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ANALYSIS OF THE DIFFICULTIES OF HUMANITARIAN LOGISTICS PRACTICED WITH THE RIVERSIDE RESIDENTS OF TARUMÃ MIRIM DURING THE EXTREME AMAZONIAN DROUGHT OF 2024 AND MITIGATION PROPOSALS

ANÁLISE DAS DIFICULDADES DA LOGÍSTICA HUMANITÁRIA PRATICADA JUNTO AOS RIBEIRINHOS DO TARUMÃ MIRIM DURANTE A SECA EXTREMA AMAZÔNICA DE 2024 E PROPOSTAS DE MITIGAÇÃO

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Abstract

This study aimed to analyze the difficulties of humanitarian logistics practiced among the riverside dwellers of the Tarumã Mirim River during the drought and to propose courses of action capable of mitigating its harmful impacts. The survey method was used, with data collected through semi-structured interviews and observation with a sample intentionally chosen from among the actors with the most significant participation and knowledge of the logistics actions practiced, analyzed with semantic and content analysis techniques, and the results presented in summary tables. The results showed that the difficulties in a) transporting goods were the reduction in river levels and the appearance of sandbanks and rocks; b) in the distribution of essential services were the failures in the supply of water and energy and health and education; in communication, the existence of few transmission towers, the lack of fiber optics, the lack of satellite communication and the high prices of communication equipment; d) the impacts of the difficulties were the reduction in the transport of goods, the impossibility of river traffic and the inability to carry out environmental logistics; and e) mitigation was to create infrastructure and access to water resources, improve transportation infrastructure, promote economic resilience, preserve the environment with sustainable resource management, strengthen participatory public policies and partnerships and universalize information and communication technology. The conclusion points to the lack of systematic humanitarian logistics during the 2024 drought, whose actions were closer to improvisation than those of other regions cataloged in scientific databases.

Keywords: Amazonian riverside dwellers. Riverside communities. Humanitarian logistics. Logistical difficulties. Logistics in the Amazon drought.

Resumo

Este estudo teve como objetivo analisar as dificuldades da logística humanitária praticada junto aos ribeirinhos do rio Tarumã Mirim durante a seca e propor cursos de ações capazes de mitigar seus impactos nocivos. Foi utilizado o método de levantamento, cujos dados foram levantados através de entrevistas semiestruturadas e observação junto à amostra escolhida intencionalmente

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dentre os atores com mais participação e conhecimento das ações logísticas praticadas, analisados com técnicas de análise semântica e de conteúdo e os resultados expostos em tabelas sintetizadoras. Os resultados mostraram que as dificuldades no a) transporte de mercadorias foram a redução do nível dos rios e o aparecimento de bancos de areia e pedras, b) na distribuição de serviços essenciais foram as falhas no fornecimento de água e energia e saúde e educação, na comunicação foram a existência de poucas torres de transmissão, inexistência de fibra ótica, inexistência de comunicação por satélite e os altos preços dos equipamentos de comunicação, d) os impactos das dificuldades foram a redução no transporte de mercadorias, a impossibilidade de tráfego fluvial e a incapacidade de se fazer a logística ambiental e e) a mitigação criar infraestrutura e acesso a recursos hídricos, melhorar a infraestrutura de transporte, promover a resiliência econômica, preservar o ambiente com gestão sustentável dos recursos, fortalecer políticas públicas participativas e parcerias e universalizar a tecnologia de informação e comunicação. A conclusão aponta para a inexistência sistematizada de logística humanitária praticada durante a seca de 2024, cujas ações estiveram mais próximas do improviso do que as práticas de outras regiões catalogadas nas bases científicas.

Palavras-chave: Ribeirinhos amazônicos. Comunidades ribeirinhas. Logística humanitária. Dificuldades logísticas. Logística na seca amazônica.

1. Introduction

Logistics is the science of supply established on the analytical dimensions of planning, organizing, monitoring, and controlling the various flows of materials and services to meet the needs of organizations and individuals (Pedersen et al., 2025; Atamanchuk; Antonevych, 2024; Nascimento-e-Silva, 2023a; Nascimento-e-Silva, 2025). As human needs grow and diversify, logistics also specializes so that it can adequately fulfill its purpose. In times of disasters, both natural and the consequences of unfortunate human actions, the demands for goods, information, and services grow extraordinarily in a short period, which has led to the emergence of humanitarian logistics as a new and fundamental area of supply (Quispe et al., 2025; Tadić et al., 2025; Zahari et al., 2025; Panizzolo, 2025). This extraordinary event occurred in the Amazon in 2024, in the form of an extreme and prolonged drought, making logistics in the region even more difficult (Nascimento-e-Silva et al., 2019a; Ferreira et al., 2021; Nascimento-e-Silva et al., 2019b).

Environmental variability, intensified by prolonged droughts, imposes difficulties directly affecting access to basic services and the ability to maintain economic subsistence. During the dry season, river levels drop drastically, compromising navigability and making it difficult to transport goods and people. Mobility is limited, communities are isolated, and access to essential items, food,

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medicine, and even health and education services becomes a daily challenge. This challenging scenario prompted the following research question: What are the main logistical challenges faced by riverside communities in Tarumã Mirim during the extreme drought observed in 2024, and how did these challenges impact access to essential goods and services? Understanding these challenges is critical to proposing sustainable interventions that can reduce the vulnerabilities of these populations.

