Ambio
https://doi.org/10.1007/s13280-026-02427-6

KUNGL. VETENSKAPS-AKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

RESEARCH ARTICLE

Knowing with the river: Situated risks of riverine communities in the Peruvian Amazon

Heidi D. Mendoza, Jonathan J. Valenzuela, Elisa N. C. Armijos, Anne F. Van Loon, Melanie Rohse, Johanna K. L. Koehler, Bryan Joel Mariano, Bruno T. C. Gonzalo, Paulo F. S. Diaz, Cesar P. A. Vasquez, Carlos J. A. Souza, Elsa A. V. Izaguirre, Juan Bazo, Jahir D. Anicama

Received: 16 May 2025 / Revised: 19 May 2025 / Accepted: 7 May 2026
© The Author(s) 2026

Abstract Dominant approaches to drought and flood risk often marginalize the social and temporal dimensions of how communities experience environmental change. This study explores how three riverine communities in the Peruvian Amazon—Bajo Belén, Tamshiyacu, and El Chino—generate and act on knowledge of river dynamics to sustain livelihoods amid increasing hydrological variability. Using storytelling with 45 participants (2023–2024), and co-produced seasonal calendars, we identified risk windows or periods of heightened vulnerability when river levels misalign with local expectations. These windows provide a situated lens into how risks are interpreted and navigated through embodied, relational, and adaptive strategies. Our findings highlight the centrality of place-based knowledge and temporal attunement to sustainable adaptation, challenging technocratic risk frameworks. By reframing hydrological extremes as relational and embedded in local rhythms, the study calls for more inclusive governance that reflects the socio-cultural and ecological specificities of hydrological risks.

Keywords Amazon basin · Hydrological extremes · Risk windows · Situated knowledge · Storytelling

INTRODUCTION

Droughts and floods are often framed as universal hazards, yet their impacts are not experienced uniformly (Di Baldassarre et al. 2026). Impacts are deeply shaped by local ecologies, social structures, and historical inequalities (Di Baldassarre et al. 2014; Savelli et al. 2022). Despite this, governance of hydrological extremes still relies heavily on standardized risk assessments that privilege technical expertise while overlooking situated experiences and local knowledge systems (Swyngedouw 2009; Klenk et al. 2017). Such exclusion constitutes a form of epistemic injustice, whereby communities are wronged in their capacity as knowers—either through testimonial injustice, where their insights are dismissed, or through hermeneutical injustice, when dominant frameworks fail to make sense of their lived realities (Fricker 2007; Tuana 2013). As a result, prescribed adaptation strategies may fail to resonate locally or reproduce marginalization by devaluing or erasing alternative ways of knowing and living with environmental change, especially when they are designed without meaningful engagement with local epistemologies and social contexts (Schlosberg 2007, 2012). For example, planned relocations that are not grounded in local capacities can result in loss of livelihoods and social networks, hence creating new forms of vulnerabilities (Mendoza et al. 2025). Similarly, adaptation strategies that only emphasize technical fixes without alignment with local values and capacities can make invisible how communities interpret risk, govern resources, and sustain socio-ecological relationships (Schlosberg 2007, 2012).

Addressing these epistemic blind spots is essential for equitable and sustainable risk governance. Doing so requires pluralistic and reflexive approaches that center the voices, worldviews, and temporalities of those most affected by hydrological extremes (Fricker 2007; Linton and Budds 2014). These approaches highlight a shift to justice-oriented and context-sensitive responses grounded in diverse socio-environmental knowledges (Boelens 2014; Zwarteveen and Boelens 2014; Sultana 2022).

To operationalize this shift, the paper is grounded on a conceptual patchwork that links knowledge production to lived experiences of risk. We begin with situated knowledges (Haraway 1988), emphasizing that understanding of hydrological extremes emerge through embodied, placed-based interactions with local ecologies. We then draw on the social construction of risk (Beck 1992; Douglas 1992) to show how these understandings are shaped by social relations, power, and historically embedded inequalities. Building on these perspectives, we expound on situated risk (Boholm 2015) as the process through which risk becomes meaningful and actionable within specific hydrosocial contexts. Finally, we patch the concepts together through operationalizing risk windows: moments when hydrological change disrupts familiar rhythms of life, revealing heightened vulnerability, varying impacts, and epistemic limits.

We explore this conceptual patchwork through empirical engagement with riverine communities in the Peruvian Amazon who live with the seasonal river regime—locally known as *vaciante* (low water) and *creciente* (high water). Our aim is to understand how local knowledge systems evolve through ongoing, seasonal interactions with the river, and how these knowledges are expressed through stories and everyday practices that shape how risk is anticipated.

CONCEPTUAL APPROACH

Situated knowledges

Situated knowledges foreground the partial, contextual, and relational nature of knowledge production (Haraway 1988; Nightingale 2003). Knowledge is an iterative process shaped through embodied encounters with the environment, social relations, and historical experience. In riverine contexts, what counts as risk often emerges through sensory, affective, and practical engagement with seasonal rhythms—such as the timing of fishing, planting, or settlement relocation. These processes unfold through everyday practices in which past experiences inform present interpretations and future expectations (Bickerstaff and Walker 2001; Castro and Sen 2022).

While situated knowledges are inherently spatial, they are also profoundly temporal. Temporality shapes how communities perceive, anticipate, and respond to environmental change, drawing on memory, cyclical patterns, and seasonal cues (Berkes 2018; Ingold 2022). Risk is therefore not only about what might happen or where but also when and for how long (Douglas et al. 2003). Under conditions of increasing hydrological variability, these temporal anchors may become unreliable, destabilizing both livelihoods and the epistemic foundations of what is considered normal or predictable (Cannon and Müller-Mahn 2010).

Social construction of risk

Building on this temporal and spatial embeddedness, risk can be understood as socially constructed rather than purely objective. It highlights how cultural values, political contexts, and historical relations shape what is recognized as risky and whose concerns are prioritized (Beck 1992; Douglas 1992; Jasanoff 2004). A seasonal flood, for example, may be framed by experts as a probabilistic hazard, while local communities may understand it as part of a broader socio-ecological rhythm (Langill and Abizaid 2020, 2025). These differences reflect distinct epistemologies and ways of knowing the world (Wynne 1996) and raise critical questions about whose realities are made visible in risk frameworks and whose futures are rendered invisible (Barbosa et al. 2016; Wheeler and Root-Bernstein 2020).

Situated risk and risk windows

Bringing these insights together, risk becomes a dynamic process shaped by routines, social relations, governance structures, and environmental rhythms. While situated risk has been widely applied in organizational and institutional settings, it remains underexplored in human–environment relationships where risks are deeply entangled with place-based ecologies (Boholm 2003; Boholm and Corvellec 2011).

Within such contexts, we operationalize risk windows as a temporal lens for understanding vulnerability and uncertainty. Risk windows refer to periods when hydrological events occur in ways or during times that disrupt locally attuned cycles of activity—not only necessarily because hazards are more intense, but because they happen outside the interpretive and anticipatory reach of existing knowledge systems. Risk windows were identified empirically through expressed uncertainties with and mismatches between expected and experienced timing of river-dependent activities. These windows often emerge in transitional phases, such as shifts between *vaciante* and *creciente*, when established strategies falter and uncertainties become acute. Risk windows thus capture spatial, temporal, and epistemic vulnerability, highlighting moments when communities' capacities are stretched and when learning, adaptation, and external support become especially critical (Berkes and Ross 2013; Pelling et al. 2015).

MATERIALS AND METHODS

Case study areas

This study focuses on three riverine communities in the Loreto region of the Peruvian Amazon: Bajo Belén,

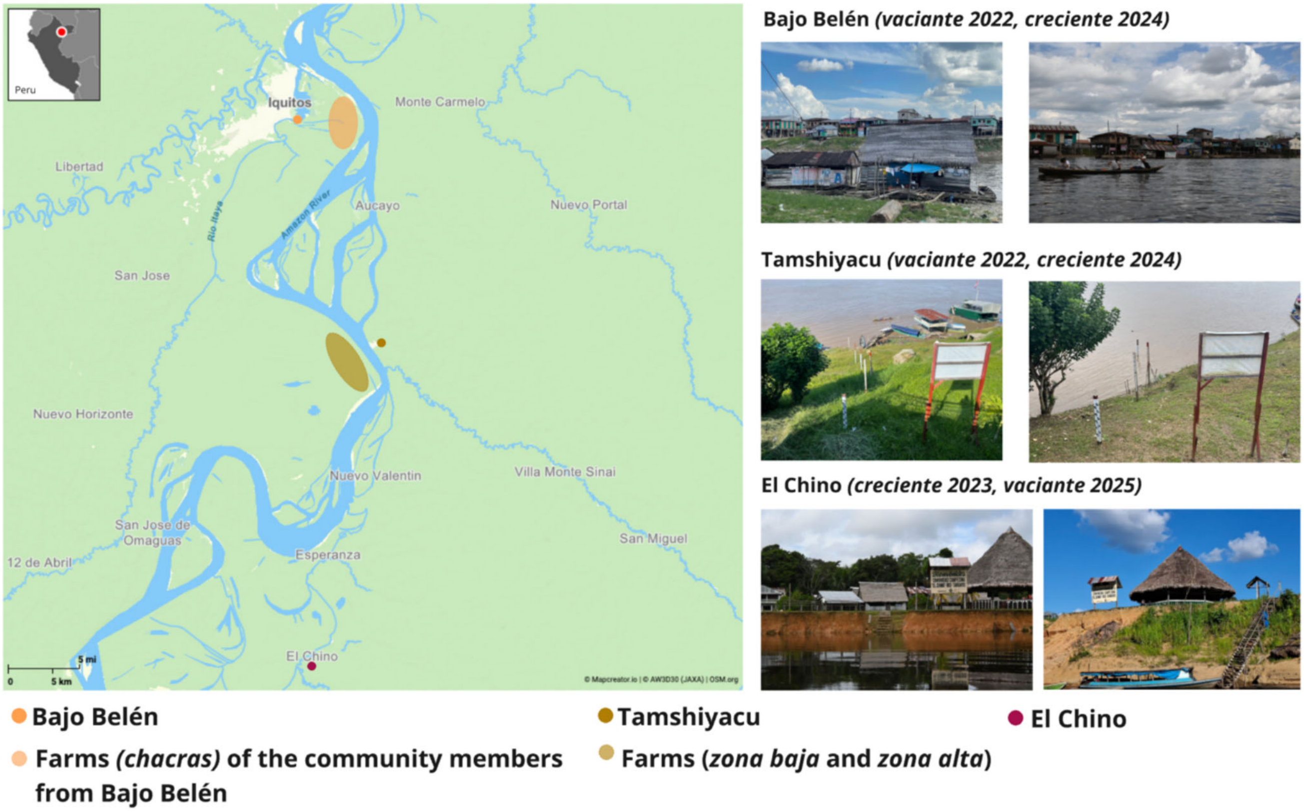

Fig. 1 Case study areas

Tamshiyacu, and El Chino (Fig. 1). Each is located along a different Amazonian river system and experiences seasonal river level fluctuations. Bajo Belén is an urban settlement located along the banks of the Itaya River. Residents engage in fishing and farming as major activities. Tamshiyacu, a semi-rural community situated on the banks of the Amazon River, has a local economy based on small-scale agriculture, commerce, and employment in municipal services. In contrast, El Chino is a small and remote village along the Tahuayo River. Livelihoods in El Chino largely depend on artisanal fishing and the selling of handicrafts made from pita fiber *(chambira).*

