Economic Valuation of Changes in the Amazon Forest Area

Value maps for Non Timber Forest Products (NTFPs)

Centro de Sensoriamento Remoto
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Abstract

As part of the project "Economic Valuation of Changes in Amazon Forest Area" this report assesses the local and regional-scale economic values from the Amazon rainforest for Non-Timber Forest Products (NTFPs), namely Brazil nut and rubber. We use spatially explicit models to measure how changes in the values of these NTFPs are distributed across the Brazilian Amazon. Our results suggest that the annual production of Brazil nut and rubber in the Brazilian Amazon as a whole could be as high as 3.7 and 1.36 million tons, respectively. However, only few regions are apt for economic production due to access and presence of communities in the vicinity, and hence supply chain. Brazil nut yields average 8.19±7.41 kg $ha^{-1}year^{-1}$, which in turn can deliver average returns of US$ 5.05±7.49 $ha^{-1}year^{-1}$. In more productive areas, where yields can be as high as 30 kg $ha^{-1}year^{-1}$, net revenues may reach US$ 46 $ha^{-1}year^{-1}$. In areas with rubber productivity above the mean (yields ≥ 3.53 kg $ha^{-1}year^{-1}$), and with government subsidies in the form of a guaranteed minimum price, net revenues to rubber production can average US$ 0.56±0.7$ha^{-1}year^{-1}$. In the southwest part of the biome, including the state of Acre and the southwest part of the state of Amazonas, net revenues can reach up to US$ 6.13 $ha^{-1}year^{-1}$ when supported by government subsidies. These results allow us to explore possible policy contexts for enhancing the value of Brazil nut and rubber production and are relevant for land-use management decisions seeking to conserve the Amazon forest.

1. Introduction

"…the Amazon forest is very valuable to me. We (my family) cannot afford to lose it. …from this forest I get the timber to build my house, … I collect medicinal plants, I extract rubber and Brazil nut …This forest is part of my identity"
(Raimundo Pereira, Chico Mendes Extractive Reserve, Acre, July 2015)

There has been significant effort made to estimate the value of Non-Timber Forest Products (NTFPs) in tropical forests. Economic studies for the Amazon have found values ranging from US$ 1 to US$ 6,330 per hectare [1], depending on the goods and services included, the market potential and methods of estimation [2]. There are two contrasting estimation methods prevalent in the literature: one based on potential harvest (stock); while another focuses on the direct use values (flow).

Measurements of stock (potential harvest) have been criticized because they generally overestimate the real economic value [3]. In these cases, potential harvest is constrained by the market reality. Furthermore, tree density and yield per ha (thus production potential) vary greatly across the biome creating a situation where supply is not consistent [4, 5].

Acknowledging the problems with stock-based estimates, recent studies have focused on "use values" of products estimated at current market prices. Within this context, ranges of forest values for the Amazon tend to be significantly lower than the ones based on production potential, but still vary widely. For example, Godoy et al. [6] found net values ranging from US$ 1 to US$ 420 $ha^{-1}year^{-1}$ for rubber and charcoal. The estimates of values for different case studies cited by Godoy et al. [6] are listed in Table 1.1. In another study, Gram et al. estimated a range from US$ 9 to 17 [2].

The great variability of estimates for NTFP in the literature is due to an array of issues [3]. First, the Amazon forest is highly diverse (in Brazil there is a saying that there is not one Amazon but several Amazons), thus valuation exercises found in the literature deal with a variety of products, as well as a variety of ways of production and trading schemes across the biome, which understandably deliver large variability in resulting economic values. Second, the estimates presented in the literature are generally based on very specific case studies, thus providing a fragmented view of the whole Amazon's socioeconomic context and dynamics [3]. In addition, a lack of a comprehensive set of valuation studies prevents effective comparison [3]. Indeed, there is yet to be a comprehensive study that differentiates forest values across the entire Brazilian Amazon. Third, a considerable body of valuation studies focuses on the values of ecosystem services of the Amazon at the global scale (*e.g.* carbon stocks and flows) delivered to people outside the region, whereas the societal values of the forest in local markets have not been properly addressed.

Table 1.1 - A summary of the NTFP values in the Amazon.

Location	Net value (US$ $ha^{-1}year^{-1}$)	Comments
Iquitos, Peru	16-22	Based on villages diaries
Iquitos, Peru	20	Potential value of 6 species of Açaí and fruits
Combu island, Guamá river, Brazil	79	Estimate is Gross value and only includes semi wild cação, Açaí and rubber
Amazon, Brazil	4.8	Estimate is Gross return $ha^{-1}year^{-1}$
Western Amazonia	5-16	Gross value depends on size of the extraction area
Amazon, Brazil	59	Unclear if it is net or gross revenues. Includes kernel, charcoal, and feed of babassu palm.
Brazil	97	Brazil nut (US$/ha) Collectors price = 97, exporter´s price 176, retail price = 1,059
Pará, Brazil	110	Value after selective thinning of Açaí palm
Iquitos, Peru	420	Value the inventory, in one ha, only includes plants
Jenaro Herrera, Peru	167	Unclear if it goss or net Value only harvest of wild camu camu
Peru	6,330	Based on potential-inventory near Iquitos
Peru	3	Brazil nut rents in forest concessions in Madre de Dios

Source: [6-8].

In Brazil, IBGE (Instituto Brasileiro de Geografia e Estatística, the Brazilian statistics office) dataset includes 33 Non-Timber Forest Products (NTFP), which are organized into 6 different categories (Table 1.2). According to IBGE [9], 30 out of 33 NTFPs found in Brazil occur in the Amazon region.

Among the 30 NTFPs reported by IBGE for the Amazon, Brazil nut collection and rubber extraction are the two most important[1], as together they provide incomes to a large number of forest communities [10]. Regardless, Brazil nut and rubber still represent only a small share of the bundle of goods the forest provides. In this report, these products were selected because they are marketed, thus their extractive activities are widespread across the Amazon and data are available.

Generally, during summer, from November to March, Brazil nuts are collected in the forest. During winter, from April to October, rubber is tapped. Table 1.3 shows the annual work calendar for ten families in Acre.

[1] Açai is currently the NTFP from the Amazon generating the highest incomes in the states of Pará, Amazonas, and Maranhão. See also Figure 4.1 in the Discussion.

Table 1.2 - NTFP organized into six IBGE categories.

Rubber	Waxes	Fiber	Tanantes	Oils	Food	Aromatic/ medicinal
Hévea (coagulated latex)	Carnaúba (wax)	Buriti	Angico (shell)	Babaçu (almond)	Açaí (fruit)	Jaborandi (leaf)
Hévea (liquid latex)	Carnaúba (powder)	Carnaúba	Barbatimão (shell)	Copaíba (oil)	Castanha de caju	Urucu (seed)
Maçaranduba	Others	Piaçava	Others	Cumuru (almond)	Castanha-do-Pará	Others
Sorva		Other		Licuri (coconut)	Erva-mate	
				Oiticica (seed)	Mangaba (fruit)	
				Pequi (almond)	Palmito	
				Tucum (almond)	Pinhão	
				Others	Umbu (fruit)	

*NTFP shaded are included into the Socio Biodiversity plan by MMA [11].
Source: [8]

Table 1.3 - Annual Calendar of 10 families in Acre.

FAM	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1	□	□	□+△	*□ ● #	* ●	* ●+	* ●	* ●	*	*––△		□
2	□△	□	□	□ ●	* ●+––	* ●	* ●	* ●	*+△	#		□
3	□	□	+#	●	* ●△	* ●–	* ●+	* ●	*	*#–△	*	*
4	□	□	□+△	□ ●	●	●*+	● *	●*	*	*#––△	*	*
5	□△	□	□#+	●	* ●	* ●+	* ●	* ●	*––△	*#	*	*
6	□	□	□#	□ ●	* ●–	* ●+	* ●	●+	–	*△	*#	*△
7	□	□	□#	●+	* ●	* ●	* ●	●+	––△	*#	*	*△
8	□	□	□#+	* ●	* ●+	* ●	* ●	* ●	*#	*△	*□	□
9	□	□△	□#+	●	* ●	* ●+	* ●–	* ●	*△	*#	*□–	□△
10	□	□	□#	* ●	* ●	* ●–	* ●	* ●	*	*#	*	□

(*) rubber, (□) Brazil nut, (●) Açaí, (#) rice (+) beans (-) cacava (△) maize. Source: [12].

Although part of the same local livelihood system, rubber and Brazil nut have very different histories and the economic value of these two products reveal contrasting dynamics [10]. Figure 1.1 shows the total production in tons and the economic value in US$ for rubber and Brazil nut for the Brazilian Amazon states [9]. Whereas Brazil nut production volume has increased over the past decade in spite of lower total values, rubber production and total value have steadily declined.

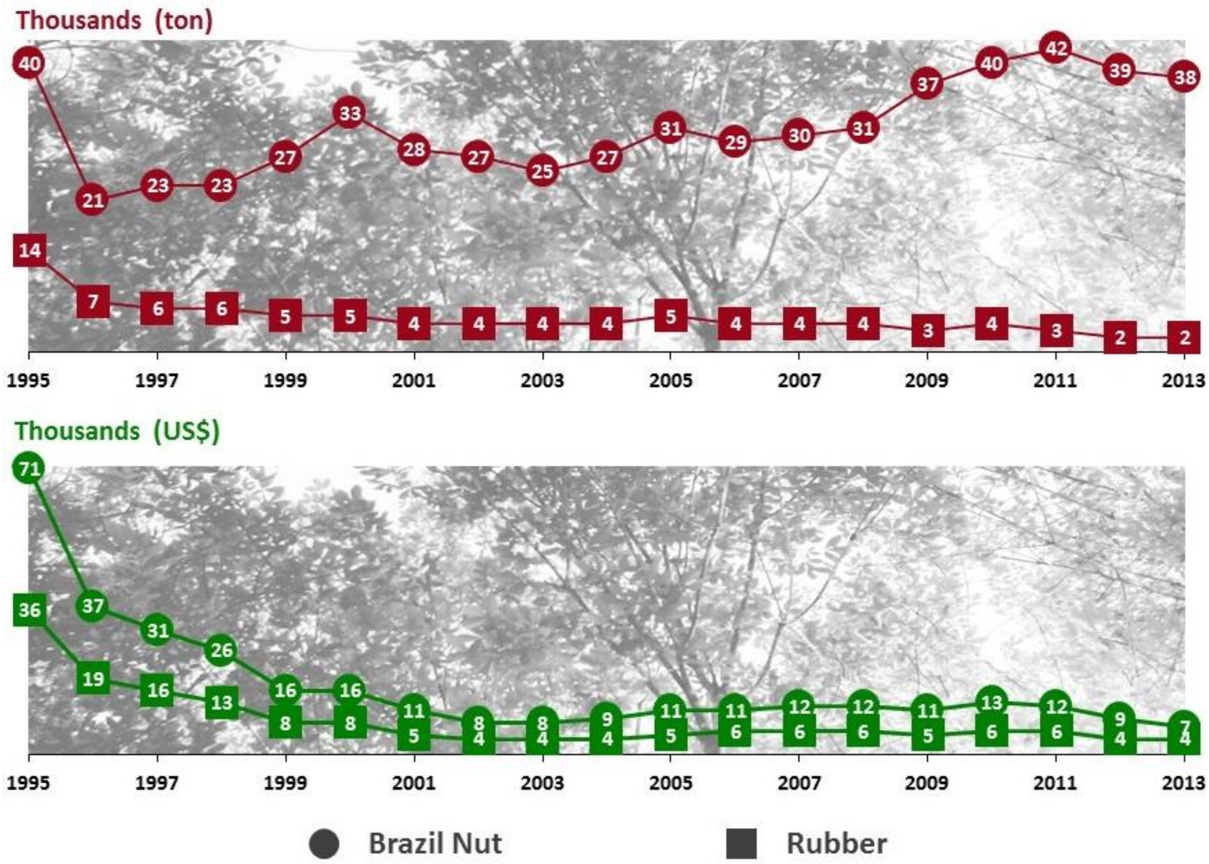

Figure 1.1 - Production (ton) and value of production (thousand dollars) of rubber and Brazil nut for all the municipalities in the Amazon biome. Source: [9].

Recently, the Natural Capital project[2] used land uses and accessibility as surrogates for geographically differentiating the importance of NTFPs across the biome. However, no attempt has yet been made to geographically differentiate rents (economic returns to production) of NTFPs.

Here we fill this gap by providing robust evidence for the current values of rubber and Brazil nuts production in order to address the changes in value that might occur if a small amount of forest area ("marginal change") is lost or degraded. Our approach compares the distribution of rents across the biome for the two products, while acknowledging the individual constraints of each production system.

Ultimately, the models allow us to explore what environmental and governance improvements are needed in the supply chain to avoid deforestation and forest degradation in the Amazon. Our modeling approach builds upon both stock (*e.g.* estimating yields based on biophysical variables and fieldwork data) and flow (*e.g.* annually marketed products) by integrating a comprehensive secondary dataset with extensive fieldwork data. As a result, our models can be used to assess the impacts of policies and economic options (scenarios) on the provisioning of these important Ecosystem Services.

[2] http://www.naturalcapitalproject.org/

The models are developed and implemented using the Dinamica EGO (EGO - *Environment for Geoprocessing Objects*) platform, developed by the Centro de Sensoriamento Remoto at Federal University of Minas Gerais (UFMG). We incorporated the most accurate and updated data currently available for public use in addition to new data collected in field surveys. All input maps are exhibited in the Supplementary Material (Table S9).

There is a great diversity in the Brazil nut and rubber collection/extraction systems [10, 13, 14]. These differences occur across geopolitical boundaries, type of infrastructure, market circuits (cooperative or intermediary), and processing plants, as well as the socioeconomic aspects of the collectors (*e.g*. sustainable reserves (RESEX) vs. settlements) [15, 16].

Our economic valuation builds upon previous work by CSR/UFMG. The value map for rubber presented in this work is an adaptation of a rubber model developed by Jaramillo et al. [17], while the Brazil nut model is based on the work of Nunes et al. [18].

We used the previous work by Nunes et al. [18] and Jaramillo et al. [17] to select the most important biophysical variables related to rubber and Brazil nut yields. In addition, we used IBGE production data for estimating production favorability (where NTFPs exist and it is extracted/collected). Then we calculated the favorability for these products over the Brazilian Amazon. To do so, we used Weights of Evidence method [21]. Independent variables include biophysical and environmental proxies (see Nunes et al., [18] and Jaramillo et al., [17]. For dependent variable (favorability), we used IBGE maximum production volume by municipality between 1994 and 2013. Favorability was then transformed into yields by applying a Probability Distribution Function (PDF) transformation so that the new distribution matches the PDF of yields from the case study areas in Acre [17, 18]. This procedure allowed us to expand the models from Acre for the entire Brazilian Amazon.

1.1. Major Methodological Steps

The first step consisted of building databases on rubber and Brazil nut production from the Brazilian statistics office (IBGE). These include the quantity produced (tons) and the value of the production (thousand reais[3]) from 1994 to 2013 for each one of the 551 municipalities of the Amazon [9] (these maps are presented in sections 2 and 3 for Brazil nut and rubber, respectively).

In parallel, we interviewed relevant stakeholders including government departments, industry actors; non-governmental organizations (NGO), and other actors (*e.g.* CONAB). Our objective was to: (1) aggregate available information on the market value chains of rubber and Brazil nut across the Amazon biome; (2) gather data on market circuits and systems; (3) assemble a database of NTFP cooperatives, including rubber and Brazil nut collection

[3] Values were afterwards converted to US$ according to the conversion factor 2.36 as shown in Table S10 (Suplementary Material).

storehouses (*armazéns*); and (4) update our information on current initiatives and projects. In general, these interviews aimed to collect information on the institution´s role and companies interest on NTFP markets. From these interviews, we were able to produce detailed descriptions of different production systems in the Amazon and descriptions of production costs for rubber and Brazil nut. In total we interviewed 10 people from six different organizations. The names and contacts of our interviewees are presented in Table S1.

In a second step, we carried out field surveys in Acre and Pará states to collect up-to-date data through semi-structured interviews and focus group. We interviewed 30 people in Acre including 6 extrativists, 10 NGOs, 10 governmental agencies, as well as professors at the Acre Federal University (UFAC, Universidade Federal do Acre). In Pará, we interviewed 9 extractivists, 2 cooperatives, 5 governmental bodies, 2 scientists, and 1 representative of the Brazil nut exporting industry (Table S2). Based on the network of contacts established during fieldwork we collected data on harvesting activities of over 11,000 families in Acre and Pará. Through semi-structured interviews, we collected market prices (from cooperatives), production costs (from extrativists), and transport costs (from both cooperatives and extrativists and their associations) (Table S2).

As anticipated, there is a great variability in the data collected in the interviews. In order to clarify some issues and to better contextualize the values, we invited all interviewees to participate in a focus group discussion that was held at the final day of our fieldwork in Acre (Figure S3). Participants in the focus group session were asked to comment, clarifyg, and contextual the production values and transport costs. Figure 1.2 shows the fieldwork interviews and focus group in Acre, from 19th to 29th of July 2015 (upper pictures) and in Pará from 13 to 17th of June 2016 (lower pictures). In Pará, we also participated in the TAPAJOARA annual meeting that congregates residents from the Flona Tapajós and Resex Arapiuns (lower right picture).

Building upon the data collected in previous research, two spatial explicit models (one for Brazil nut and other for rubber) were then developed. A detailed description of all these research steps is presented in the Supplementary Material. After running the models we re-engaged with stakeholders to receive their feedback on our estimates. We focused on gathering stakeholders' insights for crosschecking how cost estimates obtained from our fieldwork in Acre and Pará compared with costs in other states. Finally, to include more local scale data, we used CONAB data, which is a collection of monthly local costs and prices estimates while conducting on site workshops and panel discussions.

Figure 1.2 - Pictures from fieldwork.

2. Brazil Nut

2.1. A brief description of the Brazil nut market chain in the Amazon

The Brazil nut tree (*Bertholletia excelsa*) produces one of the main seeds commercially harvested in the rainforest ecosystems [4, 18, 19]. The following figures 2.1 and 2.2 display IBGE data by municipality on production (in tons) and value of production (in US$) [9]. Since it is possible that nuts produced in one municipality might enter the market in other, these values are not weighted by municipal forest area. This lack of standardization might result in municipalities with bigger area having predictably larger production values. It is important to mention that the IBGE data presents only a broad picture of the production dynamics and needs to be interpreted carefully. The mean annual production per municipality over the last 20 years (from 1994 to 2013) ranged from 0 to 1,900 tons. Figure 2.1 shows the higher mean values in the municipalities within Pará, Acre, Amazonas and Rondônia states, which produced, on average, from 1,000 to 1,900 tons of Brazil nut per year. There are also municipalities producing, on average, 100 to 1,000 tons. Lower production (less that 1 ton per year, or between 1 and 100 tons) tends to occur in the municipalities at the biome´s fringe.

The total production value of Brazil nut per municipality ranges from US$ 1 to US$ 1 million. Note that the municipalities with higher mean production (shaded in red) are also the ones with higher mean production values (Figure 2.2).

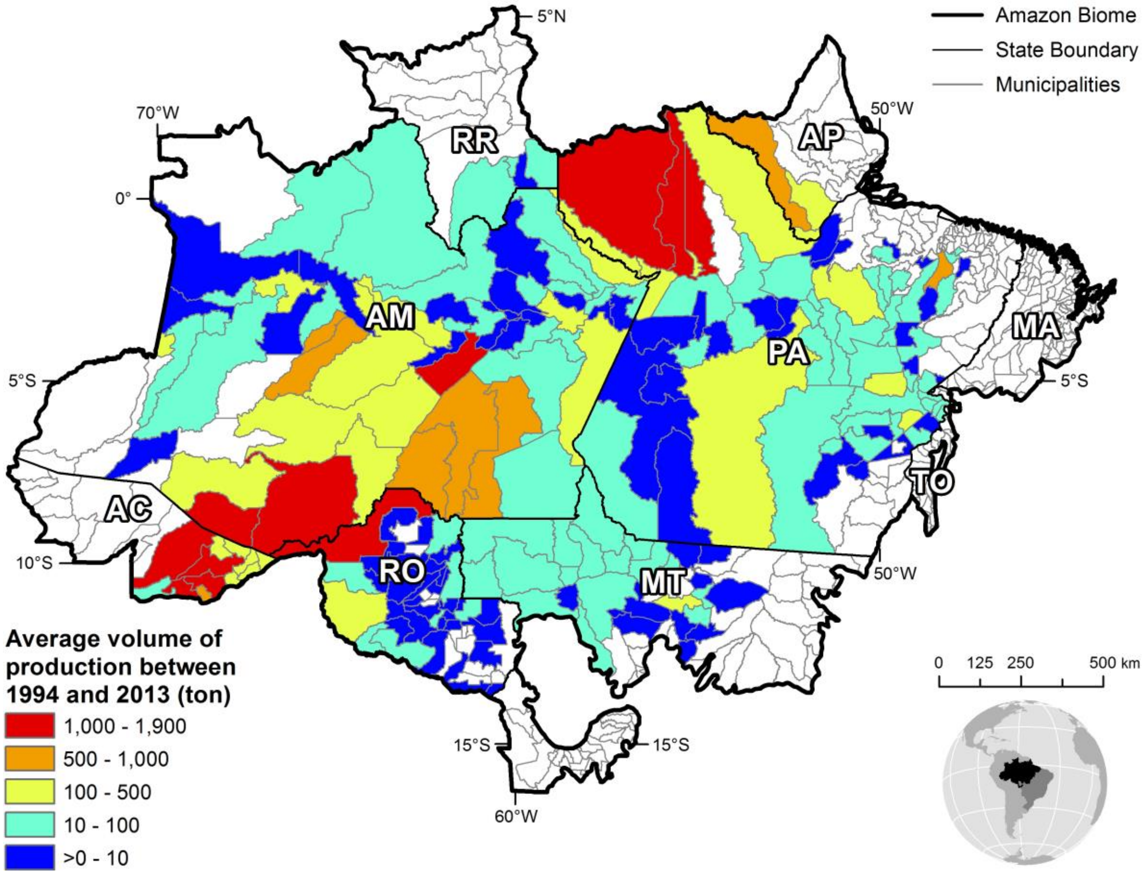

Figure 2.1 - Average volume of Brazil nut production (ton) between 1994 and 2013. Source: [9].

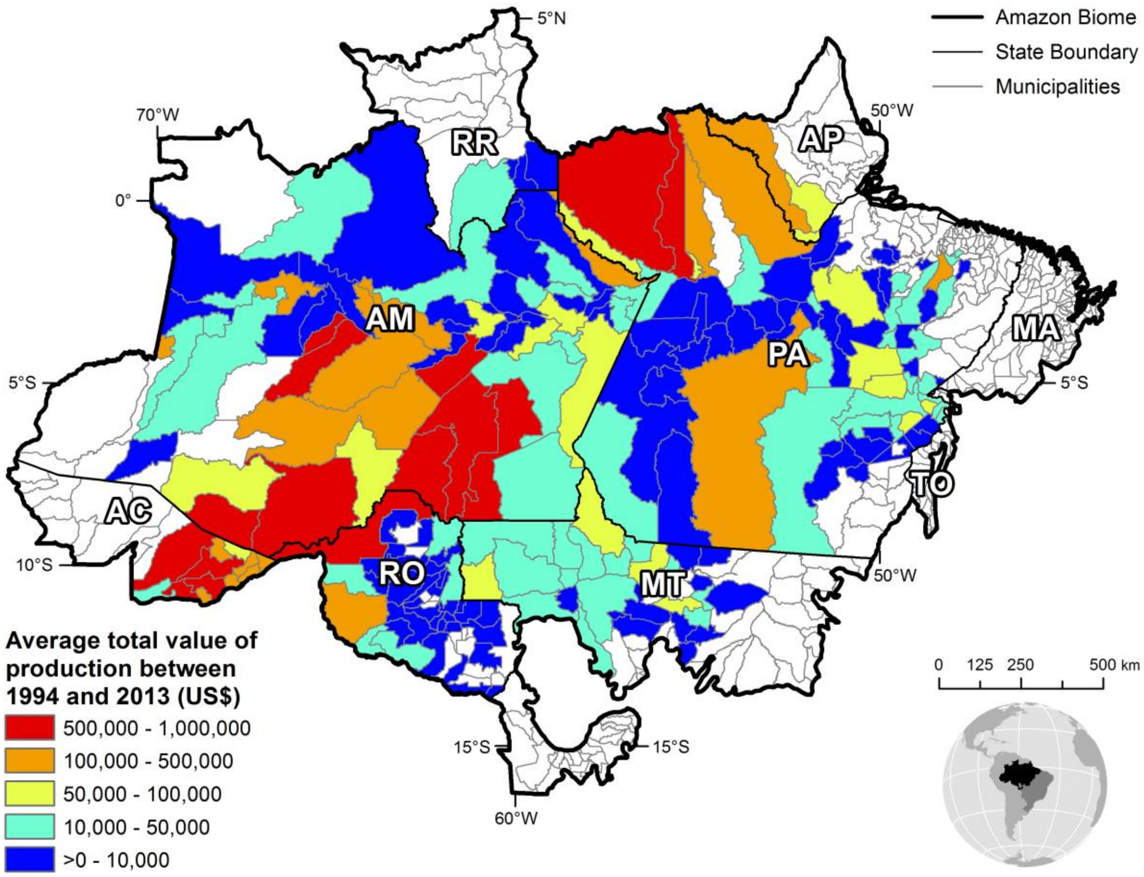

Figure 2.2 - Average total value of Brazil nut production (US$) between 1994 and 2013. Source: [9].

The mean annual values, however, hide a huge variability. For example in 2013, the production of Brazil nut in the Amazon municipalities ranged from 0 (municipalities in white) to a maximum of 3,700 ton (municipalities shaded in red) (Figure 2.3).

In 2013, the total municipal value generated from Brazil nut in the Amazon (Figure 2.4) ranged from US$ 1 to near US$ 3 million (see Supplementary Material for conversion rates). This year yielded a slightly higher estimate than the mean values presented in Figure 2.1. This is largely due to the Brazilian government's commitment after 2009 to promote several public policies enhancing NTFP chains [11]. As a result, there was a significant increase in the Brazil nut prices. These public policies increased the price by 460% to Brazil nut producers—from a mean of US$ 0.15 kg^{-1} in 2000 to US$ 0.87 kg^{-1} in 2012 and US$ 1.27 to 1.48 kg^{-1} in 2014 [19].

We also examined the maximum production volumes and values per municipality over the last 20 years (Figure 2.5). The maximum production was 7,100 tons and the maximum value was US$ 4.2 million.

To obtain the average price per kg over the last 20 years, we divided the annual production value by production volume. Figure 2.6 shows that the minimum price per kg ranges from US$ 1 to US$ 1.5 in four municipalities in the state of Amazonas (higher prices depicted in red and orange). In the municipalities shaded in light blue, the minimum price per kg ranges from US$ 0.1 to US$ 0.3, while municipalities shaded in yellow minimum prices ranges from US$ 0.3 to US$ 0.5. But, only a few municipalities have minimum price around US$ 0.5.

The average price per kg ranges from US$ 0.01 to US$ 2.20. Higher mean prices occurred in Mato Grosso and Amazonas (mean price ranged from US$ 1.1 to US$ 2.2), while in Acre, Pará and Rondônia mean prices, over the last 20 years, range from US$ 0.3 to 0.5 (light blue) and from US$ 0.5 to US$ 0.7 (yellow) (Figure 2.7). Over the last two decades, the State of Amazonas had the highest maximum price per kg of Brazil nut. From 1994 to 2013, the maximum price per kg reached US$ 26 in three municipalities in Amazonas and in one in Pará (Figure 2.8).