In this sense, this study aimed to analyze the difficulties of humanitarian logistics practiced among riverside communities of the Tarumã Mirim River during the drought and propose courses of action capable of mitigating its harmful impacts. To achieve this goal, the study was divided into the following specific objectives: to identify the main logistical challenges faced by riverside communities during the drought and the logistics practiced amid an extreme drought; to analyze whether the lack of infrastructure and environmental conditions limited the access of riverside communities to essential goods and services; and to propose strategies and recommendations capable of minimizing the impacts of the drought, focusing on sustainable solutions adapted to the local context.

2. Humanitarian Logistics and the Reality of the Amazon Riverside

Logistics can be defined as the set of activities that involve the planning, execution, and efficient control of the transportation, movement, and storage of goods both inside and outside companies (Majid et al., 2024; Ghanavatinejad et al., 2025; Tohir et al., 2025). This approach aims to ensure the integrity of the logistics cycle and compliance with established delivery deadlines. Logistics is fundamental in the contemporary business scenario, often considered the company's heart. When well organized, it ensures the continuous flow of materials and inventory efficiency, which is directly reflected in the productivity of the production line, which is the consequence of fulfilling its purpose of placing the right products, at the right time and the correct cost (Valcheva, 2024; Eljazović et al., 2025), without compromising the environment and natural resources

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(Adigüzel, 2024; Silva et al., 2024), especially in the Amazon (Barbosa et al., 2024; Silva et al., 2025; Ferreira et al., 2021).

Logistics can be understood as an operational function of utmost importance for all types of associated human activity, focusing its efforts on acquiring and making available raw materials, components, materials and services, whose most visible activities are those carried out in storage environments in the management of stocks, in-process products and finished products, such as packaging, storage and distribution to customers (Tamás, 2025; Safina, 2025; Gund; Daniel, 2024). The challenges are much greater, encompassing the entire supply chain, whose effort is to strategically manage the flow and efficient storage of raw materials, in-process stocks, and finished products, from the point of origin to the point of consumption (Chanpuypetch et al., 2025; Borumand; Nookabadi, 2025; Zils et al., 2025), always considering the achievement of predetermined objectives and customer satisfaction. This same concept structures two new branches of logistics: disaster logistics and humanitarian logistics, which are intrinsically linked. Disaster logistics was one of the first practical and scientific concerns to deal with situations that cause suffering and pain to people and regions. Table 1 shows the studies found in the literature that define this phenomenon from 2007 to 2022.

The managerial aspect consisting of planning, implementation and control actions was the most common, found in the studies by Koenen (2007); Göncü; Çetin (2022), whose focuses were the management of the flow of goods, materials, personnel, information and capital to serve people in need, beneficiaries of this logistics scheme. The study by Kapucu et al. (2007) uses the capacity approach to identify, dispatch, mobilize, demobilize, track, and record resources to achieve the objectives intended by the logistics efforts. Finally, the study by He and Jung (2018) considers disaster logistics as a process consisting of resource handling, aid distribution, and transfer of products, services, and information to victims and people affected by natural or artificial disasters, such as wars and similar situations. Few studies have defined disaster logistics, and the annual number of publications has decreased over time, mainly due to the emergence of another type of logistics, the so-called humanitarian logistics.

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Table 1. Disaster logistics: approaches, focuses, and target audiences

References	Approaches	Focus	Target audiences
Koenen (2007); Göncü; Çetin (2022)	Planning Implementation Control	Flow of goods, materials, personnel, information, and capital	Beneficiaries People in need
Kapucu et al. (2007)	Capacity	Identification, dispatch, mobilization, demobilization, tracking, and recording of resources	-
He; Jung (2018)	Process	Handling resources; distributing aid; transferring products, services, and information	Victims People affected

Source: data collected by the authors.

The literature review showed a growing number of studies on humanitarian logistics, mainly due to its replacement of disaster logistics, as shown in the data in Table 2. Several approaches were found, focusing on aspects relatively common to all. The study by Kavlak et al. (2022) uses the emergency approach of providing commercial compensation for products and services and directing them to alleviate the suffering of vulnerable people. As can be seen, emergency is a characteristic of practically all aspects of humanitarian logistics. Like disaster logistics, management is also an approach used by humanitarian logistics, focused on relief flows (Shah et al., 2020), using the management process on information and services throughout the logistics chain, to alleviate the suffering of affected people, not just the vulnerable, who are the target of emergency actions.

Table 2. Humanitarian logistics: approaches, focuses**,** and target audiences

References	Approaches	Focus	Target audiences
Kavlak et al. (2022)	Form (emergency)	Commercial counterpart, alleviating suffering	Vulnerable people
Shah et al. (2020)	Management	Flows of relief, information, and services from points of origin to the disaster site; alleviating suffering	Affected people
Ferreira; Santos (2024)	Part (logistics)	Management of resources and knowledge; helping	Affected people

