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Climate Change and Its Impact on the Agricultural Calendar of Riverine Farmers in Médio Juruá, Amazonas State, Brazil

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Abstract: The labor relationship developed by the Amazonian riverside dwellers is weakened due to changes in temperature, the flood pulse, the ebb tide of the rivers, and precipitation. In this context, this research aimed to evaluate the impacts of climate change on the socio-biodiversity chains in the region of Médio Juruá-Amazonas. Collections were carried out in two communities located in the Sustainable Development Reserve (RDS) Uacari, in July 2022, through participatory workshops. The communities affirm that the extreme flood events of the Juruá River are more intense in recent years, both concerning the extreme levels of the river and in periodicity and speed of flooding. The large floods have impacted the productive calendar, generating losses for farmers. In addition, rubber trees and cassava plantations have been dying with the large floods, and oil seeds are being carried by the water before harvest. The physical data of the Juruá River shows a trend of increasing extreme floods over the last 40 years for the period November to April, highlighting the years 2013 to 2015 and 2021 with the largest positive anomalies. Farmers have adapted their calendars, modified some planting areas to locations with higher altitudes and farther from the river banks, and have sought new rubber matrices. The results point to the need for mitigation and adaptation measures promoted by local governments.

Keywords: climate change in Amazon; riverine farmers; adaptation

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1. Introduction

The traditional populations of the Amazon have always had a strong connection with natural resources, developing a series of economic and survival activities from river and forest products. Family farming, vegetable harvest, and fishing are characteristics of the Amazon riverside dwellers who perform multiple tasks in the dynamic and plural environment. According to Decree 6040/2007, which establishes the National Policy for Sustainable Development of Traditional Peoples and Communities, these are defined as:

> "Culturally differentiated groups that recognize themselves as such, that have their own forms of social organization, that occupy and use territories and natural resources as a condition for their cultural, social, religious, ancestral and economic reproduction, using knowledge, innovations, and practices generated and transmitted by tradition." [1]

Global climate change has affected the socio-environmental relationship of traditional populations with the Amazonian environment due to the impacts caused by extreme events of flooding and ebb tides, and changes in temperature and precipitation in the region. The changes have caused environmental, social, and physical impacts that directly affect the forest populations that depend on natural resources for survival. Products from biodiversity, which are of interest to traditional peoples and communities and family farmers, are known in Brazil as Sociobiodiversity Products and have the differential of promoting the maintenance and valuation of their practices and knowledge, ensuring resulting rights, generating income, and promoting the improvement of their quality of life and the environment in which they live [2].

These populations are endowed with a set of knowledge and know-how about the natural world, transmitted orally from generation to generation, and through which they manage to develop their activities in the forest, water, and land, that is, in the multiplicity of habitats [3,4]. It is a traditional knowledge that respects the natural cycles coming from a complex knowledge inherited by the elders [3]. Thus, their ways of life are organized through the observation of natural cycles, the seasonality of rivers, and weather periods, in what can be described as environmental perception. Environmental perception becomes an essential tool for organizing work. However, due to the greater occurrence and intensity of extreme hydro-climatic events in the region, the riverside populations of the Amazon have found it difficult to follow the cycles effectively in recent years. Therefore, they seek to make spontaneous adjustments to the problem, especially in the productive calendar of the socio-biodiversity chains.

Traditional communities have a particular model of natural resource management and social organization, in which they establish the construction of social identities, common projects, and the manifestation of diversity, which are often ignored in the creation of public policies [5]. The existence of a legal framework on climate change occurred as a precursor in the state of Amazonas, where the legislation predates the national one, through State Law 3.135/2007 establishes the State Policy on Climate Change, Environmental Conservation and Sustainable Development of Amazonas, and establishes other provisions [6]. The state policy is richer in instruments and financial sources for its application. However, the measures related to the adaptation to the effects of climate change are still very timid, generating low effectiveness for the increase in the resilience of the Amazonian population, with mitigation measures having more prominence. In the federal sphere, there is a plan for adaptation to climate change that does not indicate previous dialogue with the Brazilian population, especially those located in the Amazon [7].

The municipality of Carauari is located on the bank of the Juruá River and has two conservation units in its territory: the Uacari Sustainable Development Reserve and the Extractive Reserve of the Middle Juruá. Between these conservation units, a common territory was established called the Middle Juruá. The delimitation of these protected areas was marked by an intense struggle by social and popular organizations in the region to improve the quality of life. The right to the lands was established and public health, education, basic sanitation, and income generation policies were implemented. [8].

In the Uacari Sustainable Development Reserve (RDS), populations perceive extreme climate events being the highest frequency and intensity of floods of the Juruá River as the most recurrent cited among the residents of the riverside communities. The changes have been modifying the annual schedule of farm work leading local communities to develop spontaneous adaptations. The main objective of this work is to evaluate the impacts of climate change on the productive calendar of riverside farmers in the Middle Juruá region, taking into account the analysis of the history of extreme fluvial events that occurred in the Juruá River in the last 40 years will be presented.