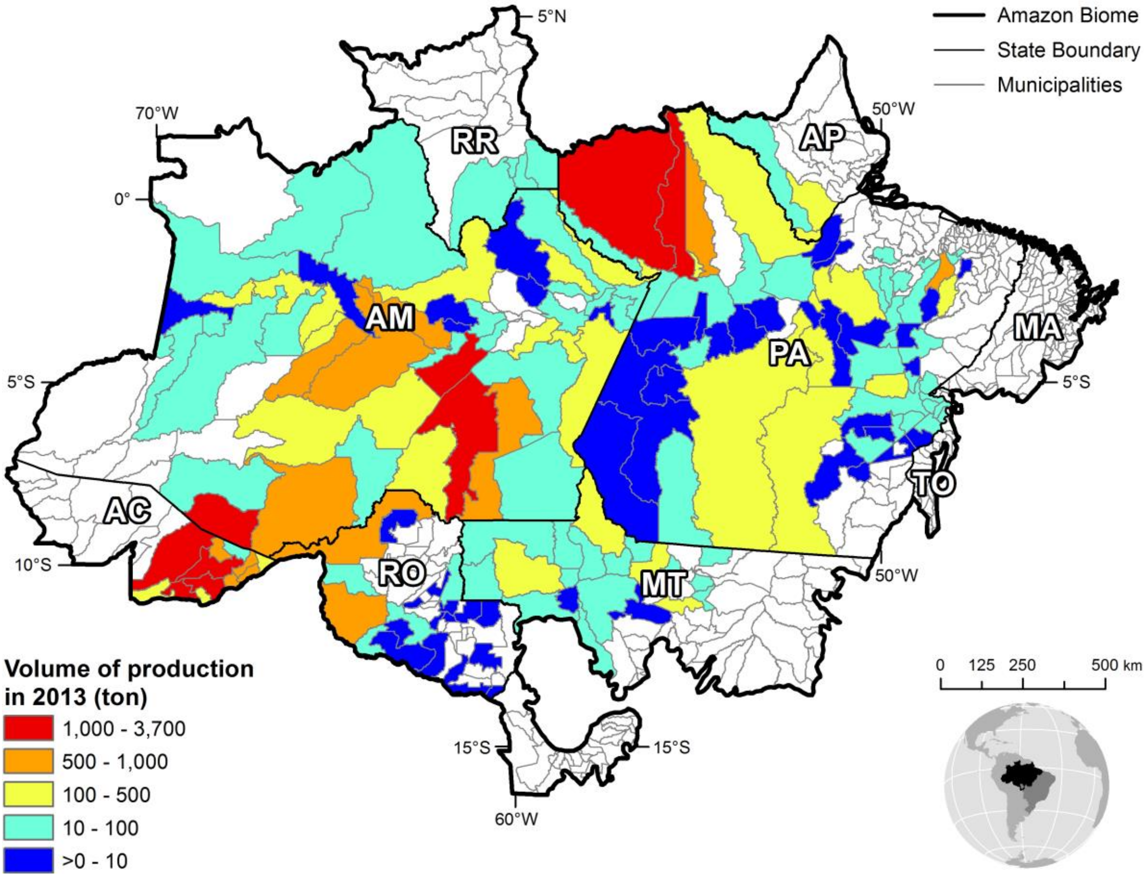

Figure 2.3 - Volume of Brazil nut production (ton) by municipality in 2013. Source: [9].

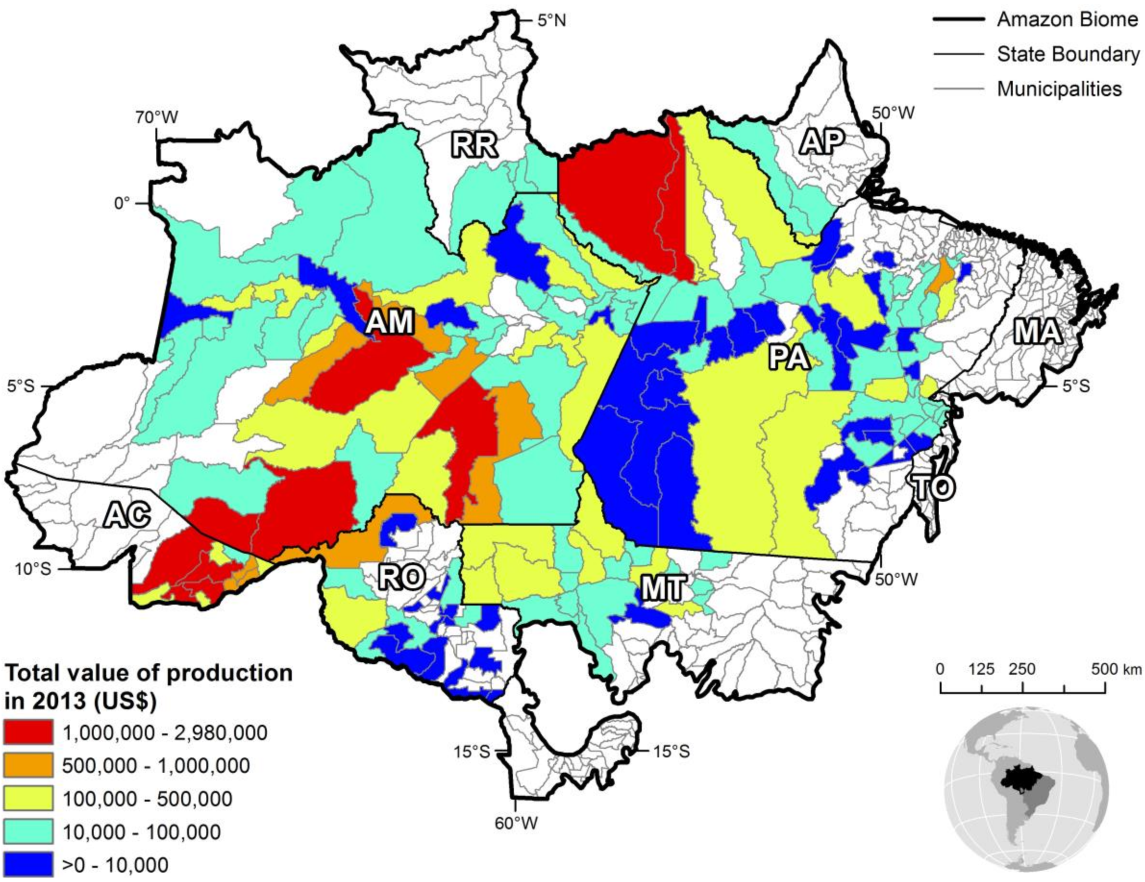

Figure 2.4 - Value of Brazil nut production (US$) by municipality in 2013. Source: [9].

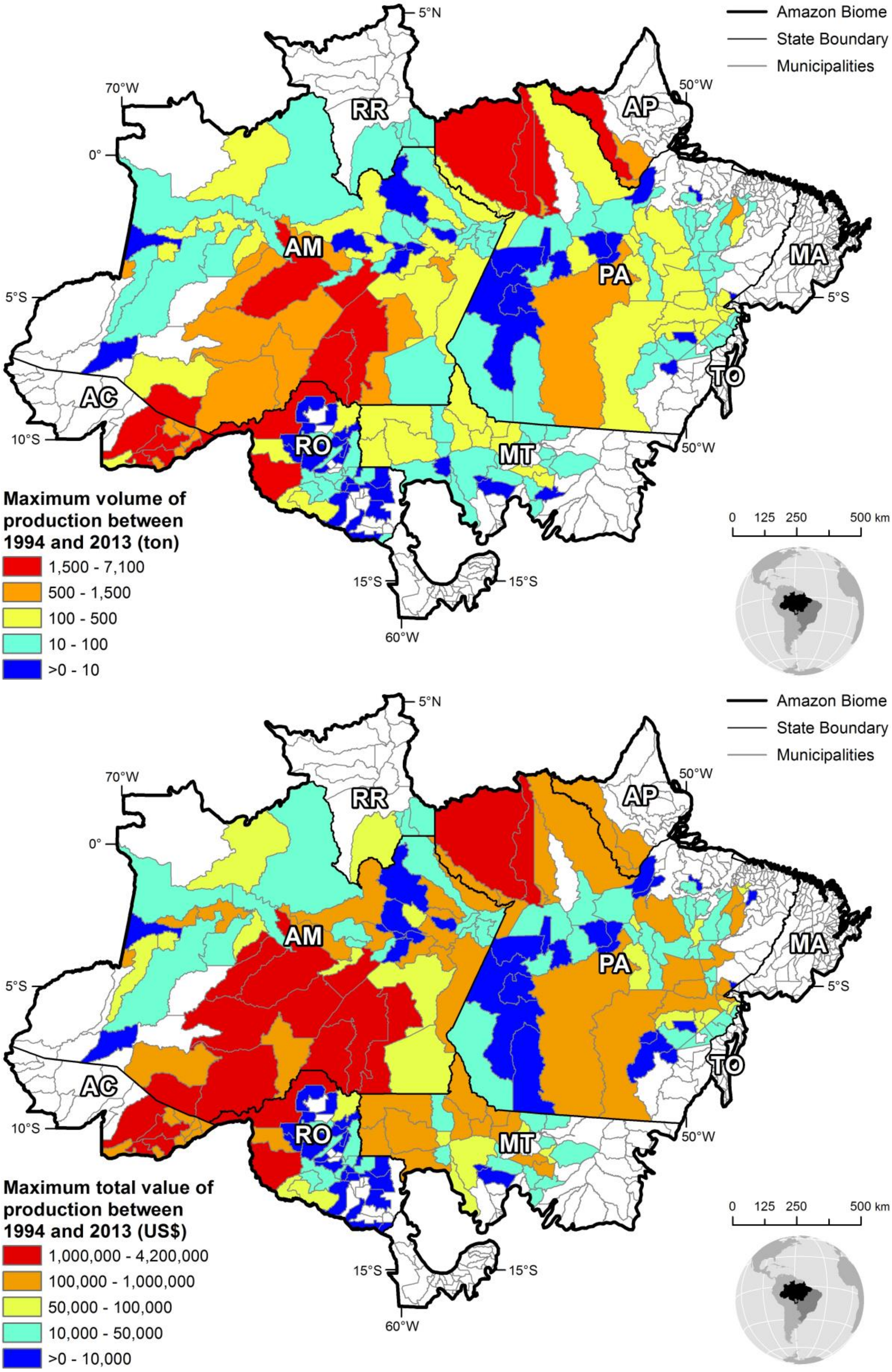

Figure 2.5 - Maximum volume of Brazil nut production in ton (upper map) and maximum value of production (lower map) over the period 1994-2003. Source: [9].

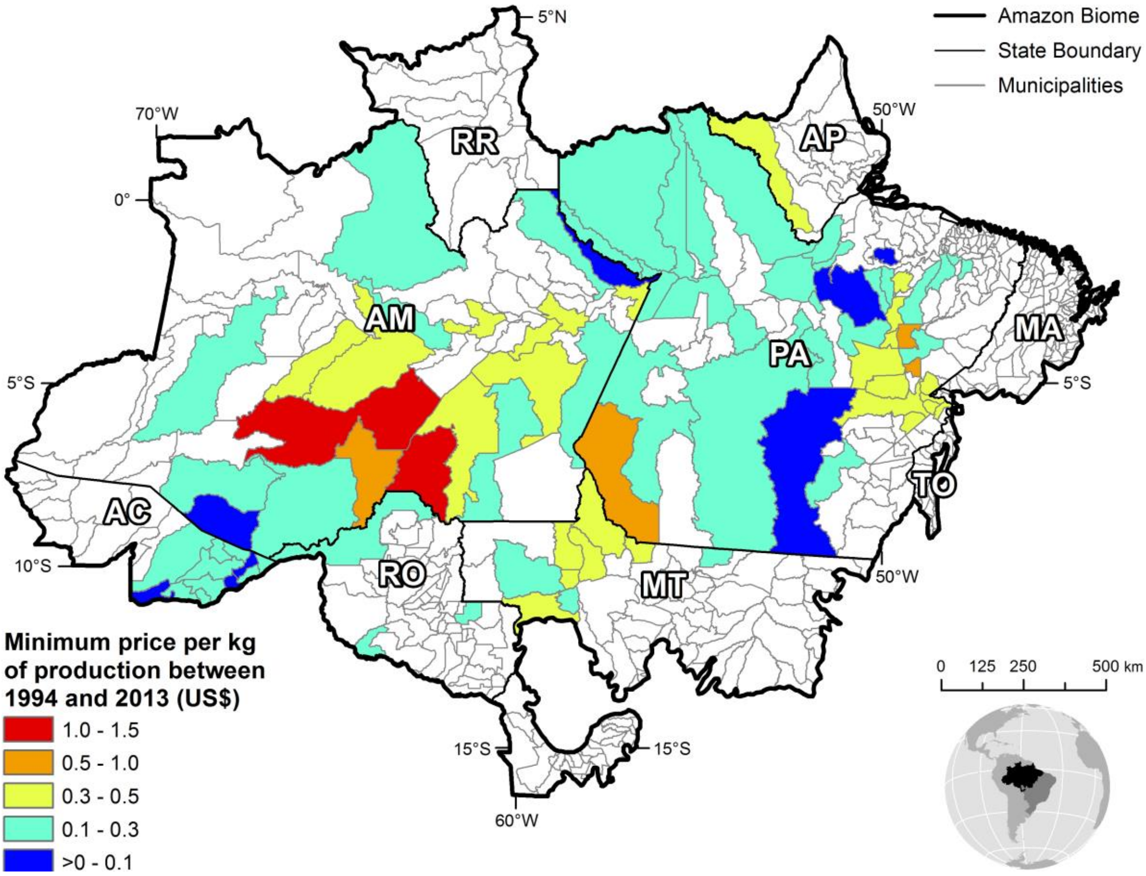

Figure 2.6 - Minimum price of Brazil nut per kg over the period 1994-2013. Source: [9].

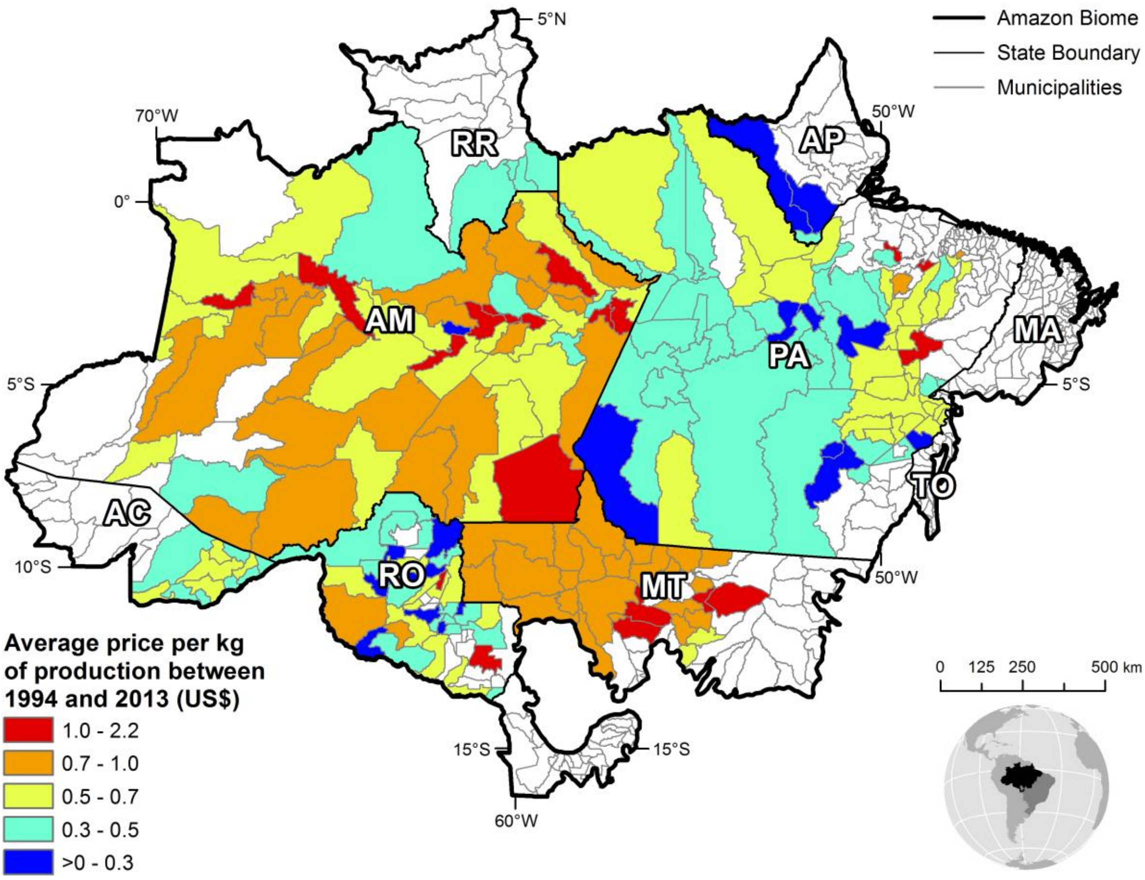

Figure 2.7 - Average price of Brazil nut per kg over the period 1994-2013. Source: [9].

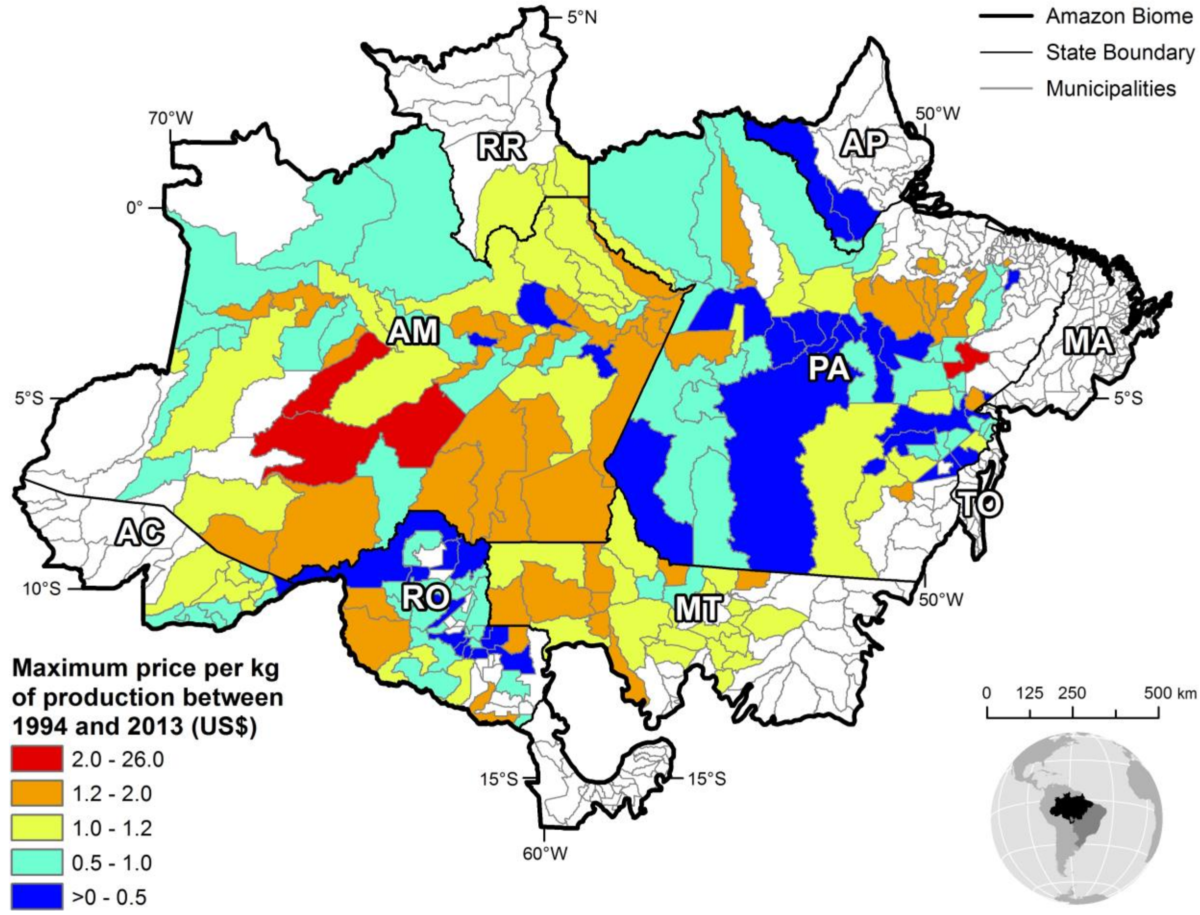

Figure 2.8 - Maximum price of Brazil nut per kg over the period 1994-2013. Source: [9].

Although the previous figures (2.1-2.8) show annual patterns, there is a considerable variation in the prices of Brazil nut paid to producers across the Amazon and over the months (Figure 2.9).

Brazil nut certification schemes have been put in place to seek higher prices in international special markets. Four main certification systems are relevant to NTFPs: (1) organic; (2) product quality; (3) fairtrade; and (4) forest management. Organic and product quality certifications emphasize health and safety standards suited for food and pharmaceutical-based NTFPs. Fairtrade certification is socially oriented and recognizes operations that ensure benefit sharing and better working conditions for small producers. Forest management certification focuses mostly on ecological aspects of harvests, but also includes social and economic standards. Forest Stewardship Council (FSC) certification is the most well known. Despite its promise, the ability of certification to provide an equitable environmental and development outcome is in question, as stark discrepancies exist between official standards and local practices. Figure 2.10 shows the diversified number of actors in the Brazil nut production chain.

Figure 2.9 - Price of Brazil nut received by producers in different states in the Amazon. Source: [20].
*AC: Acre, AM: Amazonas, AP: Amapá, RR: Roraima, PA: Pará, RO: Rondônia.

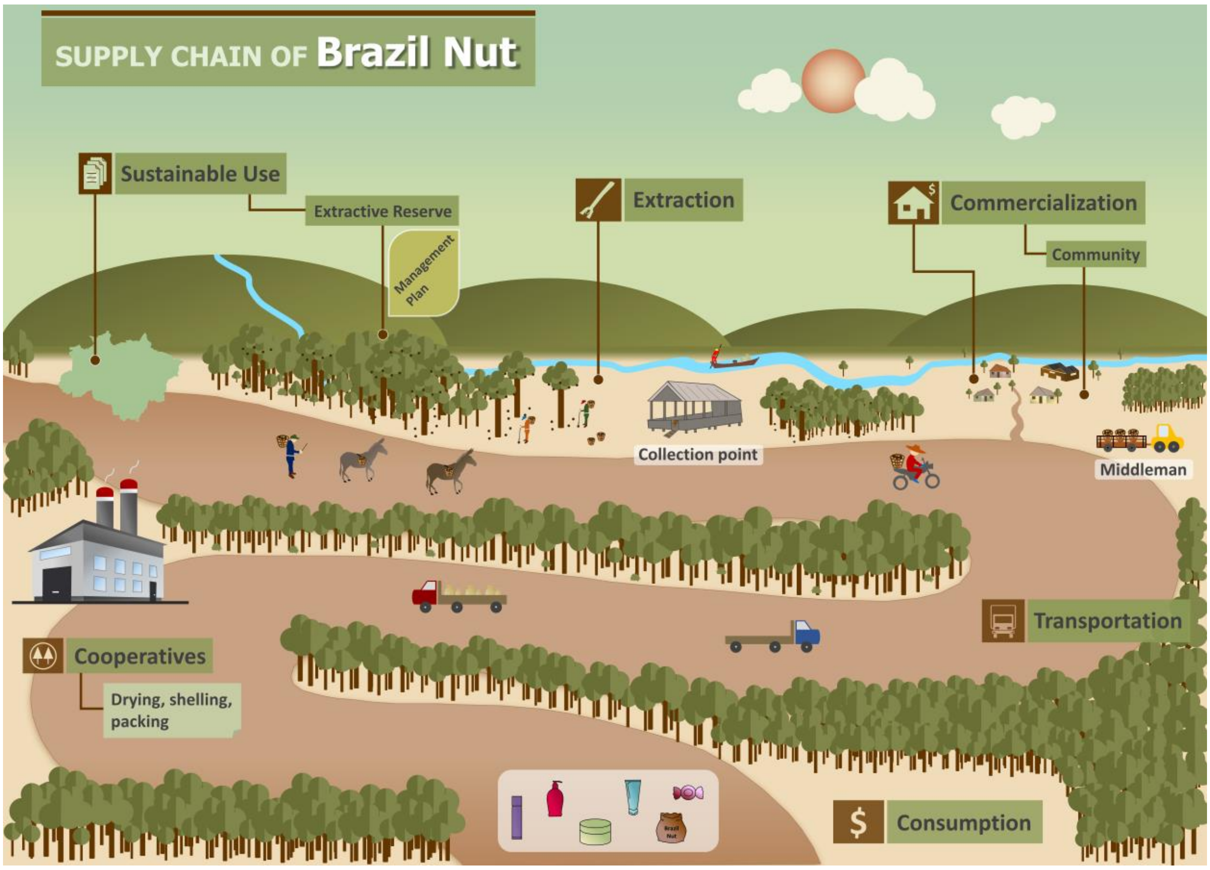

Figure 2.10 - From production to consumption: an overview of the Brazil nut chain and actors involved. Source: [11].

Brazil nut collection occurs predominantly in extractive reserves (RESEXs) from December until March in most of the Amazon states. *Bertholletia excelsa* occurs in clustered patterns normally around villages and old settlements [8]. The collection costs can therefore be differentiated as “hotspot” and “non-hotspot”.

The costs of collection of Brazil nut includes the preparation of the area, collection, and transporting all the seeds with the outer shell "ouriços" to a storage point in the forest. After all the seeds are gathered, the second stage consists of breaking the outer part of the seed "ouriço" and storing the seeds in a bucket. When the collection phases are finished, the nuts are ready to leave the forest in 70 Kg bags.

With respect to harvest costs, the collector usually has to clear a path to the trees and walk around to find the nuts. Then he collects it using a wooden stick and puts them into a basket. In some cases, in order to avoid losses, the collector brings his or her daily production to its village. When collection sites are more than 10 km away from the villages, the nuts are gathered in the forest and stored in a wood structure called "paiol" (a sort of shack) until transport is arranged.

There are also extractive systems in which the collector remains in the forest for several weeks or even months during the collection season. In these cases, they store the nuts gathered near the rivers until they have a significant quantity to arrange the boat transport. There are usually two types of possible transportation means to the nearest cooperative. The mainstream practice is that the cooperatives and local associations organize the transport to the town. In other cases, an intermediary or "atravessador" comes to the house of the extractivist and buys the nuts in the forests negotiating the price per "lata" (approximately 10 kg of nuts) including transport. In some areas, forest communities heavily rely on intermediaries to pay them in advance (outside collection season) as they contract to gather a certain amount of Brazil nut in a form of debt repayments. Traditionally, Brazil nut transport consists of two stages: 1) inside the forest from the place of collection to the nearest community (collection points); and 2) from the community to the nearest cooperative (selling points).

2.2. Brazil nut model

2.2.1. Yields

The model begins by simulating the yields of Brazil nut in the Brazilian Amazon. This is done by integrating a set of biophysical variables using the Weights of Evidence method [21]. We used bioclimatic and biophysical variables (the same as used by Nunes et al. [18] as well as time-series (1994-2013) of production data from IBGE). We also used the IBGE maximum production in each municipality (Figure 2.5, lower map) as a surrogate for production capability based on the assumption that if a municipality was able to produce such a quantity in a particular year, it would continue to hold that potential over the 20-year period. Correlated variables were removed from the model (Figure 2.11).