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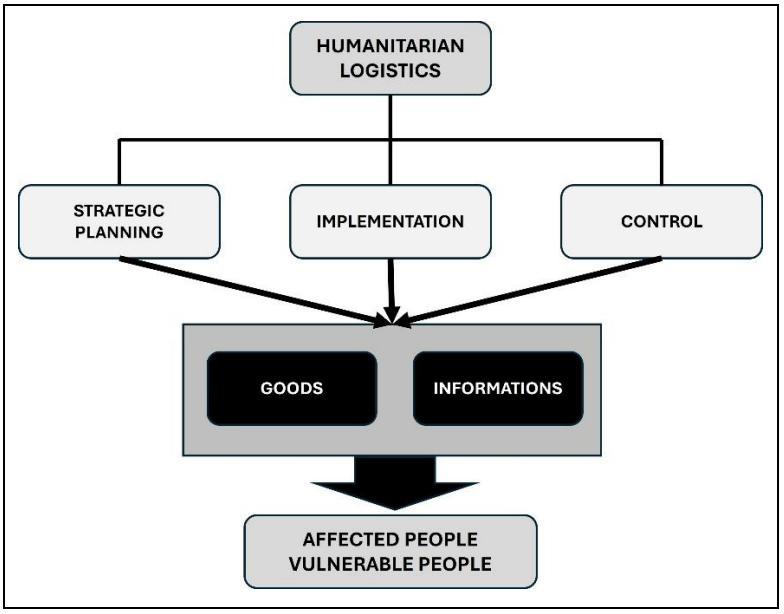
Olayanju (2022); Hassan (2022); Chin et al. (2024); Grigoli et al. (2024); Siman (2024); Gopal; Garcia (2021)	Process	Planning, implementing, and controlling the flow of goods and information from a point of origin to a point of consumption; alleviating suffering.	Affected regions
Gopal; Garcia (2021)	System	Mobilization of people, resources, skills, and knowledge; helping	Vulnerable people

Source: data collected by the authors.

The study by Ferreira and Santos (2024) confirms the practical and scientific constitution that humanitarian logistics is an official part of logistics, specialized in the management of resources and knowledge aimed at alleviating the suffering of people affected by harmful natural and human events. Process was the most frequent approach found in the literature (Olayanju, 2022; Hassan, 2022; Chin et al., 2024; Grigoli et al., 2024; Siman, 2024; Gopal; Garcia, 2021) to designate a conception of steps that need to be executed so that the objectives of alleviating human suffering can be achieved. These steps are planning, implementing, and controlling the flows of goods and information applied throughout the supply chain, from the most distant supplier to distribution to vulnerable people in the affected regions, which are its target audiences. Finally, another approach in the literature works with humanitarian logistics as a system, which has the challenge of helping vulnerable people. The resources to be mobilized (the transformation process) are people, resources, skills, and knowledge to achieve the proposed objectives. Figure 1 summarizes the theoretical architecture of the study.

Figure 1. Theoretical architecture of the study

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Source: prepared by the authors.

In this sense, for this study, humanitarian logistics in the Amazon can be defined as the strategic planning, implementation, and control of assets and information to assist people affected and the vulnerable population due to any emergency in Amazonian communities. The first stage of the process is strategic planning, which represents an effort to develop long-term action plans that involve the community. This means that the plan must have a horizon of at least five years and count on the participation of the community, both in its preparation and implementation and control, so that they are the main protagonists in solving their challenges (Bezerra et al., 2024). The plan must contain, at least, the objectives to be achieved and the strategy to be used for this, so it is possible to define the types of assets and information that should be used.

The second stage of the humanitarian logistics process is implementation. Although the plan is five-year, its implementation must be annual, even if emergencies do not occur. This procedure is recommended for its educational effect and as a motivating force for each community member. Although external institutions and organizations must participate in all process stages, community members must lead all. The implementation stage often complements the planning stage, given that emergencies can differ enormously, even though their consequences are highly predictable, as with Amazonian droughts. Similarly, by

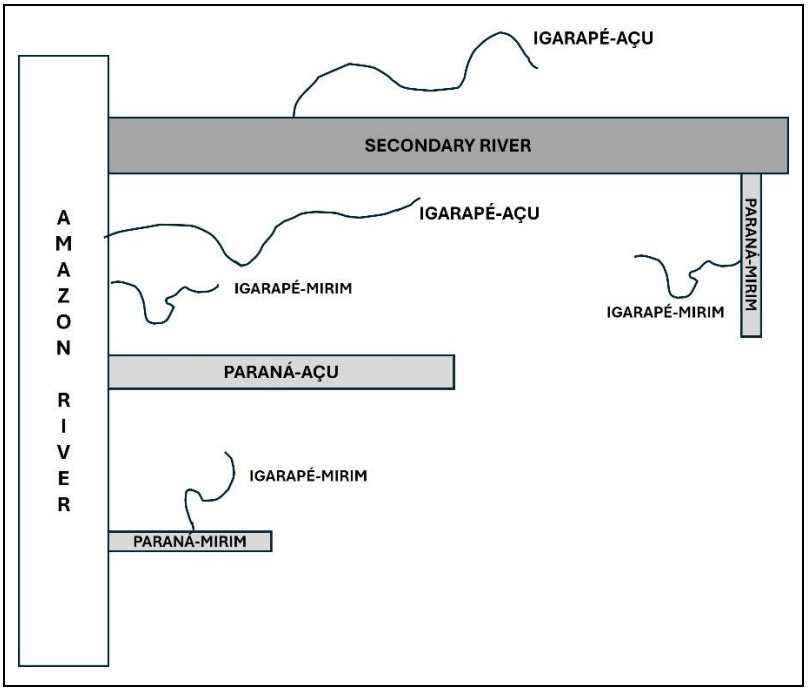
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implementing plans, one also learns to control resources and information, handling them appropriately and directing them to achieve the intended logistical objective. Therefore, the purpose is first to assist the affected and vulnerable people. In terms of Amazonian communities, humanitarian logistics is a significant historical challenge. Without exaggeration, the Amazon can be seen as a multitude of watercourses on all sides so that one can draw up an approximate architecture of its potamography.

