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Abstract: The effects of climate change are already being felt around the world; however, data on its socio-economic impacts in regions such as the Amazon are still insufficient. Thus, this article aims to reveal the socio-environmental vulnerability of riverine communities to climate change through an analysis carried out in the middle Juruá region, Brazil, focusing on the loss of agricultural production that occurred after the extreme flooding in 2021. Data were collected through semi-structured questionnaires with the participation of 638 agro-extractivists from traditional riverine communities in the municipality of Carauari in the Brazilian Amazon, as well as the collection of documentary information and field visits to quantify and qualify the damage caused by the flood. The loss of agricultural production in the territory exceeded the value of US$ 1,300,000 with greater losses in the production of cassava flour, an essential food for the riverine communities. Production chains of non-timber products, such as the case of rubber tapping and the harvesting of oilseeds, were also directly impacted. The damages caused by climate change to the Amazonian riverine sociological systems are already being experienced by the traditional communities of the middle Juruá region. Governments need to assist these populations in building adaptive measures and strengthening local resilience.

Keywords: climate change; vulnerability; extreme flooding; agro-extractivists; oilseeds; damages; resilience

1. Introduction

The traditional populations of the Amazon have a strong bond with aquatic environments. Most of the first human settlements in the Amazon were constituted in floodable areas to facilitate human displacement, access to water for consumption and proximity to the fishing areas. Therefore, these socio-ecological systems are configured as traditional riverine communities and are recognized as traditional peoples and communities by Brazilian legislation. The specific strategies that the populations of floodable areas have for the different climatic seasons lead them to possess characteristics of specific lifestyles by incorporating the seasonality of the river and the alternation of terrestrial and aquatic phases of these environments into their daily life [1,2].

This hydrological regime configures and reconfigures the rhythm of the waters and of life itself in these socio-ecological systems, which are marked by the landscape duality of the high and low

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waters of the rivers. Therefore, over time, the Amazonian riverine populations have created a way of life that is adapted to these hydrological events. However, currently, these populations are facing difficulties to adapt to the conditions produced by extreme weather events.

The advent of climate change has given rise to critical conditions in local communities in the floodplains and on the highland through the intensification of extreme weather events. Recent reports by the Intergovernmental Panel on Climate Change (IPCC) show clear evidence of increased climate variability and an increased frequency and intensity of extreme events [3,4]. This new hydro-climatological conjuncture generates insecurity in socio-ecological systems, especially those that maintain strong links with the environment, and exposes them to situations of greater risk.

Extreme events represent episodes of natural phenomena that exceed the thresholds of normality of a historical sequence. In the Amazon, extreme events have been attributed to El Niño and La Niña climate events, which correspond to the warming and cooling of the waters of the Pacific Ocean, respectively, which generate an increase or reduction in precipitation, as well as changes in river discharge and levels [5].

Nevertheless, the complexity of the hydrological system of the Amazon basin cannot be attributed to isolated factors [6]. Rainfall and river flow are also influenced by the intertropical convergence zone, from the entry of water vapor from the Atlantic Ocean by trade winds, and heat and humidity exchanges between vegetation and atmosphere in the region itself [7,8]. Another factor is linked to the continental size of the Amazon basin, which leads it to receive uneven levels of rainfall and causes the heterogeneous spatial distribution of extreme fluvial events [6,9,10].

According to the IPCC (2023) [11], climate change cannot be related to extreme events occurring in isolation, as extremes occur naturally, but the persistence of a pattern of the occurrence of these events over time can be attributed to climate changes. Therefore, the greater frequency of the occurrence of extreme fluvial events in the Amazon can already be related to climate change, since changes in the hydrological cycle are already more frequent in the region due to global climate change [10,12,13].

In recent years, an intensification of the occurrence of extreme hydrological events of flood and drought in the Amazon has been documented. The seasonal pattern of Amazonian rivers has presented alterations, which is possibly linked to global climate change [10,12]. This change implies the intensification of the frequency of occurrence of extreme fluvial events, something which directly affects the lives of riverine populations [2,14,15].

Extreme flood events generate significant impacts on the lives of riverine communities since they leave houses submerged, reduce the time available for production and damage trees due to the prolongation of the flood season in the Amazon floodplains. The hydrological regime of rivers directly affects the price of the basic food items in cities, and the rise in the levels of rivers generates an increase in the cost of foodstuffs [16–19].

