide for their parents. Participants in the historical timeline focus group believed that the abandonment of elderly parents reflects the westernization that is happening among younger generations.

Padoch et al. (2008) discussed the concept of "multi-sited households" in the Amazon, where households practice economic activities, exercise land-use rights, and/or maintain houses in both urban and rural locations. Similarly, the majority of Panaillo residents travel between Panaillo and their location of employment (e.g., Pucallpa, other rural areas with commercial plantations) in the rainy season, depending on job availability, financial resources, and household needs. Accordingly, the population of Panaillo is in a state of flux during the flooding, which was reported to disrupt government programing during the rainy season. For example, the Civil Defense's flood relief budgets are based on the number of people that are found in the community at the time of the most recent visit. However, flood relief may overshoot or underestimate the needs of the community at a given time during the rainy season.

4 Discussion and conclusion

This research aimed to characterize the current vulnerability and adaptive capacity of the Panaillo food system to flooding. In summary:

- Current and former Panaillo residents report significant challenges with household food utilization, quantity, quality, and stability.
- Climatic hazards, particularly flooding, strongly shaped the Panaillo food system and provided both benefits and challenges for traditional livelihoods and food security.
- Panaillo residents were generally unable to take advantage of the benefits that hydrological conditions provide for livelihoods and food security, predominantly as a result of non-climatic factors, including economic development, low institutional capacity, and a social model that promotes assimilation.
- The combination of these social and climatic drivers ultimately increased the vulnerability of Panaillo's food system by changing resource availability, traditional livelihoods, and adaptive strategies.
- Amidst constrained livelihoods and adaptive strategies, Panaillo community members increasingly rely on temporary or permanent migration in order to overcome flood shocks.

Traditional livelihoods and adaptive strategies have been similarly compromised by ineffective institutions, uneven economic development, resource degradation, and climate shifts in other areas of the Amazon Basin (Pinho et al. 2014; Goy and Waltner-Toews 2005; Marengo et al. 2013; Tomasella et al. 2013; Santa Cruz et al. 2013; Vegas de Cáceres 2010). Small producers in the Amazon and other areas of the world are also increasingly migrating due to the livelihood insecurity and financial losses that have resulted from resource degradation, frequent climatic hazards and market price fluctuations (Pinho et al. 2014; Padoch et al. 2014; Goy and Waltner-Toews 2005; Warner et al. 2009; McLeman and Smit 2006; McLeman and Hunter 2010).

4.1 Migration and climate change adaptation in Panaillo

This case study thus provides an opportunity to compare Panaillo's migration patterns to those observed in other empirical case studies and those described in the theoretical literature. The relationship between migration, global environmental change, and adaptation has been widely discussed in the literature (see Black et al. 2011; Warner 2010). In a special issue in *Climate and Development*, several case studies highlight how migration often does not occur in direct response to rainfall variability, but rather in response to food insecurity and livelihoods, which was similarly observed in the case of Panaillo (Milan and Ruano 2014; Etzold et al. 2014; Afifi et al. 2014). Warner and Afifi (2014) note that households use migration in distinct ways; vulnerable households migrate as part of a survival strategy, whereas resilient households migrate to increase overall resilience, build skill sets and diversify livelihoods. The high levels of food insecurity among migrants in this case study illustrates that migrants in this research were unable to successfully leverage migration to increase their own resilience mainly due to limited available employment options in the city. Similarly, a study in the Central Highlands of Peru illustrates the importance of accessibility to urban economic opportunities for migration (Milan and Ho 2014).

Renaud et al. (2011) distinguished between three types of environmental migrants: (1) environmental emergency migrants who must evacuate an area in response to a temporary environmental impact; (2) environmentally forced migrants who must leave an area as a result of severe environmental deterioration; and (3) environmentally motivated migrants who preemptively leave an area amidst signs of declining environmental conditions. In the case of Panaillo, migration patterns could fit into any of these descriptions depending on the permanence of the relocation and the household's motivation for migrating (e.g., flooding vs. employment/education). For example, individuals who temporarily migrate to the city to avoid flood conditions each year could be considered environmental emergency migrants. Permanent migrants who relocate to urban centers for employment may qualify as environmentally forced migrants since they cannot successfully carry out livelihood activities in Panaillo due to resource degradation. Migrants who permanently moved to the city in explicit response to experiencing severe flooding in consecutive years may be considered environmentally motivated migrants.