2. Materials and Methods

2.1. Study Area

The research was carried out in the Middle Juruá Region, in the Uacari RDS located in the municipality of Carauari in the southwest of the state of Amazonas (Figure 1). The RDS is a governmental protected area aiming for ecosystem preservation and achieving the sustainable development of local traditional riverside populations. The RDS Uacari was created by Decree No. 25.039 of 1 June 2005, from a demand of traditional populations in the region and has this name in honor of a primate (*Cacajao calvus uacayalii*) found in the area that is threatened with extinction [9].

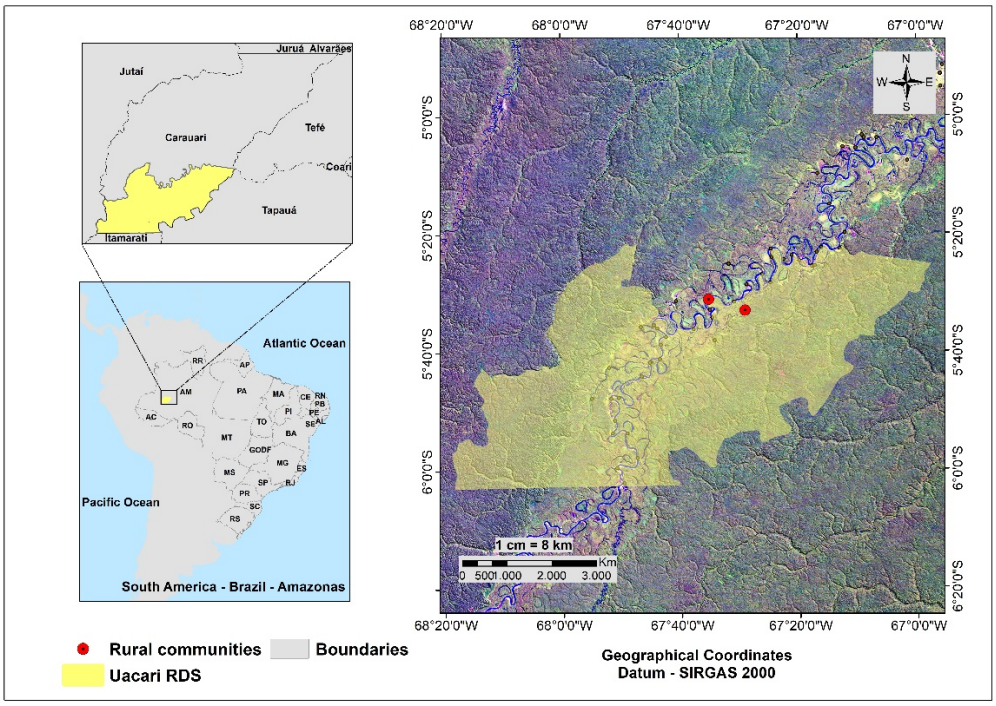

Figure 1. Location of the study area.

According to the Köppen classification, the region presents an Am climate type (tropical rainy) [10], with monsoon-type rains, with a dry season of short duration and rainfall of less than 60 mm in the driest month. The average annual precipitation is approximately 2500 mm, the average air temperature is 24 °C and humidity is above 90% most of the year. The rainiest months are from November to April [11]. During the rainy season, the Juruá River and its branches flood their floodplains, characterizing the flood period [12]. The predominant soils are Yellow Red Alic Argissolos with low clay activity [9,13,14]. The vegetation of the region is composed of Dense Ombrophilous Lowland Forest, Dense Alluvial Ombrophilous Forest, and Open Ombrophilous Lowland Forest with Palm Trees [14].

The area of the Uacari RDS is approximately 633 hectares, with 33 communities. The criteria for the selection of the communities were: proximity to the river; access only by the river; the lifetime of the community; a larger number of families in the community; and greater diversity in the productive chains of the farmers. Following these criteria and after talking to the community manager, two communities were selected: Santo Antônio do Brito and Vila Ramalho. The Santo Antônio do Brito community is established on the right bank of the Juruá River, was founded in the '90 s, and welcomes 19 families. The community has a school for all grades, a community pump to supply water to the houses, and electricity generated by a small diesel engine which is turned on only for 3 h at night. Some houses have a low-capacity solar panel system used to preserve the food in the freezer and refrigerator. The communication system with the other communities and with

the town's headquarters is done using radio and a community phone (called "orelhão" in Portuguese).

The community of Vila Ramalho has access to the Juruá River through the Igarapé do Chué. It was moved to the current location 14 years ago after the migration of the community due to problems with fallen lands in the old area. 23 families are living there. The water for the houses comes from an artesian well, and the electric power, as in Santo Antônio do Brito, is turned on at night by a light diesel engine. The community has a healthcare center with internet via satellite, supported by a solar panel, where telemedicine consultations take place. The school runs from pre-school to the last years of high school.