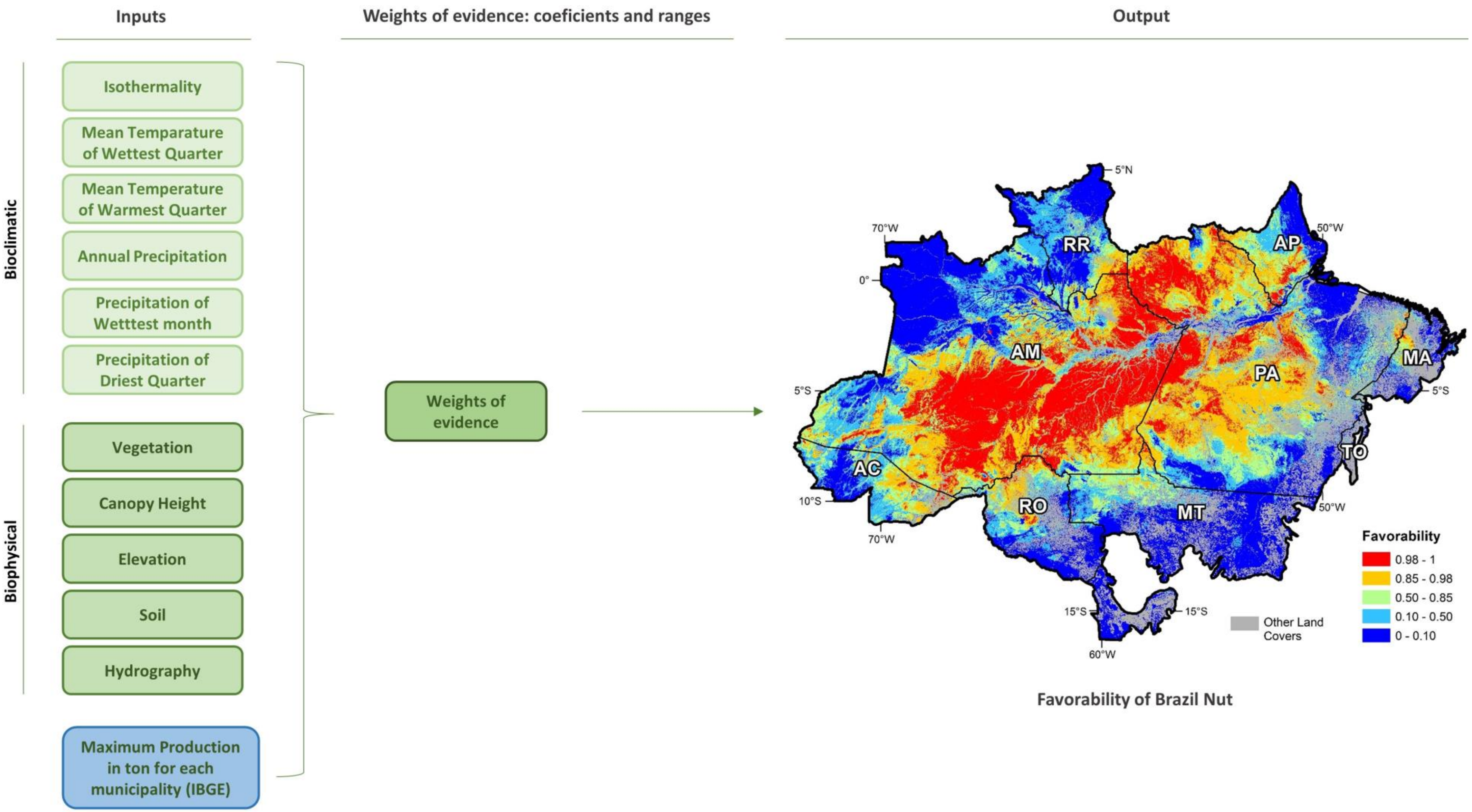

Figure 2.11 - Favorability of productivity for Brazil nut.

Favorability was then transformed into yields by applying a PDF transformation so that the new distribution matched the yield PDF from the case study areas in Acre [18]. Nunes et al. [18] used fieldwork data on tree occurrence and productivity for estimating Brazil nut tree density and yields. We used Nunes' yield distribution function for extrapolating the yields from Acre to the Brazilian amazon (Figure 2.12).

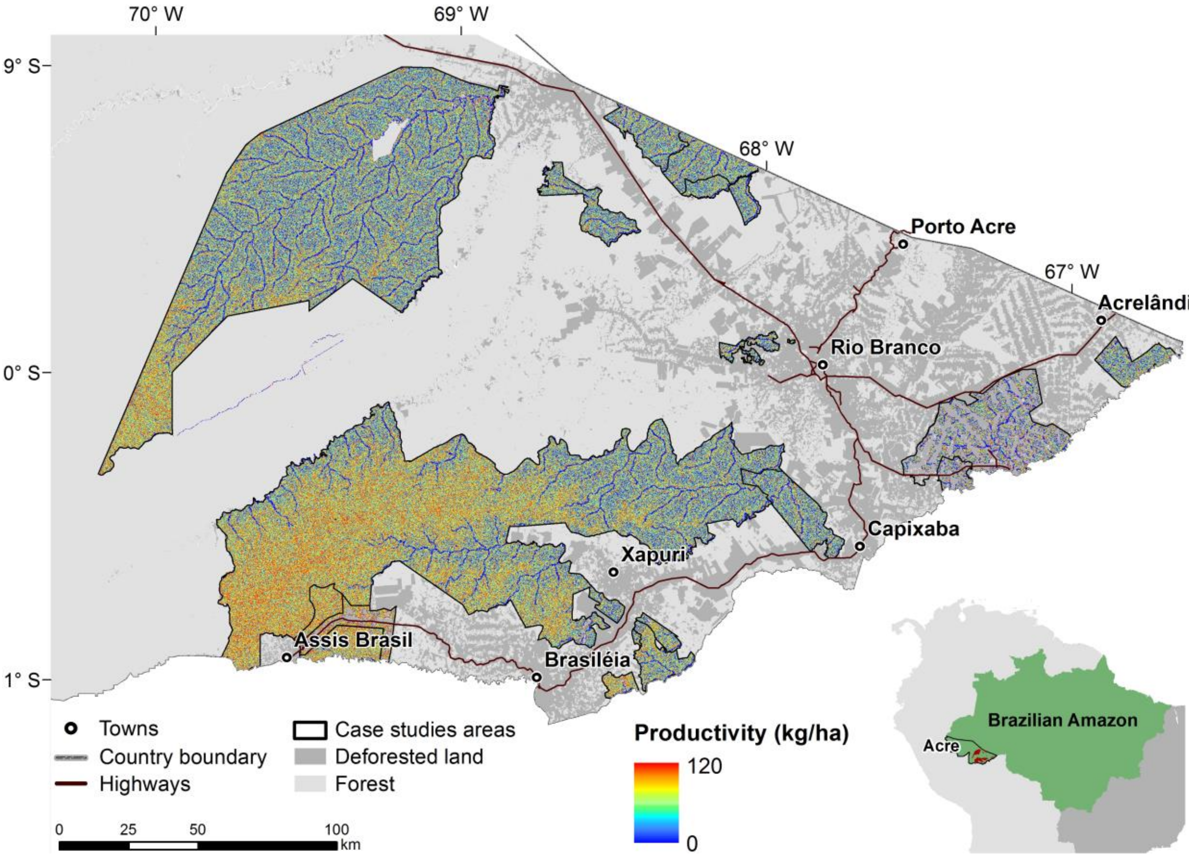

Figure 2.12 - Brazil nut yields in Acre case studies. Source [18].

To validate our results we gathered data for rubber (kg collected and annual rents) from over 10,500 families across 137 villages in Resex Tapajós Arapiuns in the municipalities of Belterra and Santarém in Pará. In Acre, we collected data from 425 families in the municipalities of Sena Madureira and Xapuri. In order to compare the outputs of our modeling approach (in kg/ha) to field data (kg collected), we divided the amount collected by an approximate harvest area. According to the interviews in Acre, extractivists use 300 ha of each "colocação" and in Pará we estimate the use of 100 ha. Our field data shows yield estimates broadly agreeing with collection by extractivists. However, the majority of families collect well below our estimated yields. Also data from the interviews makes clear there is significant product volume left on the forest floor because collection is costly and is not economically rewarding. This is also well documented in the literature [5].

2.2.2. Prices

The price paid to extractivists varies greatly depending on the year and season (Figure 2.9). The price also depends on the market circuit, namely whether it is marketed through cooperatives (approximately US$ 1.48) or intermediaries[4] (price varies from US$ 1.06 to 1.90 per kg) and depending on the data source used (*e.g*. IBGE [9] or CONAB [22]). IBGE data are self-stated by producers while CONAB is the observed production at the cooperative gate. Therefore, it is possible that IBGE data are lower than the actual as extractivists need to pay taxes for their transactions. On the contrary, in the cooperative CONAB pays the minimum guaranteed price and so extractivists are more likely to report real production and prices. Therefore, in the model, we used the maximum price paid to collectors in the period 2013 to 2014 (Table 2.1) from the CONAB dataset. In addition, the CONAB price mimics the variation shown in the IBGE data well [9] Figure 2.7.

Table 2.1 Brazil nut maximum price (US$) per kg of unshelled nuts between 2013 and 2015 used as price paid to producer in different states.

Estate	Market (US$) price per kg
Acre	1.42
Amapá	1.42
Amazonas	1.77
Pará	1.85
Maranhão	0.85
Mato Grosso	0.85
Tocantins	0.85
Rondônia	0.85

Source: CONAB [22].

The use of mean prices could seem a conservative estimate the analysis of mean prices are considerably lower than prices currently paid to producers and thus the maximum price would better estimate the current values (this was also shown in the analysis of IBGE maps in section 2.1). Furthermore, when discussing prices with stakeholders, for example with Institute Socio Ambiental, they suggested using the maximum price, saying that otherwise we would underestimate the recent efforts on enhancing the socio-biodiversity chain and related increases in selling prices for premium markets.

The model then combines yields with output prices and costs of collection, processing, and transport to estimate the annual rent per hectare for a specific forest parcel. Brazil nut trees occur in a clustered spatial pattern [18]. In more productive areas (hotspots), an individual can gather more than 100 kg of Brazil nut per day, while in other areas the daily collection is generally lower. We, therefore, consider areas of hotspot and non-hotspot productivity. Our data show that in areas where productivity (kg per ha) is higher the costs of collecting one kg

[4] A local merchant that goes to the collectors villages to buy the nuts and works as intermediate agent in the chain.

of Brazil nut is considerably lower than the costs of collecting 1 kg of Brazil nut in areas of low productivity (see next section).

2.2.3. Collection costs

Site productivity is of paramount importance for defining the cost-effectiveness of collecting Brazil nut. Hence, we estimate that in the case of low productivity (*i.e.* below the mean value of 8.19 kg $ha^{-1}year^{-1}$) the cost of collecting 1 kg of Brazil nut ranges from US$ 0.81 to 1.58, while in areas of high productivity the cost of collecting 1 kg ranges from US$ 0.14 to 0.67 (Table S4). Table S3 shows the material needed for Brazil nut collection. For matter of comparison, Table 2.2 includes other production costs reported in the literature [18, 23, 24].

Table 2.2 - Production costs

Brazil nut (cost per kg)	Low productivity	High productivity	SEAPROF [23]	EMBRAPA [24]	Nunes et al. [18]
Production costs	0.81-1.58	0.14-0.67	0.23	0.13-0.27[5]	0.13

Source: [18, 23, 24].

2.2.4. Transport costs

Transportation of Brazil nuts consists of two stages: 1) inside the forest from the place of collection to the nearest community (collection points) and 2) from the community to the nearest cooperative (selling points). The transport inside the forest (Figure 2.13) occurs from the place where the nut is gathered to place where all the nuts are temporarily stored. After shelling, Brazil nuts are transported to the collection points (located at small communities/localities) normally close to rivers or feeder roads. At this stage, collectors normally use one or two donkeys to transport the nuts. This traditional way of collecting Brazil nuts has been changing over time. Although the mule/donkey is still in use, nowadays the use of motorcycle is also widespread. Indeed, in the communities we visited in Acre and Pará, donkeys are barely used anymore. Therefore, we estimated the cost of transport across the forest by using a mixed transportation mode composed of motorcycle and donkey as of US$ 0.004 $kg^{-1}km^{-1}$ (Tables 2.3 and S5).

Table 2.3 - Cost of transport in the forest.

US$ $kg^{-1}km^{-1}$	Field work data	Nunes et al. [18]	SEAPROF [23]	EMBRAPA [24]
Total	0.004	0.003	0.03	0.025

Source: [18, 23, 24].

[5] Improved management includes selection and drying.

We used the location of communities for calculating the area of influence of each community that gathers Brazil nut. Communities were selected inside the municipalities where production was recorded by IBGE (Figures S1 and S2). In doing so, we estimated the transport costs from any point in the forest to the nearest community (Figure 2.13).

The second stage (Figure 2.14) consists of transporting the nuts from the storehouse in the communities to the nearest cooperative. We used the cooperative location maps (Figure S1, input variables) for calculating the "area of influence" for each one of the cooperatives that work with Brazil nut. In order to estimate transportation costs, the model uses a map of roads and navigable rivers. First, it calculates a cost friction surface (cost per kg and km), and then produces an accumulated cost from point of collection in the forest to the village and then to the cooperative (final destination), according to the type of road/waterway and mode of transport (boat, truck, donkey/motorcycle). In the model, we assume that the nuts are only shelled in the cooperatives[6]. Figure 2.14 depicts the methodological steps.

During fieldwork, we gathered data on the quantity of Brazil nut extracted by a community as well as the price paid to transport the unshelled nuts to the nearest cooperative. Using these data, we calculated transport costs by river and roads (Table S6) and compared those values with Nunes et al. [18] (Table 2.4).

Table 2.4 - Cost of transport from community to the nearest cooperative.

US$/kg/km	This study	Nunes et al. [18]
River	0.002	0.0004
Roads	0.001	0.001

Source: [18, 23, 24].

The accumulated transport cost ranges from 0 to US$ 3.80 per kg across the entire Brazilian Amazon (Figure 2.15). This means that for places more than than 200 km away from cooperatives or point of sale, it is never worth collecting nuts.

[6] Most locations in the Amazon sell the nuts unshelled. The processing (shelling and drying it in vacuo) mostly occurs in the cooperaticves.

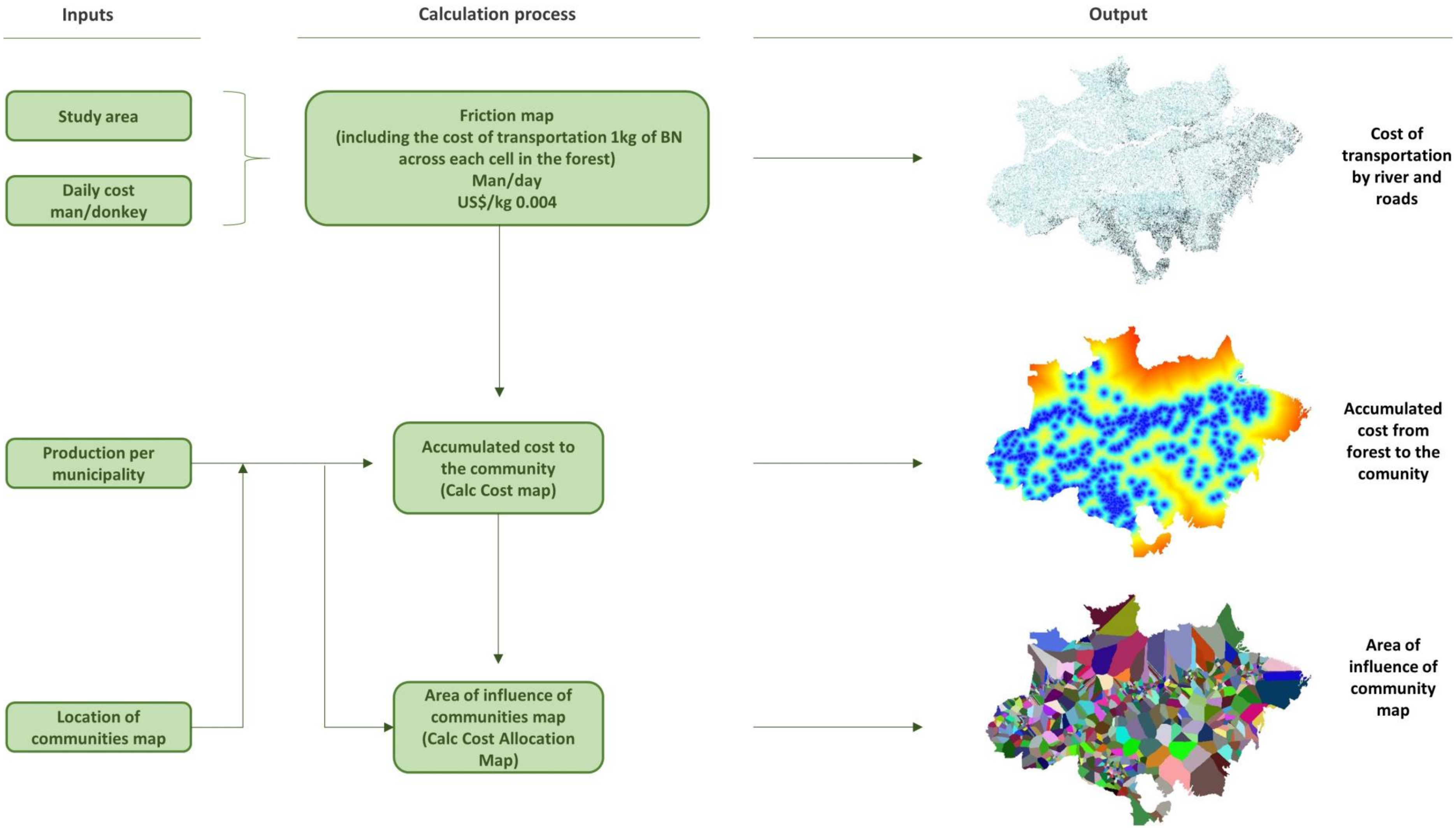

Figure 2.13 - Transport cost of Brazil nut from the forest to the community (village).

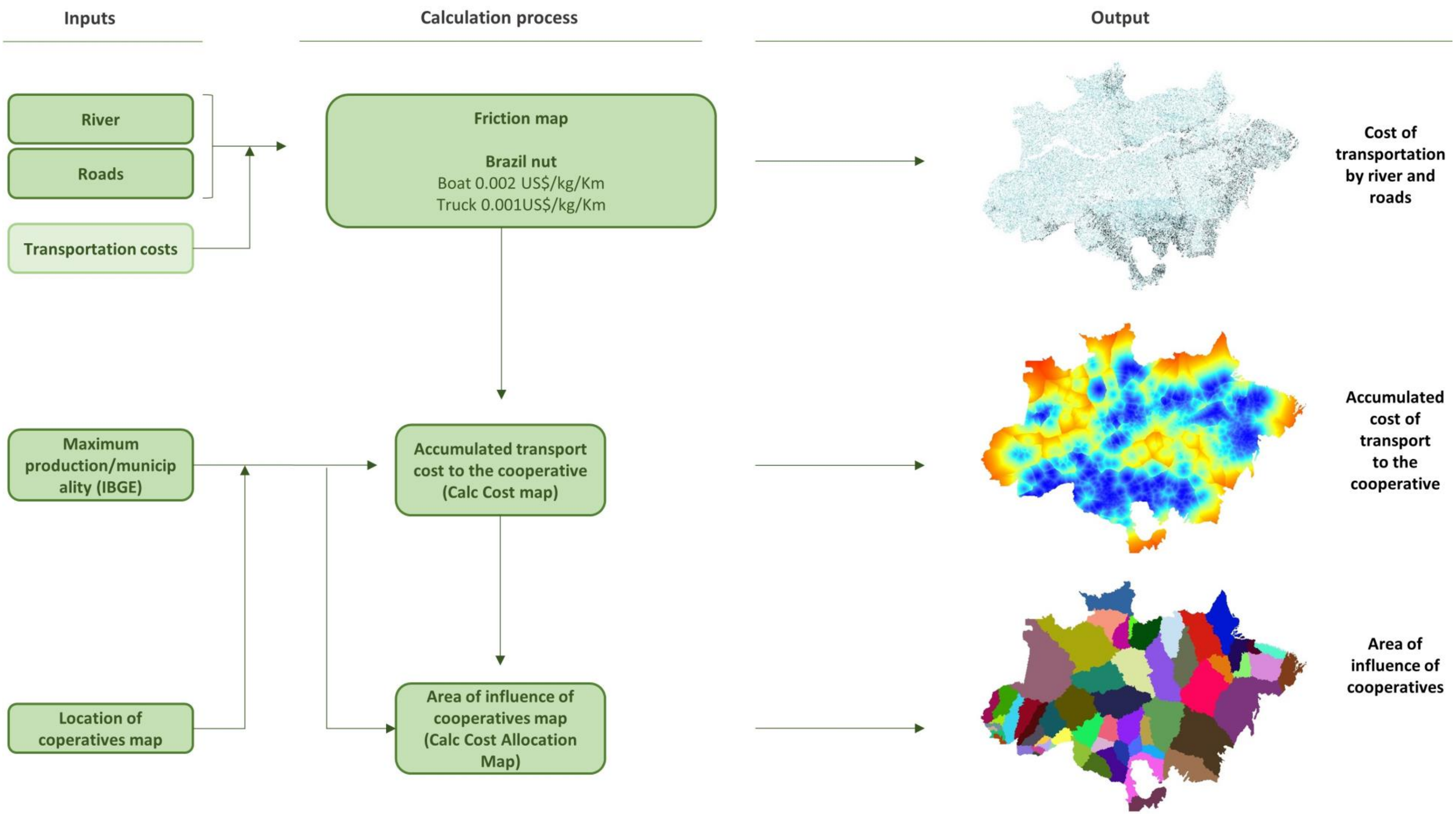

Figure 2.14 - Transport cost of Brazil nut from the community to the cooperative.

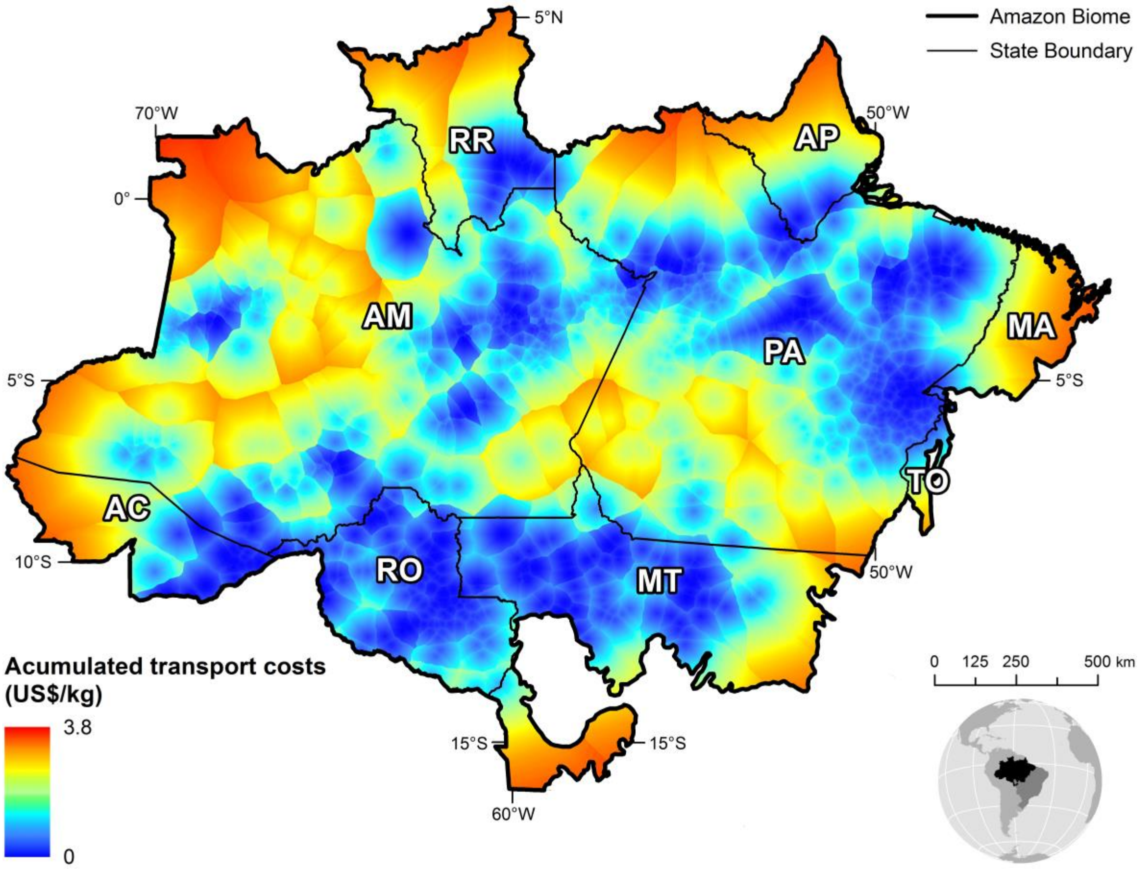

Figure 2.15 - Accumulated transport costs of Brazil nut: from the forest to the community and from community to cooperative.

We estimated rents for Brazil nut using a range of costs of collection, US$ 0.14-0.67 for higher productivity areas and US$ 0.81-1.58 for lower productivity areas. The net returns to collection are calculated by multiplying the sale price by the simulated productivity for a specific cell to get a gross product value, and then subtracting the total costs of production and transportation to the closest distribution center, collection point, or selling point (cooperative), according to the following equation:

$$Rent_{xy,n} = Q_{xy}(P_n - C_n - T_{xy,n,t}) \qquad \text{eq. (1)}$$

where Q_{xy}, is the simulated productivity for a cell with geographic coordinates (x) and (y) in kg, P_n is the sale price and C_n the cost of production in US$, and $T_{xy,n,t}$ is the transportation cost by type of transport (t) from location (x,y) to the nearest point of sale.

2.3. Value map for Brazil nut

The yields of Brazil nut are shown in Figure 2.16. This map highlights the areas where productivity is higher (red), located mostly in the southern part of Amazonas state, in the “Calha Norte” of northwestern Pará, and southwestern Pará.

In the vast majority of the Brazilian Amazon (99%) yields range between 0 to 30 kg per $ha^{-1}year^{-1}$, although there are locations where yields can reach 152 kg per ha (1% of the biome) (Table 2.5).

Annual rents of Brazil nut range from US$ 0 to 46 $ha^{-1}year^{-1}$ (Figure 2.17), with average rents of US$ 5.05 $ha^{-1}year^{-1}$ (Table 2.6).