The communities were selected based on direct dependence on rivers for activities such as fishing, agriculture, and transport; previous experiences of droughts and floods (Marengo et al. 2008; Marengo and Espinoza 2016; Bodmer et al. 2018); and the group's existing collaboration in the areas. Their differing geographies allow for comparative insights into how situated risks are experienced and navigated across diverse riverine settings.

Storytelling sessions and seasonal calendars

This research draws on two phases of fieldwork conducted between May and June 2023 and again in the same period in 2024. Our methodological approach was grounded in storytelling, because of its capacity to foreground situated knowledges—embodied, affective, and experiential insights (Moore et al. 2005). During the first fieldwork in 2023[1] The research team facilitated 45 individual storytelling sessions in total; the storytelling participants included fisherfolk, farmers, mothers, and elders. These sessions were guided by open-ended prompts that encouraged reflection on daily and seasonal practices, responses to droughts and floods, and anticipatory practices in relation to the river's seasonal rhythms. All sessions were audio-recorded and transcribed by the fieldwork team. The first author then conducted preliminary inductive coding using Atlas.ti to identify recurring patterns from how river-dependent activities were discussed in relation to seasonality and uncertainty (Braun and Clarke 2006).

The open-ended prompts used to guide the storytelling included:

- "How long have you lived here and what changes have you observed in the river?"

[1] 2023 field research team was composed of the first author and co-authors from the Universidad Nacional de la Amazonia Peruana (UNAP); 2024 field research team was composed of the first author and co-authors from the Instituto Geofísico del Perú (IGP) and UNAP.

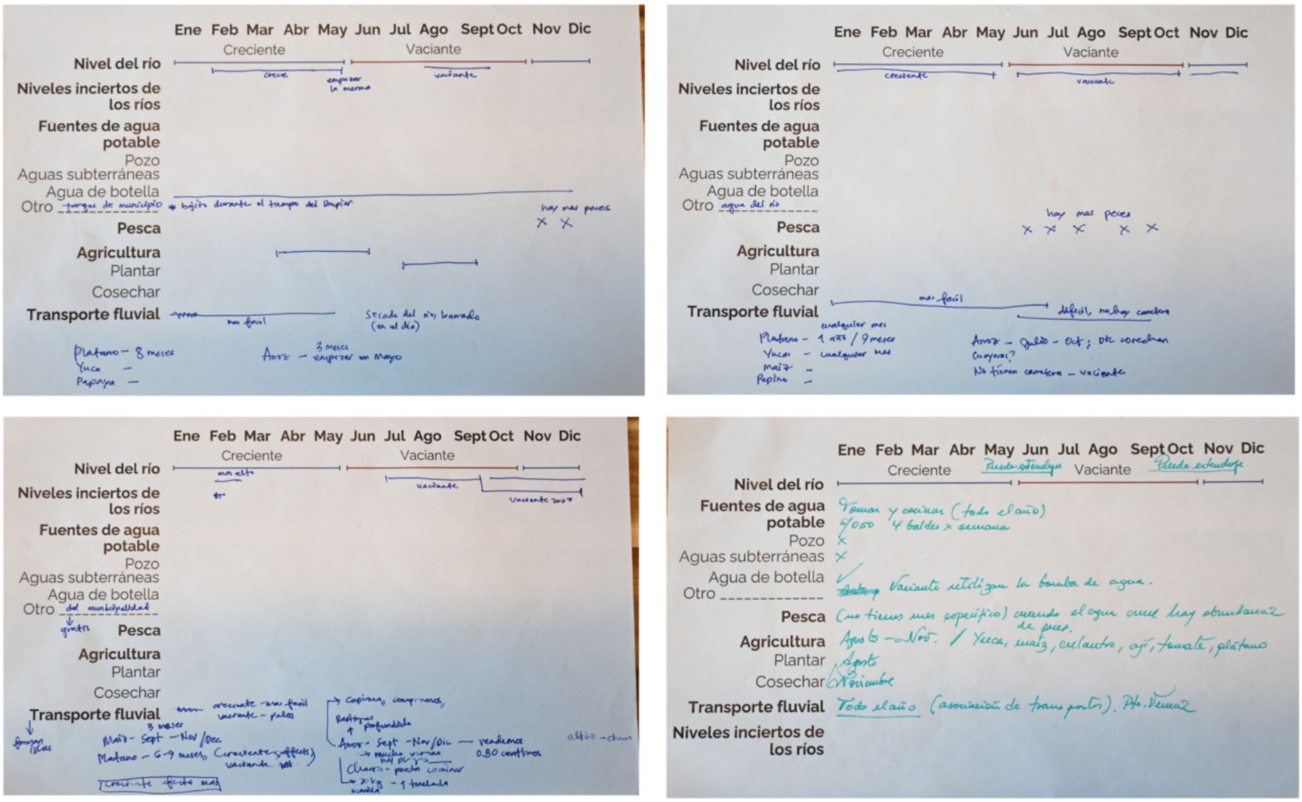

Fig. 2 Sample of seasonal calendars

- "What does your day-to-day look like?"
- "When does the *vaciante*/*creciente* start and how does your day-to-day change during this season?"
- "How does drought/flood change your day-to-day?"

Based on the initial analysis, the first author developed a seasonal calendar that mapped key river-dependent activities (e.g., fishing, planting, access to potable water) across the months of the year. This temporal mapping helped identify gaps, for example, variation in planting calendars for the same crops or ambiguity around when river levels typically shift between *vaciante* and *creciente*. These insights informed the development of semi-structured interview questions for the second round of fieldwork.

During the 2024 fieldwork, seasonal calendars were used in one-on-one interviews with the same community members to expound on their monthly river-dependent activities (Fig. 2). Participants were asked to elaborate on their daily and seasonal activities and identify specific moments in the year when anticipating changes were more difficult than usual. This mapping supported a more nuanced understanding of how the timing and intensity of seasonal changes shape daily practices and perceived risks (Nightingale 2003; Eriksen et al. 2015; Jackson 2025).

Risk windows were identified through a combination of qualitative coding and temporal mapping. In Atlas.ti, codes related to river dynamics (e.g., *vaciante*, *creciente*), livelihoods, uncertainty, and impacts were examined through code co-occurrence analysis. Periods in which codes overlapped—where changes in river dynamics co-occurred with impacts, uncertainty, or disruption of usual practices—were interpreted as risk windows. The derived risk windows were then cross-checked with the seasonal calendars that were filled out during the interview sessions.

Juxtaposing hydrological data with stories of living with river rhythms

The empirically grounded risk windows were examined alongside long-term river level data, not to validate situated knowledges, but to place lived experiences of uncertainty within hydrological dynamics (Klenk et al. 2017). Daily water levels at the ENAPU station along Itaya River (1970–2023) and the Tamshiyacu station along the Amazon River (1985–2023) were provided by the National Meteorological and Hydrological Service of Peru (SENAMHI), and levels from El Chino station along Tahuayo River (2023) were provided by the Geophysical Institute of Peru (IGP).

The climatology of daily water levels was determined by the long-term average of the daily water level for the total period. Minimum (maximum) water level anomalies were determined by the difference between the annual minimum (maximum) water level and the average of the annual minimum (maximum) water levels for the total period.

The hydrological analysis offers a way of characterizing river dynamics and hydrological extremes across the case study areas. In contrast, the qualitative analysis and identified risk windows foreground community-specific experiences. In this paper, we identify the *vaciante* and *creciente* periods and the transition periods as indicated by community members.

While hydrological analysis is effective in detecting extremes in river levels, the situated knowledges articulated through stories and seasonal calendars reveal how droughts and floods are experienced differently across livelihoods and places. Non-alignment between hydrological classifications and community-defined seasonal dynamics allows understanding of how droughts and floods have different meanings within riverine communities (Langill and Abizaid 2020, 2025). In the case study areas, droughts can either be a prolonged, early, or extremely dry *vaciante*, while floods can be a sudden increase of the river level during either *vaciante* or *creciente* and prolonged, early, or extremely high *creciente* (see Fig. 3) (Mendoza et al. 2025). Bringing the hydrological and qualitative analyses together expands understanding across scales without collapsing epistemic difference or using situated knowledges as benchmark for scientific knowledge (Linton and Budds 2014; Klenk et al. 2017).

On divergent positionalities

This paper is co-authored by an interdisciplinary team of researchers from the Philippines, Peru, the Netherlands, Germany, and France, with academic backgrounds in development studies, communication, environmental science, hydrology, water governance, human geography, and forestry. Our diverse positionalities and disciplinary orientations shaped how we approached the research. The research design—initially only focused on drought and flood adaptation—evolved through iterative and reflexive conversations with the communities which allowed us an entry point grounded in multiple epistemologies (England 1994). The storytelling sessions highlighted that what mattered most to participants were their lived, seasonal, and daily interactions with the river.