In this context, the riverine communities along the middle Juruá River, in the municipality of Carauari, are already feeling the impacts of climate change. In the traditional riverine communities of the region, the economy is based on family farming and the extraction of forest products. Understanding the quantitative impact of climate change on the lives of traditional riverine populations is crucial for consolidating adaptive measures that meet current demands [20].

Given this context, this study aims to reveal the socio-environmental vulnerability to climate change through an analysis of the riverine socio-ecological systems of the middle Juruá region, focusing on the loss of agricultural production as a result of the extreme flooding event that occurred in 2021.

2. Materials and Methods

Carauari is a municipality in the Juruá subregion, in the state of Amazonas, Brazil. The city is about 800 km in a straight line from the state capital Manaus. However, if we consider the intricacies of the rivers, the trip from Carauari to Manaus takes a total of five to six days by boat, two days by speedboat and, by plane, two hours.

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The economy of the middle Juruá region is characterized by extractivism, with its productive activities being focused on logging, production of essential oils and butter, rubber tapping, açaí production and fishing. Thus, extractivism is the main source of income of the population in the middle Juruá. It is noted that extractivism is so entrenched in the municipality that its producers have difficulty absorbing new techniques for agroforestry production.

It should be noted that it was also social mobilization, especially community mobilization, that made it possible to establish protected areas with social inclusion in the region. In this context, the middle Juruá Extractive Reserve and the Uacari Sustainable Development Reserve were created. These two entities work collaboratively to integrating the Forum of the middle Juruá Territory, the Management Council for the Distribution of Benefits and other instances of representation and social control (Figure 1).

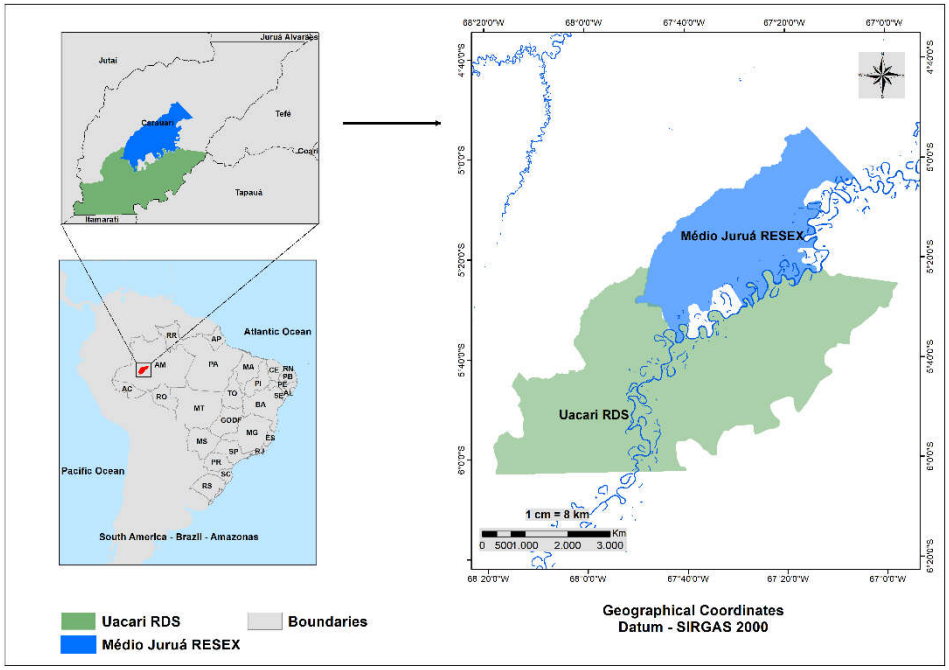

Figure 1. Map of the municipality of Carauari.

Data collection consisted of combining documentary studies with field studies. As the research involves human beings, the entire methodological procedure was submitted to the Ethics and Research Committee of the Federal University of Amazonas—CEP/UFAM CAAE and approved under No. 54763221.0.0000.5020 and permission for the study was obtained from the Authorization and Information System in Biodiversity (SISBio) under No. 80629-1.