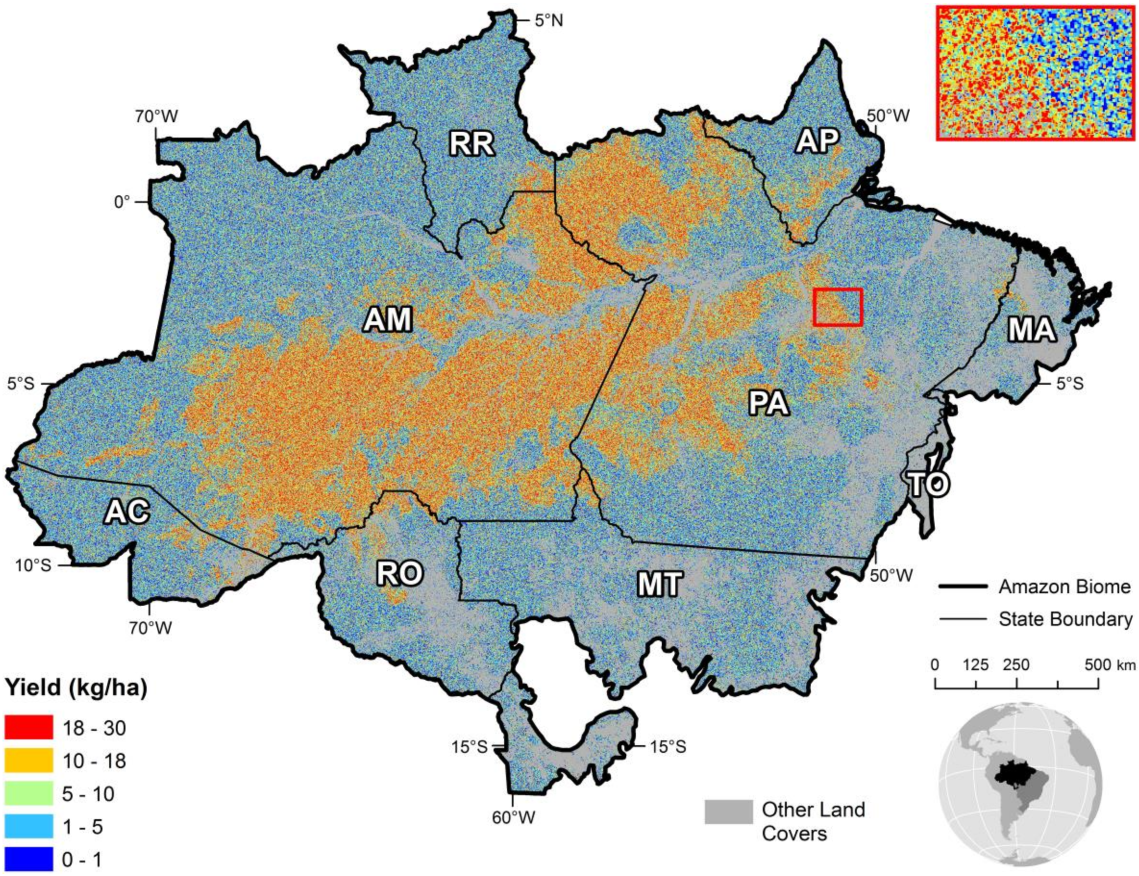

Figure 2.16 - Yields of Brazil nut.

Table 2.5 - Brazil nut yields.

Brazil nut yield ($kg^{-1}ha^{-1}$)	**Brazilian Amazon**
Minimum	0.00
Maximum	30.00
Mean	8.19
Variance	57.92
Standard deviation	7.41

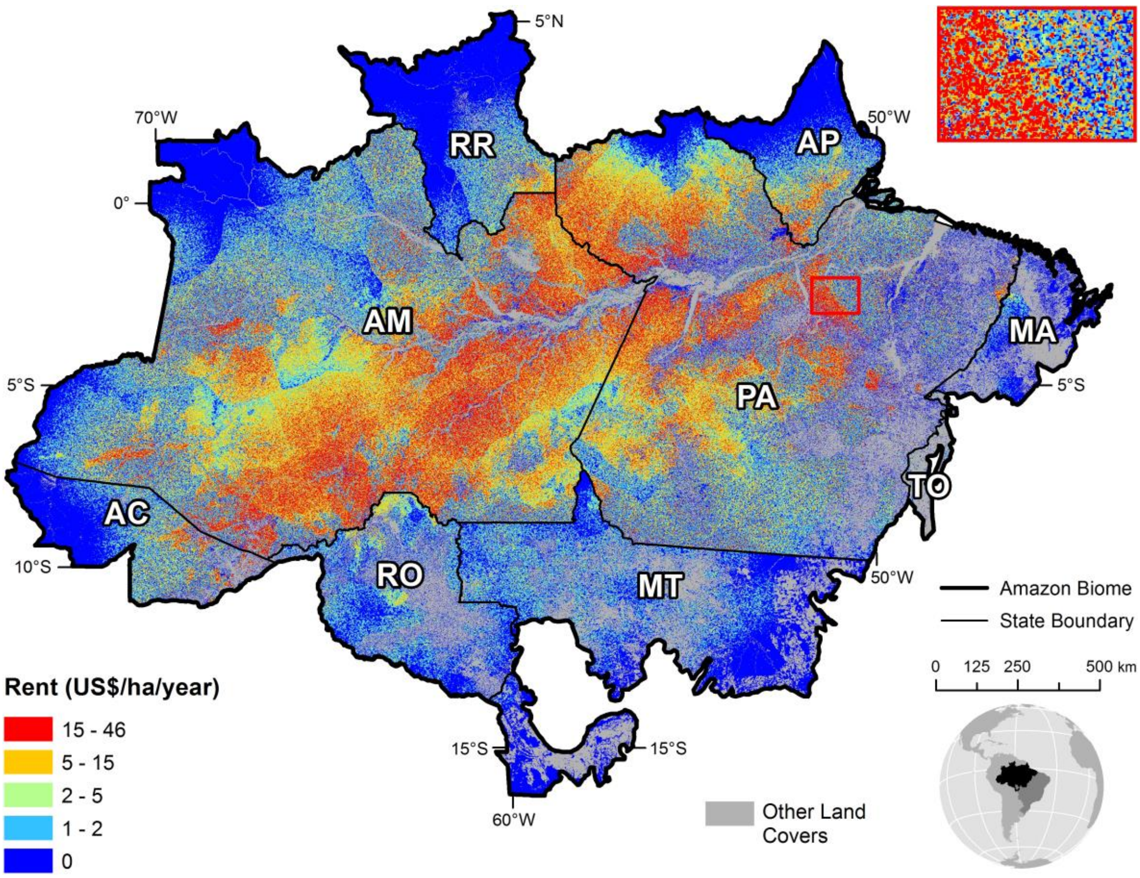

Figure 2.17 - Rents for Brazil nut.

Table 2.6 - Rent for Brazil nut.

Rent Brazil nut	Brazilian Amazon
Minimum	0.00
Maximum	46.00
Mean	5.05
Variance	56.24
Standard deviation	7.49

Production potential is the ability of a certain municipality to produce and trade Brazil nuts (Figure 2.18). We estimated the potential of each municipality in the Brazilian Amazon based on our yield estimates (in kg $ha^{-1}year^{-1}$). We then multiplied it by the total area of the remaining forest in the municipality. Finally, we compared this potential of production with the production time-series reported by IBGE. We found that generally municipalities have been trading only a small share of its production potential. Table 2.7 exemplifies the case for a set of municipalities. While, for example Alta Floresta, according to IBGE [9] had a maximum production of 29 tons, our model estimates a potential of production of nearly 4 thousand tons. The potential annual production of Brazil nuts in the Brazilian Amazon as a whole could reach 3.7 million tons (Table 2.7). However, our results show that only areas that have access and presence of communities in the vicinity are apt for economic production (Figure 2.18). For example, considering rents equal or greater than US$ 5.05 $ha^{-1}year^{-1}$, Brazil nut supply chains could be developed in 135 Mha of forests producing 2.0 million of tons per year.

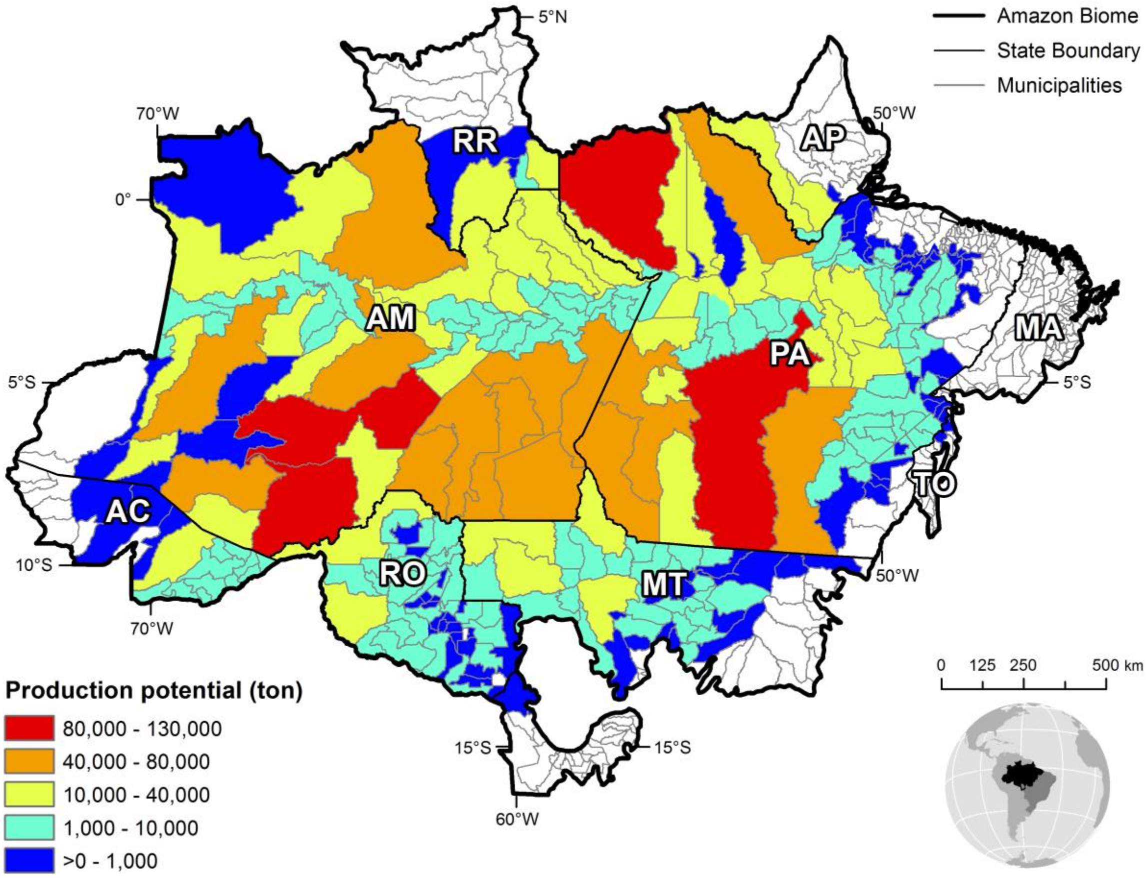

Figure 2.18 - Potential production of Brazil nuts per municipality.

Table 2.7 - Current versus potential production.

Municipality	IBGE-Max (ton)	IBGE-Min (ton)	Our simulation of potential (ton)
Alta Floresta D'Oeste	29.00	2.00	3,903
Ariquemes	21.00	14.00	2,439
Colorado do Oeste	0.00	0.00	0.00
Corumbiara	0.00	0.00	5.20
Total			3.7 million

Source: [9].

3. Rubber

3.1. The rubber production chain in the Amazon

Hevea brasiliensis is the main source of natural rubber in the world. Natural rubber has numerous applications with more than 50 thousand uses making it a versatile product. Paradoxically the demand for rubber is highly concentrated in the automobile tire market that consumes 80 to 90% of the rubber extracted in Brazil [25].

Natural rubber can be gathered either in native forests or in forest plantations, which have two very different production systems and production chains. In the Amazon, the prevalent system is rubber tapping in native forests by the traditional harvest system. Currently, rubber tapping in the Amazon is a source of income for 5 to 10 thousand families, mainly located in Acre and Amazonas states [9]. In the last 20 years (1994-2013) the range of municipal production stretched from 1 to 400 ton (Figure 3.1). The highest mean production volumes occurred in states of Amazonas, Acre, and Rondônia. Southern part of Amazonas and Acre also reached the highest mean total production values with a maximum of US$ 360 thousand (Figure 3.2).

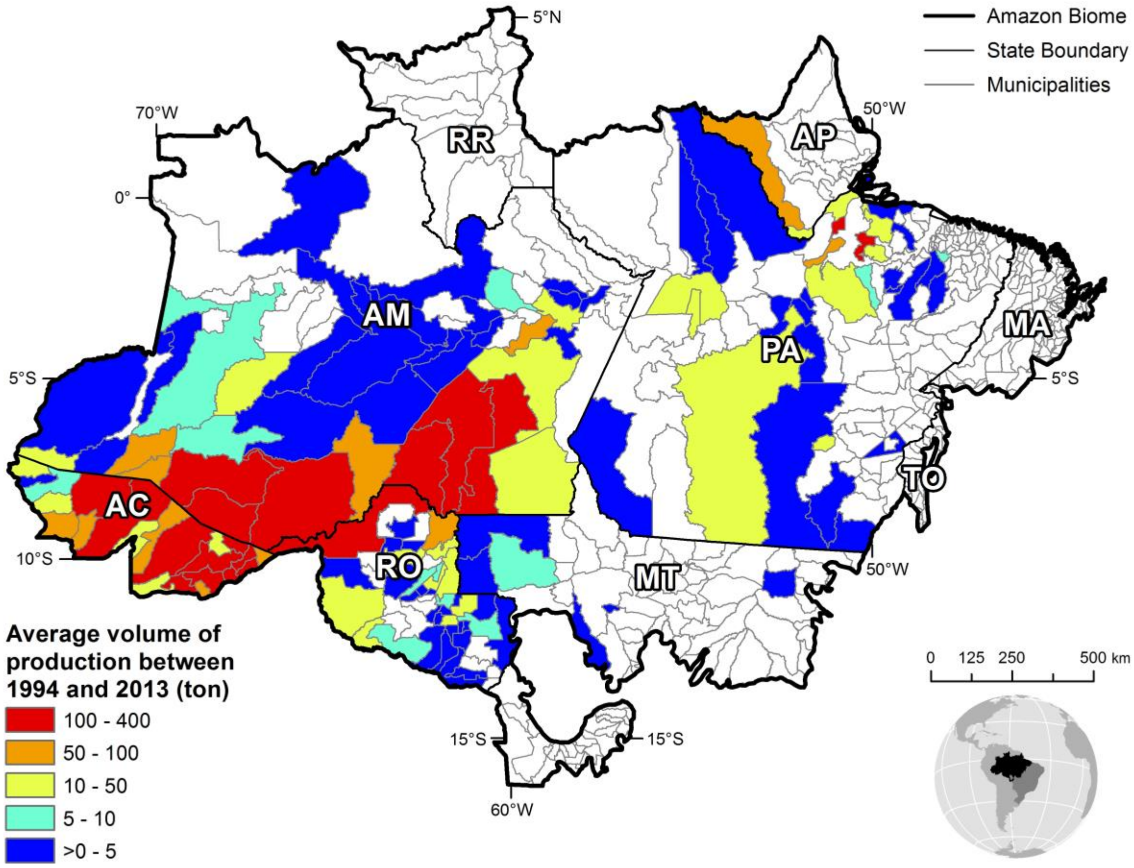

Figure 3.1 - Mean total rubber production (ton) by municipality from 1994 to 2013. Source: [9].

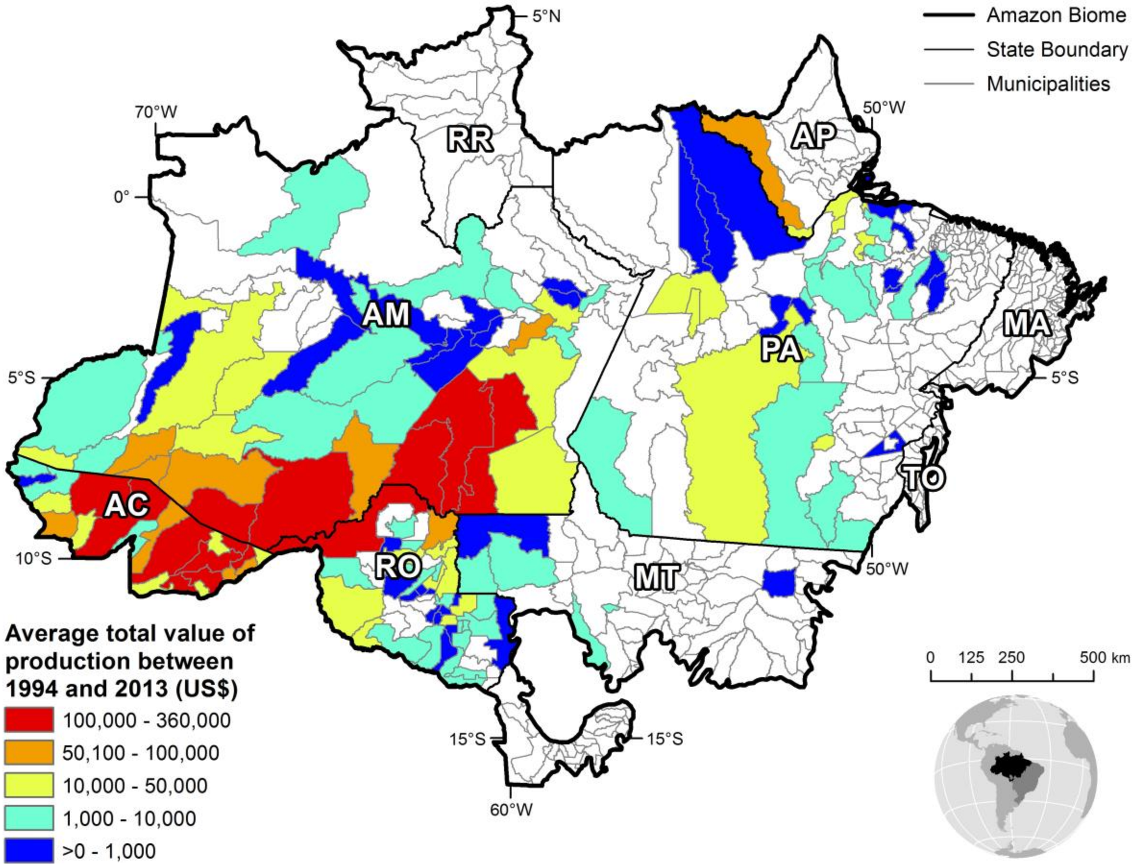

Figure 3.2 - Average total value of rubber production by municipality from 1994 to 2013. Source: [9].

As in the case of Brazil nut, the average annual production for rubber hides a great annual variability. In 2013, only four municipalities (one in Acre and three in Amazonas) produced a maximum of 300 tons of rubber. The production of rubber ranged from 50 to 100 tons (in municipalities in orange), but the majority of the municipalities in the Brazilian Amazon had no production at all (municipalities depicted in white) (Figure 3.3).

The municipalities where production was higher had higher total values of production with a maximum of US$ 500 thousand (red). The majority of the municipalities producing rubber had values of production ranging from about US$ 10 to US$ 200 thousand (in orange and yellow) (Figure 3.4).

By analyzing the maximum production per municipality over a 20-year period, we get a different picture. Figure 3.5 shows a larger number of municipalities with maximum production records that were not highlighted from analyzing only the average total values, neither 2013 data. This likely occurs because the steadily declining prices of rubber make the rubber extraction no longer economically viable to many local communities. According to Figure 3.5, the maximum production between 1994 and 2013 was 1,900 tons, whereas in 2013 it was 300 tons (Figure 3.3).

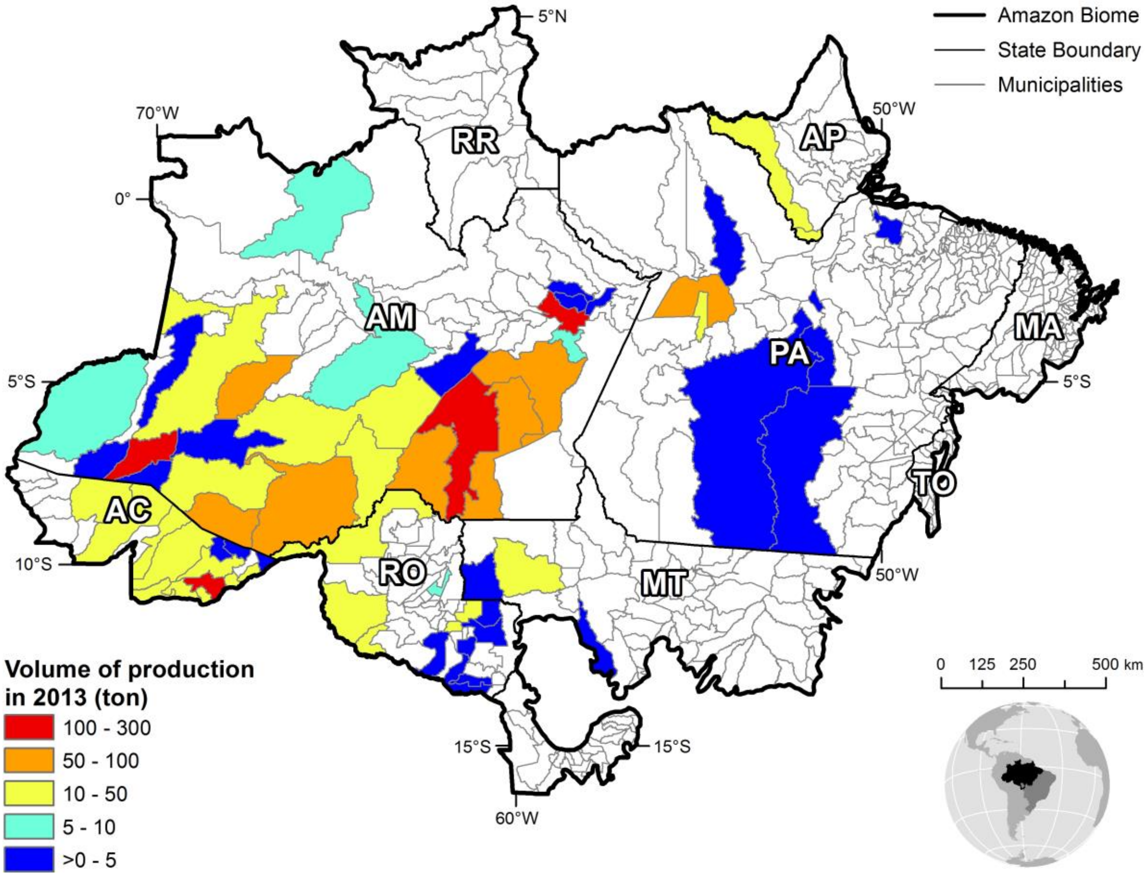

Figure 3.3 - Volume of rubber production (ton) by municipality in 2013. Source: [9].

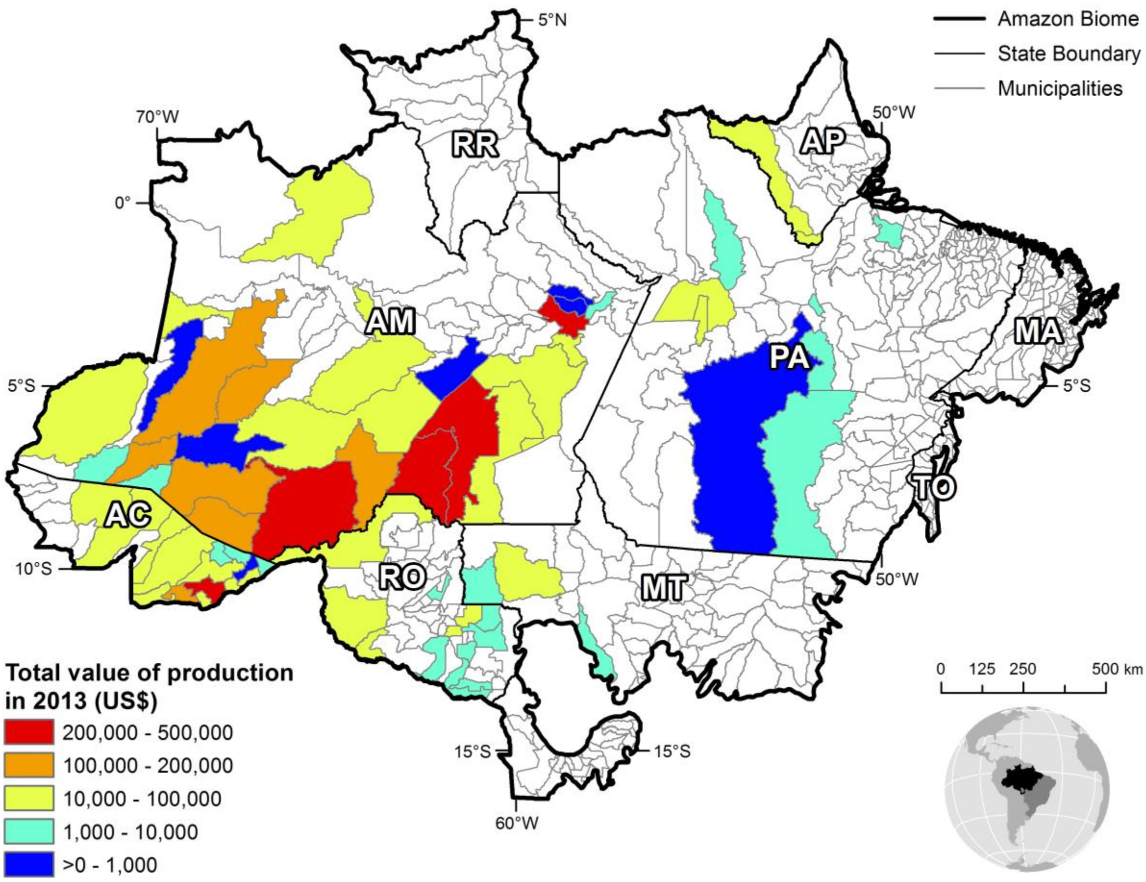

Figure 3.4 - Total value of rubber production by municipality in 2013. Source: [9].

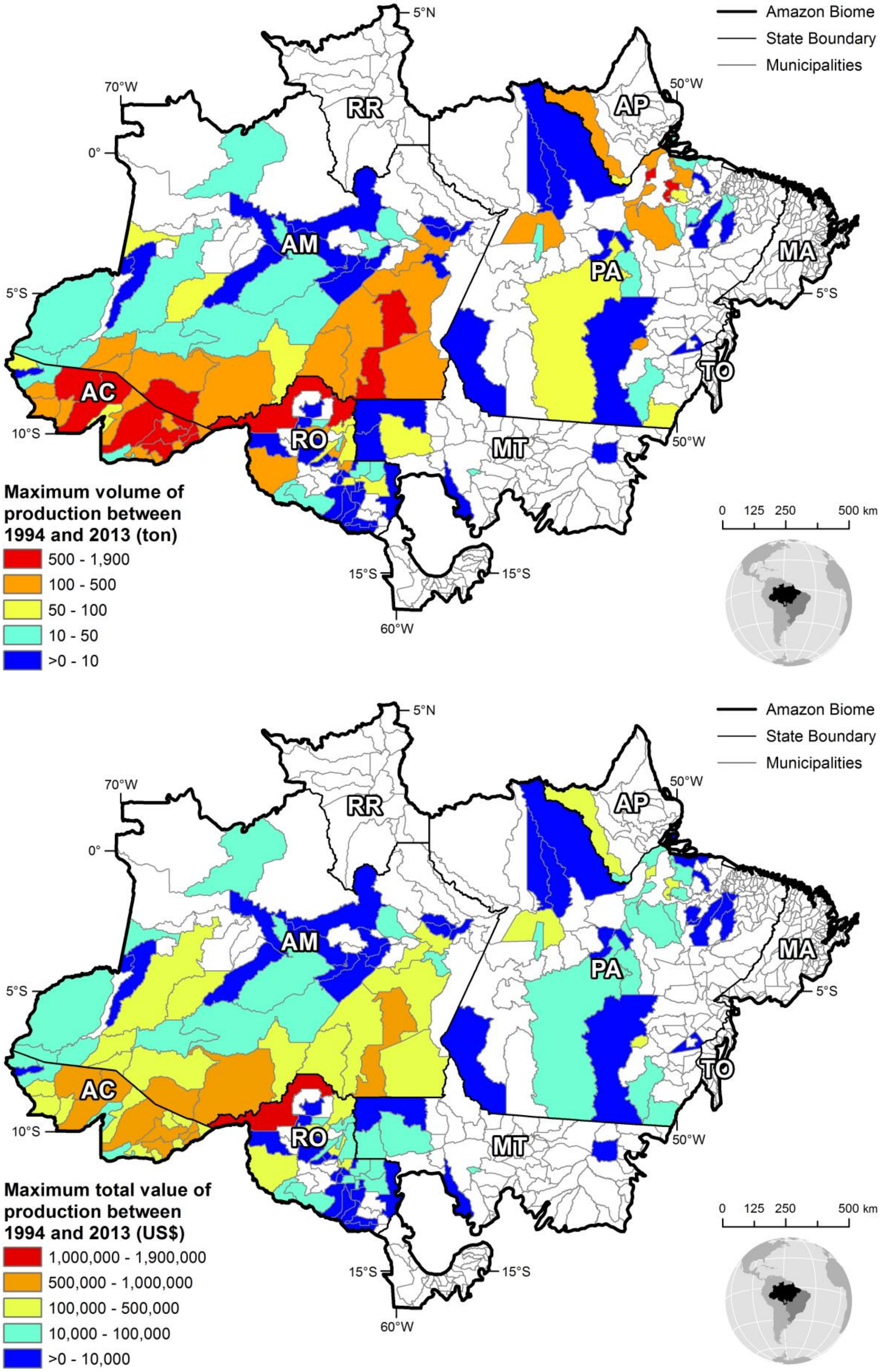

Figure 3.5 - Maximum volume of rubber production (upper map) and maximum total value of production (lower map) over the period 1994-2003. Source: [9].