The fieldworks were conducted during the *creciente* period, nearing the transition period to *vaciante*, which likely influenced the memories shared by community members. This temporal positioning is important to consider, as timing affects what stories are more readily told or remembered (Behar 2022). It is possible that during the fieldwork in 2023—before the drought impacts were more pronounced—narratives related to *vaciante* were less prominent due to seasonal salience.

RESULTS

This section is structured as follows: (1) hydrological analysis highlighting the 2012 flood and 2023 drought as extreme events in the Peruvian Amazon and (2) presentation of risk windows based on the community members' lived experiences and seasonal activities.

Seasonal variability of water level and extreme events

For the Itaya River at ENAPU station, the normal variability of water level defined by the climatology (1970–2023) is around 7.75 m; the maximum and

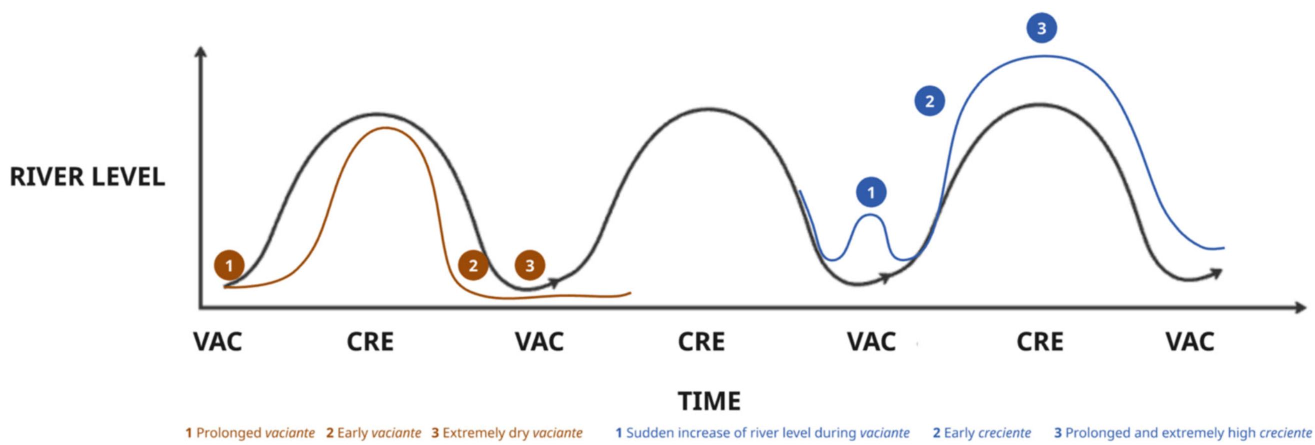

Fig. 3 Illustration of the *vaciante–creciente* cycle and different types of droughts and floods. (The visualization of the mismatches is supported by the storytelling sessions conducted from 2023 to 2024, and other research conducted in the Peruvian Amazon by Langill and Abizaid 2020, Langill and Abizaid 2025, Mendoza et al. 2025)

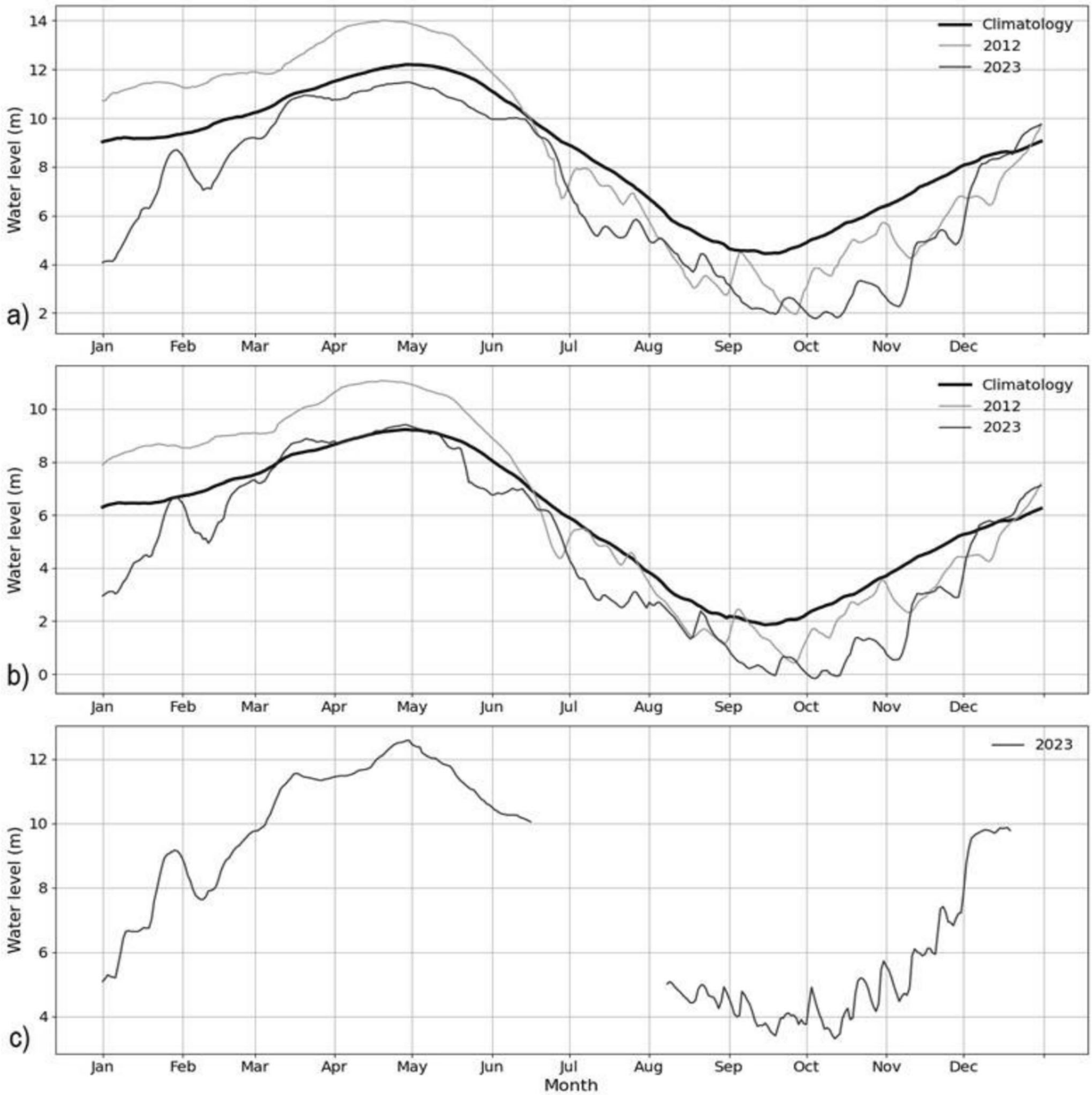

Fig. 4 **a** Daily water levels of the Itaya River at the ENAPU station comparing the climatological average (1970–2023) with the years 2012 (flood) and 2023 (drought); **b** daily water levels of the Amazon River at the Tamshiyacu station comparing the climatological average (1985–2023) with the years 2012 and 2023; **c** daily water levels of the Tahuayo River at the El Chino station for the year 2023

minimum levels occur on April 29 and September 15, respectively. In the 2012 flood, the climatological maximum level was reached on March 13 (47 days earlier than expected). Similarly, in the 2023 drought, the climatological minimum level was reached on August 10 (36 days earlier than expected) (Fig. 4a). Similar conditions were observed at Amazon River in Tamshiyacu station, where the normal variability of water level by climatology (1985–2023) is around 7.36 m. For this station in the 2012 flood, the climatological maximum level was reached 49 days earlier than expected, and in the 2023 drought the climatological minimum level was reached 33 days earlier than expected (Fig. 4b). Meanwhile, at the El Chino station on the Tahuayo River, the minimum water level in 2023 was 9.26 m lower than the maximum level (Fig. 4c). The El Chino community members noted that the 2023 drought was more intense than in previous years.