The Amazon River is a great water collector for the entire water system, and it runs through several countries. The watercourses of the whole system, composed of secondary rivers, the Paranás-Açus, Paranás-Mirins, Igarapés-Açus, and Igarapés-Mirins, flow into it. The secondary rivers are considered here as the most voluminous and long-flowing, its main tributaries, such as the Negro, Madeira, Tocantins and Tapajós. The Paranás are watercourses smaller than the secondary rivers, divided into two categories: the Paranás-Açus, which are the longest, broadest and deepest, allowing navigation by small boats even during the dry season considered normal; and the Paranás-Mirins, which are smaller, narrower and shallower rivers, which almost always prevent navigation during any drought. The Igarapés, in turn, are small, narrow, and shallow rivers, allowing difficult navigation. They are also divided into two types: the Igarapés-Açus are the largest, broadest and deepest, which only allow navigation by small boats, even during floods; and the Igarapés-Mirins, which are rivers of no more than a few kilometers, shallow and narrow, which only allow navigation by canoes or similar during floods. Figure 2 represents the architecture of the Amazonian River courses.

Figure 2. Amazonian potamographic architecture.

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Source: prepared by the authors.

During regular dry periods, it is common for most of the igarapés and paranás-mirins to dry up; during periods of severe drought, all the paranás and igarapés dry up, as do the secondary rivers, which lose much of their navigability; in extreme droughts, even the Amazon has its navigability compromised. In general, however, in all cases of severe and extreme floods and droughts, there is a need for emergency assistance to the populations of riverside communities. Therefore, each of them must have a plan, layout, roads, and evacuation proposal, as recommended by the study by Qiu et al. (2022), which are essential components of a safety project and control of these natural behaviors.

Riverside dwellers live on rivers' banks (Chaves et al., 2024), and the roads through which they communicate with their neighbors in nearby communities. Rivers are the primary means of transportation throughout the Amazon, providing mobility and enabling the trade of all goods produced or consumed by communities. The rise and fall of the waters shape the lives and activities of riverside communities, whether individually or in communities. Riverside communities are essential parts of the associated human life of the Amazonian people. They are different from urban communities because the organic life of

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their inhabitants is fundamentally structured on friendship, kinship, and neighborhood (Leal et al., 2025). For this reason, for example, there is little differentiation between these communities and, within them, even between the homes of the families that comprise them. They live through the relationships that their community members establish with each other, from sharing their fears of the hauntings of forest creatures to the hereditary transmission of their knowledge and skills. This makes a riverside community close-knit (Anwar et al., 2025). Although they have no personality, their rules, roles, and relationships create their own cultures (Wright, 2024), which makes their members learn to deal with environmental adversities.

In the Amazon, the life of the community people is linked to the behavior of the river waters and is captive to them. Emergencies arise if there is any change in drought or flooding. Despite the numerous available scientific and technological resources, Amazonian communities are little different from what they were at the end of the 19th century. The Amazon is in a region with exceptionally high rainfall. This causes floods resulting from high precipitation to invade 90% of the cities in the area (Oliveira et al., 2022), generating disastrous consequences, with high material damage and extreme risks of transmission of diseases such as leptospirosis, cholera, malaria, and hepatitis, destroying families, agriculture, and livestock. The impacts are so harmful that the study by Ramos and Pereira (2021) reports that the floods from 2013 to 2018 created around 15,000 homeless people in three cities in the metropolitan region of Manaus, without any systematic plan previously drawn up to deal with the occurrence.

Although it is the region with the richest natural ecosystem on the planet and in mineral resources, the Amazon people, in general, can be considered destitute. The situation is so critical that half of the households in the State of Amazonas have someone who receives government assistance (Dantas, 2024), which leads to the estimate that more than 50% of the population cannot generate their subsistence. In riverside communities, it is almost impossible to find schools with adequate internet access (Coutinho et al., 2024); In urban areas, primary health care is not even adequately guaranteed, requiring the creation of temporary task forces or telehealth projects to provide these services (Sachett et al., 2022).

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The very few communities that have made any progress have done so through their efforts, despite the government agencies, which often suppress progress, even to help, as can be deduced from the study by Abate (2024).

A review of previous studies on the logistical difficulties faced by riverside communities reveals a panorama full of challenges that deeply impact these communities. One of the main difficulties is related to the transportation infrastructure, which essentially depends on rivers as primary access routes. According to Monteiro and Silva (2018), the seasonal variability of water levels, with periods of flooding and drought, drastically alters navigability conditions, complicating the transportation of goods and people. These seasonal fluctuations create significant obstacles, such as the impossibility of navigation during the dry season and the risk of flooding during the rainy season, compromising the regularity of logistics services.

3. Research Methodology

This study used a qualitative research approach to explore the phenomena related to the difficulties faced by riverside dwellers during the river's low water levels. Qualitative research is suitable for understanding participants' perceptions, behaviors, and experiences in their natural context, allowing for a richer and more detailed analysis of the collected data.

3.1 Data Collection and Analysis Strategy

For data collection, semi-structured interviews were conducted with residents selected through intentional sampling. This strategy aimed to obtain diverse perspectives on the difficulties of riverside dwellers regarding logistical aspects during the drought. The interviews allowed participants to express their opinions and experiences freely and in detail, providing valuable and contextual information.