2.2. Research Subjects

The research subjects are the residents of the riverside communities of Santo Antônio do Brito and Vila Ramalho, men and women over 18 years of age. Thirty-one community members, divided between the two aforementioned communities, participated in this study. Of the total, 51.6% (n = 16) were from the Santo Antônio do Brito community and 48.4% (n = 15) were from Vila Ramalho. Of the participants, 54.8% were men and 45.2% were women. The project was previously presented to the community members and all participants signed the Informed Consent Form—ICF with CA-AE 54763221.0.0000.5020 and opinion 5.252.692 of February 2022.

2.3. Secondary Data Collection and Analysis: River Level and Precipitation of Médio Juruá Basin

Water level data of the Médio Juruá river were collected from the online database HidroWeb v3.2.7 [15]. We use maximum and minimum water level data from the river station Gavião, in the Carauari county, in the period 1982 to 2021 (40 years). The analysis was carried out for the flood (November to April) and the ebb period (May to October), and to identify extreme events, the threshold was calculated by the following equation [16]:

$$X = \frac{(\Sigma r)}{Nr} \pm \sigma f \quad (1)$$

where:

Σr is the sum of all records;
Nr is the number of records;
σf is the standard deviation (σ) by a frequency factor (f).

The time series of the water level of the Médio Juruá presents missing data in certain months. Therefore, for the analysis, we discarded the months with no data from the maximum or minimum value of the year. The years 2017, 2018, 2019, 2020, and 2021 were analyzed but not considered to calculate the threshold of maximum and minimum water levels. Due to a landslide, the ruler that was on the right bank of the river has been moved to the left bank, which has a different depth, therefore changing significantly the river water level measurements [17]. Before moving the ruler, the average for the period from 1982 to 2016 of the minimum and maximum values of the river level with their respective standard deviations were 0.76 m (0.81) and 14.39 m (0.45). In the new location on the left riverside, the average for the period from 1982 to 2021 of the minimum and maximum values of the river level with their respective standard deviations changed to 2.51 m (4.90) and 16.40 m (5.41). Precipitation data were obtained using the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 monthly reanalysis data at 0.25° × 0.25° [18]. The accumulated precipitation was calculated for the flood season (November to April) from 1982 to 2021 (30 years), for the area of coordinates −4.9° S to −6.4° S and −68.2° W–66.7° W. State-of-the-art reanalysis data were used since observation data have long periods of missing data and inconsistency. Reanalysis combines numerical simulation data with observations from around the world into a globally complete and consistent dataset.

Secondary data were used alongside the primary data to correlate the physical results with the interviews, carefully avoiding comparisons and validation.

2.4. Primary Data Collection and Analysis: Climate Perception

This research is of a quality-quantitative nature, of exploratory type [19], and provides an opportunity for the interaction of physical historical data with the climate perception of the subjects. The researchers gathered the selected communities to present the project, its objectives, and collection methods, and to confirm if they would like to actively participate in the activities. Primary data collection was carried out through the collective elaboration of the communities' agricultural calendar in its traditional period and the modified one due to the impacts caused by climate change.

According to [20] the technique of group interviews and/or focus groups has an advantage over individual interviews because it allows researchers to observe the interaction processes occurring among the participants, besides minimizing the influence of the researcher over the process, tilting the power level to the group.

Data collection was recorded with the application of a field diary and photographs. The activities were carried out in July 2022, the period of the Juruá River's ebb. In the community of Santo Antônio do Brito the workshop took place at the school, while in Vila Ramalho the activity took place at the church (Figure 2A,B).

Figure 2. (**A**) Community members of Santo Antônio do Brito and (**B**) Vila Ramalho.

The script for preparing the calendar consisted of listing the socio-biodiversity chains developed in each community, organizing them by the degree of economic importance, indicating the traditional production period, the changed production period, and the causes of these changes. The group reported the main losses caused by climate change in the communities and the spontaneous adaptations made by the community members. After the presentation of the final calendar, losses, and adaptations, the moderator questioned the group about the results and then collectively validated the answers. In this way, the results were discussed based on a descriptive analysis.

3. Results and Discussion

3.1. Seasonality of Juruá River and Extreme Events: Analysis of Water Level and Precipitation

Maximum river levels on the Médio Juruá are presented in Figure 3. Levels above 14.8 m are classified as severe floods. In between 1982 and 2016, four extreme floods were identified, and three of them occurred since the year 2010, in consecutive years, 2014 reaching the highest level of 15.7 m. Despite the years from 2017 to 2021 are not presented in the graph, due to the problems previously discussed, the years 2019 and 2021 were also

identified as major floods. The water levels reached a peak of 31 m in 2019 and 31.7 m in 2021, the highest level recorded for the river since observations started. Some studies have associated the 2021 flood with the intensification of Walker circulations caused by the anomalous cooling of the Pacific Ocean [21], this cooling phenomenon is called La Niña and is associated with the great floods observed in the Amazon during the 21st century (2009, 2012 and 2021).