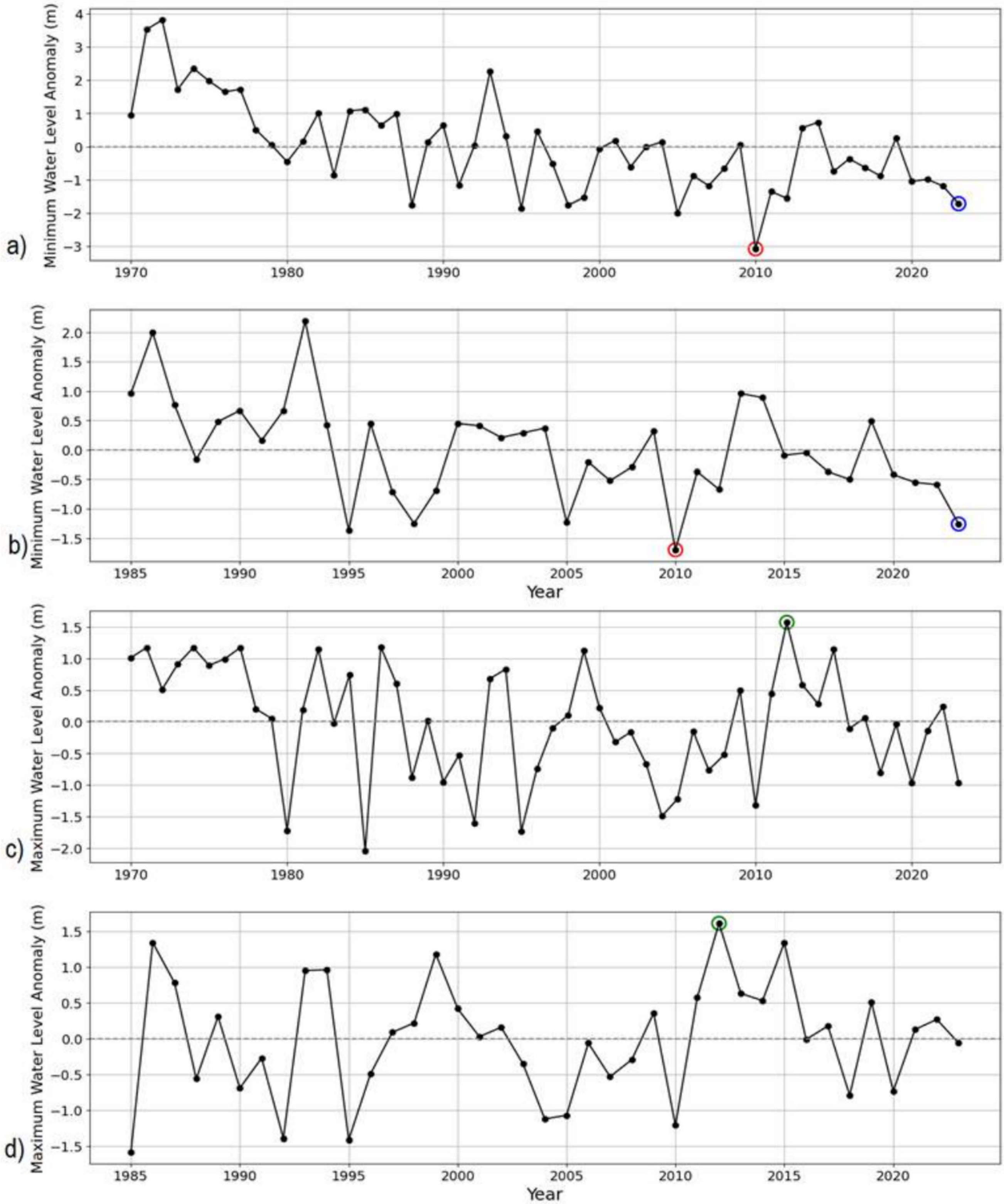

Fig. 5 **a** Annual minimum water level anomalies of the Itaya River at the ENAPU station (1970–2023); **b** annual minimum water level anomalies of the Amazon River at the Tamshiyacu station (1985–2023), with the 2010 and 2023 drought events highlighted in red and blue, respectively; **c** annual maximum water level anomalies of the Itaya River at the ENAPU station (1970–2023); **d** annual maximum water level anomalies of the Amazon River at the Tamshiyacu station (1985–2023), with the 2012 flood event highlighted in green

An analysis of annual minimum water level anomalies at the Itaya River indicates that the 2023 drought ranks as the sixth most severe event between 1970 and 2023. The water level during this *vaciante* was 1.36 m above the historical minimum recorded in 2010 and 1.72 m below the long-term average (Fig. 5a). Similarly, at the Tamshiyacu station, the 2023 drought was the third most severe event since 1985, with water levels just 0.44 m above the 2010 minimum and 1.26 m below average (Fig. 5b).

In contrast, annual maximum water level anomalies show that the 2012 flood was the most extreme event during the period of analysis. At the ENAPU station, the 2012 *creciente* exceeded the average maximum by 1.57 m (Fig. 5c), while at the Tamshiyacu station, it was 1.61 m above average (Fig. 5d). These findings highlight the increasing variability in river level dynamics.

Hydrological records define *vaciante* as occurring from late July to early November and *creciente* from late February to early June. However, across the three communities, participants described different and overlapping timings for both periods. The sections below unpack these community-specific temporalities and the emerging risk windows.

Bajo Belén

In a normal hydrological year, community members in Bajo Belén identified that the *vaciante* period spans from June to November, while *creciente* spans from December to May. These identified periods can be contrasted to the hydrological analysis that shows that maximum and minimum river levels usually occur in April and September, respectively. River-based activities in Bajo Belén are intertwined with these two periods, shaping daily routines and planning. These activities include agriculture, fishing, fluvial transportation, house maintenance, and securing potable water.

Agricultural decisions are closely synchronized with the *vaciante* period, when receding water levels expose land suitable for cultivation. These farms, located along the Amazon River, typically require a 15- to 30-min journey by boat from their community. During this period, typically from June to November, farmers cultivate a range of crops such as *plátano* (plantain), *maíze* (corn), *yuca* (cassava), and coriander. The selection of crops is strategically designed to secure continuous harvests and reduce exposure to loss from river level fluctuations. While *plátano* is a perennial crop that does not require replanting each season, it remains vulnerable to hydrological extremes; for instance, an unusually extreme *vaciante* reduces yield and also complicates transport logistics, as low water levels hinder movement of small boats from *chacras* (farms) to markets in the city. Meanwhile, crops like *maíze*, *yuca*, and coriander, which are replanted each season, are particularly susceptible to shifts in the timing or duration of *vaciante*. *"During creciente, there is more food (in the market), because people from different areas bring their produce to sell. It's easier (for them to travel with their produce). Right now in the market, there is plenty of fish, cassava, plantains, and fruits,"* Dan explained how the river dynamics also influence the amount and variety of food available in the market.

Fishing activities are similarly shaped by seasonal hydrological rhythms. Most fishers also engage in farming, resulting in a temporal division of labor that aligns with river fluctuations. Fishing usually takes place during the *creciente* period when river levels are high enough to enable boat mobility and access to fishing areas. During *vaciante period*, many parts of the river adjacent to the community become too shallow or dry, principally September and October, making fishing logistically challenging.

Households have different sources of water that vary as the river dynamics change—water pumps (during *vaciante*), bottled water (throughout the year), rainwater (throughout the year), and river water (during *creciente*). During *vaciante*, when pumps are not inundated by the river, residents consider these pumps as sources of water. To secure drinking water throughout the seasons, residents also buy bottled water from neighbors and markets. The prices of water also vary depending on factors such as demand, and overall financial situation of the city (i.e., prices were higher and supplies decreased during the pandemic). Several households also harvest rainwater for cooking and washing clothes. Additionally, they also use the river water during *creciente* for cleaning; if they want to use it for drinking, they use chlorine tablets to purify the river water.

The communities' stories helped construct the risk windows (see Fig. 6) which outlines the different activities carried throughout the months. In a normal hydrological year, two main risk windows emerge: April to June, when water reaches its annual peak and flooding may occur; and September to December, when low water levels constrain transportation, agriculture, and water access.

Extreme events such as droughts or floods can shift and intensify these risk windows. During the 2023 drought, an unusually extended and severe *vaciante*, community members reported declining crop yields, severe limitations on fluvial transportation, and the accumulation of solid waste along riverbanks due to reduced water flow. In contrast, extreme flooding events like that of 2012 brought rapid water level rise and prolonged inundation (sudden and extreme *creciente*), undermining efforts to renovate homes ahead of the *creciente* and leading to crop loss from flooded fields. In both cases, the disruption was not solely

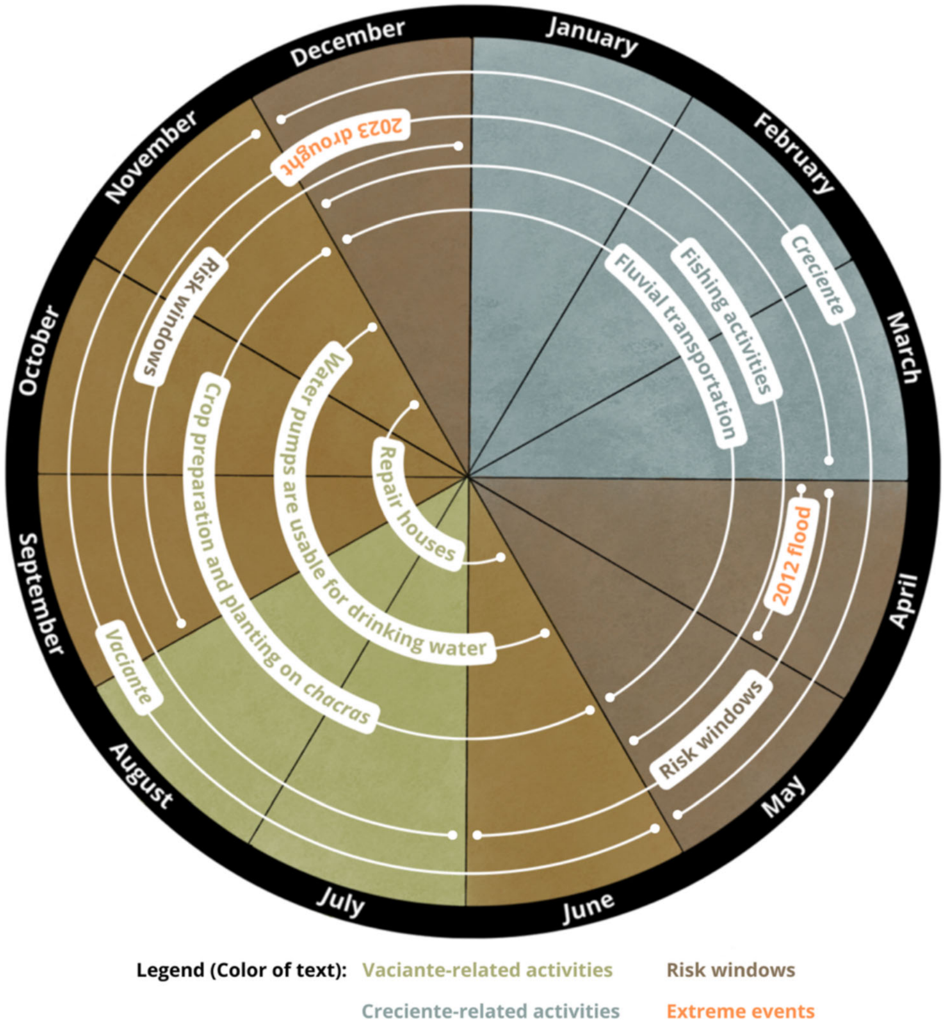

Fig. 6 Bajo Belén's seasonal calendar

due to the physical magnitude of the events, but to their misalignment with expected seasonal rhythms.

