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Title

Forced mobility as an adaptation strategy due to climate change in the Brazilian Amazon: bridging Indigenous local realities and scientific knowledge

Abstract

This study investigates the effects of environmental and climatic changes on the livelihoods strategies of riverine and Indigenous communities in the Alto Solimões region, Brazilian Amazon. Using a mixed-methods approach, we combined a systematic literature review with a qualitative and quantitative analysis based on responses to a semi-structured field survey involving local communities. The systematic review followed the PRISMA protocol to ensure a standardized search and a robust analysis of the articles. This strategy was applied in the Scielo, Scopus, and Web of Science databases. The search resulted in 136 articles that were screened, selected, and analyzed. The qualitative phase consisted of the application of a semi-structured questionnaire with 71 participants in the Alto Solimões region of the Amazon. Respondents had an average age of 55 years, and most self-identified as Indigenous. The quantitative analysis was conducted through a network analysis based on the codes systematized from the transcriptions. The code “forced mobility” was connected to 13 nodes and 22 edges, showing strong co-occurrence with other codes such as floods, droughts, and health. We thus integrate the qualitative surveys with official data on disasters in order to identify and link quantitative information regarding damages of disasters and extreme events. The analysis indicates that environmental and climatic changes significantly affect livelihood strategies of Amazonian communities, influencing agricultural practices, household income, and health conditions. In this context of impacts caused by extreme climatic events, mobility emerges as one of the adaptive strategies, representing a reconfiguration of survival practices in response to environmental pressures and, in some situations, an amplification of existing vulnerabilities.

Introduction

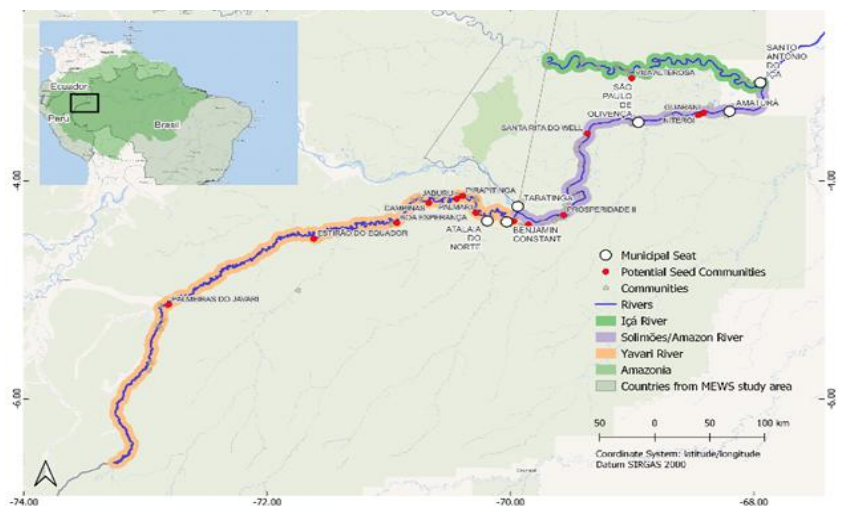
Climate change has gained growing attention in current research agendas and attracted interest from different scientific fields, including demography, since extreme events such as floods and droughts can significantly affect population dynamics and increase the vulnerability of certain groups. This study is based on the understanding that climate change effects are not experienced uniformly but vary according to the characteristics of the affected populations, especially due to factors such as population density and sources of livelihood (Perez et al., 2020).

Evidence shows that climate change influences both the intensity and the frequency of adverse environmental events, which in turn can affect vulnerability and drive demographic transformations (Black et al., 2011). Demographic research has advanced in analyzing the complex interactions between climate change, natural disasters, and population mobility. In the Brazilian context, climate change can impact livelihood strategies of many families. Some are able to rebuild their lives through community resilience, while others are forced to move, forming what has been described as a population of “environmental refugees” (Barbieri, 2011; Barbieri et al., 2017).

From this perspective, this article analyzes the impacts of climate change on mobility, as part of livelihood strategies, in the Alto Solimões region, located in the western Brazilian Amazon, at the border with Peru and Colombia (Figure 1). The approach combines a systematic literature review with a mixed qualitative and quantitative analysis based on primary data collected from key informants in 29 riverine and Indigenous communities distributed across six municipalities (Figure 1).