The analysis of demographic data was conducted through a quantitative approach for data related to age group, level of education, and other nominal

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variables; qualitative data, content, and semantic analysis techniques were used to understand the difficulties and their differentiating characteristics accurately. The data were transcribed, coded, and later transformed into categories when emerging themes in the responses were identified. This process allowed for identifying patterns and understanding the nuances in the participants' responses. The findings revealed the difficulties for each dimension of the study's theoretical architecture, from which it was possible to develop and propose improvements to mitigate these difficulties through significant insights that the results provided. In addition, the qualitative approach allowed for capturing the complexity and subjectivity of the participants' experiences, contributing to a deeper understanding of the phenomenon studied (Nascimento-e-Silva, 2021; 2023a; 2023b).

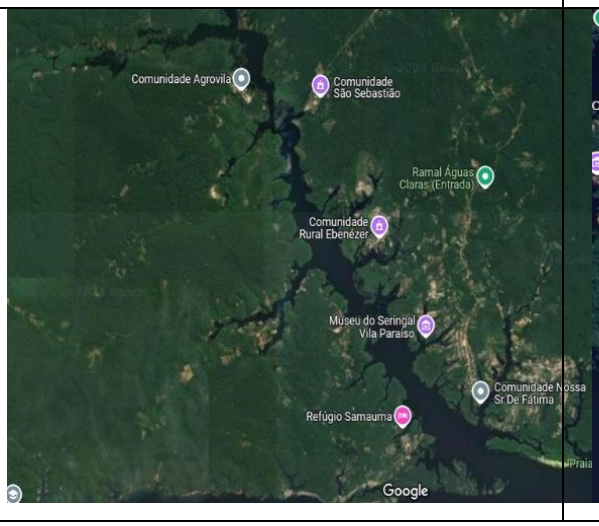
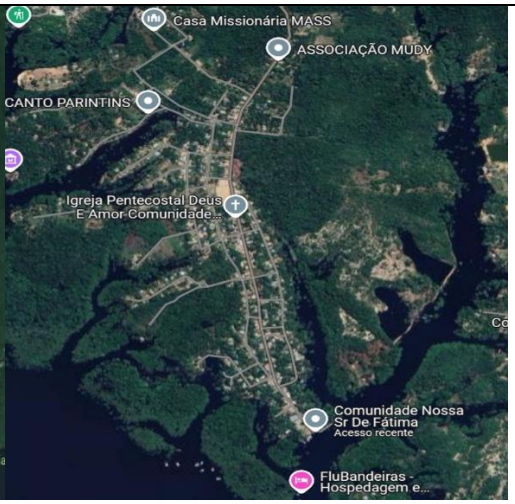
3.2 Population Characteristics and Sampling

The population of this study consisted of residents of the Tarumã Mirim riverside area, located on the banks of the Tarumã-Mirim creek, which flows into the Negro River, in the rural area of Manaus, which is one of the most essential creeks in the rural area of the city. It becomes a large open-air aquarium, with shallow waters during the dry season, making it difficult to reach their communities. The population of Tarumã Mirim is mainly made up of riverside dwellers who depend directly on the rivers and creeks for their daily activities. Fishing, subsistence farming, and extractivism are these residents' primary sources of income and livelihood. However, the strong dependence on rivers as the primary means of transportation creates substantial logistical challenges, especially during the flood and dry seasons, when navigability conditions can become quite adverse.

During the flood season, the Negro River transforms the Tarumã Mirim into a large river with dark waters and extensive igapós. Since hunting and fishing are the primary sources of income, the riverside dwellers begin to look for other activities to try to escape river flooding, such as extractivism, commerce, and, eventually, tourism. On the other hand, the large volume of water during this period allows navigation throughout the entire stream, allowing visits to more

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distant places. Among the communities located on the Tarumã, the one that was the object of our study was the Nossa Senhora de Fatima Community, located approximately seven km from Manaus and can be accessed by river and land routes. Figure 1 shows the geographic area of the research, while Figure 2 shows the location of the community studied.

Fig. 1. Geographical area of research	Fig 2. Location of the community studied
	

Source: Google Street View (2024).

The river route starts at Porto Marina do Davi, at the end of Estrada da Ponta Negra, and runs along the Negro River and the Tarumã Mirim and Tarumã Açu streams, both located on the left bank of the Negro River. The journey takes about 15 minutes with an outboard motor or express boat, or approximately one hour by canoe with an outboard motor, with a stop at one of Manaus' popular beaches, Praia da Lua, frequented by residents, nearby communities, and tourists. For the past 27 years, the communities of Tarumã Mirim have had access to a regular river transport service, organized by the “Cooperativa de Profissionais de Transporte Fluvial da Marina do David à Fátima” (COOP-ACAMDAF). According to Coutinho (2012, p.17), Marina do David, which in addition to providing river transport to nearby communities and tourist attractions, is located in an Environmental Protection Area (APA), which, according to the Municipal Secretariat for the Environment and Sustainability (SEMMAS), is associated with

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the correct use of natural resources and occupation control, and for meeting the requirements of the Maritime Authority Standard (NORMAM).

Another option for accessing the Nossa Senhora de Fátima Community is by road, from the BR-174 highway, which connects Manaus to Boa Vista. The route begins at Km 21 of the Pau Rosa branch, where you travel 14 km on a paved road. Then, you must enter the Cooperativa branch, where you travel 36 km on a dirt road until you reach the Main Fátima branch. The trip by car takes approximately 1h30 to 2 hours, although the road can become impassable during the rainy season, according to residents. The age range of those interviewed indicated that 30% of the participants were over 55 years old, 25% were between 17 and 24 years old, 17.5% between 34 and 45 years old, 10% between 25 and 34 years old, 10% were under 16 years old and 7.5% were between 46 and 54 years old. These data suggest a significant presence of older adults in the community, while 25% of the residents are in the young age group (17 to 24 years old), reflecting a trend of population renewal. Many young people have reported living in the community since childhood, while others have been recent arrivals, which indicates a growth in the local youth population. This preliminary analysis provides an overview of the age structure of the community. It can contribute to future discussions on public policies and services needed to meet the needs of these different age groups.