A systematic literature review was conducted on the categories of the study (socio-biodiversity chains, impacts of climate change and traditional peoples and communities) and the observed impacts of extreme events on socio-ecological systems in other locations in the Amazon. In addition, a survey of agricultural production losses for the year 2021 in the municipality of Carauari was carried out.

This survey was based on the self-declarations of family farmers about the production losses caused by the 2021 flood. The data for this stage were collected from the Amazonas State Institute for Sustainable Agricultural and Forestry Development (IDAM), a technical assistance agency of the government of the state of Amazonas. The data collection took place through field interviews, in which the families informed the type of crop they produce and the amount lost as a result of this extreme event.

A total of 638 families from traditional riverine communities who suffered loss of production due to flooding in 2021 participated in the data collection process.

The data were tabulated in spreadsheets and processed using the technical coefficients provided by IDAM for rural production (Table 1) and the values practiced in local businesses were obtained in

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the monthly price surveys of this research. The data collection took place from March to April 2021 along the Juruá River and its tributaries in Carauari.

Table 1. Production coefficients from the Institute of Agricultural and Forestry Development of the government of the state of Amazonas.

Products	Scientific name	Productivity (ha)
Avocado	*Persea americana*	200–300 kg of fruit/ha
Pineapple	*Ananas comosus*	32-40 tons of fruit/ha ou 30,000 fruits/ha
Pumpkins	*Cucurbita moschata*	12–16 tons of pumpkins/ha
Açaí	*Euterpe precatoria*	12 tons of açaí/ha
Lettuce	*Lactuca sativa*	55,000 heads/ha or 25,000 heads
Banana	*Musa acuminata Cavendish Subgroup*	1,000 to 1,500 bunches
Potatoes	*Solanum tuberosum*	10 tons/ha
Sweetsop	*Annona mucosa*	4,000 fruits/ha
Cashew	*Anacardium occidentale*	200 kg of nuts or 2 tons of fruits/ha
Sugar cane	*Saccharum officinarum*	4 tons of muscovado sugar/ha
Chives	*Allium schoenoprasum*	250,000 bunches/ha
Coconuts	*Cocos nucifera*	4,000 fruits/ha o6 6 tons of fruits/ha
Cupuaçu	*Theobroma grandiflorum*	2,000 fruits/ha or 400 kg of pulp/ha
Guava	*Psidium guajava*	10 tons of fruit/ha or 800 kg of pulp /ha
Inga	*Inga sp.*	300 kg of fruit/ha
Rose apple	*Syzygium jambos*	14 tons of fruit/ha
Oranges	*Citrus × sinensis*	22 tons of fruit/ha
Limes	*Citrus limon*	7 tons of fruit/ha
Papaya	*Carica papaya*	22 tons of fruit/ha
Cassava	*Manihot esculenta*	12 tons of cassava/ha or 3 tons of cassava flour/ha
Mangos	*Mangifera indica*	15 tons of fruit/ha
Passion fruit	*Passiflora edulis*	20 tons of fruit/ha
West Indian gherkin	*Cucumis anguria*	5 tons of fruit/ha
Corn	*Zea mays*	3 tons/ha
Habanero-type pepper	*Capsicum chinense 'Adjuma'*	2 tons of fruit/ha
Black pepper	*Piper nigrum*	4 tons of fruit/ha
Peach palm fruit	*Bactris gasipaes*	1,600 bunches/ha
Tangerines	*Citrus reticulata*	40 tons of fruit/ha

Many of the family farmers interviewed presented the amount of production loss in units or other measurements, for example, cassava planting holes. This information was converted for later calculation of the economic impacts of the flood on the riverine communities. The value of production losses caused by the 2021 flood in the municipality of Carauari was calculated based on the technical coefficient of production and the amount of loss declared by the farmers. The data were tabulated in Excel® spreadsheets and data analysis was performed by categorizing these products into common classes in order to group them for better graphical representation. Throughout the text, images and the comments of social actors from the middle Juruá as a way of conferring on them the role of subjects of this research, evidencing the protagonism in the production and reproduction of their space and in the observation of the existing rhythms in it.

3. Results

After tabulation and standardization of the data, the amount of lost production was totaled at US$ 1,350,778.35. Loss of items such as vegetables was reported, with emphasis on habanero-type pepper, which alone presented a loss of US$ 16,208.66 due to the floods that occurred in 2021 (Figure 2).