Another important contribution to understanding the role of migration in climate change vulnerability can be found in Scheffran et al's (2012) discussion of adaptation-preventing-forced-migration, migration-as-adaptation, and migration-for-adaptation. Adaptation-preventing-forced-migration refers to how, in certain contexts, households may be able to avoid permanent migration by adapting to socioeconomic and biophysical changes. Seasonal migration can be considered an adaptive strategy in this case since it prevents permanent migration out of distress. Several studies have also highlighted how the temporary migration of a household member may serve as a risk reduction strategy for climate and non-climate risks by diversifying household income sources (Renaud et al. 2011; Ellis 2000; Warner 2010; Adger 1999).

However, the recent rise of permanent migration in Panaillo suggests that seasonal migration has not sufficiently mediated migration stressors. Given the precarious location of Panaillo on a shifting riverbed, permanent relocation to higher ground may be necessary if other preventative measures are lacking or ineffective. Accordingly, migration-as-adaptation describes a situation when permanent migration serves as an appropriate adaptive response since climate change impacts threaten survival and local adaptation efforts and protection are insufficient (Scheffran et al. 2012).

Finally, migration-for-adaptation emphasizes the positive influence migrant networks can have on the origin area. Technology, knowledge, skills, social capital, and remittances may flow between migrants and original communities, resulting in benefits for both groups by building social resilience, increasing flexibility and diversity, and even fostering innovation (Scheffran et al. 2012; Adger 1999). However, communication and interactions between former and current Panaillo residents are often strained since both groups lack the financial resources needed to support each other. For Panaillo to develop migrant networks that serve an adaptive purpose, it is important to strengthen the mutual flow of resources between migrants and community members, as well as foster skill sets and stronger livelihoods for both migrants and Panaillo residents.

4.2 Potential socioeconomic and climatic trends for the Peruvian Amazon: Future food system vulnerability

The examination of Panaillo's current food system vulnerability to climate variability provides insight into the food system's potential future vulnerability amidst climate change. While the future trends are highly unpredictable, examining projected climate change impacts and socioeconomic trajectories can help identify potential future trends. As previously mentioned, flood regimes are expected to change in the Amazon Basin (Magrin et al. 2014). Several studies project lower crop yield, increased soil erosion, reduced water availability, and increased plagues and diseases in response to changes in seasonality (Brondizio and Moran 2008; Santa Cruz et al. 2013; Vegas de Cáceres 2010). The lack of predictability in climate patterns could also disrupt planting and harvest calendars and inhibit planning (Vegas de Cáceres 2010; Santa Cruz et al. 2013). Since local markets are controlled by supply and demand, lower agricultural production and lower fish catches could raise food prices and increase reliance on food imports in the Ucayali region, which could further reduce incomes and food consumption for impoverished families that depend on agro-fishing livelihoods. In this case study as well as other research in the Amazon, populations are already reporting significant challenges with food price fluctuations, diminishing incomes, and changes in climate, flora and fauna populations (Marengo et al. 2013; Pinho et al. 2014; Padoch et al. 2014). Projected climate change impacts thus have the potential to further impede agro-fishing livelihoods and traditional adaptive strategies in this region.