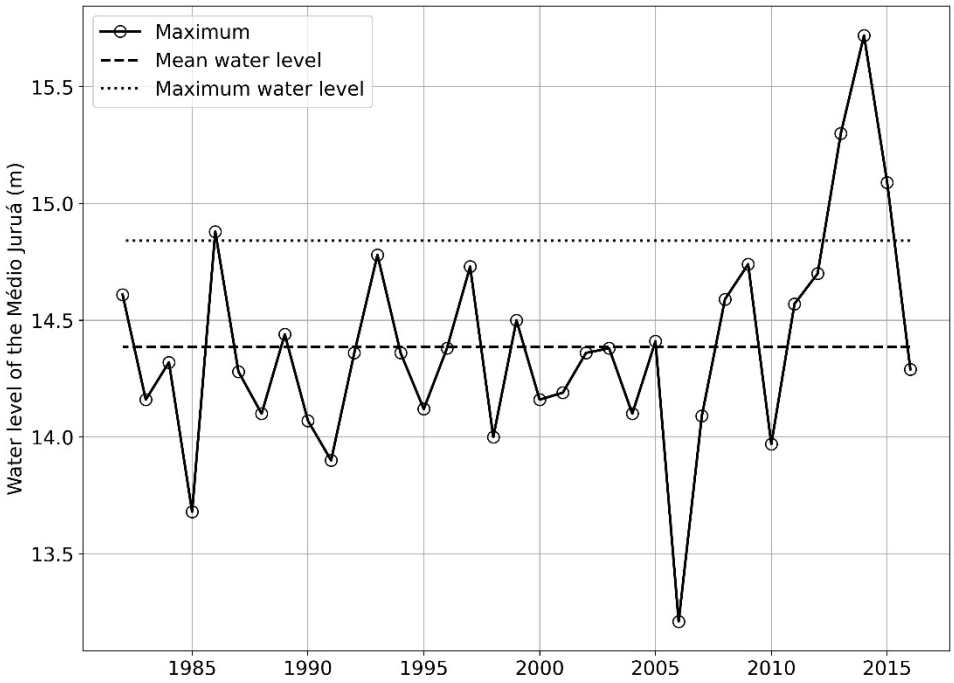

Figure 3. Maximum water levels recorded on the Médio Juruá river in Carauari from 1982 to 2016.

For ebb extreme events, the threshold is set to −0.05 m (Figure 4). Of four major ebb events, three have occurred since the year 2000 (2005, 2006, 2010). Particularly, the year 2005 stands out as an extreme ebb event, the drought of 2005 was said to be "once in a century" and its cause was associated with the warming of the Tropical North Atlantic Sea [22,23]. Although these years do not surpass the threshold for extreme events, it is worth noting that the years 1983 and 2011 are close to being considered extreme drought years and are identified as extreme drought years using other methodologies [17]. Recent studies link the intensification of droughts and floods in the basin to anomalous sea surface temperatures (SST) from the Atlantic and Pacific oceans [23–27].

Figure 5 shows the total rainfall for the flood period (November to April) from 1992 to 2021 over the Middle Juruá basin. The variability of precipitation totals is 90% above the average of 1500 mm per year, except for the years 2004 and 2010, which were below this value [28]. According to [22] and [29] the two droughts were associated with the occurrence of large-scale ocean-atmosphere coupled systems (El Niño and Atlantic Dipole).

With the waters of the Pacific and North Atlantic Oceans anomalously warmer, there was a reduction of moisture transport by the northeast trade winds towards the Amazon [30]. In addition, there was a weakening of the vertical upward motion over this part of the Amazon, resulting in reduced convective development and reduced precipitation [31]. In contrast, precipitation totals above 1750 mm stand out in the years 2011 to 2017, with emphasis on the year 2013, where the precipitation total was above 2000 mm/year. In the year 2021, total precipitation was above 1700 mm and caused flooding in the region. [21] related this high precipitation value to the La Niña phenomenon, where rainfall intensification occurred in the region.