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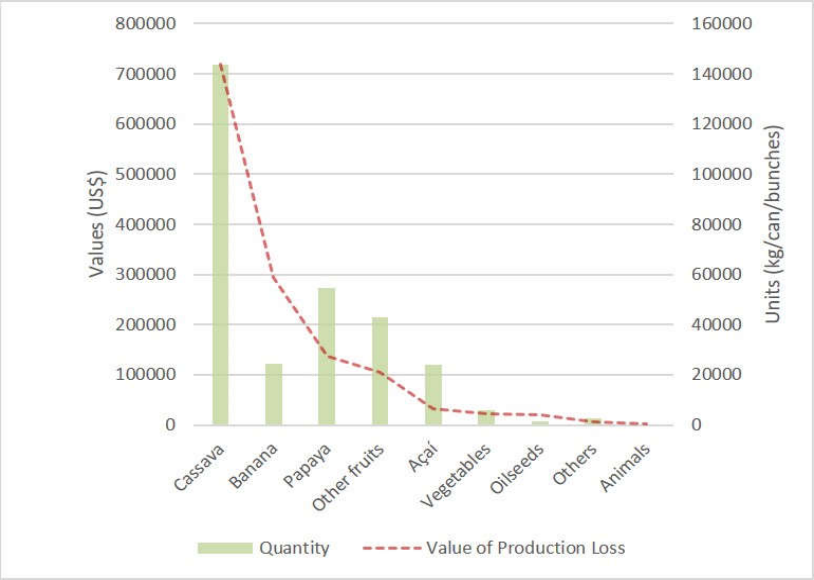

Figure 2. Products that had losses in production and economic losses as a result of the floods in 2021.

As a way to circumvent this impact on food security, some families choose to produce some vegetables in raised planting beds known as "jiraus" (Figure 3).

Figure 3. Production in raised planting beds during the 2021 flood in the Uacari Sustainable Development Reserve (Photo credit: Author).

The loss of animals such as chickens, ducks and pigs was also reported by rural producers in the riparian areas of Carauari. Part of the losses are related to the floods and the other part is related to common factors in the region predation by alligators and snakes.

Other products that have economic importance for the middle Juruá are the oilseeds used in the production of vegetable oils, namely crabwood (*Carapa guianensis*) and murumuru (*Astrocaryum murumuru*) seeds. The production and commercialization of these oils occurs through the Mixed Cooperative for Sustainable Development and Solidarity-based Economy of the Extractive Reserve of the Middle Juruá (CODAEMJ) and the Association of Agroextractivist Residents of the Uacari Sustainable Development Reserve (AMARU). Both organizations sell their productions to the Natura company that has contracts with them. Seed collection occurs from January to May and the production of oils in the agribusiness begins in February and lasts until June (Figure 4).

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Figure 4. Collection of crabwood (*Carapa guianensis*) seeds in the middle Juruá extractive reserve (Photo credit: Authors).

The annual seed production is of around 180-200 kg of seeds per tree [22]., thus it is an important extractive activity of the region with high added value as a result of the processing that occurs in the middle Juruá itself in the community of Roque, in the middle Juruá extractive reserve, and in the Bauana community in the Uacari SDR.

The loss of production of oilseeds occurs due to the presence of these species in the floodplain regions [23] and, due to flooding, its fruits are carried away by the water, making harvesting unfeasible. According to M. C., another factor was linked to the period of precipitation in the region:

> "In 2021, the rainy season took a long time to begin and, with that, there was a delay in the production of fruits by the trees. As a result, the trees bore fruit very late, and most of them fell into the river "(M. C., rubber tapper, 2021).

Among the oilseeds harvested the crabwood tree has a fruiting period related to the period of greatest precipitation [24,25]. Despite presenting a high resistance to water stress, its physiological activities are reduced in the absence of water for long periods of time [23]. Thus, the perception of the rubber tapper reported above is consistent with aspects that are intrinsic to this species.