The study area is highly vulnerable to extreme climatic events such as droughts and floods, where environmental, health, and demographic challenges are deeply

Figure 1: Location map of surveyed Indigenous and traditional riverine communities and adjacent municipal seats.



Source: Research MEWS NIHAID RO1.

interconnected. The aim of the study is to understand how these interactions shape local adaptation strategies and produce new forms of vulnerability.

Methods

Data

The data retrieved through keyword searches were obtained directly from databases SciELO, Scopus, and Web of Science. The semi-structured interviews are part of the MEWS NIH-AID RO Project and were conducted with prior authorization, and aimed to collect information on socioeconomic, health, livelihoods and mobility of Amazonian communities in the context of climate change.

Method

The systematic literature review began with the formulation of a research question. The search strategy combined controlled vocabulary and keywords using Boolean operators, applied to the SciELO, Web of Science, and Scopus databases. The search terms included (“climate change” OR “climate changes”) AND “Amazon” AND (“mobility” OR “migration” OR “demographic”). The results were organized to allow a comparative qualitative synthesis, following the PRISMA guidelines (Moher et al., 2016). Thematic analysis and data organization were supported by the software Atlas.ti, ensuring clarity and consistency in the process.

The interviews were conducted directly in the communities and properly documented. All interviews were recorded, and participants signed an informed consent form. The recordings were fully transcribed, carefully read, coded, and analyzed. The data were anonymized to ensure the integrity and confidentiality of participants. Based on the coded interviews, a co-occurrence network of qualitative codes was constructed, where each code was represented as a node and the co-occurrences within excerpts formed the edges. This approach follows the methodological proposal of Cottica et al. (2023), which demonstrates the potential of network analysis to simplify and visualize complex sets of qualitative codes. Centrality and clustering metrics were calculated in Gephi 0.10.1, allowing a deeper understanding of the relational structure between themes and the role of each code within this field of meanings.

Preliminary Results

Systematic Literature Review

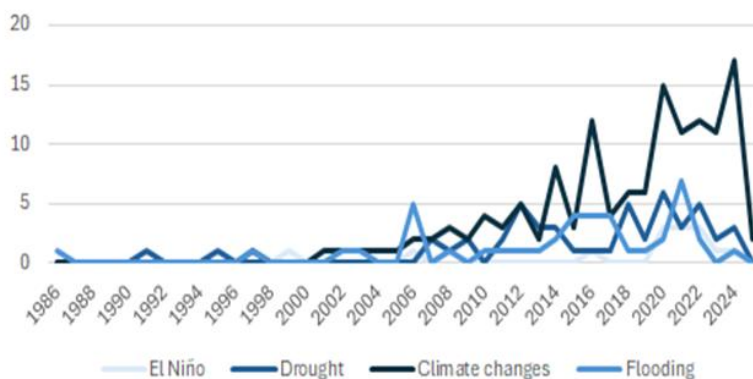
The systematic literature review using the selected keywords resulted in 136 articles. The distribution of articles by search term shows a predominance of the expression “climate change,” which appeared in more than one hundred publications and surpassed other keywords such as “drought,” “flood,” and “El Niño.” The temporal analysis covering the period from 1986 to 2025 reveals a clear upward trend in the number of publications, with a sharper increase from the mid-2000s onward (Figure 2).

The period after 2015 stands out as the most productive, coinciding with the Paris Agreement and the strengthening of the international debate on climate change. While articles mentioning “El Niño” remain relatively infrequent over time, the terms “drought” and “flood” show a more significant increase, especially after 2010.

Recent studies show how environmental and climatic changes directly affect the health and mobility of Amazonian populations. Seasonal mobility in the Peruvian Amazon, for example, has been associated with malaria outbreaks, reinforcing the importance of integrated surveillance systems (Janko et al., 2023). In addition, deforestation and rising temperatures increase the risk of vector-borne diseases such as malaria, dengue, and yellow fever, particularly in forested areas that remain relatively preserved (Arisco et al., 2024; Wilke et al., 2025). The simultaneity of these conditions with crises such as COVID-19 compounds a worrying scenario for public health (Poveda, 2020). Changes in land use also affect local livelihood strategies, while extreme events such as floods and droughts threaten food security, leading to forced migrations and increasing malnutrition (Barbieri, 2023; Sherman et al., 2016).