Regarding employment status, the results showed that 65% of the interviewees stated that they were not currently working, while only 35% indicated that they had a formal job. These data demonstrate a significant rate of unemployment or informal employment among the community's residents, indicating the need for more formal job opportunities or local economic support initiatives. Many residents reported that they depend on welfare programs, such as Bolsa Família and retirement benefits. In total, 40% of the interviewees reported receiving government assistance, while 60% stated they did not receive any benefits. In addition, some residents mentioned receiving Fishermen's Aid.

Regarding education level, 32.5% have completed high school, while 22.5% are still studying. Another 15% of residents have a college degree, and 5% have a postgraduate degree. However, 12.5% have only completed elementary

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school, and another 12.5% are illiterate. These results indicate a diversity in the level of education among the community's residents, with a significant proportion having completed high school, while a smaller portion have higher education. The presence of illiterate residents and those with low levels of education points to the need for basic education and educational inclusion initiatives in the region.

It was found that 52.5% of the interviewees do not have children. Among those who do have children, 35% stated that their children study at the school in their riverside community, while 12.5% study at schools in the urban area of Manaus. These data indicate that, although most of the residents' children study at the local school in the community, a portion manage to attend schools and vocational courses in the city, which are generally associated with higher-income families. It is worth noting that, despite being a school in a rural area, the local institution is viewed positively by residents, with qualified and dedicated teachers, ensuring a quality education within the community itself.

Many riverside dwellers receive government assistance, but some work in the city or the community. Activities in the community include employment in small businesses, schools, basic health units, and the sale of cultivated products and fishing. Among those interviewed, 46.2% stated that they did not have a formal job, surviving on farming, fishing, or other informal activities. On the other hand, 33.3% work within the community, while 20.5% have jobs in Manaus. These data reflect the diversity of livelihoods of the riverside dwellers and the importance of local and informal activities for the community's economy, in addition to indicating a significant dependence on agricultural and fishing activities for survival. Regarding the time they have lived in the community, the data showed that 35% have lived in the region for more than 16 years, some since the early days of the community's formation. Another 27.5% have lived in the area for between 7 and 10 years, while 17.5% have lived there for 11 to 15 years. In addition, 12.5% have lived in the community for 3 to 6 years, and 7.5% are more recent residents, having lived there for only 1 to 2 years. These results reveal that many residents have a long history of living in the region, contributing to strengthening community ties and preserving local culture. At the same time, the presence of new residents indicates a continuous flow of migration and potential demographic renewal.

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4. Results and Discussion

4.1 Logistical difficulties in the Transport of Goods

During the dry season in the Amazon, riverside communities face additional difficulties in river transportation. The main challenges caused by the drought observed were the reduction in river levels, the appearance of sandbanks and rocks, access to services and resources, economic impact, and increased transportation costs and time. Regarding the reduction in river levels, it is understood that river levels can drop significantly during this season, making navigation difficult. In some cases, stretches of rivers may become inaccessible to larger vessels, forcing riverside communities to use smaller boats or travel long distances on foot to access navigable areas. Table 3 summarizes these results.

Table 3. Logistical difficulties and impacts on the transportation of goods

Difficulties	Impacts
Reduction in river levels	Difficulty accessing services and resources Economic impact, increased transportation costs, and time
Appearance of sandbanks and rocks	Increased risk of accidents and groundings. Can damage vessels and delay transportation

Source: data collected by the authors.

Regarding the appearance of sandbanks and rocks, as the water level drops, submerged sandbanks and rocks become dangerous obstacles, increasing the risk of accidents and groundings, which can damage vessels and delay transportation. The same occurs with access to services and resources, where navigation difficulties have limited access to essential services, such as health and education, and hinder the transportation of supplies, such as food and medicine. This can further aggravate the situation of riverside communities, which already face geographic isolation. Such tasks have a significant economic impact on the population, since fishing and the transportation of goods are fundamental to the economy of riverside communities. During the dry season, limited

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navigation can negatively affect these activities, reducing access to markets and the ability to transport products. Increased transportation costs and times are caused by rising river levels, which make river trips longer and more expensive. Vessels must take alternative routes or make more stops, increasing travel time and fuel consumption. These difficulties make the dry season particularly challenging for riverside communities in the Amazon.

4.2 Difficulties in the Distribution of Essential Services

The difficulties in providing water, electricity, health, and education that the community experienced during the Amazon dry season have demonstrated numerous additional challenges in accessing electricity and drinking water, which further aggravate the population's living conditions, as shown in the data in Table 4. The main difficulties observed in electricity were the dependence on diesel generators for electricity generation, as they are not connected to the conventional electricity grid. During the dry season, the difficulty of river transport increases the cost and difficulty of fuel supply, which can result in prolonged periods without electricity. Furthermore, the Tarumã Mirim community does not use renewable energy sources, such as solar and wind, and the infrastructure can be limited and often does not support the full energy needs of the communities. During the dry season, maintenance and transportation of equipment for repairs become more difficult. In the observations made regarding drinking water, the river level dropped significantly during the dry season, compromising the water quality, making it cloudy, and increasing the concentration of sediments and contaminants. This makes it challenging to directly use the water for consumption and other basic needs.