Tamshiyacu

In a normal year, *vaciante* spans from June to November, with May to June as identified transition periods, while *creciente* spans from December to May. River-dependent activities in Tamshiyacu include agriculture, fishing, fluvial transportation, and access to potable water. The agricultural system is spatially divided into *zona baja* (low-lying areas) and *zona alta* (higher areas); each serves distinct functions within farming cycles and is impacted differently by river seasonality. This distinction is crucial, as crop choices and vulnerabilities vary by location. Rice and *maize* are cultivated in the *zona baja* and a mix of perennial (*plátano*, cacao) and seasonal crops (pineapple, *yuca*) in the *zona alta*. Farmers plant rice along the *zona baja* during *vaciante*. Planting ranges from May to July, while they harvest in September before the river level rises. "*It has just started to rain (late April), and it will last for five to six months. In May, it will be time to plant rice, and we will plant the rice in the muddy fields. When the water recedes, mud remains, and that is where the rice is planted and irrigated. In September, we will be harvesting rice. That is how we work in the jungle; that is how this year ends and the next year begins. Before, my parents worked just for the sake of working. But now we have to find products that grow faster,*" Robin, a farmer in Tamshiyacu, explained how their farming activities highly depend on the river levels. While *vaciante* season offers fertile conditions for planting, rice areas remain sensitive to sudden changes in river levels. An unexpected rise in river levels (locally called as *repiquetes*) can impact planting stages when seeds can be washed away by the rising river and also during the early growth stage. These sudden changes can lead to reduced yields.

Springer

Zona alta supports year-round cultivation of diverse crops, providing both subsistence and supplementary income. Farmers plant *plátano* (9–12 months before harvest), *yuca* (7–8 months), pineapple (3 months), and a variety of vegetables. *"My father plants yuca and plátano. Yuca needs 8 months before you can harvest it, and for plátano, it needs 1 year. We need to look for other crops that can give us higher income and can be more productive,"* Pablo shared about how their family continuously looks for different types of crops to plant in *zona alta* to generate higher income. Cacao is also cultivated in the *zona alta*, with harvest times distributed throughout the year depending on crop health and environmental conditions. Farmers noted that while the *zona alta* is generally less exposed to river fluctuations, extreme *creciente* events can still inundate the area.

Fishing is practiced throughout the year, though community members report increased fish availability during *vaciante*. They attribute this to the *mijano*, a seasonal fish migration from forest lakes into rivers and streams, which concentrates fish populations in more accessible waterways. However, residents have observed a decline in fish catch and fish size in recent years. They attributed this change to shifting river dynamics—prolonged *creciente* and shorter *vaciante period*s—as well as increased river pollution and ecological degradation from past flood events.

Access to potable water is provided by the municipal service that treats river water for household use. This service is provided daily, usually between 5:00 and 9:00 AM, and is free of charge after paying a minimal installation fee. Residents noted that interruptions in service occur when the municipality undertakes maintenance due to sediment build up, typically after periods of high turbidity from *vaciante*. While the system generally functions year-round, some families choose to purchase bottled water as a supplemental resource.

Community members identified two primary risk windows: (1) May to June, marking the transition from *creciente* to *vaciante*; and (2) August to October, when the river levels drop to the lowest of the year and the variability in river levels is perceived to be highest (see Fig. 7). These periods are associated with heightened uncertainty in relation to planting schedules, crop performance, and river transport. A key source of unpredictability during these windows is *repiquetes*—sudden rises in water level during *vaciante* that can damage growing crops and disrupt the timing of field activities in the *zona baja*.

These risk windows become even more pronounced during extreme events. For instance, during the 2012 flood, the river inundated not only the *zona baja*, but also parts of the *zona alta*, resulting in widespread agricultural losses. Rice fields in the *zona baja* were completely submerged, while *plátano* in the *zona alta* remained underwater for extended periods, reducing their productivity. During the 2023 drought, there was reduced window of opportunity for planting and harvesting and exacerbated constraints on water access and fluvial transportation.

El Chino

In a normal year, *vaciante* spans from July to October, while *creciente* spans from November to June. River-based activities in El Chino include fishing, fluvial transportation, and access to potable water. Most men are engaged in fishing activities throughout the year, although they note an increase in fish catch during the *vaciante period*. However, they have observed a decline in overall catch volumes and a reduction in the size of key species—*boquichico*, *palometa*, and *sabaló*—which serve as essential protein sources.

Access to potable water in El Chino comes from different sources. One major source is the *quebradas*—small streams accessible only by small boats. Residents take water containers to these streams to supply their households. The second source is a solar-powered water tank that draws groundwater and supplies water twice a week (Tuesdays and Fridays). This water tank was installed by the community members together with a partner Non-Government Organization (NGO).

Fluvial transportation is crucial for accessing livelihoods and social services for residents of El Chino. Fluvial transportation allows access to healthcare facilities, transportation of fish to nearby markets, traveling to *quebradas* for water collection, and harvesting fruits from trees along the riverbanks. The primary school teachers rely on fluvial transportation to reach the community each week. Bigger vessels similarly depend on the river to deliver supplies. Fluvial transportation can also be significantly impacted by seasonal variations in river levels. During the *vaciante period*, although navigation remains possible, it can become precarious. Boats frequently get stuck or damaged due to submerged logs and vegetation. In extreme *vaciante* conditions, some *quebradas* dry up or become less accessible, requiring residents to walk considerable distances to retrieve water. On the other hand, during extreme *creciente*, higher water levels generally facilitate smoother transportation, especially for larger vessels.

Community members identified the risk windows from October to February (see Fig. 8). During these critical months, the community's anticipatory capacities are stretched, as evidenced by disruptions in fishing, difficulties in water collection, and the increased vulnerability of nearby farms.

These dynamics become even more pronounced during extreme events. "*The vaciante begins in July and (the river*

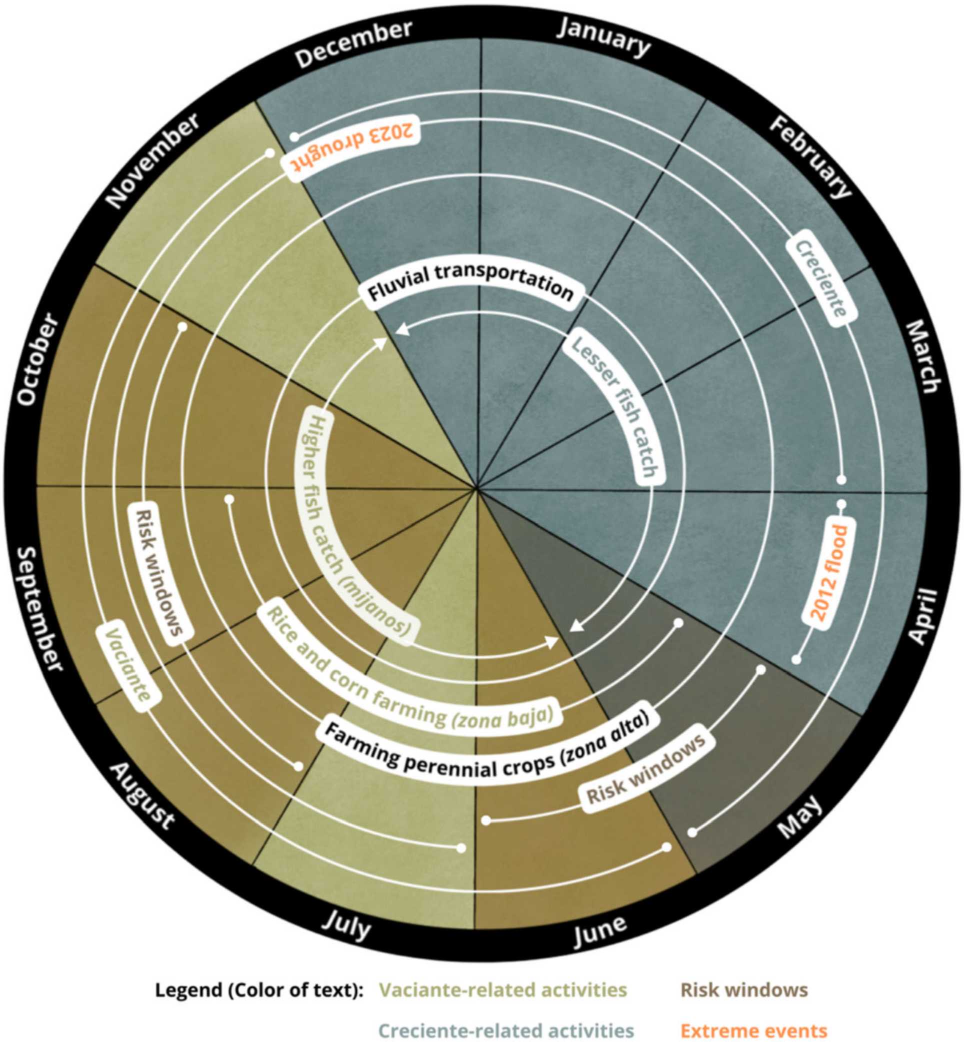

Fig. 7 Tamshiyacu's seasonal calendar

level) is usually low until October, but this year (2023) it changed. In the past years, it has been normal from July to October, and it has been as how we expected the river levels to be. But this time it changed. In February it was still low, about 3 m lower. We were used to the water being 30 to 40 cm or almost at ground level. But not this year," Frederico a fisher and farmer described how their anticipated river levels were different in 2023. Drought conditions in 2023 negatively impacted fish migration patterns that resulted to significantly reduced fish catch and made it more difficult to access potable water from the *quebradas*. In search for fish, fishermen had to navigate long distances upstream toward the *pozas*, a section of the Tahuayo river where the depth can reach up to 7 m even during a drought. Conversely, extreme flood can inundate the entire community. During the 2012 flood, rising waters submerged houses. *"Some years are normal, but there are some years when we see changes. Not all creciente are the same. There are some crecientes where there is just enough water, and some where the water stays. In 2012, the river (level) got very high, right where the chair is (pointed at the other chair in their living room), and from that day something has changed. From that flood until today, it has not happened again. The river (level) does not even reach our (house) floor,"* Frederico shared memories from the 2012 flood. He also emphasized that no *vaciante* or *creciente* are the same; while the rhythms take place annually, its dynamics and timing are different each year.