Recent trends in Peru's political economy indicate that current extractive practices will continue or even intensify in the future (Pantigoso 2014; Finer and Orta-Martínez 2010; Law 30230). According to the World Economic Situation and Prospects 2014 (WESP) report, Peru's economy is expected to continue to grow by 6.1 % in 2014 and 6.5 % in 2015, making it the second fastest growing economy in Latin America (United Nations 2014). To a great extent, this economic growth is expected to come from mining, oil and gas industries (United Nations 2014; Pantigoso 2014). Since 2003, hydrocarbon investments in the Peruvian Amazon have increased to unprecedented levels (Pantigoso 2014; Finer and Orta-Martínez 2010). Over 84 % of the Peruvian Amazon has been or is currently zoned for oil and gas activities and over half of those concessions are located on legally titled indigenous territories (Finer and Orta-Martínez 2010). As illustrated in this case study, urbanization and the expansion of extractive industries in indigenous territories could seriously threaten traditional customs and knowledge and influence migration patterns in the area. Current human activities and significant changes in land-use are exacerbating climate change in the Amazon (Davidson et al. 2012; Cook et al. 2012; Nebel 2001; Vegas de Cáceres 2010). It is thus increasingly important to consider the sustainability of current operations and to improve the effectiveness and equity of Peruvian institutions in order to properly manage the impacts of climate changes in this area. In 2014, Lima hosted the United Nations Framework Convention on Climate Change (UNFCCC) 20th session of the Conference of Parties, although it remains to be seen if this event provided the impetus needed to inspire climate change adaptation action in Peru. The continuation of current socioeconomic and biophysical trends would likely exacerbate food system vulnerability in the near future for indigenous and rural communities like Panaillo.

4.3 Recommendations

To pragmatically address food system vulnerability in Panaillo and other areas of the Peruvian Amazon, it is important to consider both the proximal and distal drivers of the food system. Firstly, improving the administrative capacity and transparency among local institutions in the Peruvian Amazon is crucial to ensure that the necessary services are provided to vulnerable populations and that climate risks are managed in an efficient and timely manner. Enhancing institutional capacity may be brought about by facilitating cross-cultural communication, raising awareness of community needs, improving communication and collaboration between institutions, and building capacity among indigenous leaders so that they may properly solicit the services to which they are legally entitled (Goy and Waltner-Toews 2005; Santa Cruz et al. 2013; Vásquez et al. 2012). Although capacity building among institutions may be accomplished in a decentralized system, it is critical that the Peruvian government supply the necessary resources and training to subregional levels in order to ensure effective and equitable development (Cueto et al. 2011). It is also important to foster institutional memory, for example, by enforcing a 15-day period to transfer functions between new and old officials (Vásquez et al. 2012).

Since vulnerable populations in Peru cannot always been relocated to safer sites, feasible solutions must be implemented for housing and agro-fishing livelihoods in low-lying areas such as Panaillo (Vásquez et al. 2012). Improving access to markets and information on market prices, increasing the frequency and regularity of visits from agricultural extension workers, and consistently building technical capacity among local residents have the potential to improve agricultural livelihoods in Panaillo as well as other rural communities in the Peruvian Amazon (Vásquez et al. 2012; Vegas de Cáceres 2010; Lilleør and Van den Broeck 2011; Ziervogel et al. 2006). Given the increasingly unpredictable nature of the flood regime, it will be particularly useful to improve the flexibility and adaptability of agricultural calendars (Santa Cruz et al. 2013; Lilleør and Van den Broeck 2011).

Since environmental changes in the region have resulted not only from global climate change, but also from deforestation and extractive industries, it is also critical to address these socioeconomic activities and to assume a more preventative and holistic approach in climate risk management (Finer et al. 2008; Marengo et al. 2013; Sherman 2014). Regulation and monitoring of extractive activities will need to be strengthened, especially in the Peruvian Amazon, in order to maintain fish and animal populations and to limit further changes to ecosystems and flood regimes (Finer and Orta-Martínez 2010; Davidson et al. 2012). However, alternative income-generating livelihoods, such as traditional handicrafts, should also be promoted in flood-prone communities in the Amazon since flooding will inevitably constrain agriculture and fishing at certain times of the year.

Further research is needed to evaluate the extent of resource degradation and the drivers of hydrological changes in this area (Davidson et al. 2012; Finer and Orta-Martínez 2010; Espinoza et al. 2009), as well as how environmental changes affect migration (Renaud et al. 2011; Lilleør and Van den Broeck 2011; McLeman and Hunter 2010). The findings from this research hope to improve the understanding of the adaptive capacity to extreme hydrological events in Panaillo and other rural indigenous communities in the Peruvian Amazon, as well as to contribute new insight to the climate change adaptation scholarship.

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