Likewise, the reduction in river flow increased the concentration of pollutants, including organic waste and heavy metals, which made the water unfit for consumption without treatment. The lack of access to adequate treatment systems, such as filters and purifiers, aggravates the problem. Thus, the riverside community resorted to artesian wells or rainwater collectors, but these resources are still limited and insufficient to meet demand, especially during prolonged periods of drought.

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Table 4. Difficulties in the distribution of essential services

Difficulties	Impacts
Failure in water and energy supply	Dependence on diesel generators. Increased generation costs Compromise on drinking water quality
Failures in health and education services	Lack of transportation for professionals and medicines Compromises children's learning

Source: data collected by the authors.

Regarding education, during this period, the Tarumã Mirim community faced significant challenges in accessing education and health services, which further aggravated the vulnerability of these populations. The main difficulties include river transportation, which is essential for students to travel, and is compromised. School boats are often unable to navigate stretches of river with very low water levels or full of sandbanks, forcing children and young people to miss classes or face dangerous and longer journeys. Likewise, it was observed that riverside schools became inaccessible during the drought, which interrupted classes. Teachers who live in more distant areas face difficulties in reaching schools, affecting the continuity of education. In addition to other adversities encountered, the drought aggravated structural problems in schools, such as the lack of water for consumption and basic hygiene, making it difficult for institutions to function regularly and harming the learning environment. In terms of health, transporting patients and health professionals has become more difficult due to low river levels, delaying emergency care and regular medical appointments. This is especially problematic for cases that require ongoing or emergency treatment. This difficulty in navigation impacts the transportation of medicines, vaccines, and medical equipment. With the increased transportation costs and risks, many supplies do not arrive on time or are lost during the journey. Thus, it is understood that drought directly affects water quality, increasing the risk of waterborne diseases, such as diarrhea, hepatitis A, and other infections. The lack of drinking water and the difficulty in maintaining adequate hygiene practices worsen health

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conditions in the community. In addition, the lack of drinking water and proper sanitation during drought increases the incidence of diseases, resulting in high rates of school absenteeism. Children fall ill more frequently and, without access to fast and effective health care, recovery times are prolonged.

The interruption of educational and health services affects children's physical, cognitive, and emotional development. Lack of access to quality, continuous education, and adequate healthcare during childhood can have long-lasting effects. These difficulties during drought are therefore challenging for the Tarumã Mirim community, which faces structural and social constraints. Thus, infrastructure improvements, targeted public policies, and local adaptive solutions are essential to minimize these impacts and ensure continued access to education and healthcare.

4.3 Communication Difficulties

The Tarumã Mirim community faces several limitations in accessing communication technology and the internet, significantly impacting its social, economic, and educational development. The community is in a remote and isolated area with no mobile phone or internet coverage. Telecommunications infrastructure is scarce, with few cell towers and fiber optic lines, which limits access to modern communication services. Thus, the difficult geographical access and the lack of roads make installing communication infrastructure, such as fiber optic cables and transmission towers, very costly and complicated for operators. The cost of equipment such as cell phones, computers, and routers is high for many riverside families, who often live in low-income conditions. Furthermore, mobile data packages and satellite internet are expensive when available, making internet access inaccessible to many. Thus, internet speeds are often low in the few areas where connectivity exists, and connections are frequently interrupted, especially during adverse weather conditions or due to technical limitations. Table 5 summarizes these findings.

Table 5. Communication difficulties

Difficulties	Impacts

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Few transmission towers	Low connectivity
No fiber optic cabling	Lack of communication
Satellite communication is expensive	Inaccessibility to the population
Expensive equipment	Reduced access to the internet

Source: data collected by the authors.

The lack of training and education on digital technologies limits the effective use of the internet and communication devices. Many people lack the necessary skills to fully utilize digital tools for education, work, and other needs. As a result, the lack of adequate internet access affects access to distance learning opportunities, especially relevant during crises such as the COVID-19 pandemic. This widens the educational gap and limits the possibilities for learning and development.

Therefore, without reliable internet access, the Tarumã Mirim community has difficulty accessing vital information about health, vaccination campaigns, disease prevention, and virtual medical consultations, negatively impacting the population's well-being. This lack of access to technology and the internet limits e-commerce opportunities and participation in digital markets, affecting the economic development of communities and contributing to social isolation, making it challenging to communicate with family and friends in other regions. These limitations in access to communication technology and the internet in the Tarumã Mirim community highlight the need for investments in infrastructure, inclusive public policies, and digital training programs to reduce the digital divide and promote sustainable development in the region.

4.4 Impacts of Logistical Difficulties

Droughts in rivers in the Amazon have significant economic and environmental impacts on the Tarumã Mirim community, affecting their livelihoods, local economy, and ecosystems, as specified in Table 6. Among the impacts observed, fishing was one of the main economic activities affected. During droughts, the decrease in river levels affects the availability of fish, as many species migrate or are confined to deeper areas. This results in a lower fish catch,

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directly affecting the income of families that depend on fishing for subsistence and commercialization. Furthermore, drought reduces the navigability of rivers, making it difficult to transport goods to more distant markets, as shown in the data in Table 6. This increases transportation costs and limits access to urban markets, where products are sold at higher prices. Drought periods affect the community's riverside agriculture, which depends on river water for irrigation. The lack of adequate water compromises food production, such as cassava, bananas, and vegetables, reducing local supply and food security. In livestock farming, water shortages also affect cattle, leading to weight loss and lower milk production. As a result of the reduced food supply and the difficulty in transportation, the prices of products increase, raising the cost of living in the Tarumã Mirim community.