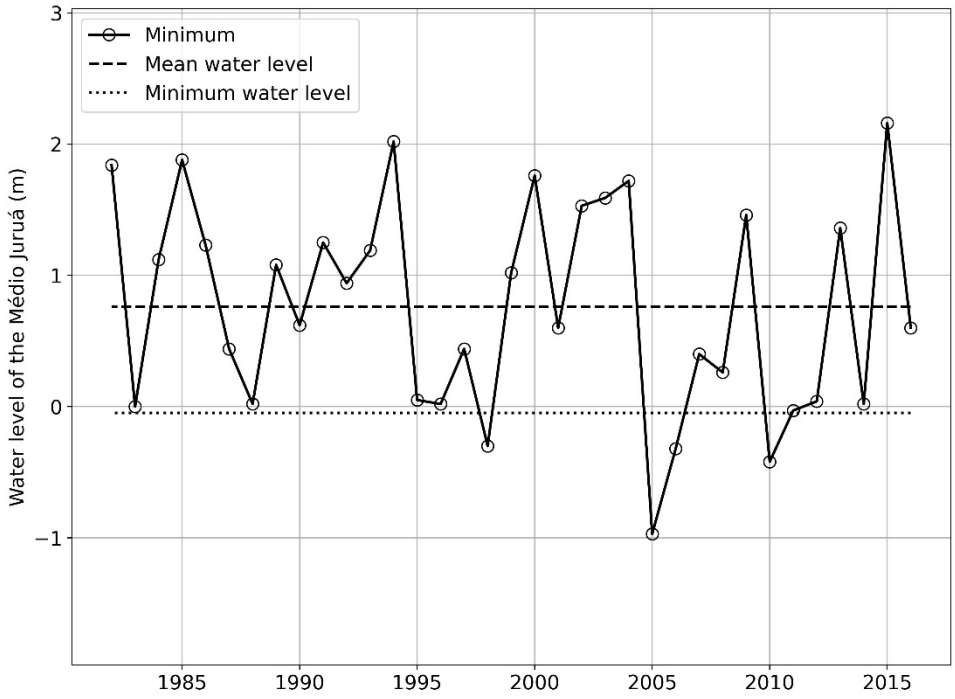

Figure 4. Minimum water levels recorded on the Médio Juruá river in Carauari from 1982 to 2016.

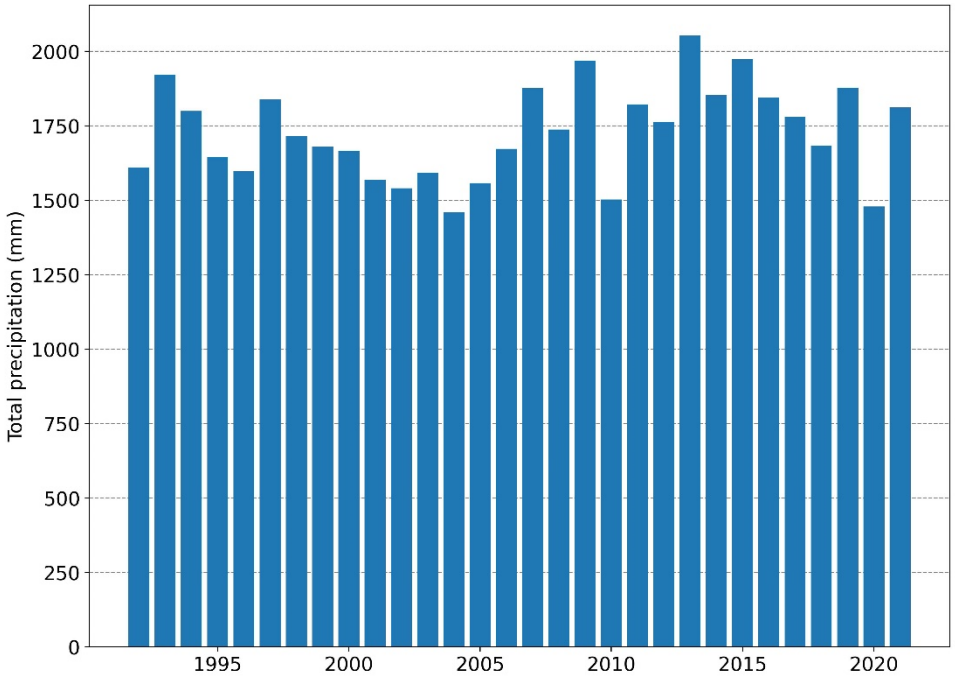

Figure 5. Total precipitation (mm) from the ERA5 reanalysis over the Médio Juruá basin for the flood season (November to April) from 1992 to 2021.

Agricultural calendars in the Amazon are mainly based on meteorological (rainfall regimes) and/or hydrological (river levels) seasonality, thus perceptions of climate change are especially relevant in this context as they may influence the cultivation practices adopted by these communities [32].

3.2. Farmers' Perceptions and Adaptability to Extreme River Events in the Juruá River

Community members presented the list of socio-biodiversity chains developed in the communities and these were subsequently organized to a degree of economic importance. The communities of Santo Antônio do Brito and Vila Ramalho have the same chains and a similar degree of economic importance (Figure 6A–F). The chains listed, already in order of importance, were rubber from the rubber tree (*Hevea brasiliensis*), vegetable oils from Andiroba (*Carapa guianensis* Aubl.) and Murumuru (*Astrocaryum murumuru*), manioc flour (*Manihot esculenta Crantz*), managed fishing of Pirarucu (*Arapaima gigas*), Açaí (*Euterpe* spp.) and monitoring of Amazonian turtles, including the Amazonian Tartatuga (*Podocnemis expansa*), the Tracajá (*Podocnemis unifilis*) and the Iaçá (*Podocnemis sextuberculata*). Therefore, the research subjects identify themselves as farmers, extractivists, collectors, rubber tappers, and fishermen who multitask in the dynamic and plural environment that is the Amazon.

Figure 6. Socio-productive and conservation activities of the populations of Médio Juruá: (**A**) rubber tapper; (**B**) seed collector; (**C**) farmers in manioc flour house; (**D**) Pirarucu fisherman; (**E**) açaí collector, and (**F**) watchmen at turtle protection beaches.