As depicted in Figure 3.5, the majority of the municipalities producing rubber had relatively high (orange to red) values and volumes of production. However, the maximum value occurred only in Rondônia (municipality of Porto Velho) in the year of 1995.

We calculated the price per kg by dividing production value by volume of production. The minimum price over the last two decades was of US$ 0.3 while the maximum was of US$ 2.1 in the municipalities in Acre (Figure 3.6).

Average prices were highest in Amazonas (around US$ 2), following in Acre and Rondônia with mean prices (over the last two decades) around US$ 1. Pará had mean prices of US$ 0.5 (Figure 3.7). Maximum prices per kg of rubber, which reached as high as US$ 3.9, occurred in municipalities of Amazonas, Acre, and Pará (Figure 3.8).

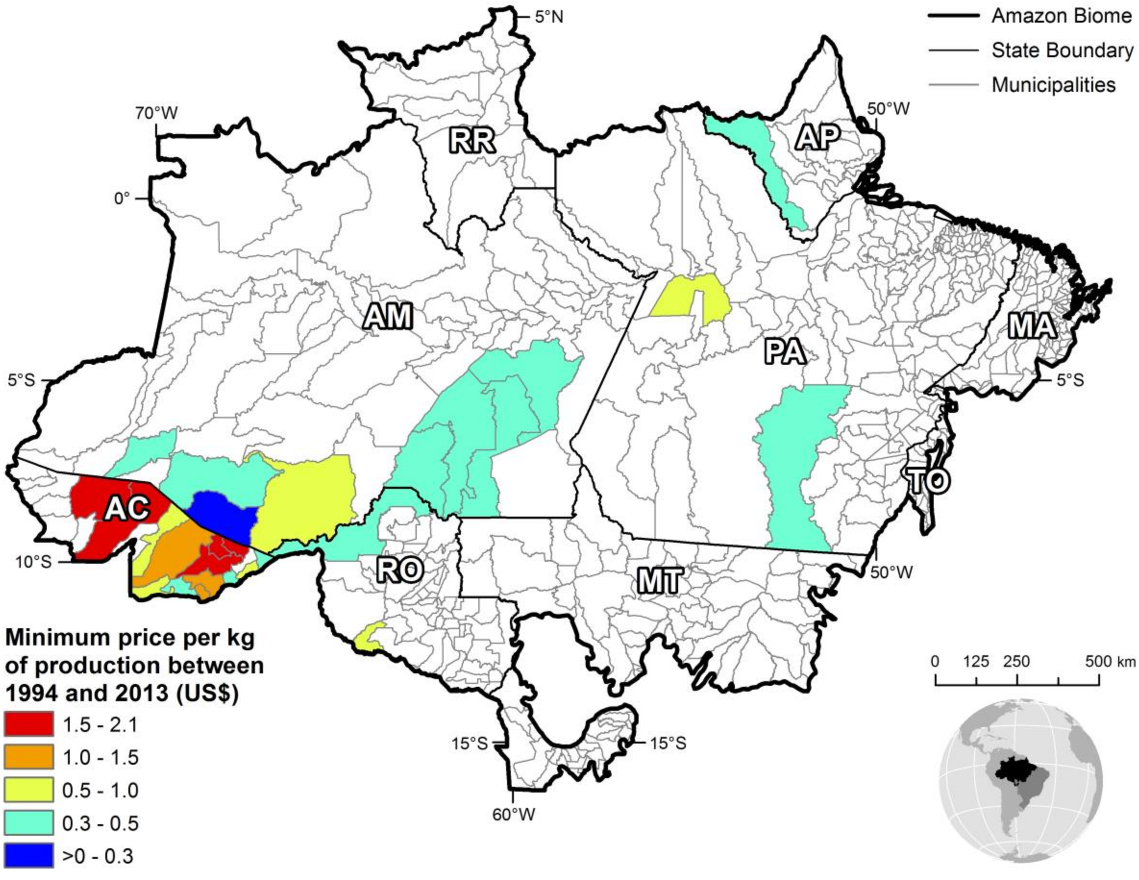

Figure 3.6 - Minimum price of rubber per kg by municipality over the period 1994-2003.
Source: [9].

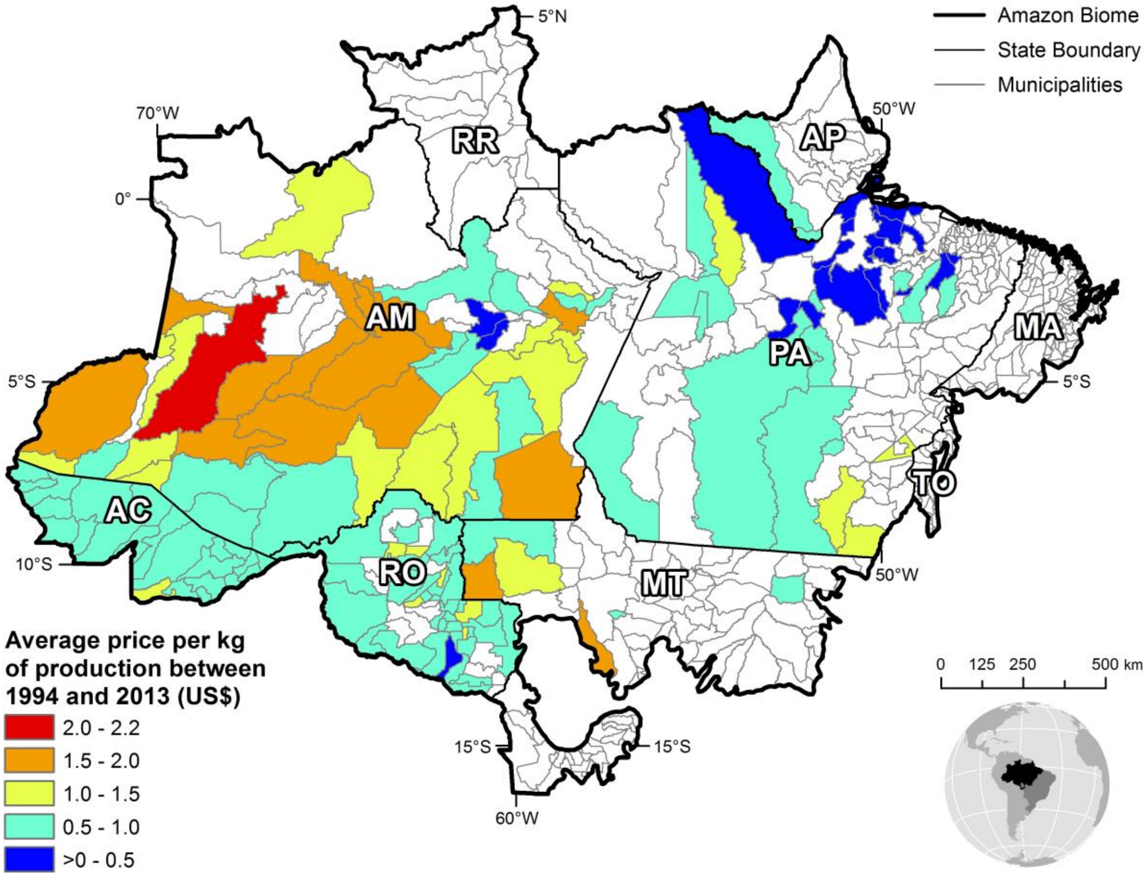

Figure 3.7 - Average price of rubber production over the period 1994-2003. Source: [9].

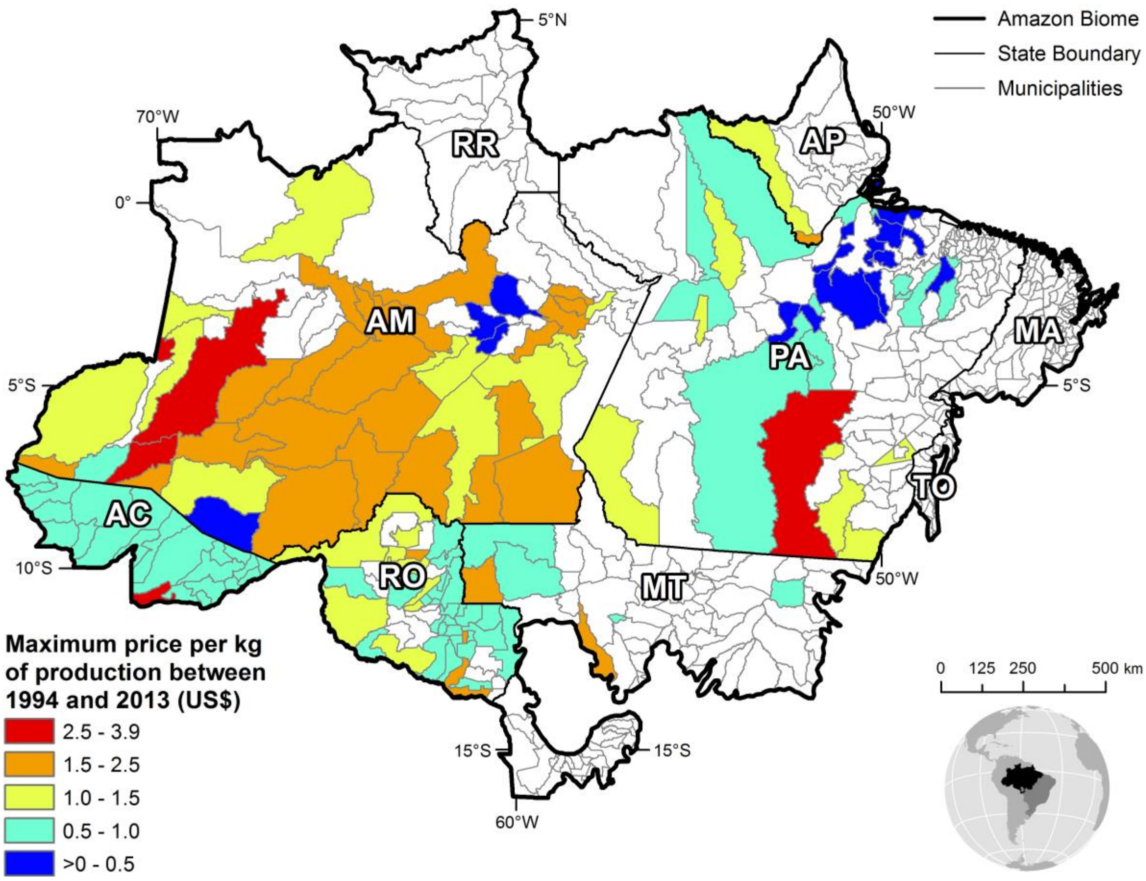

Figure 3.8 - Maximum price of rubber per kg over the period 1994-2003. Source: [9].

The IBGE datasets do not distinguish the different products derived from rubber, although those products have different market prices. The product list for rubber collected in the Brazilian Amazon includes:

1) **Pressed Virgin Rubber (PVR**), which is produced throughout the Amazon. PVR is the raw material of GEB (Granulado Escuro Brasileiro) used in the automotive industry. This product represents 80 to 90% of the market share in the Amazon.
2) **Liquid Smoked Sheets (LSS),** which are sheets of rubber coagulated by Pyroligneous acid. LSS technology was developed by the department of chemistry of the Federal University of Brasilia (UNB)[7] to generate thin sheets of pure rubber for many applications, but currently mainly used as shoe soles. This product has a small share (around 5%) of the market and it has been promoted based on national and international community-industry partnerships [8,9].
3) **Liquid Latex (LL)** also holds a small share of the market. LL is used to produce toys and other objects. It is the main raw material for the NATEX factory. In order to diversify production chain, the Acre State Government set up in 2005 a factory of condoms in Xapurí. This was the first factory in the world producing condoms from rubber extracted from native trees [26].

In this study, we modeled only the rents for PVR due to its dominance in the market (Section 3.3.1). We nevertheless describe the LSS and LL productive systems in Acre (Section 3.3.2).

Recently, as depicted from IBGE data [9], rubber prices have been steadily decreasing. Rubber is an international commodity and so prices are set through international markets[10] (Figure 3.9). Estimates show that as production decreases 1,000 tons, 2,500 families leave the rubber activity in the Brazilian Amazon [27]. Countrywide, the prices are also declining. States where the rubber prices have been steadily decreasing are São Paulo, Bahia, and Espírito Santo, with values around the minimum price of US$ 0.76 per kg. In the Amazon, although there is a decreasing trend in prices, the prices paid to producers have so far kept relatively steady (Figure 3.9).

[7] Available at: <http://www.unb.br/noticias/unbagencia/unbagencia.php?id=8750>. Accessed in 15 May 2015.

[8] Available at: http://www.wwf.org.br/wwf_brasil/?40102/wwf-brasil-busca-valorizar-a-borracha-nativa-da-amaznia>. Accessed in 15 May 2015.

[9] Available at: <https://jamaraqua.wordpress.com/produtos-latex/>. Accessed in 15 May 2015.

[10] Available at: <http://rubberboard.org.in/rubberprice.asp?url=internationalrubberprice.asp>. Accessed in 15 May 2015.

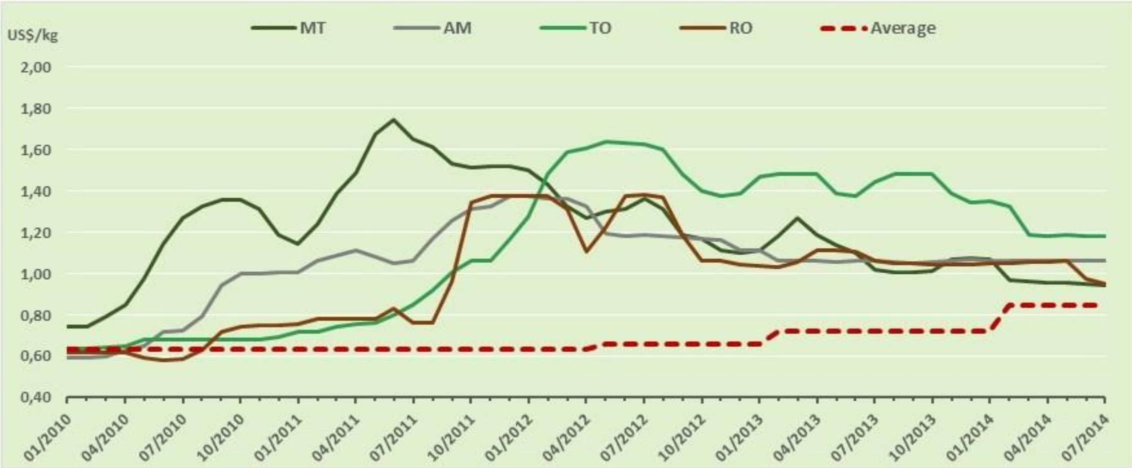

Figure 3.9 - Price received by producers by kg of PVR. Source: [28].
*AC: Acre, AM: Amazonas, AP: Amapá, RR: Roraima, PA: Pará, RO: Rondônia.

PVR has very low market prices (average US$ 0.76). Low prices added to the low productivity of the native forest results in a very low income [29]. In order to produce 1 kg of PVR, approximately 2 liters of latex are needed since the Dry Rubber Content (DRC) is 0.53. The tappers must walk several hours a day to collect the equivalent of 1 kg of dry rubber and they are fully dependent on the local buyers "middlemen" as well as governmemt subsidies.

LSS is commercialized as processed vulcanized sheets that have a market value of US$ 3.30 kg^{-1}. LSS requires the latex in liquid form and it has to be processed in the same day of collection. Thus, collecting latex for LSS implies that the rubber tapper has to do two journeys in the forest in the same day (cutting the tree, placing the pots, and, in the way back, gathering the latex, and transporting it to the nearest community for processing it in the same day). The area of forests normally used to gather latex for LSS is around 10 to 20 km around the villages[11]. LSS processing requires a substantial infrastructure (listed in Table S8 in Supplementary Material) and small processing centers. LSS and other differentiated products from rubber (*e.g.* FSA - Folha Semi Artefato) do attract higher prices. They are differentiated products based on specific market niches. Examples of these are the new vegetable *encauchados*[12], which have process based on a social-eco-technology [30]. Figure 3.10 summarizes the rubber production chain and the actors involved.

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[11] A man walks around 10-20 km a day to bring the latex in liquid form to process in the same day in LSS.
[12] Available at: <http://www.poloprobio.org.br/site/index.php?option=com_content&view=article&id=38:teve-inicio-no-mes-de-maio-proximo-passado-a-segunda-etapa-do-projeto-encauchados-de-vegetais-da-amazonia-patrocinado-pela-petrobras-por-meio-do-programa-desenvolvimento-a-cidadania-estao-sendo-desenvolvidas-acoes-nos-estados-do-acre-amazonas-para-e-&catid=1:noticias>. Accessed in 15 May 2015.

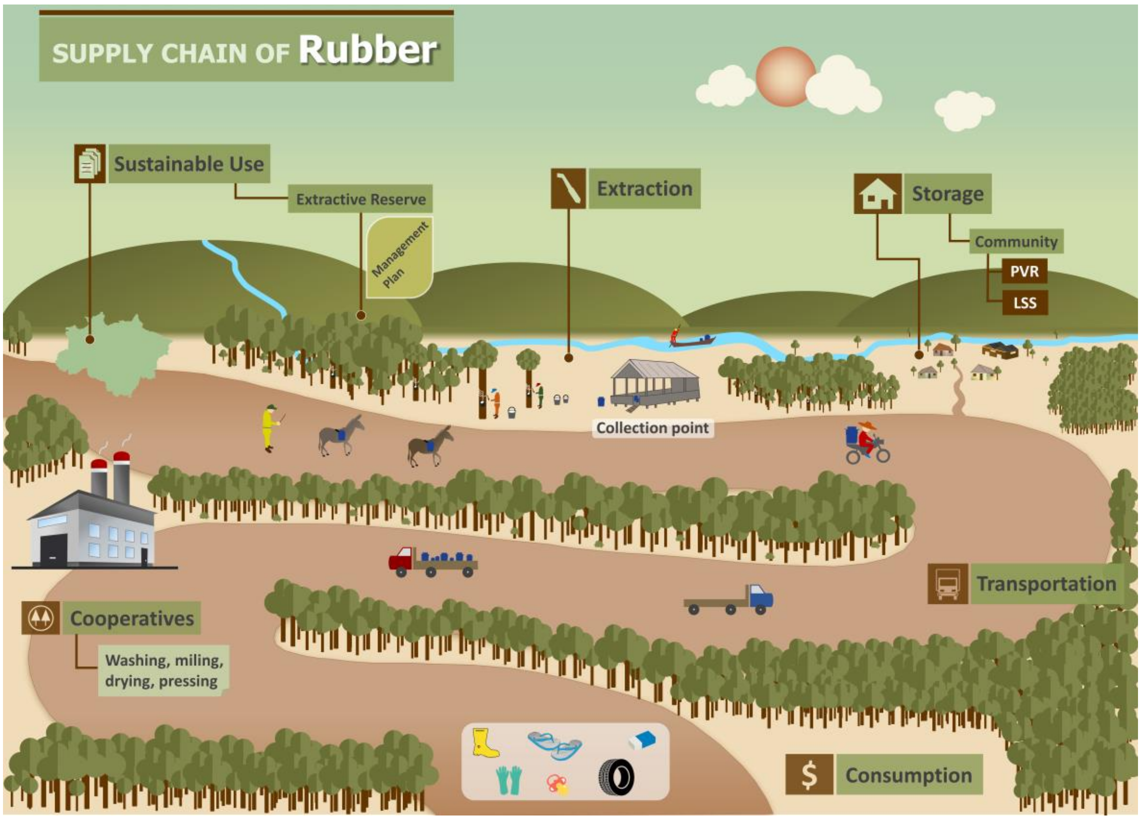


Figure 3.10 - Rubber market chain and actors from extraction/production to the final products. Source: [11].

The adult population of rubber trees (*Hevea spp*) is one of the hyperdominant species in the Amazon. Unlike the Brasil nut tree, which grows in concentrated hotspots, the *Hevea brasiliencis* has a random spatial distribution within the forest[17]. In extractive reserves, the rubber tappers have their own trails "estradas de seringa" in their land called "colocação" covering, for example, around 300 ha of forest each in Acre.

The rubber extraction in native forests comprise two stages:

Preparing extraction - Clearing a trail leading to the rubber trees is done once a year. Before tapping one still needs to clean the tree "painel ou bandeira" and place the pots to collect the rubber. This stage consists in carving the bark of the tree and placing of the pots in each tree (it can be more than one pot depending of the opening of the panel).

Collecting - Cutting the rubber tree (sangria) using a knife "faca de seringa". A man can cut from 80 to 120 trees a day. For Press virgin Rubber PVR the collection might occur over 3 days (called D3) or five days (called D5). In the case of LSS or LL, a daily collection varies from 20 to 20 liters in one path with approximately 120 trees. The liquid latex is then transported to the rubber tapper house where the latex is pre-processed.

3.2. Rubber model

The major rubber products (PVR, LSS, and LL) differ in terms of fixed production and operating costs and prices (Table S7). Our model computes different total costs for each product and includes materials and time demanded for cleaning roads, collecting latex, internal transport (a map of land cover is used to spatially allocate the different means of transport), post-harvest treatments of latex, and storage (Table S8).

Production and transportation costs were collected during field surveys. The potential rents (US$ ha^{-1}) are calculated according to the following equation:

$$Rent_j = (Q_{xy} * P_n) - (Q_{xy} * CTprd_n) - (Q_{xy} * Ctr_n\_d_z) \qquad \text{eq. (2)}$$

where Q_{xy} is the simulated production for a cell with coordinates (x,y) in $kg^{-1}ha^{-1}$; P_n and CT_{prdn} correspond to respectively, selling price and the cost of production in US$/kg of product n and the cost of secondary transportation (Ctr_n) of the product n by means (d_z) from the location (x,y) to the nearest cooperative.

In order to calculate rents, we differentiated high and low productivity areas. Our estimates include the price paid to extractivists according to the guaranteed minimum price. The rubber tapper is paid per kilo of dry rubber, at an affiliated institution, and in addition to the market price, receives a share of the subsidy up to a minimum price.

As previously explained, we estimated rents across the Brazilian Amazon for only PVR (section 3.3.1) as this is the major rubber product. We only calculated LSS and LL rents for Acre (section 3.3.2) where data are available.

3.2.1. Yields

The estimation of rubber favorability followed an equivalent methodological approach as the one for the Brazil nut. The favorability map was transformed into rubber yields (kg $ha^{-1}year^{-1}$) based on the Probability Density Function (PDF) of the yields in the Acre case study (Figures 3.11 and 3.12). While rubber yields varied from 0 to 6 kg per ha in Acre (Figure 3.11), our results for the entire biome vary from 0 to 14 kg $ha^{-1}year^{-1}$ (Figure 3.13). The mean rubber yield in the Brazilian Amazon is 3.53 kg $ha^{-1}year^{-1}$ (Table 3.1). Highest yields are found in the southwest part of the biome including the state of Acre and the southwest part of Amazonas. From these highest production areas, the yield then decreases to the east across the center of the biome, increasing slightly once one nears the state of Pará.

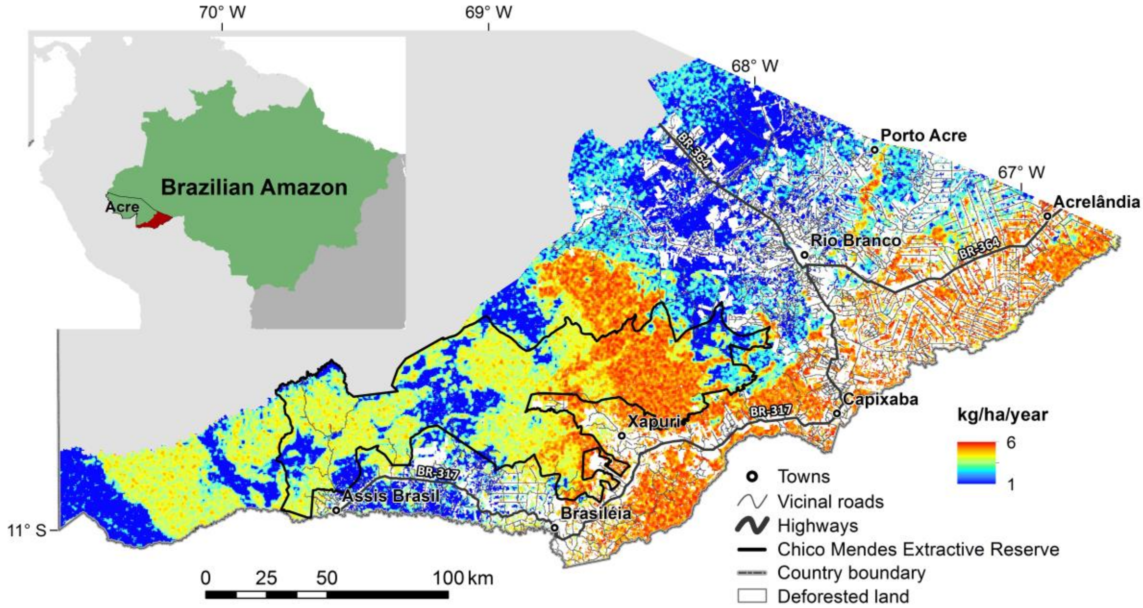


Figure 3.11 - Rubber yields by Jaramillo et al. [17].