The reduction in the harvest of andiroba and murumuru seeds was not considered by the interviewees to be a direct impact of the 2021 flood. It should be noted that the harvesting of oilseeds is still considered a secondary economic activity by many families in the middle Juruá ; therefore, the value related to the loss of production in this productive chain is subestimated. In order for this problem to be considered a cause of loss of production, information was collected and analyzed about the production of vegetable oils by CODAEMJ in the last three years in the region (Figure 5).

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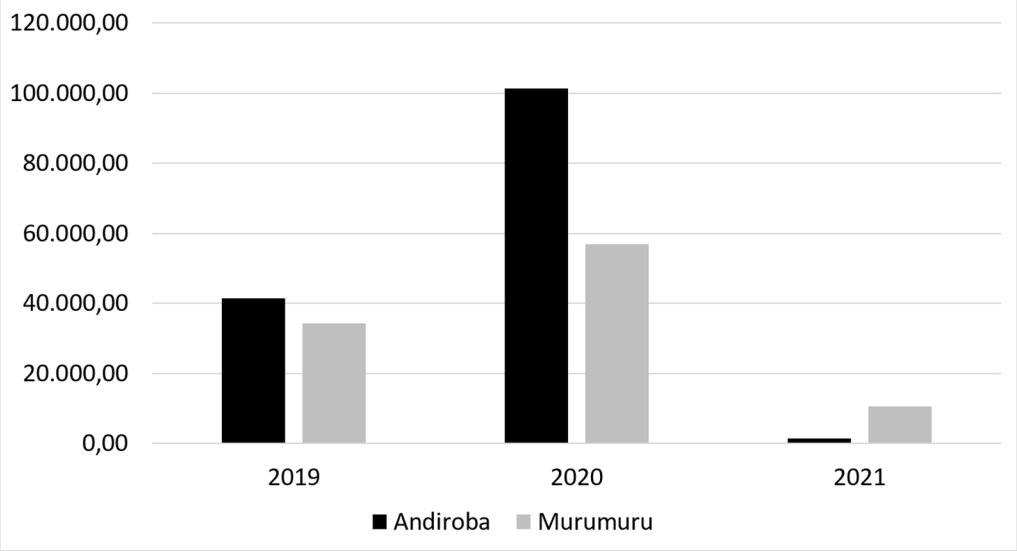

Figure 5. CODAEMJ vegetable oil production values for the period 2019-2021 (Source: Authors).

As of 2021, CODAEMJ had a production contract for 10 tons of crabwood seeds and 10 tons of murumuru seeds. However, the flood drastically affected this production, resulting in a total of only 288 kg of andiroba seeds and 1,431 kg of murumuru seeds. The production of vegetable oils was the lowest in the triennium and affected the management of organizations that work with this chain, causing difficulties in the payment of suppliers and in the continuity of production processes in their agro-industries.

> "After the great flood, the tree becomes fragile and the woodlouse gets into the truck at the base. Then, after a time, the crabwood tree cannot stay up and it falls, taking with it everything that is nearby "(S. S., seed collector, 2022).

Another species that has a high mortality rate due to the effects of flooding is the rubber tree (*Hevea brasiliensis*), symbol of the process of occupation of the banks of the Juruá River and the creation of reserves that make up the territory of the middle Juruá. This species still has a huge economic importance for the families of the region. However, its constant mortality is perceived with an enormous frequency by the rubber tappers.

> "In the old days, you didn't see so many fallen trees in the woods. It's not to do with the age and it's not to do with the wind. You go walking and you see the damage caused by a fallen tree. One falls and takes the others with it. I pay attention to this. I go out looking at the stumps of the trees that fell. They all are diseased [...]. It is sick, its heartwood was dead [...]. In the flood of 2015, I only lost 60 trees (rubber trees) on one row. It makes me think that it is not cold that made the woodlouse bore and spawn inside the wood" (A.M., rubber tapper, 2021).

A.M., a rubber tapper from the community of São Raimundo in the extractive reserve of the middle Juruá, points out the mortality of rubber trees in the forest and cites the possible causes related to this phenomenon. For him, from his daily observations of the dynamics of the forest, there is an intrinsic relationship between floods and the death of rubber trees.

By spatializing the socio-environmental vulnerability of the communities of Carauari in the face of the 2021 flood, we can observe that communities with a higher demographic density and greater productive diversification had greater losses in agricultural production (Figure 6).