The region of Médio Juruá is marked by struggles and conquests for the occupation of the lands. The history of rubber work is linked to the rubber plantation bosses, who for a long time exploited the labor of the locals who migrated mostly from the Northeast region of Brazil. In this context, according to [33], nature, although generous in milk trees, was barbaric, and hostile to human life. With all the adversities, rubber tappers had to learn to relate to the surrounding nature, and, through experiences, built their environmental perceptions of the seasonal cycles of the rivers, rains, plants, and animals. This knowledge enabled them to select the best rubber trees, the best technique for cutting the trunks, and the best time for the activity. Currently, rubber extraction work represents the greatest income for the community. The price of rubber is around 18.00 BRL per kilogram and they produce up to 8 kg per day.

The rubber cycles also negatively marked the history of the Juruá region. The exploration of this natural resource was marked by the exploitation of the labor of northeasterners, indigenous and black people, in conditions similar to slavery, with death threats, and extreme poverty conditions in the middle of the forest [34]. The denial of basic rights

such as education and health revolted the populations living along the Juruá River, but its residents felt that there was no hope for the social transformations necessary for their lives.

The process of territory conquest went through the social organization of the communities and social segments of Médio Juruá, mainly mobilized by the Base Education Movement (MEB). From the initiatives of popular education promoted by MEB and the creation of the National Council of Rubber Tappers (CNS), today of the Extractivist Populations, local organizations were created for the defense of rights and fundraising for the territory. These civil society organizations joined forces with government agencies, such as the Institute for Agricultural and Sustainable Forestry Development of Amazonas-IDAM, the State Department of Climate Change and Conservation UnitsDEMUC/SEMA and the Chico Mendes Institute for Biodiversity Conservation—ICMBio, as well as with the business sector, to mobilize strategies for the sustainable development of communities and strengthening socio biodiversity chains in the region [8]. The governance of the territory by organizations from different sectors and levels gives Médio Juruá a model of polycentric governance in the Amazon [8,35].

The Médio Juruá has a huge potential for vegetable oils produced from vegetable components of species such as andiroba, murumuru, mutamba, and ucuúba. This potential enabled the creation of a processing plant of vegetable oils of the Mixed Cooperative of Sustainable Development and Solidarity Economy of the Resex of Médio Juruá (CODAEMJ) within the community of Roque, Resex of Médio Juruá [36]. The collection of oil seeds occurs in the riparian communities of Médio Juruá and is bought by CODAEMJ and the Association of Residents of the RDS Uacari (AMARU). All this harvest is destined for the company Natura & Co., which already has a long relationship with the territory and makes the payment of benefit sharing from the marketing of products based on vegetable oils purchased in the region.

Cassava flour is part of the food culture of the Amazonian populations and in much of the region, is among the largest chains developed, both for trade and for consumption. In the communities studied, cassava planting is mainly intended to feed families. Community members report that due to the exhausting work and the increasing heat in recent years, they have put aside this crop. It is expected that throughout the 21st century, jobs associated with agriculture will be drastically reduced due to the increase in temperature and the increase in the cases of diseases caused by the high-temperature sensation and contact with ultraviolet radiation [37].

The pirarucu management chain began in 2017 in the Lower and Middle Juruá region with the support of the Association of Rural Producers of Carauari-ASPROC, ICMBio, DEMUC/SEMA, and the Juruá Institute. The management of pirarucu and other fish occurs to guarantee sustainable development, food security, and conservation of the actinia fauna of the region. Over the years this chain was established in the region with the fish processing through the industrialization of the production by the ASPROC processing unit, located at the Carauari headquarters. According to information obtained by the Association of Agro-extractive Residents of the Lower Middle Juruá (AMAB) in the year 2021, there was a catch of 60 tons of pirarucu in the communities of the Lower Juruá in Carauari/AM. In addition to the conservation of species of economic interest, fishing management enables the protection of other fauna species due to the strategy of protecting lakes in the region [38].

Açaí is a fruit of an Amazonian palm tree that is part of the local diet and is consumed as a drink prepared with fresh pulp in water, called wine, without alcohol [39]. The areas of açaí cultivation in both the headquarters of Carauari and the RDS Uacari are next to forest massifs and are established as an interaction of family farming to ecological maintenance services [40]. For the author [39], starting in the 2000s, the drink was spread to the Brazilian domestic market. Since then, its export has been growing significantly, including in the municipality of Carauari from 2011, presenting a drop in the following years, but rising again in 2016. However, there is a complexity in the production chain that involves risks in the collection of the fruit [40]. In the evaluated communities, there is the trade of açaí,

but in little relevance, because families prioritize wine for consumption in virtually all daily meals.