DISCUSSION

Situated risks in the different case study areas

For riverine communities in the Peruvian Amazon, risk is highly context-specific, temporally sensitive, and

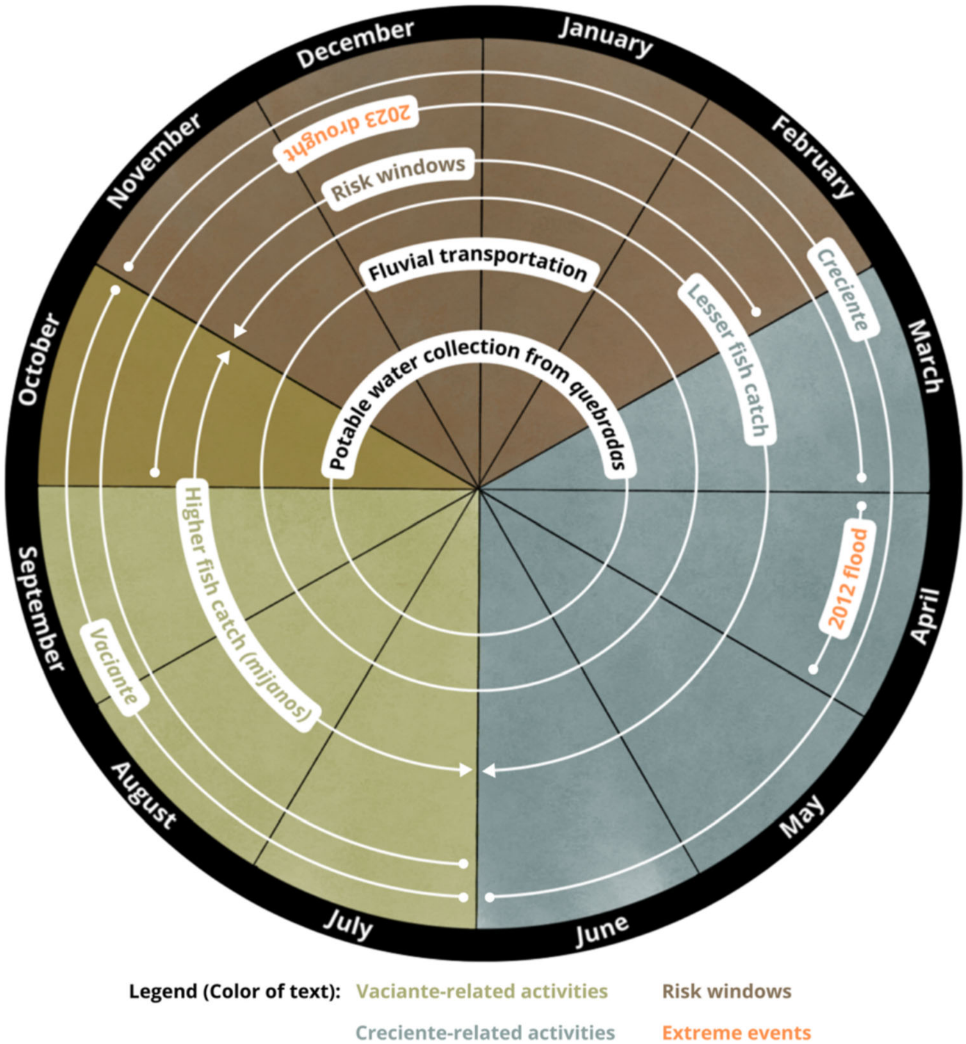

Fig. 8 El Chino's seasonal calendar

relationally constructed. The cases of Bajo Belén, Tamshiyacu, and El Chino illustrate how risk perception and response are shaped by the timing, duration, and cascading impacts of hydrological events on agriculture, fisheries, water access, and livelihoods (Matanó et al. 2022; Valenzuela et al. 2023; Mendoza et al. 2025). For instance, communities differentiate between a *vaciante* and a drought, or between a *creciente* and a flood. These distinctions are based on how events intersect with daily rhythms and the timing of key livelihood activities. A *vaciante* that arrives earlier or persists longer than usual can severely disrupt planting cycles, while an early *creciente* can inundate croplands or damage homes (Langill and Abizaid 2020). These seasonal constraints illustrate how environmental rhythms are embedded within broader livelihood strategies and how disruptions to these rhythms can cascade through interconnected subsistence systems.

A telling comparison emerges across the case study areas. All of the case study areas are exposed to the same overarching hydrological regimes—*vaciante* and *creciente* cycles—yet the impacts of extremes such as the 2023 drought varied significantly. These variations reflect differences in infrastructural provision, proximity to the river, access to potable water, levels of market integration, and the configuration of surrounding river channels. In Bajo Belén, on the periphery of Iquitos City, the drought's impacts were most visible in compromised access to clean water, increased water contamination from stagnant or drying tributaries, restricted mobility due to shallow waterways, and disruption to livelihood activities such as market-bound fishing and farming. These effects were exacerbated by the community's reliance on small canoes for transportation, lack of piped water infrastructure, and spatial marginalization within the urban fabric of Iquitos (Sax 2020). In contrast, Tamshiyacu, a semi-rural community with stronger links to the Amazon River, experienced the drought primarily as a loss of fishing income. Local fishers reported that low water levels disrupted fish migration patterns, limited access to usual fishing spots, and increased the labor and fuel costs associated with navigating to more productive zones. Here, market-oriented livelihoods were more sensitive to changes in fish availability and transport logistics. In El Chino, a small community located along Tahuayo River, the effects of the drought were acutely felt through reduced fish catch and resulting food insecurity. Unlike Tamshiyacu, El Chino's economy is largely subsistence-based, with fish as a primary source of protein. As water levels dropped and fish availability decreased, households faced nutritional stress, with limited alternatives due to their geographic isolation, minimal access to markets, and reliance on the river also for transport and domestic water use. The absence of diversified food systems and external support amplified the community's vulnerability, underscoring the entanglement of environmental and social systems in shaping risk (Adger 2003; Adger et al. 2005; de Steenhuijsen Piters et al. 2021). These cases show that risk is co-produced through place-based interactions between communities, institutions, and environments. Responses to the 2023 drought varied; in Bajo Belén, urban exclusion and poor infrastructure deepened impacts; in Tamshiyacu, market dependence increased vulnerability; and in El Chino, geographic isolation and subsistence pressures played a key role.

Degrees of temporal constraint and responsiveness

Across the case study sites, community members engage in continuous observation of river conditions, particularly during transitional periods between *vaciante* and *creciente*. For instance, in Bajo Belén, farmers stagger the planting of *maíze*, *yuca*, and coriander to align with expected water level changes, reducing the risk of total harvest loss. Fisherfolk similarly attune their practices to seasonal hydrological rhythms: fishing in Bajo Belén intensifies during *creciente*, while in Tamshiyacu and El Chino, fish catch is more abundant during *vaciante*. Crucially, these anticipatory practices are informed by locally defined risk windows. In Bajo Belén, risk associated with low water is most pronounced from April to June, while high water risks peak between September and December. These windows reflect situated temporalities or community-specific ways of understanding and acting within time, shaped by cumulative knowledge, affective cues, and embodied relationships with the river (Bohle et al. 1994; Leach et al. 2010).

Across the cases, we observe that river-dependent practices vary in their degree of temporal constraint. Some activities—such as planting rice or renovating houses—require precise timing in relation to river levels. If the specific timing for response was missed, it can result in significant material and livelihood losses. These practices are strongly time-bound and rely on habitual practices and memory (Nightingale 2017; Ingold 2022; Tran et al. 2025). Other practices allow for greater temporal adjustment, such as also having fruit trees instead of only relying on annual crops or sourcing potable water from alternative locations, which reflect a capacity to reconfigure timing in response to changing conditions. Other activities, including fishing and fluvial transport, are ongoing but demand continuous responsiveness to sudden and unpredictable changes in water levels, relying on improvisation and everyday decision-making (Castro and Sen 2022; Jackson et al. 2022, 2025).

These variations illustrate how communities navigate uncertainty through multiple and overlapping temporal orientations. It means that strategies have varying degree of being tied to the river rhythms, and to how much room exists for temporal negotiation. In this sense, adaptation expands from a linear process of planning and control to an ongoing practice of sensing, adjusting, improvising, and responding within shifting river rhythms. This perspective challenges dominant risk and adaptation frameworks that privilege stability, predictability, and predefined response options. Instead, it foregrounds the importance of understanding temporal orientations and the capacities of communities to act within uncertainties by working with, rather than against, changing river rhythms (Folke et al. 2002; Adam 2008; Berkes and Ross 2013). Understanding adaptation through the lens of situated temporalities and risk windows highlights that sustainability demands sustaining relationships, practices, ways of knowing, and knowledges that enable ongoing negotiation and improvisation with change (Adger et al. 2011; West et al. 2020).

Reframing risk and epistemic justice through highlighting local temporalities

A key theoretical contribution of this study is the articulation of risk windows which are generated through ongoing observation, memory, and interpretation. They represent a temporally situated epistemology of risk, rooted in the dynamics of local place-making (Cresswell 2004; Massey 2005). From a situated risk perspective, risk windows reveal how communities interpret uncertainty through dynamic interaction with the river. While Boholm's original formulation focused on institutional contexts, our findings extend the concept to socio-ecological systems, illustrating how everyday practices such as improvising fishing routes or timing house repairs are temporally dependent river rhythms (Ingold 2022; Tran et al. 2025).

These windows also highlight the importance of temporal attunement, the ability to perceive and respond to change over time, as a core dimension of adaptive capacity. In the context of climate variability and shifting baselines (Scoones and Stirling 2020; Kreibich et al. 2022), such attunement becomes essential to sustainability to enable communities sustain life amid uncertainty. Risk windows contribute to operationalizing epistemic justice in such contexts by making visible how local temporalities shape uncertainties and possibilities for different river-dependent activities (Fricker 2007). Crucially, risk windows offer actionable insights for climate governance. They present an opportunity to bridge standardized early warning systems with local knowledge by aligning alerts and interventions with community-identified temporalities. Co-defining risk windows with affected stakeholders into early action protocols could enhance the relevance and timing of warnings (Marchezini et al. 2018; Sufri et al. 2020).

CONCLUSION

Dominant approaches to understanding drought and flood risk frequently overlook the situated and socially embedded nature of knowledge-making in local contexts. Policies solely based on technical risk assessments may fail to grasp complex and relational ways in which people experience and respond to environmental change. In this study, through the cases of three riverine communities in the Peruvian Amazon—Bajo Belén, Tamshiyacu, and El Chino—we explored how communities learn with the river, and how different river-dependent activities are both spatially and temporally situated. Through storytelling sessions in 2023, and the use of seasonal calendars in 2024, we identified risk windows—moments of heightened uncertainties that stem from changing river dynamics that disrupt normal rhythms of riverine life.