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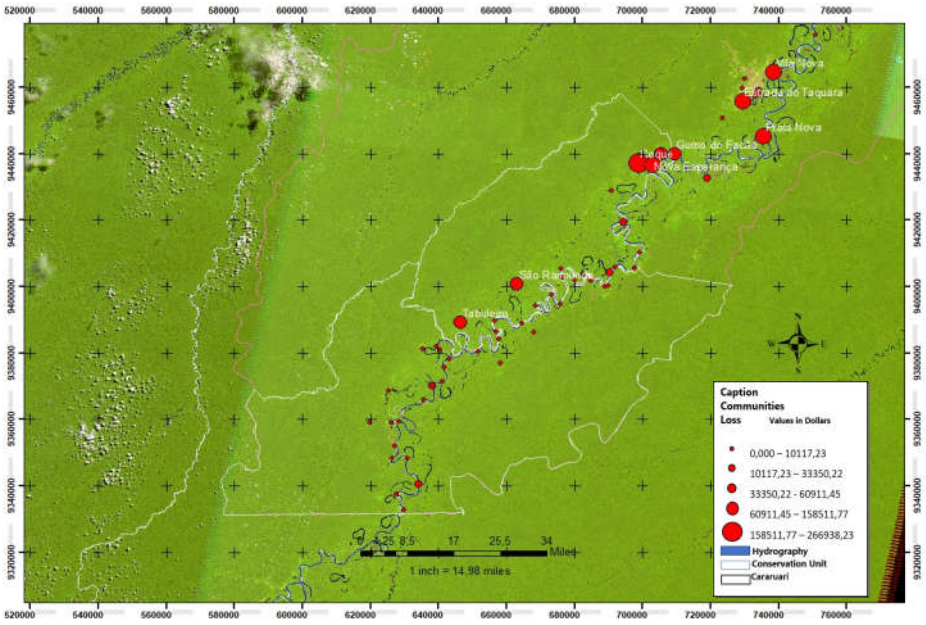

Figure 6. Map showing losses in agricultural and extractivist production (Source: Authors).

The communities with the highest losses in production were, respectively, Roque, Nova Esperança, Praia Nova, Taquara, Vila Nova, Tabuleiro, Gumo do Machão, Novo Horizonte and São Raimundo. It should be noted that the community of Roque reached an estimated loss of US$ 270,576.89, which were mostly related to cassava crops. Of the nine communities with the greatest losses highlighted, six are in the middle Juruá extractive reserve. The losses reported by the residents of the Uacari sustainable development reserve occur in a more fragmented way and not as concentrated as in the middle Juruá extractive reserve.

4. Discussion

When comparing these values with data from the gross domestic product (GDP) of the municipality of Carauari in 2019, which was US$ 1,646,074.52 [21], this loss is equal to 82.06% of the municipality's agricultural GDP. This data reflects the magnitude of the impacts caused by the extreme flood events in the region.

In the municipality of Carauari, several rural and riverine communities have agriculture as their main economic activity. In these socio-ecological systems, in addition to agricultural activity, another characteristic is the extractivism that is part of the labor reality of this population since the time of the rubber boom. The riverine populations have agriculture, extractivism, creative activity and fishing as their economic and subsistence activities [14,26,27]. This versatility is a historical strategy of adaptation to environmental conditions, since activities such as agriculture cannot be developed throughout the year due to the dynamics of the rivers.

The main purpose of agricultural production in the region is the provision of the food for the families in these communities and the surplus is sold in fairs, shops or by the Association of Rural Producers of Carauari. Among the items that come from Carauari are cassava flour, açaí, bananas, rubber, essential oils, and farmed fish.

In this sense, the main economic loss is related to the food security of the Amazonian population, as it is related to the production of cassava flour. Cassava planting is directly related to the diet of riverine populations, which is based on fish and cassava flour. The maintenance of the plantations occurs throughout the year, but planting of the cassava begins in the floodplain regions in the period from May to June. Its production is related to food, but the greater portion of its production occurs for the generation of income for these families who sell it through the Association of Rural Producers of Carauari (ASPROC), via the Riverine Commerce Project of Citizenship and Solidarity (CRCS).