According to the farmers, the agricultural calendar is organized following the seasonality of the Juruá River and the rainy season in the region (Figure 7). They consider the months from December to May as winter, the rainy period that marks the rise of the Juruá river that reaches its maximum quota in mid-April. Summer occurs between the months of June and November, and the Juruá River reaches its minimum quota between the months of August and September. Traditionally, the populations collected the oilseeds and açaí, and harvested manioc in the winter, from February to May. The extraction of latex from the rubber tree always happens in the dry months, when the trees are completely uncovered by the water of the river, and those located in the lower areas remain submerged in the flood of the Juruá. According to the rubber tappers, the rain hinders the collection of rubber, since it prevents them from moving around in the forest since the activity is carried out during the early hours of the morning. When the river level is lower, it is possible to fish for pirarucu in the lakes and rivers, and this is the period when the river beaches appear and indicate the spawning season of the Chelonians in the region.

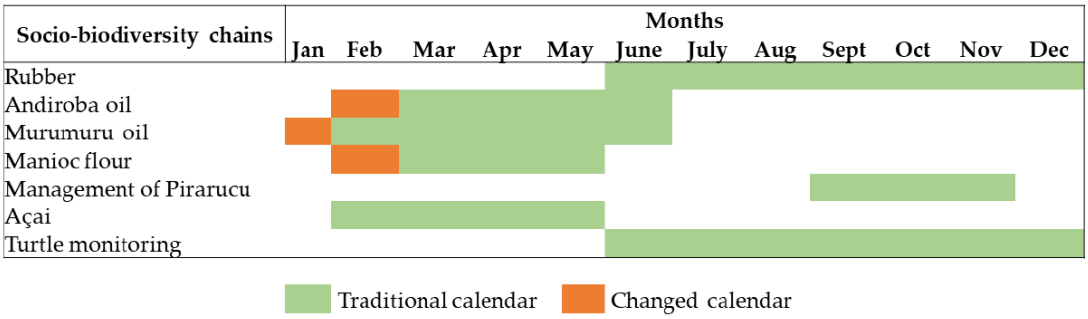

Figure 7. Traditional and modified production calendar.

In the rubber production calendar, there is no adaptation regarding the collection period, because the extraction is totally dependent on the river's flow. However, in recent years, with a longer duration of the period of major floods, rubber trees are dying, and farmers have noticed this phenomenon since the year 2015. According to the rubber farmers:

> "The trees have always stayed in the water during the river's flood period, but today the water rises higher and takes longer to drain, which ends up killing the rubber trees. A borer appears on the trunk of the tree, which with time causes the latex to dry out and then the trees begin to fall." (Resident of Santo Antônio do Brito)

Because of the sociocultural relationship that the rubber tappers have with working in the forest, they can accurately report the number of trees from which they extract rubber, and therefore, the number of trees they have lost in recent years due to the great floods:

> "I've had a rubber road for 15 years and I used to work with 100 trees. Starting in 2015 they started to get sick with the consecutive years of big floods. In total, I lost 20 trees." (Resident of Santo Antônio do Brito)

There is evidence of the death of rubber trees caused by flooding in the municipality of Itacoatiara/AM [ARAÚJO, 2010], due to the vulnerability of the base of the stem of these trees making possible the attack of xylophagous insects that feed on the cellulose of the wood.

The populations point out alterations in three socio-biodiversity chains caused by extreme flooding events of the Juruá River. The adaptations in the agricultural calendar have happened in the oil and manioc flour chains. According to the farmers, the Juruá River has not only experienced major floods in recent years but has also been rising ahead

of schedule, generating impacts on the production of fruit and manioc. The community members report:

> "The floods have been higher since 2015. The river has been rising fast and taking a long time to recede, this year it filled up and leaked faster." (Residents of Santo Antônio do Brito)

> "The water takes the fruits of the andiroba and the murumuru. The difference is that the andiroba floats and gets stuck to the branches of the trees, but the murumuru sinks and cannot be collected." (Resident of Santo Antônio do Brito)

> "When the flood is above the limit, it floods the areas where manioc is planted and kills the plantation. It takes away the andiroba and murumuru fruits. In 2021 and 2022 we couldn't collect the seeds and this impacted the families' income." (Resident of Vila Ramalho)

In the historical data series of river levels of the Porto do Gavião station, Carauari/AM, 06 extreme climatic flood events were identified in the years 1986, 2013, 2014, 2015, 2019, and 2021 [17]. The extreme climatic events of floods that occurred in the Amazon are consequences of global climate change since the alteration of the hydrological cycle of the region was predicted as a direct effect of climate change [41,42]. These changes have direct impacts on riverine social-ecological systems that have a direct dependence on the natural resources of the region.

Extreme flood events cause substantial impacts on family farming in the Amazon floodplain regions. In Carauari it is estimated that the loss of agricultural production caused by the 2021 flood was more than R$7.2 million (seven million two hundred thousand reais) [17]. While extreme floods impact the socio-ecological systems of Médio Juruá they facilitate other chains such as managed fish and the collection of ucuuba (*Virola surinamensis*) and açaí (*Euterpe* sp.) [43].

The community members have sought to minimize losses by anticipating the fruit harvest, but, like the seasonality of the Juruá River, the period when the fruit falls is independent of the demands of the residents. An alternative found by them is the installation of barriers with tree branches that hold the andiroba fruits, which tend to float in the water. To collect the murumuru, the community members have improvised with sieves made from perforated plastic bowls, because this seed tends to sink in the water.