Our findings offer three key insights into situated risks: (1) riverine communities learn with and depend on the river in differentiated ways—ranging from farming and fishing to house repair and water collection; (2) even minor anomalies in river behavior—such as sudden level shifts or altered seasonal transitions—can produce disproportionate disruptions; and (3) situated risks enunciate varying degrees of temporal constraints and responsiveness. Our study points to several research recommendations that can expand the understanding of situated risks and identification of risk windows. These include (1) designing a longer field-based method where the research group and the community can co-create seasonal calendars that capture salient memories on both *vaciante* and *creciente*, and (2) using scenarios where community members can engage with revisiting risk windows and potential new vulnerabilities and impacts in case of unprecedented extremes.

Acknowledgements We would like to express our gratitude to the community members who gave us their time and shared their stories with us. This work will not be made possible without their trust and openness. We would also like to thank the reviewers who gave constructive and valuable feedback that helped us improve our work. Valenzuela, J.J., and Armijos, E.N.C were supported by the Project—Contract No. PE501095835-2025-PROCIENCIA.

Data availability The data that support the findings of this study are available on request from the corresponding author, Mendoza, H.D. The data are not publicly available due to privacy issues (e.g., transcripts containing information that could compromise the privacy of research participants).

Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical approval The studies involving humans were approved by VU Amsterdam BETHCIE ethics committee. The studies were conducted in accordance with the local legislation and institutional requirements. Verbal consent for participation in this study was provided by the participants or their legal guardians/next of kin.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

REFERENCES

Adam, B. 2008. Future matters: Futures known, created and minded. *Twenty-First Century Society* 3: 111–116. https://doi.org/10.1080/17450140802095102.

Adger, N.W., N.W. Arnell, and E.L. Tompkins. 2005. Successful adaptation to climate change across scales. *Global Environmental Change* 15: 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005.

Adger, W.N. 2003. Social capital, collective action, and adaptation to climate change. *Economic Geography* 79: 387–404. https://doi.org/10.1111/j.1944-8287.2003.tb00220.x.

Adger, W.N., J. Barnett, F.S. Chapin III., and H. Ellemor. 2011. This must be the place: Underrepresentation of identity and meaning in climate change decision-making. *Global Environmental Politics* 11: 1–25. https://doi.org/10.1162/GLEP_a_00051.

Barbosa, M.C., K. Alam, and S. Mushtaq. 2016. Water policy implementation in the state of São Paulo, Brazil: Key challenges

and opportunities. *Environmental Science & Policy* 60: 11–18. https://doi.org/10.1016/j.envsci.2016.02.017.
Beck, U. 1992. *Risk society*. California: SAGE Publications Ltd.
Behar, R. 2022. *The vulnerable observer: Anthropology that breaks your heart*. Boston: Beacon Press.
Berkes, F. 2018. *Sacred ecology*. Amsterdam: Routledge.
Berkes, F., and H. Ross. 2013. Community Resilience: Toward an Integrated Approach. *Society & Natural Resources* 26: 5–20. https://doi.org/10.1080/08941920.2012.736605.
Bickerstaff, K., and G. Walker. 2001. Public understandings of air pollution: The 'localisation' of environmental risk. *Global Environmental Change* 11: 133–145. https://doi.org/10.1016/S0959-3780(00)00063-7.
Bodmer, R., P. Mayor, M. Antunez, K. Chota, T. Fang, P. Puertas, M. Pittet, M. Kirkland, et al. 2018. Major shifts in Amazon wildlife populations from recent intensification of floods and drought. *Conservation Biology* 32: 333–344. https://doi.org/10.1111/cobi.12993.
Boelens, R. 2014. Cultural politics and the hydrosocial cycle: Water, power and identity in the Andean highlands. *Geoforum* 57: 234–247. https://doi.org/10.1016/j.geoforum.2013.02.008.
Bohle, H.G., T.E. Downing, and M.J. Watts. 1994. Climate change and social vulnerability: Toward a sociology and geography of food insecurity. *Global Environmental Change* 4: 37–48. https://doi.org/10.1016/0959-3780(94)90020-5.
Boholm, Å. 2003. Situated risk: An introduction. *Ethnos* 68: 157–158. https://doi.org/10.1080/0014184032000097713.
Boholm, Å. 2015. *Anthropology and Risk*. Routledge.
Boholm, Å., and H. Corvellec. 2011. A relational theory of risk. *Journal of Risk Research* 14: 175–190. https://doi.org/10.1080/13669877.2010.515313.
Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3: 77–101. https://doi.org/10.1191/1478088706qp063oa.
Cannon, T., and D. Müller-Mahn. 2010. Vulnerability, resilience and development discourses in context of climate change. *Natural Hazards* 55: 621–635. https://doi.org/10.1007/s11069-010-9499-4.
Castro, B., and R. Sen. 2022. Everyday Adaptation: Theorizing climate change adaptation in daily life. *Global Environmental Change* 75: 102555. https://doi.org/10.1016/j.gloenvcha.2022.102555.
Cresswell, T. 2004. *Place: A short introduction*. London: PhilPapers.
de Steenhuijsen Piters, B., E. Termeer, D. Bakker, H. Fonteijn, and H. Brouwer. 2021. *Food system resilience—Towards a joint understanding and implications for policy*. Wageningen Economic Research.
Di Baldassarre, G., J.S. Kemerink, M. Kooy, and L. Brandimarte. 2014. Floods and societies: The spatial distribution of water-related disaster risk and its dynamics. *Wires Water* 1: 133–139. https://doi.org/10.1002/wat2.1015.
Di Baldassarre, G., M. Madruga de Brito, S. Lindersson, F. Albrecht, and M. Rusca. 2026. Breaking vicious cycles of hydrological disasters and socioeconomic inequalities. *Hydrological Sciences Journal* 71: 191–198. https://doi.org/10.1080/02626667.2025.2593331.
Douglas, M. 1992. Risk and danger. In *Risk and Blame*. Amsterdam: Routledge.
Douglas, M., M. Thompson, and M. Verweij. 2003. Is Time Running out? The Case of Global Warming. *Daedalus* 132: 98–107.
England, K.V.L. 1994. Getting personal: Reflexivity, positionality, and feminist research*. *The Professional Geographer* 46: 80–89. https://doi.org/10.1111/j.0033-0124.1994.00080.x.
Eriksen, S.H., A.J. Nightingale, and H. Eakin. 2015. Reframing adaptation: The political nature of climate change adaptation. *Global Environmental Change* 35: 523–533. https://doi.org/10.1016/j.gloenvcha.2015.09.014.
Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C.S. Holling, and B. Walker. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio* 31: 437–440. https://doi.org/10.1579/0044-7447-31.5.437.
Fricker, M. 2007. *Epistemic injustice: Power and the ethics of knowing | Oxford Academic*. Oxford: Oxford University Press.
Haraway, D. 1988. Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies* 14: 575–599. https://doi.org/10.2307/3178066.
Ingold, T. 2022. *The perception of the environment: Essays on livelihood, Dwelling and skill*. Amsterdam: Routledge.
Jackson, S., E.P. Anderson, N.C. Piland, S. Carriere, L. Java, and T.D. Jardine. 2022. River rhythmicity: A conceptual means of understanding and leveraging the relational values of rivers. *People and Nature* 4: 949–962. https://doi.org/10.1002/pan3.10335.
Jackson, S., N.C. Piland, E. Woodward, P. McTaggart, A. Wali, A.A. Lemos, D.A. Reyes, J. Lins, et al. 2025. Understanding temporality in the lives of rivers and riverine human communities through seasonal calendars. *Freshwater Science* 44: 239–250. https://doi.org/10.1086/735837.
Jasanoff, S. 2004. *States of knowledge: The co-production of science and the social order*. Amsterdam: Routledge.
Valenzuela, J., M. Figueroa, J. Elisa Armijos, S.W. Espinoza, and J.J. Ramirez-Avila. 2023. Flooding risk of cropland areas by repiquetes in the western Amazon basin: A case study of Peruvian Tamshiyacu City. *Journal of Hydrology: Regional Studies*. https://doi.org/10.1016/j.ejrh.2023.101428.
Klenk, N., A. Fiume, K. Meehan, and C. Gibbes. 2017. Local knowledge in climate adaptation research: Moving knowledge frameworks from extraction to co-production. *Wires Climate Change* 8: e475. https://doi.org/10.1002/wcc.475.
Kreibich, H., A.F. Van Loon, K. Schröter, P.J. Ward, M. Mazzoleni, N. Sairam, G.W. Abeshu, S. Agafonova, et al. 2022. The challenge of unprecedented floods and droughts in risk management. *Nature* 608: 80–86. https://doi.org/10.1038/s41586-022-04917-5.
Langill, J.C., and C. Abizaid. 2020. What is a bad flood? Local perspectives of extreme floods in the Peruvian Amazon. *Ambio* 49: 1423–1436. https://doi.org/10.1007/s13280-019-01278-8.
Langill, J.C., and C. Abizaid. 2025. The everyday of inundation: livelihoods and lifeways dimensions of flooding experience in Amazonian Peru. *Environmental Hazards*. https://doi.org/10.1080/17477891.2025.2538510.
Leach, M., A.C. Stirling, and I. Scoones. 2010. *Dynamic sustainabilities: Technology, environment, social justice*. London: Routledge. https://doi.org/10.4324/9781849775069.
Linton, J., and J. Budds. 2014. The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum* 57: 170–180. https://doi.org/10.1016/j.geoforum.2013.10.008.
Marchezini, V., F.E.A. Horita, P.M. Matsuo, R. Trajber, M.A. Trejo-Rangel, and D. Olivato. 2018. A Review of Studies on Participatory Early Warning Systems (P-EWS): Pathways to Support Citizen Science Initiatives. *Frontiers in Earth Science*. https://doi.org/10.3389/feart.2018.00184.
Marengo, J.A., and J.C. Espinoza. 2016. Extreme seasonal droughts and floods in Amazonia: Causes, trends and impacts. *International Journal of Climatology* 36: 1033–1050. https://doi.org/10.1002/joc.4420.
Marengo, J.A., C.A. Nobre, J. Tomasella, M.D. Oyama, G.S. de Oliveira, R. de Oliveira, H. Camargo, L.M. Alves, et al. 2008. The drought of Amazonia in 2005. *Journal of Climate* 21: 495–516. https://doi.org/10.1175/2007JCLI1600.1.
Massey, D. 2005. *For Space*. California: Sage Publications Ltd.