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In the middle Juruá region, the sale of produce is carried out through canteens (a species of store), which are part of the solidary riverine trade project, maintained by ASPROC. Through this system, family farmers sell their production and buy basic items such as food, household items and personal hygiene items with the balance of their sales in these canteens.

Cassava plants have some resistance to water stress; however, they are not very resistant to excess water [2]. Thus, in floods such as the one that occurred in 2021, the waters rose so quickly that it made it impossible for farmers to harvest the tubers in a timely manner for flour production. At the time, several community groups carried out the harvest and produced the cassava flour, but it was not possible to avoid the enormous nutritional and economic damage caused by the extreme flood event that left many roots rotting along the Juruá River (Figure 7).

Figure 7. Community groups working in the production of cassava flour (Photo credit: Authors).

In the study by Vasconcelos et al. (2022) [28], carried out in the middle Juruá region, the authors point out that cassava that is in the ground during the flood period tends to be smaller and darker and, therefore, the flour produced is of lower quality and consequently has a lower commercial value.

An alternative found was to plant cassava in areas of higher ground, but this usually hinders the farmers because the areas are further away from the communities and endanger the lives of the community members, in addition to affecting the transport of the harvest [28,29].

In addition to cassava, banana and papaya production also have enormous importance for the food and income generation of families in the Juruá region. These species have little resistance to water stress [30,31]. Other fruits, such as limes, tangerines, oranges, ingá, sweetsop, avocado, pineapples, coconuts, cupuaçu, cashew, mangos, guavas and rose apples, are mainly destined for consumption by the family and only the surplus is sold via ASPROC or in markets in the seat of the municipality of Carauari.

Forest species that grow on the floodplains, despite having resistance to flooding because they are adapted to lowland regions, as is the case of crabwood, have their adaptive capacity exhausted during prolonged periods of flooding. The prolongation of the flood period causes the death of plant tissues and the change from aerobic to anaerobic respiration as a result of soil saturation [32]. Therefore, water saturation alters the metabolism of root cells that culminate in the death of the trees [33].

The impacts of flooding on seed collection were also identified by Estevo (2023) [34] and Sitawi (2020) [35]. The authors pointed out that, in extreme floods along the Juruá River, there is a difficulty in collecting seeds of murumuru, crabwood and baboonwood (*Virola surinamensis*) and açaí (*Euterpe* sp.).

The rubber tree has a high resistance to stress caused by excess water [36]. According to works by the same author in the Madeira River region, the death of Brazil nut trees (*Bertholletia excelsa* H. & B) and rubber trees was reported as a result of the extreme hydrological flood events in 2014/2015. In the Amazon River region, in the municipality of Itacoatiara, there are also records of deaths of rubber

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trees caused by flooding [37]. It is noteworthy that the death of these forest species does not occur immediately with the occurrence of extreme flood events, but gradually due to the attack of insects at their base (Figure 8).

(a) (b)

Figure 8. Death of rubber trees in the middle Juruá extractive reserve. A) Rubber tree in a row of rubber trees in the community of São Raimundo attacked by termites at its base; B) Dead rubber tree in a row of rubber trees in the same community (Photo credit: Authors).

The loss of these trees in the rows causes a lower rubber production for the workers and impacts their trade with ASPROC. In addition, the impacts of economic interest on forest species reveal the environmental impact on the forest ecosystem of the region caused by extreme climatic events. In this way, other forest and fauna species may also be suffering a reduction in their populations that is generated by these climatic phenomena.

Similar impacts to those perceived in Carauari were found in the state of Acre in 2015 [38]. According to the authors, approximately 25,000 families were directly and indirectly affected, representing 35% of the population of the municipality of Rio Branco, capital of the state of Acre. In addition, based on a mathematical model, the authors calculated the economic loss and concluded that:

> "The equivalent variation corresponds to a measure of well-being and indicated that there was a 39.24% reduction in the consumption of products and services, which represents, in absolute values, a loss of approximately US$ 685.5 million. The reduction in family welfare corresponded to approximately 16.60% of the state's GDP. (Translated by the authors, p. 137) [38]"

> "In absolute values, agriculture, commerce, real estate services and private services were the sectors that concentrated the largest reduction in the value of production. Losses in these sectors corresponded to 56.41% of losses in the value of state production (Translated by the authors, p. 148) [38]."