At the same time, communities develop their own ways of responding to these challenges. Local strategies, such as raising houses to avoid floodwaters, demonstrate adaptive capacity but are limited by the lack of urban infrastructure and planning (Szlafsztein & de Araújo, 2021). Indigenous peoples rely on local ecological knowledge to cope with periods of drought and flooding (Esteban et al., 2021). Even so, extreme events continue to compromise access to basic resources like water and food, increasing health risks (Langill & Abizaid, 2020). Finally, the growing pressure of climate change on mobility is evident, with an increase in climate-induced movements and rural-to-urban displacements, posing social challenges that demand public policies focused on the protection and support of

Figure 2 Temporal distribution of publications (count) by climate-related keyword in Amazonian mobility/migration studies



Source: Authors' compilation based on systematic review.

communities in conditions of greater vulnerability (Do Lago et al., 2024; Gori Maia & Schons, 2020; Franco et al., 2024).

Semi-structured Interviews

The profile of the interviewees is predominantly composed of adults and older persons, with ages concentrated between 35 and 70 years and an average around 55. This age distribution indicates a predominance of individuals in later stages of the life cycle, which is consistent with the presence of community leaders and people who play consolidated roles in local organization and decision-making processes. Most respondents self-identified as Indigenous, with the Tikuna, Kokama, Kulina, Kanamary, Matsés, Kambeba, and Marubo peoples standing out, reflecting the ethnic diversity of the Amazon region. Interviews also included riverine dwellers and institutional representatives, which broadens the understanding of interactions between traditional communities and external actors. Regarding sex at birth, there is a slight predominance of men, although women's participation is expressive and relevant especially among Indigenous and riverine leaders.

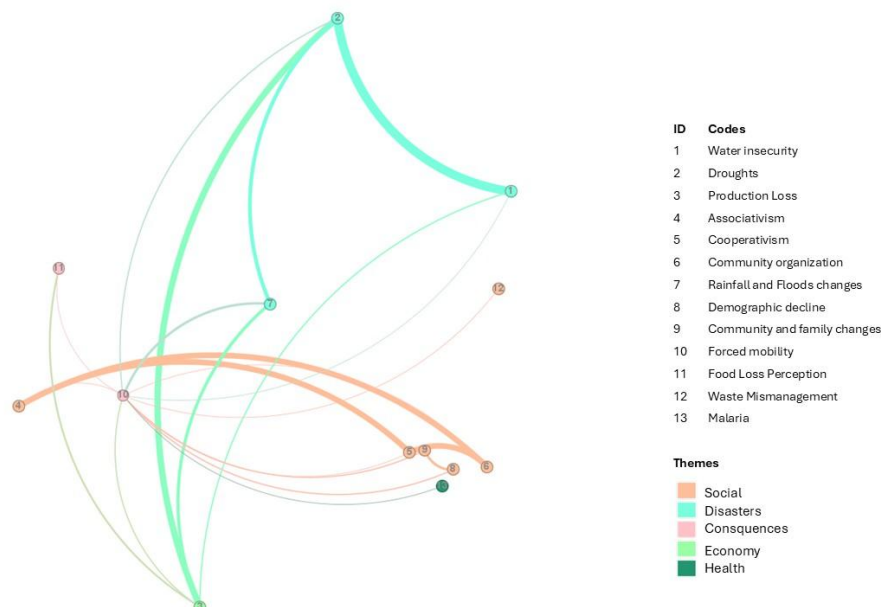
The interviews with Indigenous leaders, community members, and health professionals indicate that climate change has increasingly affected the lives of local populations. Extreme events such as prolonged droughts and severe floods compromise food security and disrupt traditional productive activities such as fishing, small-scale agriculture, and forest gathering. The reduction in water availability, combined with rising temperatures, has intensified health problems such as heat-related illnesses and increased the incidence of vector-borne diseases including malaria, dengue, and other arboviruses. Respondents also reported persistent difficulties in adapting agricultural practices, with frequent crop losses and growing dependence on wells and external inputs, which strain household economies and threaten traditional ways of life.

At the same time, mobility emerges both as a strategy for coping and that generates new vulnerabilities. Seasonal mobility to urban centers in search of services, employment, or medical care was highlighted in the initial exploratory analyses of the interviews. These displacements can expose populations to health risks, experiences of discrimination, and precarious housing conditions in urban areas. Internal tensions also arise within communities, especially regarding local income generation and cultural norms that restrict economic initiatives inside Indigenous territories. These elements help to understand how the effects of climate change intersect with sociocultural, economic, and institutional dimensions, shaping a complex framework of vulnerabilities that demands integrated responses in the areas of health, social protection, and territorial management.