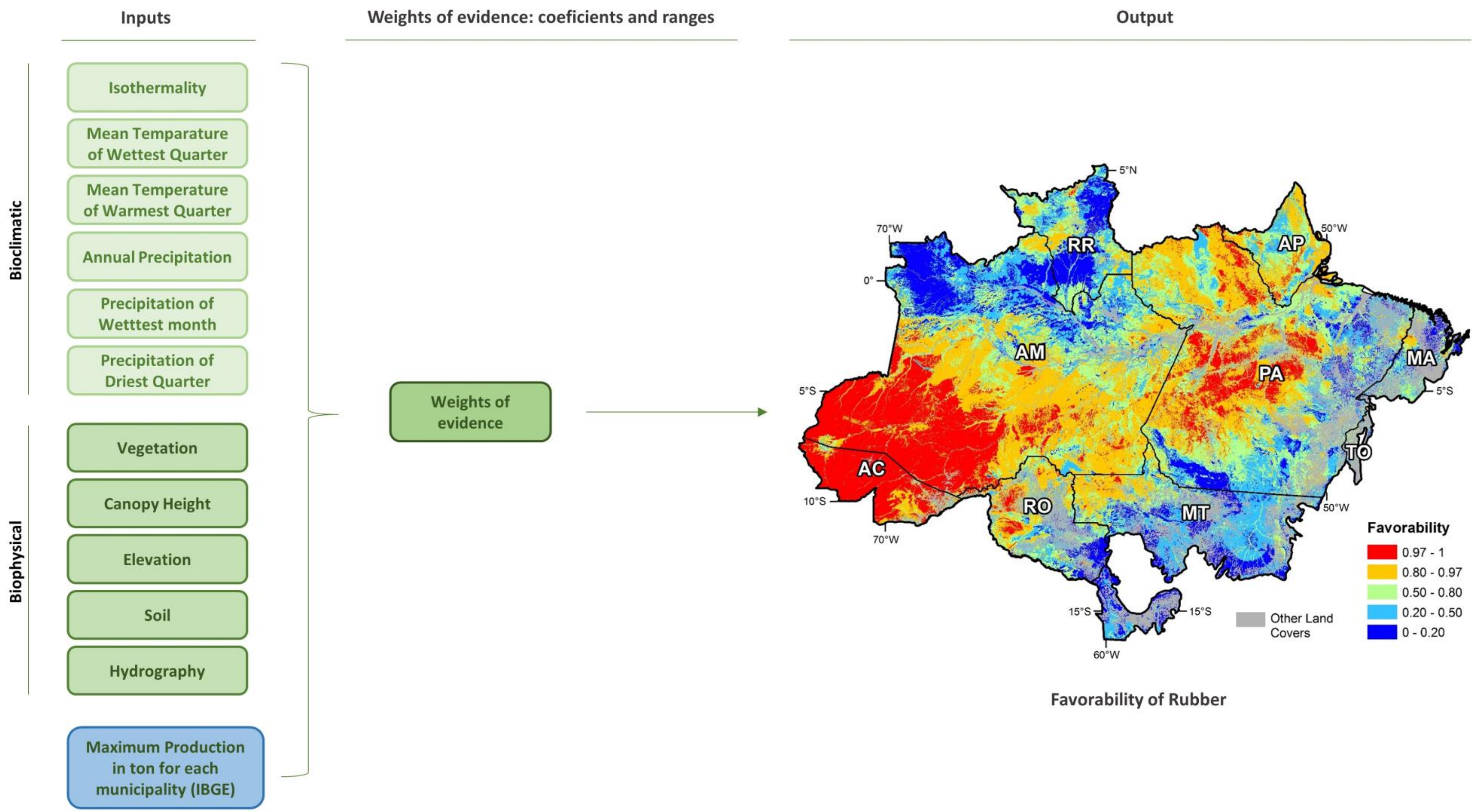


Figure 3.12 - Favorability of productivity for rubber.

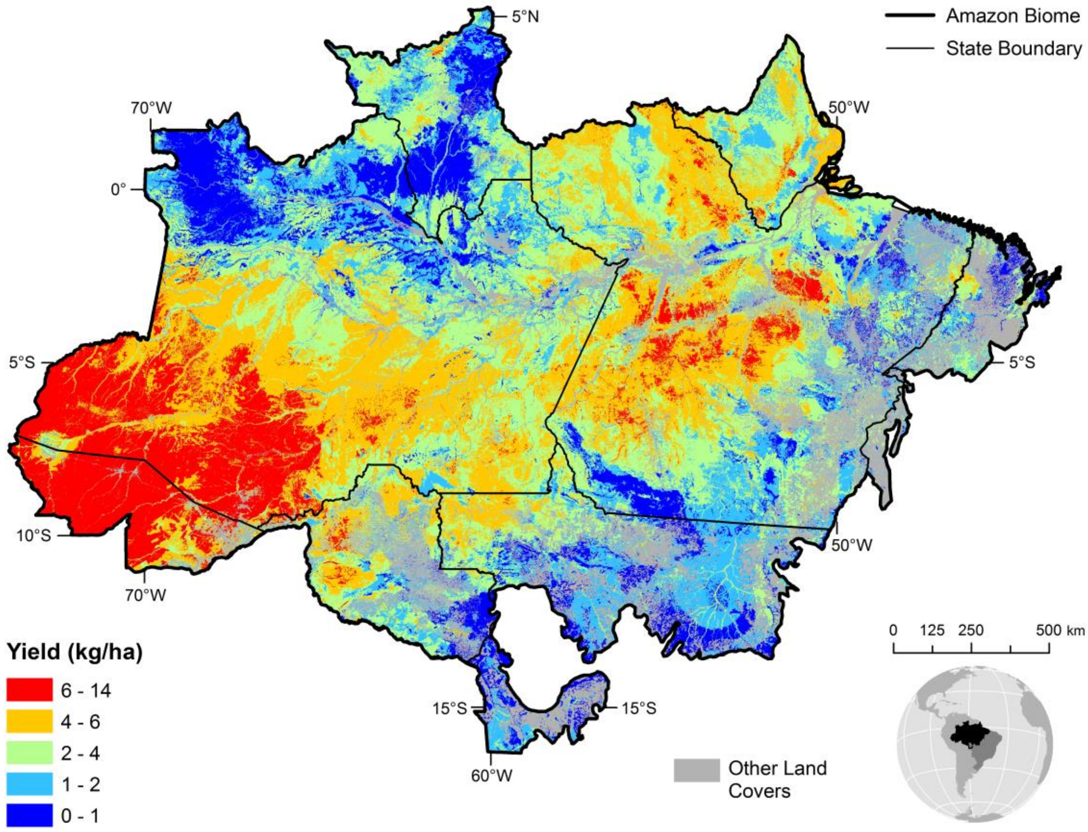


Figure 3.13 - Rubber yields.

Table 3.1 - Rubber yields for the Brazilian Amazon.

Rubber yield ($kg^{-1}ha^{-1}$)	Brazilian Amazon
Minimum	0.00
Maximum	14.00
Mean	3.28
Variance	4.84
Standard deviation	2.20

3.2.2. Prices

As in the case of Brazil nut, the price paid to tappers varies depending on the year/season. In the model, we used the maximum price from the cooperatives in the period 2013 to 2014 (Table 3.2) from the CONAB dataset.

Table 3.2 - Price paid to producer.

State	US$ per kg
Acre	0.80
Amapá	1.09
Amazonas	1.09
Pará	1.21
Maranhão	1.09
Mato Grosso	1.25
Tocantins	1.09
Rondônia	1.12

3.2.3. Extraction costs

The average cost of extracting 1 kg of rubber for PVR ranges from US$ 0.25 to 0.38 for high productivity areas (*i.e*. yield ≥ 3.28 kg per $ha^{-1}year^{-1}$) and from US$ 1.32 to 1.93 for lower productivity areas (Table 3.3). The latter means that is not worth collecting rubber if yields are below the average. For LSS and LL, it is of US$ 1.50 and of US$ 1.27, respectively (Table 3.3). A detailed description of the production costs are provided in the Table S7.

Table 3.3 - Production costs per kg rubber in US$.

Extraction costs per kg of rubber (in US$)	Low productivity	High productivity	Jaramillo et al. [17]
PVR	1.32-1.93	0.25-0.38	0.25
LSS (in production units)	1.50		0.32
LL within 100 km from NATEX	1.27		0.30

Source: [31].

3.2.4. Transport costs

We estimated transport costs for rubber across the forest (Figure 3.14) and from the communities to the nearest cooperative (Figure 3.15). We then combined these maps into the accumulated transportation cost from the forest to the cooperative (Figure 3.16). Across the forest, we use only one-man workday cost (US$ 0.003) because the rubber extraction has recently been so low that rubber tappers do not need donkeys to help transport the product. Based on the transport cost from the forest to the communities in which rubber is produced (we selected only the communities within the municipalities with record of production), we calculated the area of influence of the community and the transport costs from any forest parcel in the forest to the community. Using data from semi-structured interviews, we calculated the cost of transporting one kg of rubber per km by truck and by boat (Table 3.4).

Table 3.4 - Transport costs from communities to the nearest cooperative.

US$ $kg^{-1}km^{-1}$	Fieldwork data	Jaramillo et al. [17]
River	0.001	0.005
Roads	0.0015	0.0011

Source: [31].

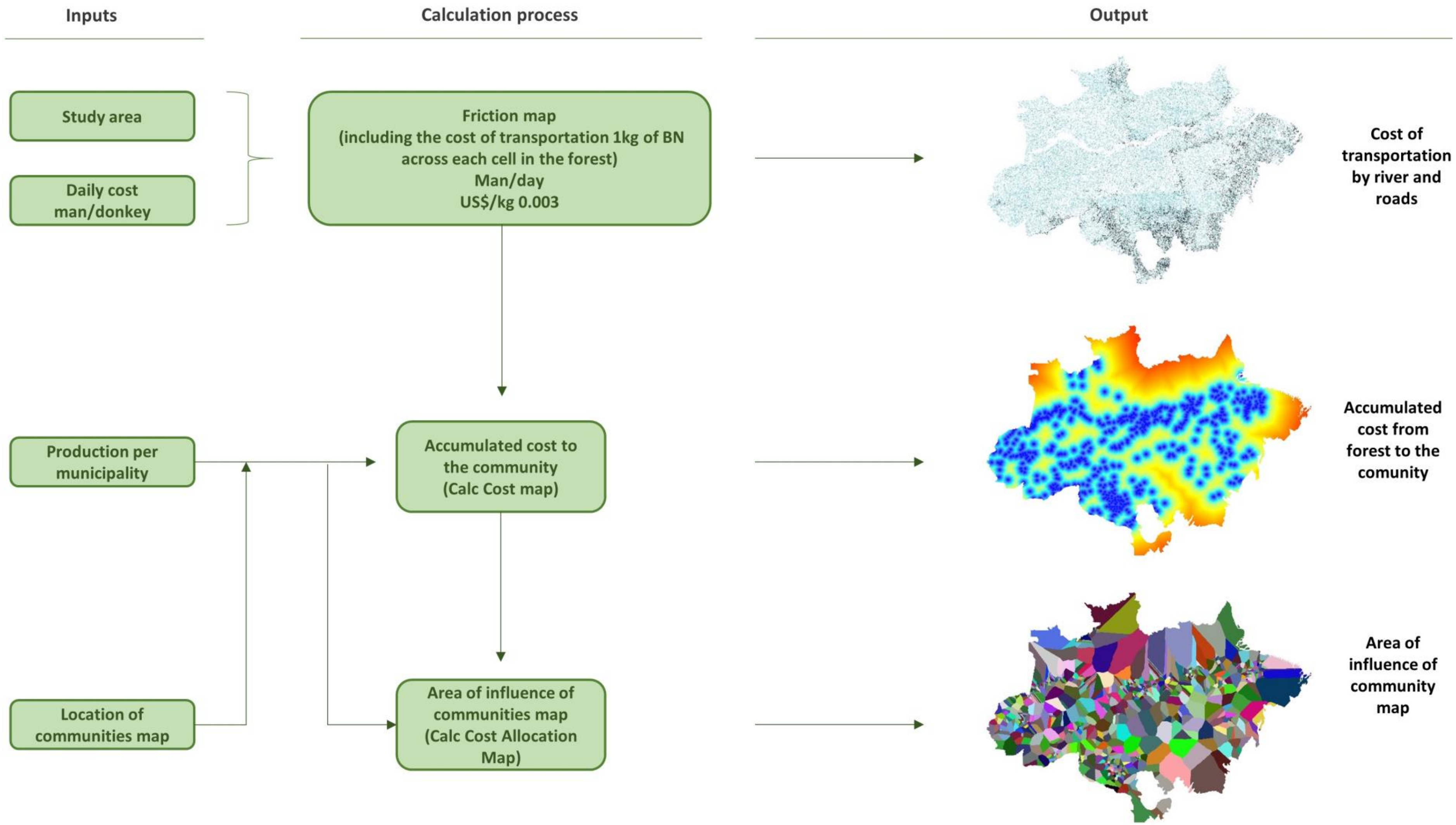


Figure 3.14 -Transport cost of rubber from the forest to the community (village).

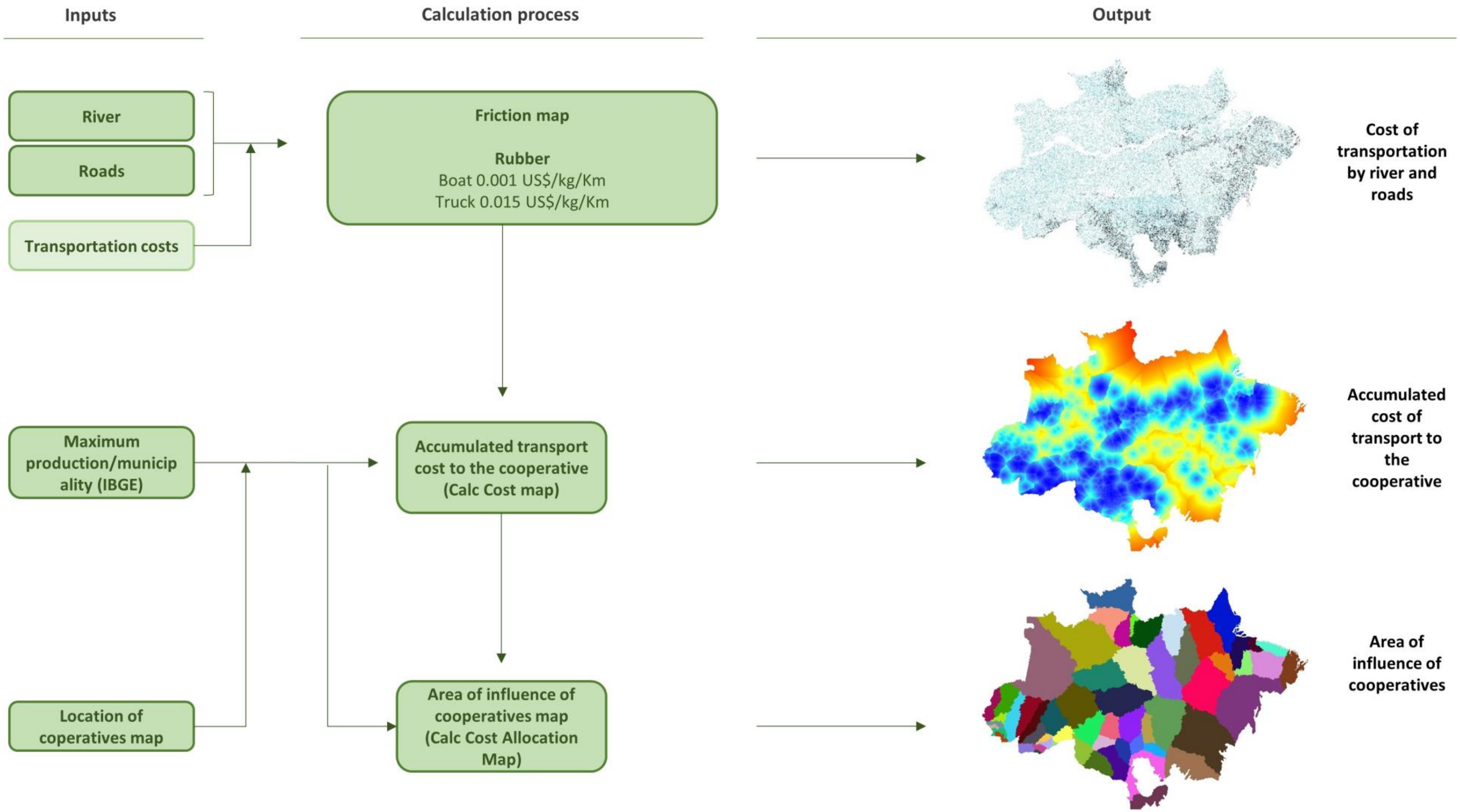


Figure 3.15 - Transport cost of rubber from the community to the cooperative.

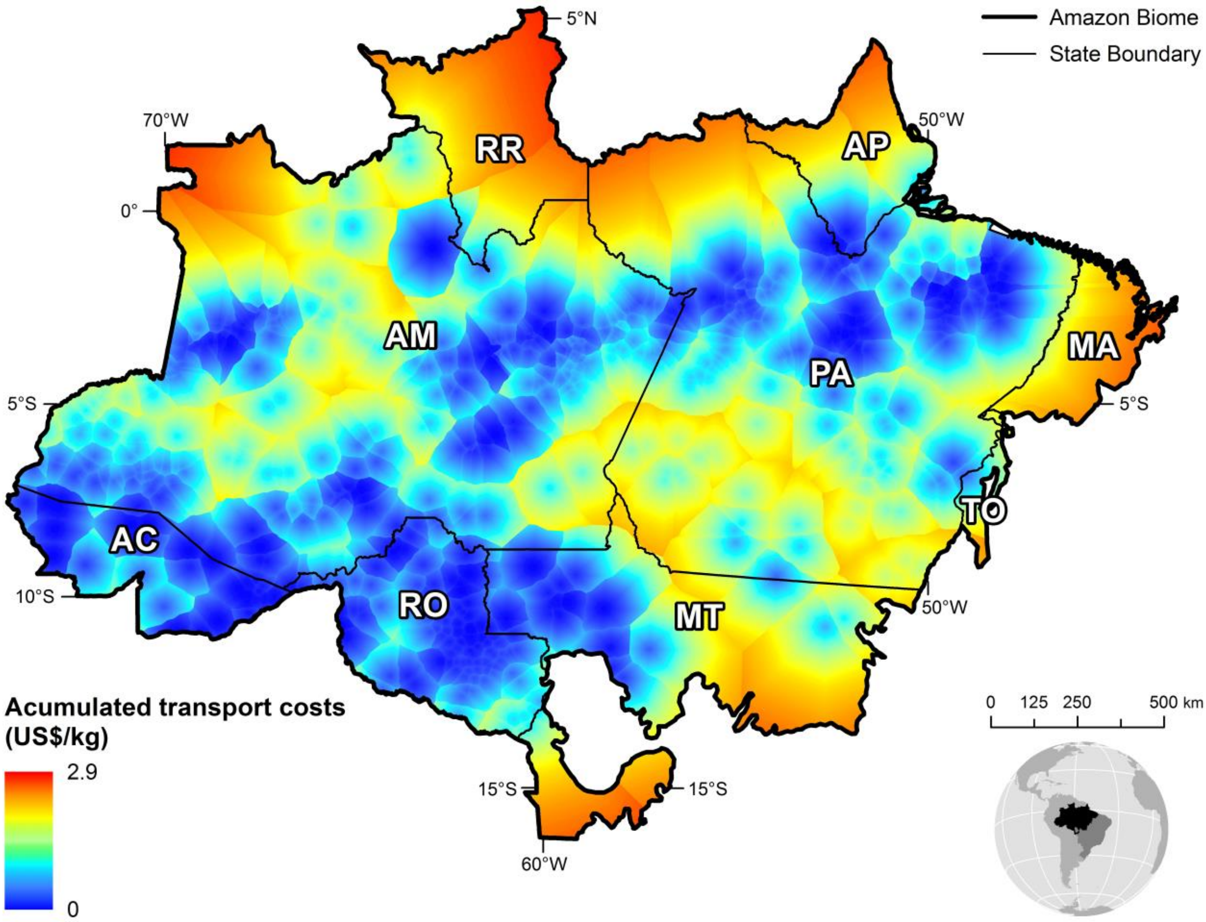


Figure 3.16 - Cost of transport of rubber from the forest to the community and from the community to the cooperative.

3.3. Value map for rubber

3.3.1. PVR in the Amazon

The areas in red in Figure 3.17 show the locations with highest rents. Rubber extraction in the Amazon is not profitable in areas of low productivity even with subsidies to guarantee a minimum price to rubber tappers. In the presence of governmental subsidies and in areas of high productivity, rents average US$ 0.56 $ha^{-1}year^{-1}$, varing from 0 to US$ 6.13 $ha^{-1}year^{-1}$ (Figure 3.17, Table 3.5). Our estimates of potential production for rubber, presented in Figure 3.18, shows that the south part of Amazonas, central Acre, and central Pará hold the highest production potential that can reach a maximum of 61 thousand tons (Figure 3.18).

Although the potential annual production of rubber in the Brazilian Amazon as a whole could reach 1.36 million tons (Table 3.6), our results show that only few areas are profitable due to better access and the presence of labor, and hence supply chain. Considering rents equal or greater than US$ 2 $ha^{-1}year^{-1}$, rubber supply chains could be developed only in 20 Mha of forests producing 150 thousand of tons per year. Table 3.6

exemplifies the case for a set of municipalities. While, for example, Alta Floresta D'Oeste, according to IBGE had a maximum production of 9 tons, our model estimates a potential of production of nearly 1.4 thousand tons.

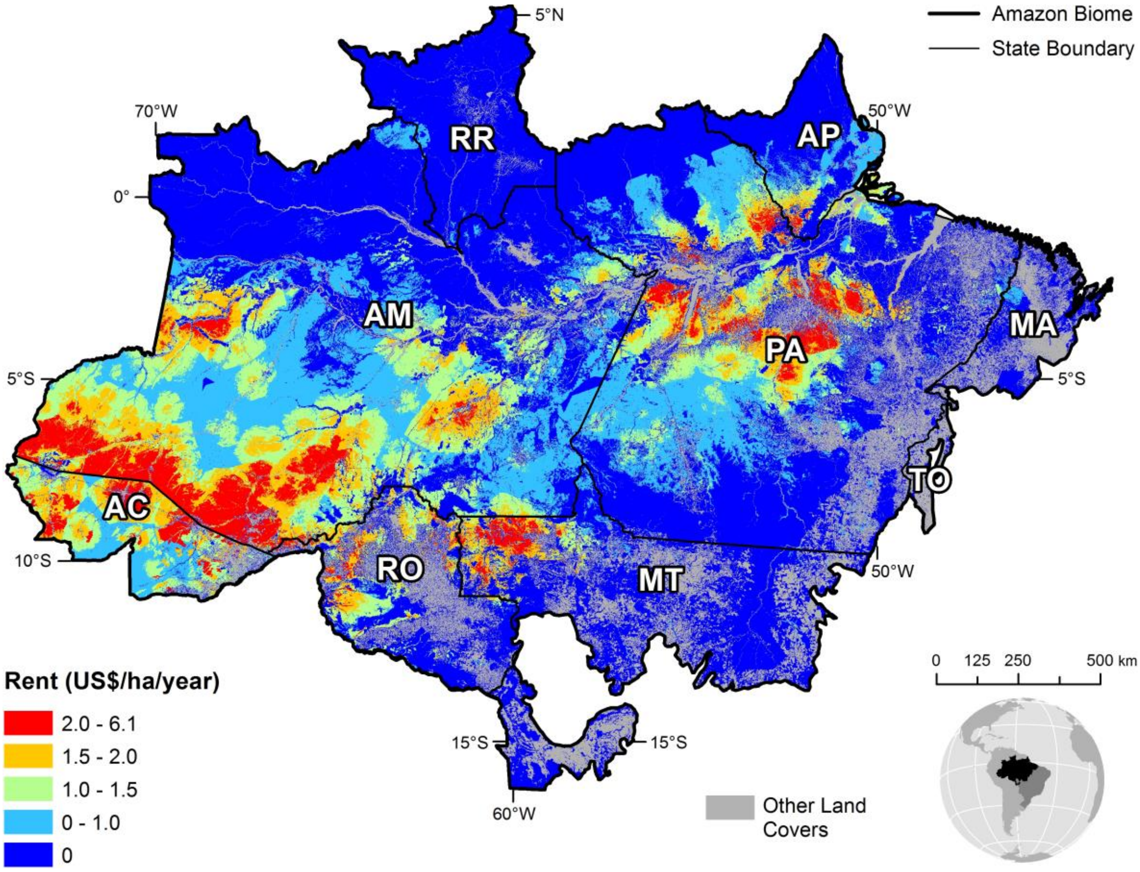


Figure 3.17 - Rents rubber extraction.

Table 3.5 - Rents for rubber.

Rents (US$ ha^{-1})	Brazilian Amazon
Minimum	0.00
Maximum	6.13
Mean	0.56
Variance	0.57
Standard deviation	0.76

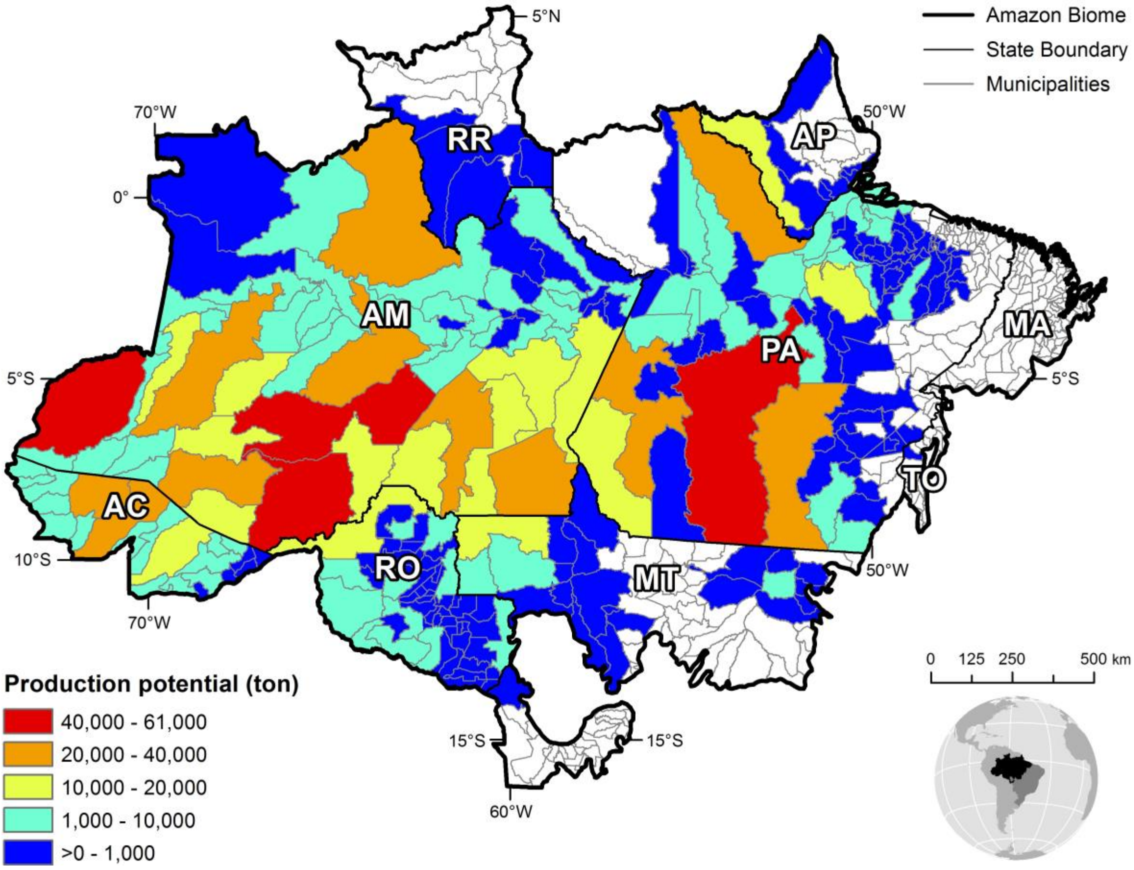


Figure 3.18 - Potential production of rubber per municipality.

Table 3.6 - Current versus potencial production.

Municipality	IBGE-Max (ton)	IBGE-Min (ton)	Our simulation of potential (ton)
Alta Floresta D'Oeste	9.00	2.00	1,402
Ariqemes	105.00	2.00	989
Cabixi	0.00	0.00	99
Cacoal	42.00	8.00	643
Cerejeiras	8.00	2.00	335
TOTAL			1.36 million

Source: [9].