As a way to mitigate production losses caused by the flooding in 2021 in the state of Amazonas, through Resolution No. 2/SAF/MAPA, the state government developed the crop guarantee program, which ensures a sum of US$ 158.07 for farmers who join the program and have their productive areas affected by floods. In the first year of the program, 655 family farmers were enrolled in the scheme in partnership with IDAM, Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) and Secretaria Estadual do Meio Ambiente (SEMA).

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In addition to the impacts on the fruiting and harvesting of andiroba seeds, the prolongation of flooding in the forest can cause the death of trees of forest species. Several reports from seed collectors highlight the economic damage caused by the flood in the areas where harvesting occurs.

The economic impacts for families in the middle Juruá, which has family farming and plant extractivism as the main income-generating activities in the region, have brought about financial insecurity. Many families have had their ways of life and their productive and adaptive strategies, which have been developed over time, weakened in the face of the new context caused by climate change.

In the state of Amazonas, the main extreme event that generates impacts on socio-ecological systems are floods [39]. These events expose the vulnerability of human settlements that are in the vicinity of water bodies. In this perspective, geoprocessing is an important tool for identifying areas with greater socio-environmental vulnerability. In the environmental sector, several areas of knowledge use geoprocessing in an inter-multidisciplinary manner [40]. The Geographic Information System (GIS) allows analyses that guide decision-making aimed at improving the quality of life of the population. Vulnerability maps, which aggregate socio-economic and environmental information, are important tools for planning the occupation of cities, especially in the face of the dangers triggered by climate change [41,42].

Communities outside the protected areas of the municipality of Carauari also suffered from the impacts of the extreme flood by choosing to be traditional riverine communities and by having plantations in floodplain regions due to greater ease of plant growth due to soil fertility. It should be noted that the 2021 flood caused impacts on communities that are in high floodplains, such as São Raimundo, which had already been built at an altitude above the normal flood level in the region.

5. Conclusions

The greater intensity of extreme events that has occurred in the middle Juruá region, in fact, in the entire Amazon region, did not allow the actors of the riverine social-ecological systems to adapt gradually. The sudden changes in hydro-climatic rhythms have generated enormous socio-environmental impacts in these systems. Thus, the new conditions imposed by climate change weaken the adaptations developed by riverine socio-ecological systems, thus hindering the continuity of local ways of life, causing dysrhythmias.

Biodiversity itself is already "feeling" the prolongation of periods of flooding in the region, which results in the death of forest species that are economically important for these traditional populations. The observed data reflect this influence mainly in species that have economic interest; however, they may represent only the tip of the iceberg, since other species of fauna and flora, with equal ecosystem importance, have possibly been affected due to extreme events of this nature.

The high loss of products from family farming reveals the worsening of the climate crisis in the region, which damages the productive system and leads many of these families to need humanitarian aid to ensure basic food supplies. Therefore, extreme events have made traditional communities vulnerable, and these communities are at the forefront of this climate process since they are the first to feel its effects. These events become disasters when they impact communities, generating productive, economic and social consequences for these populations.

The reports from the residents of the middle Juruá reproduce the transformations of seasonality and the impacts generated by these transformations on biological and social rhythms. This new situation affects the very adaptability of forest species, whose occupation in the region is older than human occupation, resulting in an increase in water levels and the duration of the seasonality of climatic dysrhythmia in the region [43,44]. The rhythms imposed by the climate, evidenced by anthropocentric extreme events that modify the seasonality of the river, begin to interfere in the social, economic and biological rhythms of the region. Therefore, the riverine socio-ecological systems of the middle Juruá live in the occurrence of extreme events, panarchical conditions [45], overcoming the adaptive strategies built over the years to live with the seasonality of the river and reducing the resilience of these systems in the face of the new conditions imposed by climate change. This new situation of insecurity, generated by climate change, tends to modify relations and even

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force transformations in socio-ecological systems, and may even bring about a rural exodus. The middle Juruá, which had to overcome the difficulties inherent to the rubber-tapping system in the past, finds itself today under a new threat, the climatic one. In addition to the financial impacts, there is food insecurity caused by the loss of agricultural production, thus generating a high social vulnerability for riverine populations. These aspects are intensified with the increase in the prices of food items and the reduction in the income of these families.

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