Network Analysis

Figure 3 presents the co-occurrence network of qualitative codes, highlighting how social, economic, health, and environmental themes are connected within the narratives. The colors indicate thematic groups, showing that the axis formed by Droughts, Water insecurity, and Rainfall and Floods changes (in aqua green) structures the environmental core of the network. This cluster is strongly linked to the code Forced mobility (in orange), which occupies a central position and bridges environmental impacts and social dimensions. This intersection shows how extreme climatic events are directly associated with population movements, family transformations, and shifts in community organization.

Figure 3. Co-occurrence network of qualitative codes on climate change and mobility



Source: Author's elaboration based on qualitative data from the MEWS/NIH-AID RO Project. Analysis performed using Gephi 0.10.1.

The lower and peripheral areas of the network show less connected codes such as Food Loss Perception, Waste Mismanagement, and Malaria. Although they have fewer links, these nodes represent concrete outcomes and significant consequences of the transformations observed in the communities. The social nodes (Associativism, Cooperativism, and Community organization) appear close to one another, forming a subgroup that expresses collective responses to environmental impacts. Taken together, the network illustrates a field of meanings in which Forced mobility emerges as the main axis linking environmental, social, and economic dimensions, synthesizing the interdependence between climate vulnerability and community dynamics.

The network contains 13 nodes and 22 edges, with an average degree of 3.38 and a density of 0.28, indicating a relatively well-connected structure with some relationships concentrated around specific codes. The diameter of 2 confirms that the connections among themes are close, suggesting that the narratives interlink subjects in a recurrent and integrated way. The average clustering coefficient (0.47) points to the presence of small cohesive thematic groups, while the average path length (1.71) reinforces the idea of a compact network in which codes are connected through few intermediaries (Table 1).

Table 1. Centrality and clustering indicators of qualitative codes

Code	Theme	Degree	Eigenvector Centrality	Clustering Coefficient
Forced mobility	Consequences	High	High	Medium
Droughts	Disasters	High	High	High
Water insecurity	Disasters	High	High	Medium
Rainfall and Floods changes	Disasters	Medium-high	Medium	Medium
Production Loss	Economy	Medium	Medium	High
Community and family changes	Social	Medium	Medium	High
Associativism	Social	Medium-low	Medium	Low
Cooperativism	Social	Medium-low	Medium	Low
Community organization	Social	Medium	Medium	Medium
Demographic decline	Social	Low	Low	Low
Food Loss Perception	Consequences	Low	Low	Low
Waste Mismanagement	Social	Low	Low	Low
Malaria	Health	Low	Low	Medium

Source: Author's elaboration based on qualitative data from the MEWS/NIH-AID RO Project. Analysis performed using Gephi 0.10.1.

Among the centrality indicators, both degree and eigenvector values show that a few codes concentrate most of the connections, revealing their central roles in the structure of the discourse. The code Forced mobility stands out as an intersection point between social and environmental dimensions, showing high centrality scores and acting as a bridge between different thematic groups. Codes such as Droughts, Water insecurity, and Rainfall and Floods changes appear close to one another, forming a strongly connected environmental core. On the other hand, themes like Malaria and Food Loss Perception occupy more peripheral positions, indicating lower recurrence in direct associations. Overall, the network reveals a narrative in which climatic impacts are deeply intertwined with social and economic dynamics, with Forced mobility positioned at the center of this web of interconnections, an essential adaptive response to the occurrence of extreme events and climate variability.

Within the mobility scenarios, five interviews reported cases of entire communities that were forced to relocate due to extreme climatic events. In addition, several other accounts mentioned that even migration for education or work is influenced by economic losses and failures in agricultural production caused by droughts. These findings highlight the importance of studying forced mobility to better understand the vulnerabilities experienced by Indigenous and riverside populations in the Amazon.

For the final version of this article, we will cross-reference the information from the interviews and the systematic literature review with quantitative data from the Atlas of Natural Disasters in Brazil, which compiles the number of disasters, related damages, and the number of displaced and homeless persons. We will thus be able to identify and link quantitative information regarding damage of disasters and extreme events to the community qualitative survey. This integration will allow the study to examine the issue from multiple perspectives and methodologies, providing a more comprehensive understanding that is necessary for analyzing complex phenomena such as responses to extreme climatic events and environmental change.