3.3.2. Rents from LSS, LL, and PVR in Acre

Acre is the only state in the Amazon that has consistently invested in diversifying rubber products. In in 2005 the Acre State Government set up a condom factory in Xapurí, named Natex Condoms. This was the first factory in the world producing condoms from Liquid Latex (LL) extracted from native rubber tree [26]. Since 2006, various other municipal initiatives have also supported different associations to produce

Liquid Smoked Sheet, (LSS) used as shoe soles. LSS technology was developed by the department of chemistry at the Federal University of Brasilia (UNB) to generate thin sheets of pure rubber.

In stark contrast to other other Amazon state, where PVR is the only product, the consolidation of the rubber chain in the Acre is moving forward based on 3 major rubber products: Liquid Latex (LL); Liquid Smoked Sheet (LSS); and Pressed Virgin Rubber (PVR). Therefore, we developed estimates for the rents of the three major rubber products in Acre. In order to do so, we divided the yield map for the Acre state into 3 major “product specific” regions:

1. From a 100 km radius from Xapuri, where Natex condoms industry is located, we assigned the yields to the production of LL only. Natex industry told us that it collects all the latex from a 100 km radius. In the model, we therefore allocated a 100 km buffer area around NATEX for producing exclusively LL.
2. From our fieldwork interviews, we collected the number of production units of LSS in the different municipalities in Acre. We assumed that in these municipalities the remaing available product is transformed into PVR (Table 3.7)
3. The volume in the remaining municipalities (excluding the 100 km buffer from NATEX and the municipalities producing LSS) was also assigned to PVR production.

Table 3.7 - Allocation of Acre yield between LSS and PVR.

Municipality	Production units of LSS	% of yield into LSS	% of yield into PVR
Assis Brasil	90	90	10
Feijo	20	20	80
Tauruaca	20	20	80
Marechal Thaumaturgo	50	50	50

The results show that the average profitability of rubber is significantly higher than the ones we found only for PVR for the rest of the biome. Our estimates show that the highest rent from PVR is of US$ 11.26, while maximum rents for other rubber products reach US$ 38.61 and US$ 27.85 in the case of LSS and LL, respectively (Table 3.8). By summing up the rents for the three rubber products, annual rents of rubber can reach a maximum of US$ 40 $ha^{-1}year^{-1}$ (Figure 3.19). This value is considerably higher than the US$ 6.1 average for the Brazilian Amazon (Figure 3.17).

Table 3.8 - Rents for the three major rubber products in Acre (US$ $ha^{-1}year^{-1}$).

Rents	PVR	LSS	LL
Min	0	0	0
Max	11.26	38.61	27,85
Mean	3.24	2.95	0.79
Variance	4.04	21.89	9.41
Standard deviation	2.01	4.67	3.06
Area (in million ha) with positive rents	15	6	1

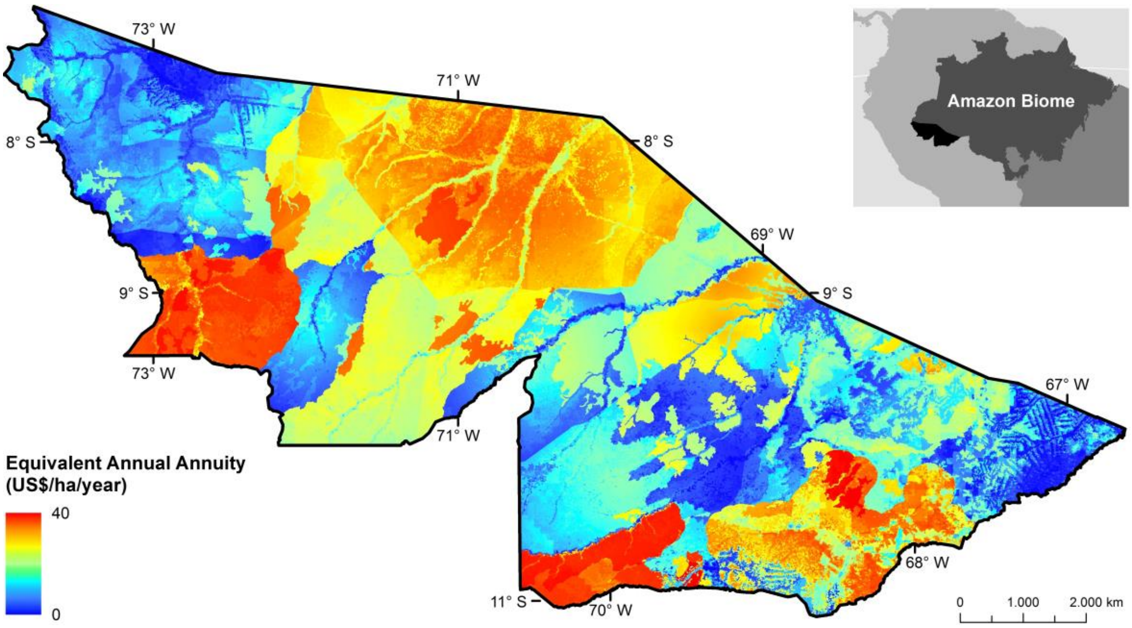


Figure 3.19 - Rents for three rubber products (PVR, LSS, and LL) in Acre.

4. Discussion and Final Remarks

Whether Non Timber Forest Products (NTFPs) in the Amazon enhance local livelihoods while helping to reduce deforestation has been the topic of a prolonged debate [32]. From the 70s onwards, NTFPs were regarded as “promising” due to their likelihood of achieving both conservation and development goals, and were thus incentivized through public policies, although via “narrow” market chains based on specific products [32]. Recently, disenchantment seems to be the norm about the sustainable forestry “solutions”. Regardless of potential conservation outcomes from sustainable collection/extraction of NTFPs, they are undoubtedly important economic options for forest-friendly livelihoods and, therefore, need policies to secure and enhance their supply chains [8]. In this respect, we must recognize the importance of NTFPs for biodiversity conservation and maintenance of forest livelihoods, and as such, we need to value the importance and sustainability of local extraction activities in order to find alternatives to market failures. Rather than attempting to valuate ecosystem services per se, this is therefore the aim of our study.

Our modelling approach is based on flow—the capture of annual rents delivered by rubber and Brazil nut collection. Returns to Brazil nut harvest average US$ 5.05 $ha^{-1}year^{-1}$, while rubber extraction in the Amazon is not profitable in areas of low productiviy. However, in areas with yields above the mean (yields ≥ 3.53 kg $ha^{-1}year^{-1}$) and in the presence of governmental subsidies, rubber rents average US$ 0.56±0.7 $ha^{-1}year^{-1}$. Thus, our results shows, in line with the literature, that NTFPs seldom account for a large share of a household's total income since the rents are relatively low, especially in the case of rubber.

To our knowledge, this is the first study to estimate annual rents for the entire Brazilian Amazon, so it is difficult to compare our result with those focusing on local production. The Natural Capital project, the only biome wide assessment did not monetize NTFPs. We may assert however that our results broadly agree with the ones from the case study literature (Table 1.1). Godoy et al. [6] found annual returns of US$ 4.8 $ha^{-1}year^{-1}$ in the Amazon, or rents of US$ 97 $ha^{-1}year^{-1}$ for a set of three products (rubber, açaí and fish) along the Guamá river. Our estimates also largely agree with Gram et al. [2].

It is important to note that while our study shows that rents are low, the production potential is substantial. The potential annual production for Brazil nut and rubber in the Brazilian Amazon as a whole could reach 3.7 and 1.36 million tons, respectively (Figures 2.18 and 3.18). However, only a few areas are profitable due to the quality of access and presence of a work force, and hence supply chain. This finding highlights a mismatch between what is annually harvested and the potential production of areas that could be further exploited. Conversely to results by Peres et al. [4] which reported unsustainable trends of Brazil nut collection, our results suggest that the flow annually collected falls well below the biome potential harvest. Our findings are also supported by other studies [33, 34].

Areas that systematically present higher annual rents are located nearby villages/towns with better access and larger population (Figures 2.17 and 3.17). These areas, by contrast, are also the areas with higher rates of deforestation. Thus, it seems likely that factors that influence the rents at the local level also drive forest conversion. However, NTFP development in the form of better markets, improved infrastructure and higher product demand and/or prices, could provide an alternative to forest conversion to agriculture, and hence be an ally of forest conservation. Unfortunately, this is not the current situation. Our results show that rubber and Brazil nut collection do not suffice as income providers. In fact, although both activities complement each other throughout the year, the collector (*extrativista*) heavily relies on intermediaries to pay them in advance and begin collection in debt.

A key difference between most NTFPs and agricultural products is that they often come from locations that are a fair distance from the harvester's home and over which the collectors have no secure tenure. Storage, processing and transport, can also be complex (Figures 2.13, 2.14, 3.14 and 3.15). Moreover, if the product is traded internationally, as in the case of rubber and Brazil nut, export and import requirements—including but not limited to quality standards, phytosanitary regulations, permits and taxes—must be fulfilled. Certification schemes (particularly for timber and Brazil nut) require a high level of organization and technical sophistication, especially with regard to management plans, monitoring, and product traceability and marketing. In addition, the prohibitive costs involved in obtaining certification prevent most NTFP harvesters in Amazon from participating in such initiatives. Even once these obstacles have been overcome, experience suggests that certification does not necessarily guarantee a higher market price.

All these hurdles make non-timber products currently not able to sustain livelihoods in forest dependent communities. Of great concern, the demise of rubber collection seems near if we are unable to find other ways to aggregate value in its supply chain [17]. Selling products in mainstream markets that are dependent on global market prices has proven ineffective (section 3.3.1). In Acre, however, (section 3.3.2) profitability of rubber is substantially higher, reaching a maximum of US$ 40 per $ha^{-1}year^{-1}$, when we consider the possibility of rents from three major products (Figure 3.19). This shows that adding value on the rubber raw material may pay off, but this requires considerable investment. So far, the Acre government has been able to support investments (projects such NATEX condoms industry and LSS initiatives), but this is not the case in other states of the Brazilian Amazon.

On the other hand, a variety of 'green' and 'fair-trade' niche markets might be a useful starting point. However, we need to go beyond the protected arena of fair-trade markets. Another issue is that as NTFPs are often the product of a range of production strategies carried out by different people. Thus, interventions must address both commercialization and subsistance livelihoods.

The results of this study allow us to question the effectiveness of "narrow" market chains based on specific products. We need thus to explore possible policy contexts for enhancing the value of the Amazon forests within a more holistic approach that focuses on the forest as an entity providing multiple ecosystem services. So far, the narrow market chains of sustainable timber and NTFPs were unable to do the job they were meant for because they do not aggregate values to the products that are of paramount importance to sustain local livelihoods. As a result, new solutions are required. Sustainable timber and NTFPs are used as components in people's livelihood strategies according to their economic conditions. Development interventions need to consider this fact and not focus on one product only. To this end, economic diversification is key given that there is a whole range of NTFPs that could be harnessed to boost the rubber and Brazil nut production chains, such as the promising case of açai (Figure 4.1). Public policies should therefore consider timber and the broad variety of NTFPs in the context of the overall forests communities' socio-biodiversity and their potential to conserving the Brazilian Amazon forest.

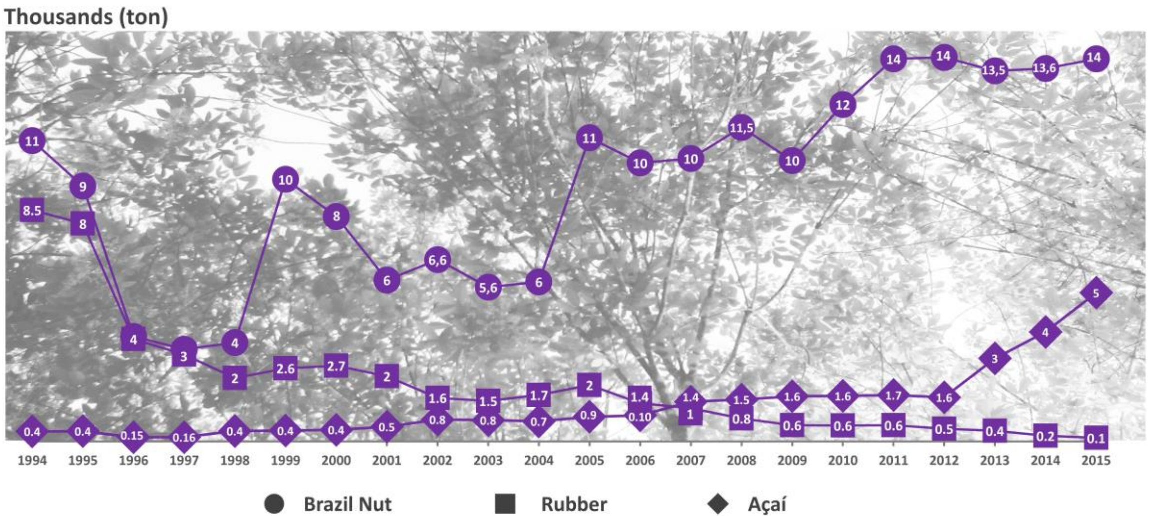


Figure 4.1 - Historical trend of major Amazon NFTPs. Note the recent rise in Açaí production. Source: [35].

5. Supplementary Material

Semi structured interviews (phone/skype)

We contacted organizations across the biome and conducted fieldwork in Acre and Pará.

First, we contacted supply chain stakeholders via email and phone/skype (Table S1). At this stage the topics of discussion were:

1. Describing the different production systems of rubber and Brazil nut across the Amazon States.
2. Contacting major agents on the rubber and Brazil nuts chains (*e.g.* list of cooperatives).
3. Getting detailed descriptions of prices and costs of extraction of rubber and Brazil nut across the biome.

From these interviews, we obtained a detailed list of cooperatives that we mapped at Centro de Sensoriamento Remoto (CSR), and localities in Amazon (Figures S1 and S2).

Table S1 - Institution, stakeholders and major discussion topics.

Rubber	
CONAB Companhia NACIONAL de Abastecimento	Humberto Pennachio Email: humberto.pennacchio@conab.gov.br Tel: (61) 3312-6263 Humberto talked about how is the production of rubber and Brazil nuts varies different states of the Amazon.
CEPLAC Comissão Executiva do Plano da Lavoura Cacaueira	Adonias de Castro Virgens Filho Engenheiro Agrônomo, D. Sc. Pesquisador do MAPA/CEPLAC/CEPEC adoniascastro@cepec.gov.br Tel: 55-73-32143201 Adonias talked about the process of sangria and the processing of rubber to be accepted in the Brazilian market.
Câmara Setorial de Borracha em São Paulo	Fernando Val Guerra – Presidente da Câmara Email: fernando.guerra@santahelenasp.com.br Fernando explained how the production of planted rubber is in southeast of Brazil.
Brazilian nut	
COOPMAS Cooperativa Mista AgroEXTRATIVISTA SARDINHA AM	Astrogildo Oliveira da Costa Fone: (97) 3331-1453 E-mail**:** coopmas-lbr@hotmail.com Astrogildo talked about the collection processes, transportation and marketing of nuts in Coopmas cooperative.
Projeto RECA - RO	Jersiane Tel: (69) 3253-1007 ou (69) 3253-1046. Email: atendimento@projetoreca.com.br

	The project exists to 25 years, with several products involved among them Brazil nuts. Project operational area: the border between RO, AC and AM.
Coomaru - AM	Ignácio Oliete presidente da COOMARU Email: ignacio@fva.org.br; saúde@fva.org.br Tel: (92) 36424559 ou (92) 996141188 Ignácio explained how the process of harvesting, buying and selling in Coomaru cooperative.
Coovema - AM	Presidente da cooperativa Adaldino da Paixão Veiga dos Santos. Email: covemmamanicore@hotmail.com Tel: (97) 33852293 ou (97) 96120929 Adaldino talked about transportation costs, collection and processing in Coovema cooperative.

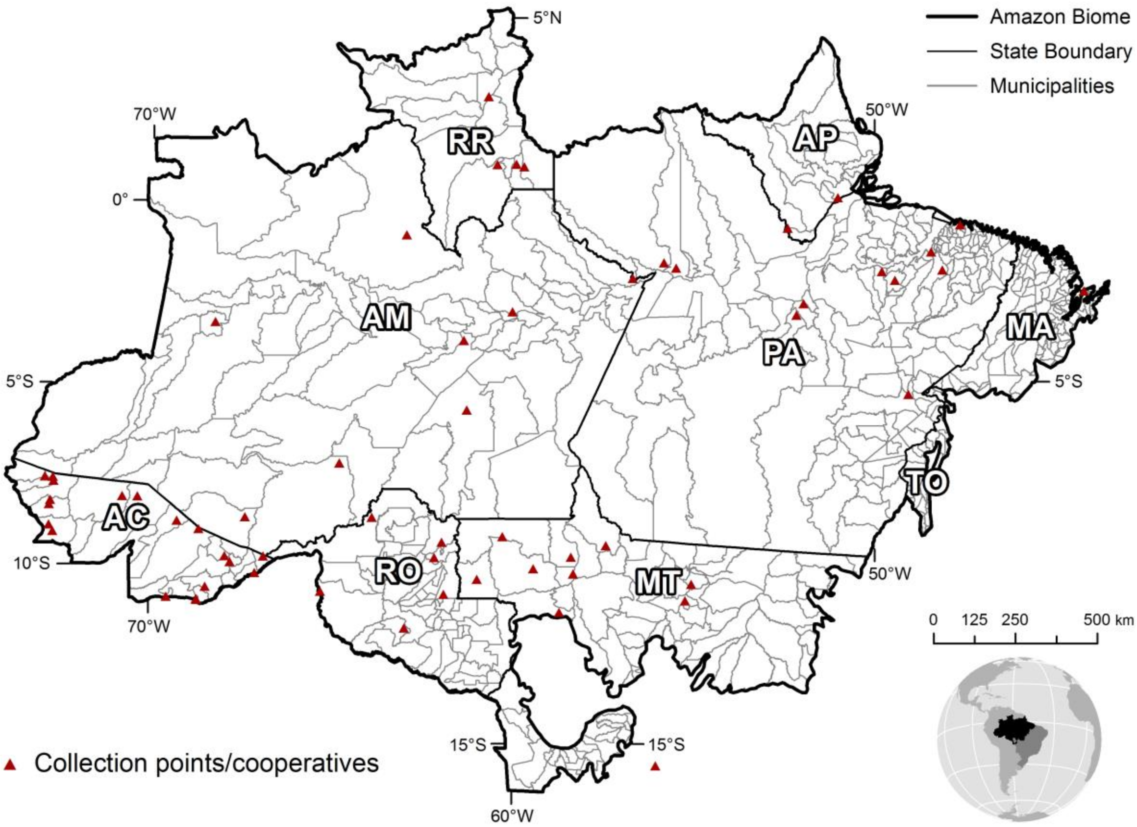


Figure S1 - Location of cooperatives and collection points.

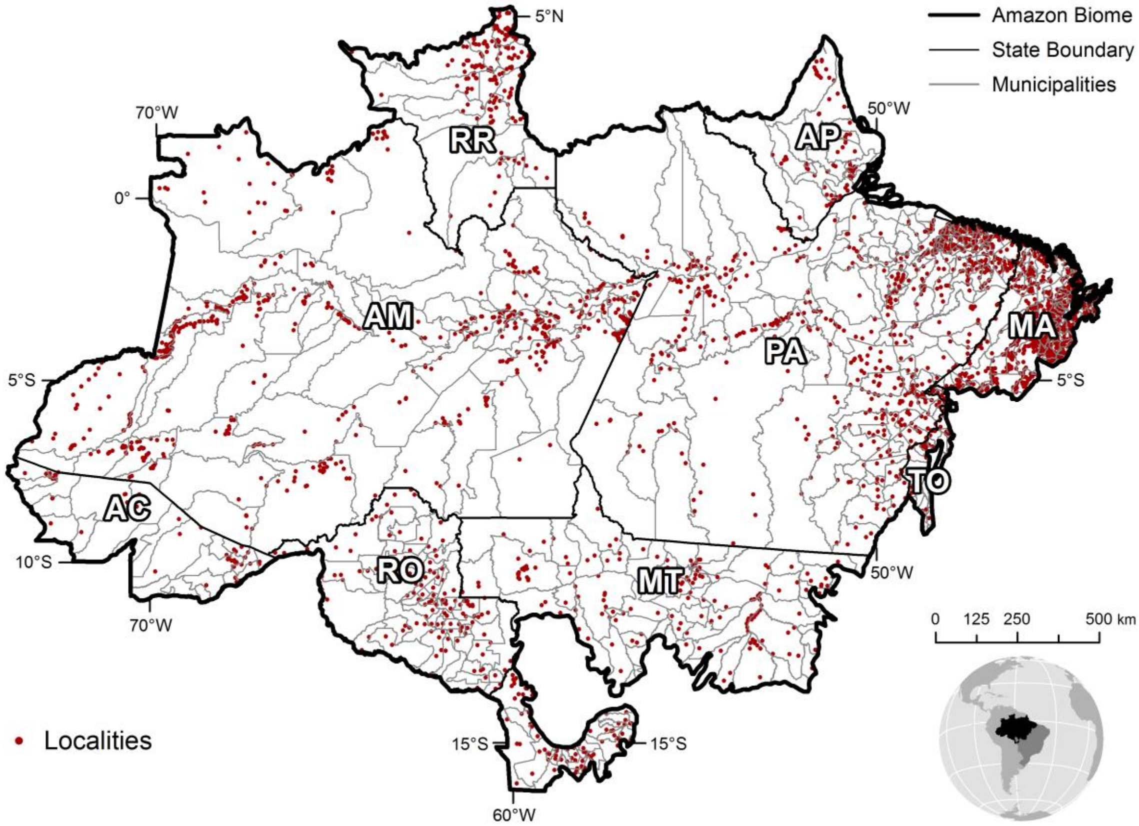


Figure S2 - Amazon localities.

Face to face semi structured interviews in Acre and Pará

The fieldwork in Acre took place in 2015 and in Pará in 2016. In Acre, our team included 4 researchers (2 Master students, and 1 post doc from CSR/UFMG) and 1 consultant from Rio Branco, Acre. In Pará, the team consisted of 5 researchers (project coordinator, two post docs, one master student, and one local consultant).

The interview sheet has three topics:

1. NTFP production
2. Description of costs and annual rents by NTFP
3. Influence of fire on NTFP

During fieldwork in Acre, we interviewed 6 extrativists, 3 cooperatives, 1 middleman, 10 Institutions and ONGs and 6 Researchers. In Pará, we interviewed 9 extractivists, 2 cooperatives, 4 Institutions and 2 researchers. Table S2 lists all the interviewees.

Table S2 - List of interviewees.

Estate	Type of agents	Municipality-Stakeholder
ACRE	6 Extractivists	Sena Madureira-Amopreceb Capixaba (Tião) Assis Brasil (De Araújo) Xapuri (Raimundão) Xapuri- Leila Capixaba- Francisco
	Cooperatives	Cooperacre, Rio Branco Cooperiaco, Sena Madureira Cooperfloresta, Rio Branco
	Middle man	Acrelandia- Saw
	Institutions	SEAPROF – Secretaria de Extensão Agroflorestal e Produção Familiar Andiroba CTA – Centro de Trabalhadores da Amazônia IMC - Instituto de Mudanças Climáticas GIZ - *Gesellschaft für Internationale Zusammenarbeit* SEMA – Secretaria do Meio Ambiente IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis TECMAN SEDENS – Secretaria de Desenvolvimento Florestal EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária
	Researchers	Allison Melo William Flores Zenobio Silva Foster Brown Lucia Wadt (skype) Rivadalve Golçalves (skype)
PARÁ	Extractivists	6 extractivists in a community in Obidos municipality CNS- Conselho Nacional de Seringueiros TAPAJOARA- Associação Flona e Resex STTR-STR sindicato trabalhadores Rurais Santarém e Obidos
	Cooperatives	COOMFLONA ASCOPER
	Institutions	IMAFLORA ICMBio IPAM IDELFLORA
	Researchers	Ricard Scoles (UFOPA) José Manuel Lima (CEAMA)
	Industry	Mundial Exportadora

Focus group in Rio Branco, Acre

The focus group protocol consisted of presenting to participants a summary of the responses we obtained from the interviews. We printed out two maps (one for rubber other for Brazil nut) and two tables (the same tables we used to get the detailed description of costs in the semi-structured interviews) at a large format. Following a brief presentation of the goals of the study, participants moved around the maps and tables to comment on the values we had presented. The participants were given small sticky dots, green, and red to place on the values they agreed or disagreed with, respectively (Figure S3).

Figure S3 - Pictures of the focus group in Acre.

A detailed description of the results we got and the ways we used this fieldwork data in the modeling is presented below.

The collection of nuts depends on a small amount of infrastructure (Table S3). SEAPROF reports for the Cachoeiras community, an infrastructure capital of US$ 6,557 in 2008. This infrastructure includes wooden structures called “paiol” (shed) where the nuts are gathered in the forest as well as the storehouse (armazéns) in the communities. In addition to this infrastructure, the following material is needed (Table S3).

Table S3: Material needed for Brazil nut collection.

Material needed	Quantity	Price in dollars in 2013 per unit
Knife[13] (annual depreciation 50%)	2	12.71
Lima chata[14]	2	4.24
Stick to collect the outer shell (mão de onça)	2	4.24
Basket to collect the wood	2	21.19
Rubber boats	2	10.59
Trousers	2	10.59
Basket to measure nuts	1	4.24
Bags	(60 bags)	2.11
Twine (Barbante)	1	2.11

In the interviews, we gathered different estimates for the extraction costs. Both the individual collectors and cooperatives were unsure about giving us their experiences on that. Most of them said that they do not know, as they never thought of it. They simply do it without properly accounting their costs. Despite some initial skepticism from our interviewees, we got estimates that we could rely on. The majority of the collectors revealed that in order to collect 300 buckets (3,000 kg as each bucket has approximately 10 kg) of Brazil nut, collectors needed 30 person days for gathering the nuts and 24 person days for breaking of the outer shell "ouriços", other referred to costs of 8 person days to clean the path, 36 days for collecting and breaking all together. In the focus group, we asked the reason of such variations in the production costs and participants highlighted that the in hotspot areas the costs are lower as they collect more easily one kg. We were told that both SEAPROF and EMBRAPA had different estimates for these costs as while SEAPROF looked for a mean cost on non-hotspot the study of Embrapa reports estimates for hotspot areas. The work by Embrapa also reflects an improved collection system (*e.g.* drying and selecting the nuts before sending it to the cooperative), which is not a common practice all over the Amazon[15].

In addition to the costs gathered in the semi structured interviews and focus group, we also based our estimates on the published work by SEAPROF for the non-hotspot areas and the EMBRAPA for the hot spot areas (Table S4). These estimates are slightly above the estimate by Nunes et al. [18].

[13] Depreciation proportional to the "life cycle": *e.g*. 2 years of life cycle = annual depreciation of 50%.
[14] Consumed during one extraction cycle.
[15] Exception is made to South Amazonas were a great part of the nuts are unshelled locally in small usinas so they can get better prices.

Table S4 - Collection costs of Brazil nut.

Cost of collecting one kg of Brazil nut	Based on SEAPROF [19]	Based on EMBRAPA [24]	Nunes et al. [18]
US$	**Non hot spot**	**Hot spot**	
Total costs[16]	0.8136-1.5805	0.144-0.679	0.13

Source: [18, 19, 24].

Transport costs

Within the Forest (from forest to the community)

There is a great variation in the transport costs we got from different interviewees. Within such a variation, transporting 300 buckets (3,000 kg of Brazil nut) requires one man for 15 days = 15 day/man). The cost of each person day is of US$ 12.71 (15*12.71 dollars) = US$ 191. One man can only transport 30 to 40 kg per journey. The cost per kg is then US$ 0.063 (one bucket has 10 kg). The collector transports the nuts as far as 20 km per day, yielding US$ 0.0032 $kg^{-1}km^{-1}$. In order to increase transport effectiveness collectors normally use donkeys or motocycles.