Table 6. Other impacts of logistical difficulties

Difficulties	Impacts
Reduction in the transport of goods	Food shortages
The impossibility of river traffic	Production flow is compromised
Environmental logistical incapacity	Environmental degradation

Source: data collected by the authors.

In terms of environmental impacts, reducing river levels during droughts can lead to the degradation of aquatic habitats, such as lakes and streams, affecting local biodiversity. Fish and other marine organisms can be threatened due to the lack of water, increased water temperatures, and reduced oxygen, which can result in the death of many species. Likewise, intensified drought can also cause damage to riverine ecosystems, such as floodplain forests, which depend on the periodic flooding of rivers to sustain their flora and fauna.

Prolonged droughts can alter the composition of plant and animal species, impacting biodiversity and ecosystem services, such as the regulation of the water cycle and carbon sequestration. Thus, vegetation along riverbanks can be lost during these periods, leading to soil erosion. The eroded soil can be transported to riverbeds, resulting in siltation and reducing the rivers' depth and navigability. The dry season can also increase the risk of forest fires, which can be

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exacerbated by inadequate agricultural and management practices that, when left unchecked, cause habitat destruction and biodiversity loss, and release large amounts of carbon into the atmosphere, contributing to global warming.

4.5 Mitigation Strategies and Proposed Solutions

Among the strategies to address the challenges associated with droughts in the region found in the literature, six main solution factors can be highlighted: (1) infrastructure and access to water resources, (2) improvements in transportation infrastructure, (3) promotion of economic resilience, (4) environmental conservation and sustainable resource management, (5) strengthening public policies and partnerships, and (6) technology and communication. For infrastructure and access to water resources, it is understood that implementing rainwater harvesting systems and building cisterns or reservoirs to store water during the rainy season should guarantee a supply during the dry season. These structures can be used for domestic consumption and small agricultural activities. Similarly, drilling artesian wells can be a viable solution for drinking water during droughts, especially when surface water becomes scarce or contaminated. Thus, water treatment systems such as sand filters, chlorinators, and purifiers should be introduced to ensure access to safe drinking water even when river levels are low and water quality is compromised. Furthermore, investing in infrastructure to improve river navigation, such as dredging to remove sediments and sandbanks and regular maintenance of navigation channels would help maintain navigability during dry periods, as well as creating alternative land or air transport routes for the community, using adaptive technologies such as small airfields or improvements to rural roads to facilitate access to essential services and goods.

To promote economic resilience, it is essential to encourage and promote the diversification of economic activities in riverside communities to reduce dependence on fishing and agriculture, such as developing ecotourism, crafts, and other sustainable economic activities. Likewise, the creation of cooperatives should be encouraged to facilitate the joint marketing of products, reduce transportation costs, and improve market access.

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From the perspective of environmental conservation and sustainable resource management, reforestation programs and the protection of riverside vegetation should be promoted to prevent soil erosion and river silting, helping to maintain water quality and the stability of local ecosystems. Likewise, environmental monitoring systems should be implemented to predict droughts and other climate changes, allowing communities to prepare in advance for extreme weather events.

Regarding strengthening public policies and partnerships, it is understood that one of the strategies can be highlighted through creating public policies focused on community sustainability and resilience, incorporating community participation in the planning and implementation of adaptation strategies. Furthermore, establishing partnerships with NGOs, universities, and the private sector to provide technical, financial, and logistical support for local drought mitigation and adaptation initiatives is another tangible option.

Improving access to the internet and communication technologies to allow riverside communities access to critical information, such as weather forecasts, health guidance, and market opportunities, is also a factor that will enable community well-being. Adopting adaptive technologies, such as efficient irrigation systems, soil moisture sensors, and natural resource management applications, can help communities better adapt to drought conditions. When implemented in an integrated and participatory manner, these strategies can help reduce the negative impacts of droughts on the riverside community of the Amazon, promoting resilience, sustainability, and improving quality of life.

5. Conclusion

This study showed that humanitarian logistics is poorly implemented in the Tarumã Mirim community. What is practiced is closer to improvisation than to a responsible and consistent logistics system. The empirical evidence collected differs radically from the theoretical architecture constructed, given the lack of a strategic and operational plan for the community and the lack of participation of community members in the implementation and control of goods and information handled to deal with the consequences of the drought. What is evident is the

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almost complete absence of the community as a protagonist in logistics actions, nearly all of which are carried out by government agencies or organizations under direct government supervision. Any possibilities of integrating existing logistics modes (rivers, roads, and airways) are disregarded, so it is not known whether government investments and support are the most appropriate and integral, much less whether the workforce is qualified or not to participate in these actions.

For these reasons, some actions were listed as recommendations so that logistical efforts are more consistent with humanitarian logistics architectures practiced in other parts of the world and whose validity is already documented in the available stock of scientific knowledge: 1) create infrastructure and access to water resources to obtain drinking water and for agriculture, such as wetlands, 2) improve transportation infrastructure during droughts, including the use of helicopters and drones, 3) promote economic resilience, with new production and partnership systems, 4) develop a scheme for environmental conservation and sustainable management of available resources, including strategic storage, 5) strengthen public policies and partnerships, but with the community playing a leading role, so that goods, money and information are not diverted and 6) universalize the use of information and communication technologies among all members of the community.

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