Matanó, A., M.C. de Ruiter, J. Koehler, P.J. Ward, and A.F. Van Loon. 2022. Caught between extremes: Understanding human-water interactions during drought-to-flood events in the horn of Africa. *Earth's Future* 10: e2022EF002747. https://doi.org/10.1029/2022EF002747.

Mendoza, H.D., A.F. Van Loon, J.K.L. Koehler, M. Rohse, B.G. Tuesta Cartagena, P.F.S. Diaz, C.P.A. Vasquez, C.J.A. Souza, et al. 2025. Injustice flows along Itaya River: capabilities from living with river rhythmicity in Bajo Belén, Iquitos, Peru. *Sustainability Science*. https://doi.org/10.1007/s11625-025-01771-y.

Moore, N., N. Pidgeon, P. Simmons, and K. Henwood. 2005. The use of narrative to explore risk in everyday life. In *Narrative, memory & everyday life*, 33–41. Huddersfield: University of Huddersfield.

Nightingale, A. 2003. A Feminist in the Forest: Situated Knowledges and Mixing Methods in Natural Resource Management. *ACME: An International Journal for Critical Geographies* 2: 77–90. https://doi.org/10.14288/acme.v2i1.709.

Nightingale, A.J. 2017. Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum* 84: 11–20. https://doi.org/10.1016/j.geoforum.2017.05.011.

Pelling, M., K. O'Brien, and D. Matyas. 2015. Adaptation and transformation. *Climatic Change* 133: 113–127. https://doi.org/10.1007/s10584-014-1303-0.

Savelli, E., M. Rusca, H. Cloke, and G. Di Baldassarre. 2022. Drought and society: Scientific progress, blind spots, and future prospects. *Wires Climate Change* 13: e761. https://doi.org/10.1002/wcc.761.

Sax, S. 2020. Invisible territory: mapping land-use change and power in the Peruvian Amazon. *Journal of Land Use Science* 15: 290–305. https://doi.org/10.1080/1747423X.2019.1682697.

Schlosberg, D. 2007. 6 Justice to Nature 2: Incorporating Recognition, Capabilities, and Participation. In *Defining Environmental Justice: Theories, Movements, and Nature*, ed. D. Schlosberg. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199286294.003.0006.

Schlosberg, D. 2012. Climate Justice and Capabilities: A Framework for Adaptation Policy. *Ethics & International Affairs* 26: 445–461. https://doi.org/10.1017/S0892679412000615.

Scoones, I., and A. Stirling. 2020. *The Politics of Uncertainty: Challenges of Transformation*. Amsterdam: Routledge.

Sufri, S., F. Dwirahmadi, D. Phung, and S. Rutherford. 2020. A systematic review of Community Engagement (CE) in Disaster Early Warning Systems (EWSs). *Progress in Disaster Science* 5: 100058. https://doi.org/10.1016/j.pdisas.2019.100058.

Sultana, F. 2022. The unbearable heaviness of climate coloniality. *Political Geography* 99: 102638. https://doi.org/10.1016/j.polgeo.2022.102638.

Swyngedouw, E. 2009. The Political Economy and Political Ecology of the Hydro-Social Cycle. *Journal of Contemporary Water Research & Education* 142: 56–60. https://doi.org/10.1111/j.1936-704X.2009.00055.x.

Tran, T.A., J. Rigg, V.H.T. Pham, M.L. Yong, O. Van Vo, P.X. Pham, P.T. Dang, H. Van Tran, et al. 2025. Erosion of traditional ecological knowledge under conditions of hydrosocial rupture: Insights from the Mekong floodplains communities. *Ambio*. https://doi.org/10.1007/s13280-025-02172-2.

Tuana, N. 2013. Gendering climate knowledge for justice: Catalyzing a new research agenda. In *Research, Action and Policy*, pp. 17–31. Springer Netherlands. https://doi.org/10.1007/978-94-007-5518-5_2.

West, S., L.J. Haider, S. Stålhammar, and S. Woroniecki. 2020. A relational turn for sustainability science? Relational thinking, leverage points and transformations. *Ecosystems and People* 16: 304–325. https://doi.org/10.1080/26395916.2020.1814417.

Wheeler, H.C., and M. Root-Bernstein. 2020. Informing decision-making with Indigenous and local knowledge and science. *Journal of Applied Ecology* 57: 1634–1643. https://doi.org/10.1111/1365-2664.13734.

Wynne, B. 1996. Misunderstood misunderstandings: social identities and public uptake of science. In *Misunderstanding Science?: The Public Reconstruction of Science and Technology*, ed. A. Irwin and B. Wynne, 19–46. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511563737.002.

Zwarteveen, M.Z., and R. Boelens. 2014. Defining, researching and struggling for water justice: some conceptual building blocks for research and action. *Water International* 39: 143–158. https://doi.org/10.1080/02508060.2014.891168.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

AUTHOR BIOGRAPHIES

Heidi D. Mendoza (✉) is a Postdoctoral Researcher at the Copernicus Institute of Sustainable Development, Utrecht University, and a Guest Researcher at the Institute for Environmental Studies, Vrije Universiteit Amsterdam, where she did her PhD. Her research interests are within the themes of hydrosocial variabilities, climate adaptation and anticipation, and human–environment futures. Alongside her academic work, she writes poetry and short story that brings to surface emotions and tensions of being a Filipina researcher in Western academic institutions. Her creative work is available at https://wearenotdata.org/.

Address: Institute for Environmental Studies, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands.
e-mail: h.d.mendoza@vu.nl

Jonathan J. Valenzuela is a researcher at the Instituto Geofísico del Perú (IGP). His research interests include hydrological extremes and agricultural systems, specifically in the Peruvian Amazon.

Address: Instituto Geofísico del Perú, Calle Badajoz #169, Mayorazgo IV Etapa, Ate Vitarte, Lima, Peru.
e-mail: jonathan_valcar@outlook.com

Elisa N. C. Armijos is a researcher at the Instituto Geofísico del Perú (IGP). Her research interests include hydrology and sedimentology, specifically in the Amazon Basin.

Address: Instituto Geofísico del Perú, Calle Badajoz #169, Mayorazgo IV Etapa, Ate Vitarte, Lima, Peru.
Address: Universidad Nacional Agraria La Molina, Lima, Peru.
e-mail: earmijos@igp.gob.pe

Anne F. Van Loon is a Professor at the Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, The Netherlands. Her research interests include socio-hydrology, hydrological extremes, and systems dynamics modeling.

Address: Institute for Environmental Studies, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands.
e-mail: anne.van.loon@vu.nl

Melanie Rohse is an Associate Professor at the Global Sustainability Institute, Anglia Ruskin University. Her research interests include environmental change, energy and water sectors, and community resilience and transitions.

Address: Global Sustainability Institute, Anglia Ruskin University, East Road, Cambridge, Cambridgeshire CB1 1PT, UK.
e-mail: melanie.rohse@aru.ac.uk

Johanna K. L. Koehler is an Associate Professor at the Public Administration and Policy, Wageningen University and Research. Her research interests include governance of sustainability transformations, innovations in water services, and governance of hydroclimatic extreme events.
Address: Public Administration and Policy, Wageningen University and Research, Hollandseweg 1, 6706KN Wageningen, The Netherlands.
e-mail: johanna.koehler@wur.nl

Bryan Joel Mariano is a PhD candidate at the Eberswalde University for Sustainable Development, Germany. His research interests include more-than-human geographies and forest conservation.
Address: Eberswalde University for Sustainable Development, Schicklerstraße 5, 16225 Eberswalde, Germany.
e-mail: bryan.mariano@hnee.de

Bruno T. C. Gonzalo is a MSc graduate from the Universidad Nacional de la Amazonia Peruana (UNAP). His research interests include urban forestry and community-based forest management.
Address: Universidad Nacional de la Amazonía Peruana, Sargento Lores 385 Iquitos, Loreto, Peru.
e-mail: bgonzalo9825@gmail.com

Paulo F. S. Diaz is a MSc graduate from the Universidad Nacional de la Amazonia Peruana (UNAP). His research interests include forest conservation and community-based forest management.
Address: Universidad Nacional de la Amazonía Peruana, Sargento Lores 385 Iquitos, Loreto, Peru.
e-mail: paulofrancesco09@gmail.com

Cesar P. A. Vasquez is a MSc graduate from the Universidad Nacional de la Amazonia Peruana (UNAP). His research interests include urban forestry and forest conservation.
Address: Universidad Nacional de la Amazonía Peruana, Sargento Lores 385 Iquitos, Loreto, Peru.
e-mail: vasquezamasifuencesarpaul@gmail.com

Carlos J. A. Souza is a BSc graduate from the Universidad Nacional de la Amazonia Peruana (UNAP). His research interest includes fish parasitology and immunology.
Address: Universidad Nacional de la Amazonía Peruana, Sargento Lores 385 Iquitos, Loreto, Peru.
e-mail: carlos.jack.souzaa2017@gmail.com

Elsa A. V. Izaguirre is a MSc graduate from the Universidad Nacional de la Amazonia Peruana (UNAP). Her research interests include women empowerment, forest conservation, and sustainable forest livelihoods.
Address: Universidad Nacional de la Amazonía Peruana, Sargento Lores 385 Iquitos, Loreto, Peru.
e-mail: elsaizavilca@gmail.com

Juan Bazo is a Senior Climate and Data Science Advisor at the Red Cross Red Crescent Climate Centre. His research interests include climate sciences and anticipatory actions.
Address: Red Cross Red Crescent Climate Centre, Anna Van Saksenlaan 50, 2593 HT The Hague, The Netherlands.
e-mail: bazo@climatecentre.org

Jahir D. Anicama is a Lecturer at the Universidad de Ingeniería y Tecnología (UTEC). His research interests include disaster risk reduction and management, and anticipatory action.
Address: Universidad de Ingeniería y Tecnología, Jr. Medrano Silva 165, Barranco 15063, Peru.
e-mail: janicama@utec.edu.pe