The production of manioc flour has suffered impacts on the harvest, because the planting areas are close to the river to facilitate the displacement of farmers by canoes, and these have been completely covered by the waters of the Juruá. This year the families anticipated the harvest and preparation of the flour in approximately 20 days (Figure 8A–C). However, the flood went up fast and part of the plantation was flooded. Cassava that goes through the flooding period tends to be smaller and darker, and therefore the flour produced is of lower quality and consequently has a reduced commercial value. One alternative found was the search for higher areas for planting, but this generally hinders the work because the areas are further away from the communities and put the lives of community members at risk from jaguars and poisonous animals, in addition to impacting the flow of production.

Farmers do not report direct impacts of climate change on pirarucu fishing, but they believe that the fishing lakes are shallower and this has decreased the number of fish for consumption in the communities. In this case, this indicates that although the impacts of large floods are being reported more frequently by the research participants, drought events have also caused problems for the populations. Drought events in the Juruá river were observed in 1988, 2005, 2006, and 2010. Overall, the events were concentrated after the year 2000, thus indicating an increase in the frequency of these events in the basin.

The Amazon Chelonian protection trays are beaches that appear during the period when the Juruá River flows and are protected for the animals' spawning and reproduction. The main focus of protection is the Chelonians, but it extends to the birds and lizards that also breed on the beaches. The beach watchers are community members who work

collectively at night so that no one can take the eggs of the animals from the dens made on the beaches. Besides the guarding work, there is the monitoring of the birth of babies, which is coordinated by the Federal University of Amazonas—UFAM, through the Pé-de-pincha Project. The project has achieved its objectives of chelonian conservation, but the size of the Médio Juruá region has made this possible due to the partnership between the government managers of the RDS Uacari and the RESEX of Médio Juruá, the communities, and the Non-Governmental Organizations that operate in the region. Regarding the impacts caused to this socio-biodiversity chain, the community members inform that the anticipated rise in the Juruá River tends to destroy the turtle egg nests, which each year go up to areas further away from the riverbanks to lay their eggs.

Figure 8. Stages of manioc flour production: (**A**) cassava; (**B**,**C**) preparation of cassava flour.

The climatic perceptions of the community point to the changes caused in their lives as a consequence mainly of the great floods of the Juruá River. When asked about their expectations from governments and research institutions, they make clear their desire to be part of the process of building solutions, since they already make spontaneous adaptations through their local collective organization. The observation of the community members is valid, especially when we analyze the National Plan for Climate Adaptation [7] and there are no identified proposals and elements that are directed to the riverside populations of the Amazon, pointing to the lack of dialogue between stakeholders and impacted parties.

Family farming represents half of the wealth produced by the primary sector of Amazonas [44]. According to information from the Institute of Agricultural and Sustainable Forestry Development of Amazonas [45], in 2020, farmers represented 97% of the total number of rural producers in the state. This subsistence agriculture is responsible for more than 70% of the food produced in Brazil [46], and it ensures the food and nutritional security of the Brazilian population. Therefore, seeking alternatives that minimize the impacts caused by climate change on rural producers in Carauari should be a priority in the public policy agenda.

According to [47] a better understanding of climate change perceptions and adaptation patterns of populations is needed, for the development of adaptation policies, including rural farmers who already develop spontaneous adaptations. Farmers' perceptions have a direct influence on the selection of adaptive adjustments. Furthermore, cooperation and interaction among farmers are important for the perception of changes in climate and the adoption of effective measures through collective exchanges of adaptation experiences [47].

4. Conclusions

Climate change negatively affects the agricultural productivity and livelihoods of riparian farmers in the Médio Juruá region. Farmers seek to reduce economic losses by

adapting their agricultural calendars, however, adaptation is not always possible due to ecological issues of plant species and lack of technical and governmental assistance.

The results of the study show that perceptions of an increased occurrence of extreme flood events on the Juruá River match well with observed trends. The study reveals the importance of farmers' perceptions of climate change, the negative impacts caused, and their influence on spontaneous adaptations. Through their understanding, farmers have carried out basic crop management practices and changes in the periods of planting, harvesting, and collection of agricultural products.

In addition, it is recommended that governments provide easier access to information and advanced mitigation and adaptation measures to riparian farmers so that they can continue to develop their activities and reduce the negative impacts of climate change. Thus, policies are needed to adapt to the productive calendar through qualified rural technical assistance, and agricultural financing to strengthen the chains developed in the region and encourage the use of personal protective equipment to avoid the impacts of sun exposure. Another alternative is the payment for environmental services performed by traditional communities of the Médio Juruá when reconciling their ways of life with ecological conservation.

The transformations of the productive calendars of the traditional communities along the Juruá River reveal the socio-environmental implications of climate change in the Amazon region. Therefore, the federal government and the state and municipal entities in Brazil need to implement public policies of climate adaptation, mainly directed at traditional communities that are deeply dependent on natural resources and are the most vulnerable to climate change.

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