Costs for transport with a donkey

Each donkey transports 100 kg per journey of 10 to 20 km. The maintenance of a donkey costs US$ 1,059 per year (including vaccines, maize, and salt) [20]. For the collection of Brazil nut, donkeys work about 4 months only. As the donkey transports 100 kg on a journey of 20 km, the cost kg per km of a donkey is US$ 0.0012. The cost of transport using donkey plus that of the man totals US$ 0.004 kg per km for the transport nuts in the forest (Table S5).

Table S5 - Costs of transport in the forest.

Cost in US$ in kg per km	Field work	EMBRAPA [24]
Walking	0.0032	0.003 (in 2004)
Donkey	0.0012	
Total	**0.004**	

Transport from the community to the nearest cooperative

River

There is a great variation in the river transport costs, including across different rivers. We obtained a table from one of the local cooperatives (Cooperiaco) with all quantity of Brazil nut transported from the collectors' locality to the cooperative. Table S6 summarizes the transport cost data from fieldwork. In the area we did field work, there

[16] Only in Porongaba.

are 7 major rivers (classified of level 7 and 8 by ANA see input data hydrography). By summing up the cost of transport by river and the quantity of Brazil nut transported, we calculated the cost of transporting Brazil nut. We then measured the distances traveled in each river (we could only do so for 4 out of the 7 rivers) calculating the transport cost per kg per km. We averaged the costs of kg per km by river as some rivers, for example the Iaco river (the cheapest river) is responsible for 64% of the Brazil nut transport in the area.

Table S6 - Transport costs by river.

River name	Transport cost (US$)	Kg of Brazil Nut transported	Costs per kg (US$)	km river	Cost km by river (US$)	Transport $kg^{-1}km^{-1}$	Percentage of transport in the river	Averaged mean (US$) (by % transport in the river) ($kg^{-1}km^{-1}$)
Caciriã	175.75	8,103	0.021				0.417	0
Caeté	593.53	12,513	0.047	91	0.0474	0.0012	0.064	0.00003
Iaco	6,526.03	124,485	0.052	270	0.0524	0.0005	0.640	0.00012
Macauã	834.94	32,354	0.026	250	0.0258	0.0002	0.166	0.00002
Purus	426.31	16,614	0.026	160	0.0257	0.0004	0.085	0.00001
Rio	0	60	0					0
Riozinho Grande	6.10	240	0.025					0
TOTAL	**8,559.67**	**194,369**	**0**			**0.0005**		**0.00019**

The cost of US$ 0.0019 for transporting one kg of Brazil nut over one km was calculated for the area of Sena Madureira where transport is cheapest because it is arranged by the Coperiaco cooperative. Acknowledging this issue, we estimated for the entire Brazilian Amazon a cost 10% higher at US$ 0.002.

Transport by truck

Transport of Brazil nut by truck is rare in most of states In the Amazon. In Acre, however, transport of Brazil nut by truck is very common. Based on field survey and using the Cooperiaco[17] data we found that the cost of transporting one kg of rubber by truck for 200 km was US$ 0.0230. For one km, the cost is US$ 0.0001153. This value is lower than

[17] This cooperetive was one of the exceptions that gave us the data they had engaged enthusiastically with the research.

other estimates (*e.g*. Nunes et al. [18], 0.07 in 70 km = 0.001 per kg per km). This cost for transporting one kg of Brazil nut over one Km was calculated for the area of Sena Madureira and transport is cheapest because it is arranged by the Coperiaco cooperative. Acknowledging this issue, we estimated for the entire Brazilian Amazon that the cost is 10 % higher at US$ 0.001.

Rubber

The way we got the production and transport costs for rubber followed the same approach as the one described above for Brazil nut.

Production costs

The adult population of rubber trees (*Hevea spp*) have a random spatial distribution [17]. Table S7 shows production costs for 3 major rubber products.

Table S7 - Production costs for the 3 major rubber products.

Production costs per kg of rubber (US$)	Field work	Jaramillo et al. [17]
PVR	0.25 to 0.38 (high productivity) 1.32 to 1.93 low productivity	0.25
LSS within 10 km from villages or processing centers	1.49	0.32
LL within 100 km from NATEX	1.27	0.30

LSS Liquid Smoked Sheets

According to SEAPROF an investment of US$ 8,877 is needed to set up one production unit of LSS.

Table S8 shows the structure of costs involved in the LSS production also listing the material that is needed to prepare the LSS final product.

Liquid Latex – LL

The majority of LL extracted in Xapuri in Acre is bought by NATEX and the factory buys all the LL produced within a radius of 100 km. The Natex factory gives the rubber tappers buckets with the ammonia (the quantity of ammonia varies according to the capacity of the bucket) and rubber tappers add the liquid latex to the bucket. Every 15 days the Natex industry collects the latex. We estimated a cost of US$ 1.27 per kg of latex extracted. This cost includes two journeys in the forest (cutting and placing the pot) and collecting the liquid latex on the same day using on the way back. These costs also include depreciation.

Table S8 - LSS fixed and variable costs.

	Quantity	Price in dollar per unit (for 2013)	Total
Fixed costs			
Material depreciation (collection)			205.08
Knife "terçado" (annual depreciation 50%)	2	12.71	25.42
Knife "de bainha"	1	12.71	12.71
Lima	2	4.24	8.47
Pot	500	0.11	52.97
Bica	500	0.11	52.97
Cutting edge	2	2.97	5.93
Rubber boats	2	10.59	21.19
Trousers	2	10.59	21.19
Cabrita	2	2.12	4.24
Material depreciation (transformation)			259.32
Bucket (20 liters)	1	10.59	10.59
Tray1	2	2.12	4.24
Tray2	70	0.85	59.32
Water box 500 liters	1	23.31	23.31
Calandra lisa	1	105.93	105.93
Funil	1	2.97	2.97
Jar 2 liters	1	1.27	1.27
Carote 10 liters	1	10.59	10.59
Rope 3mm proliprolipeno	2	16.95	33.90
Plastic pan	2	2.54	5.08
Plastic pan 100ml	2	1.06	2.12
Depreciation infrastructures(transformation)			204.08
Varying costs			**2,822.03**
Pepraring latex collection			1,271.19
Cleaning path	4	12.71	50.85
Cleaning tree panel+pot	6	12.71	76.27
Rubber tapping+ preparing LSS	112	12.71	1,423.73
Consumption (in transforming lates to LSS			164.41
Pirolenhoso acid	9	2.12	19.07
fungi	13	10.59	137.71
Formic acid	3	2.54	7.63
Total cost			**3,654.93**
total cost per kg			**7.31**
market price per kg			**5.04**
Net rent per kg			**-2.27**

Transport costs

Total transportation cost—the least cost pathway—represents the distance from this collection point to the nearest community or cooperative (assigned according to the area of influence) multiplied by the transportation cost by type of terrain.

Within the Forest (from forest to the community)

In the case of rubber, we did not consider the use of donkeys since the quantity extracted is low and then can be carried manually. The collector transports the rubber up to 20 km per day, resulting into value of US$ 0.0031 kg/km.

Transport cost from the community to the nearest cooperative

In interviews with rubber tappers, we observed that they could not afford to pay the transport costs of rubber. In fact, they usually transport the rubber bundled in the transportation of other goods. The few that said to pay transport estimated around US$ 42.37 for transporting 800 kg of rubber from the feeder roads around the community to the town (a journey of 230 km) – equivalent to US$ 0.00023 per kg. This was calculated for the area of Sena Madureira where transport is cheapest because it is arranged by the Coperiaco cooperative. In Pará the cost of transporting one kg of rubber was 0.19 (ASCOPER) in 70 km, this making the price per km as US$ 0.0027. Averaging the transport costs of Acre and Pará we got 0.0015.

Table S9 - Inputs.

Model/ Variables	Rubber	Brazilian nut	Source
1.1. Environmetal			
Land Cover	X	X	INPE - Instituto Nacional de Pesquisas Espaciais. Monitoring Tropical Forest form Space: the PRODES digital project. Resolution: 60 m. Date 2010. Available in: Instituto Nacional de Pesquisas Espaciais (INPE). Projeto PRODES - Sistema de Monitoramento da Amazônia por Imagem de Satélite. <http://www.obt.inpe.br/prodes/index.php>
Soil	X	X	SIPAM - Sistema de Proteção da Amazônia Available in: http://www.dpi.inpe.br/amb_data/Shapefiles/Solos_SIPAM/
Hydrography (distance to)	X	X	ANA - Agência Nacional de Águas. 2012. Available in: http://www.ana.gov.br/bibliotecavirtual/solicitacaoBaseDados.asp Ottobacias ANA
1.2 Bioclimatic			
Isothermality	X	X	Worldclim. Resolution 30 arc-second (~1 km^2). Mean values for the period 1950-2000; http://www.worldclim.org
Mean Temperature of Wettest Quarter	X	X	
Mean Temperature of Driest Quarter	X	X	
Annual Precipitation	X	X	
Precipitation of Wettest Month	X	X	
Precipitation of Driest Month	X	X	
1.3 Geopolitical			
Study area	X	X	Own elaboration (CSR/UFMG)
Municipalities	X	X	IBGE - Instituto Brasileiro de Geografia e Estatística. Date: 2013. Available in: http://www.ibge.gov.br
1.4 Economic data			
Costs and Revenue	X	X	SEAPROF - Secretaria Extensão Agroflorestal e Produção Familiar; CONAB - Companhia Nacional de Abastecimento.

Maximum production of Rubber from 1994 to 2013	X		IBGE - Instituto Brasileiro de Geografia e Estatística. Produção da Extração Vegetal e da Silvicultura - 2013. Available in: http://www.sidra.ibge.gov.br/bda/pesquisas/pevs/default.asp?o=29&i=P
Maximum production of Brazil nut from 1994-2013		X	IBGE - Instituto Brasileiro de Geografia e Estatística. Produção da Extração Vegetal e da Silvicultura - 2013. Available in: http://www.sidra.ibge.gov.br/bda/pesquisas/pevs/default.asp?o=29&i=P
Collection points (CP)/ armazens and cooperatives	X	X	Own elaboration (CSR/UFMG) based on CONAB tables.
Map of communities/ localities	X	X	IBGE - Instituto Brasileiro de Geografia e Estatística. 2010. Available in: http://www.ibge.gov.br/home/geociencias/default_prod.shtm#TERRIT
1.4 Infrastructures			
Transport network	X	X	Vicinal: CSR/UFMG - Centro de Sensoriamento Remoto de Minas Gerais (2004). Major roads: MT/PNLT - Ministério dos Transportes/Plano Nacional de Logística e Transportes (2014).
Transportation cost	X	X	Transport costs [R$/($m^3$ or kg)/km] reflect the friction: of the different transport means. For each transport type (boat, donkey, truck).

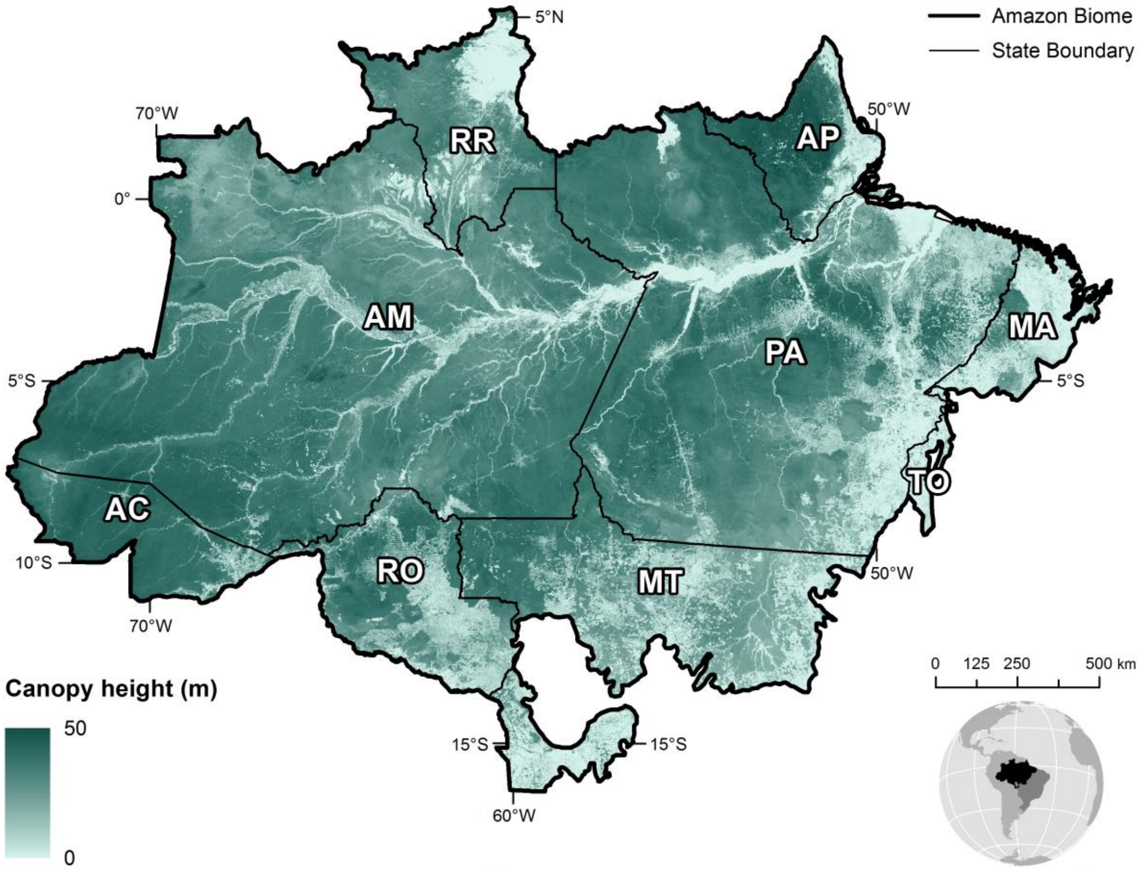
Table S10 - Conversion of real to dollar.

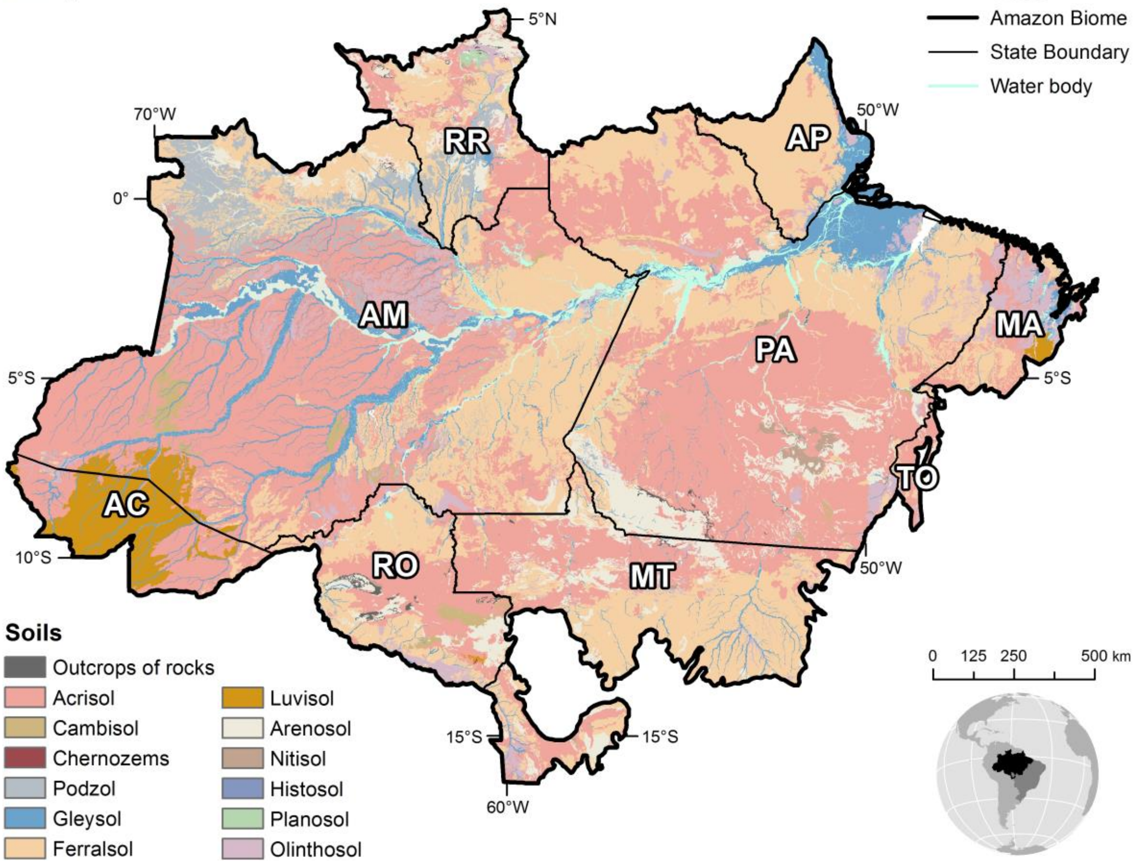
Year	Conversion factor
1994*	0.87
1995	0.92
1996	1.01
1997	1.08
1998	1.16
1999	1.81
2000	1.83
2001	2.36
2002	2.93
2003	3.06
2004	2.93
2005	2.44
2006	2.17
2007	1.95
2008	1.83
2009	2.00
2010	1.76
2011	1.67
2012	1.95
2013	2.15
2014**	2.36

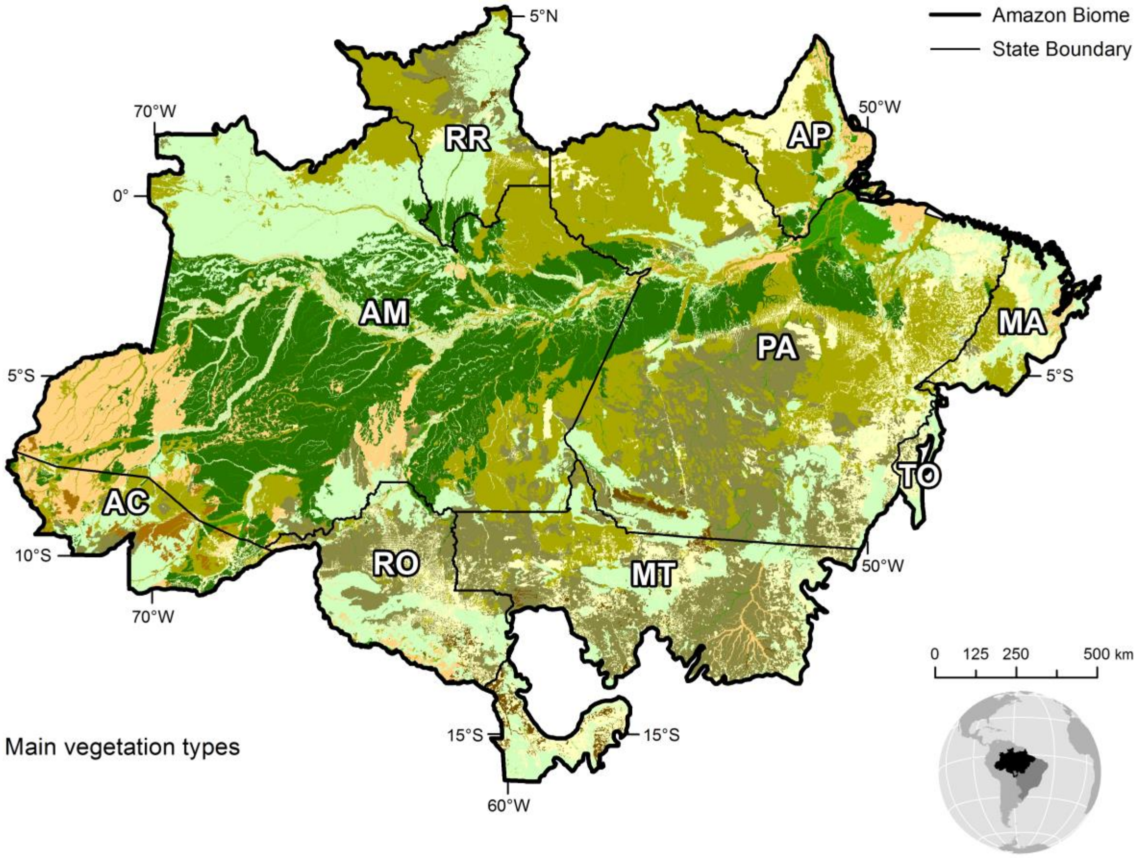
*Only considers 6 months - July to December - until June 1994 Brazilian currency was Cruzeiros Reais.
**We used the conversion factor of 2.36.

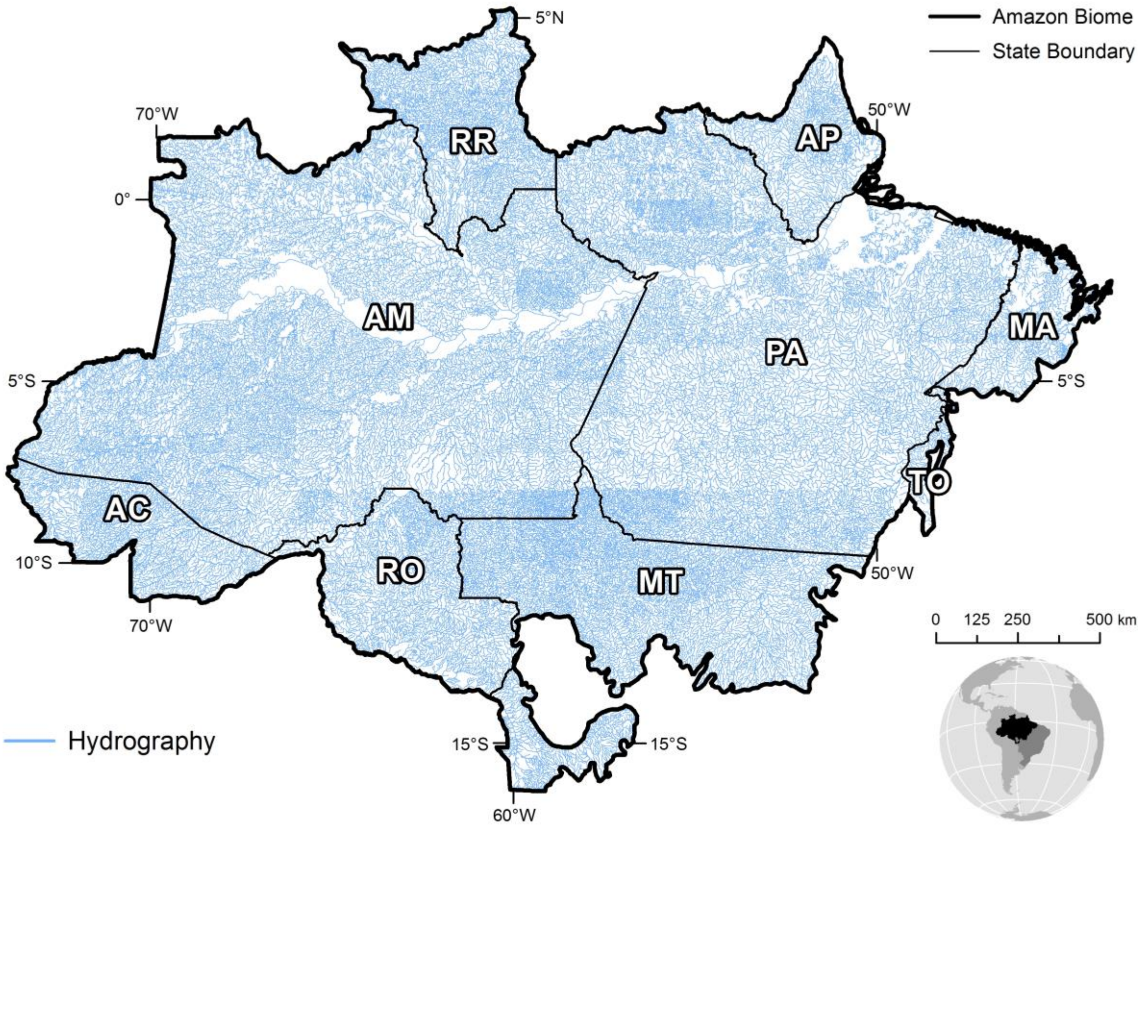
Inputs maps

Environmental






Amazon Biome
State Boundary
5°N
70°W
0°
5°S
10°S
50°W
RR
AP
AM
PA
MA
AC
RO
MT
TO
15°S
60°W
0 125 250 500 km
Main vegetation types


Amazon Biome
State Boundary
5°N
70°W
0°
5°S
10°S
50°W
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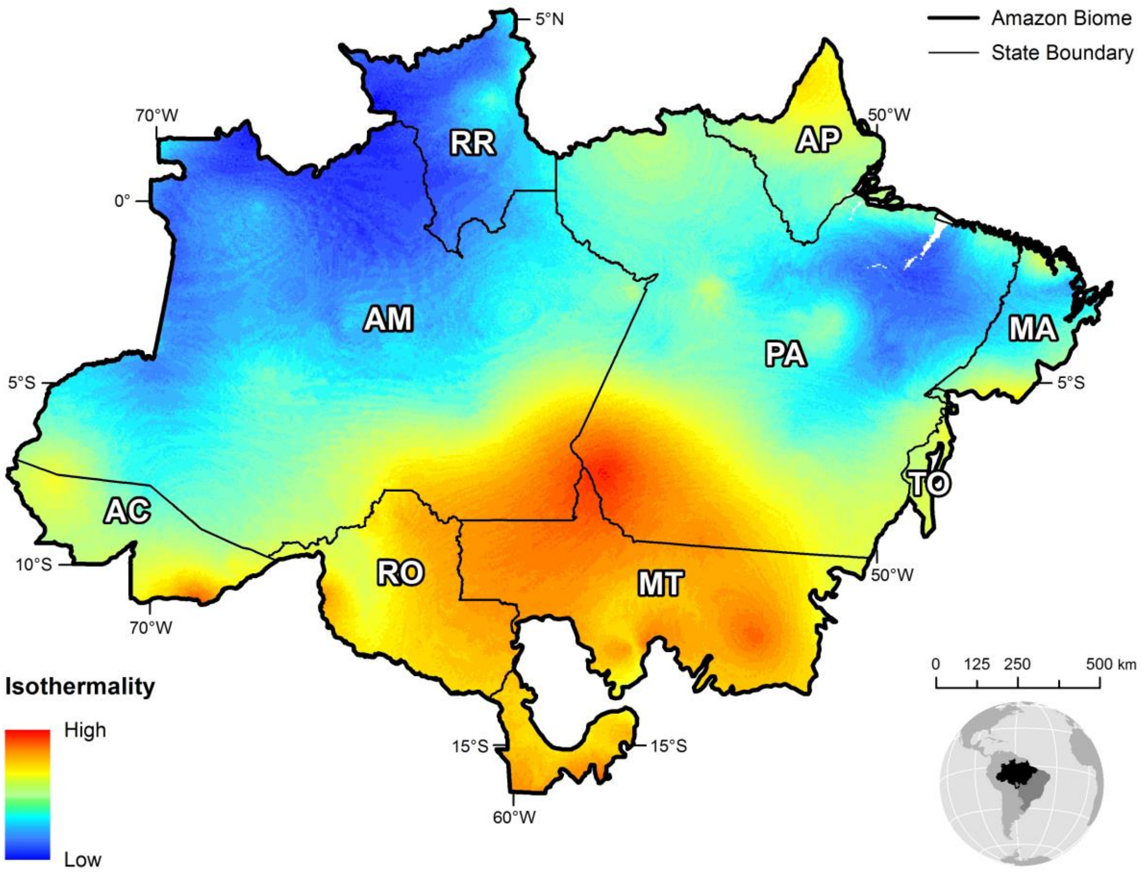
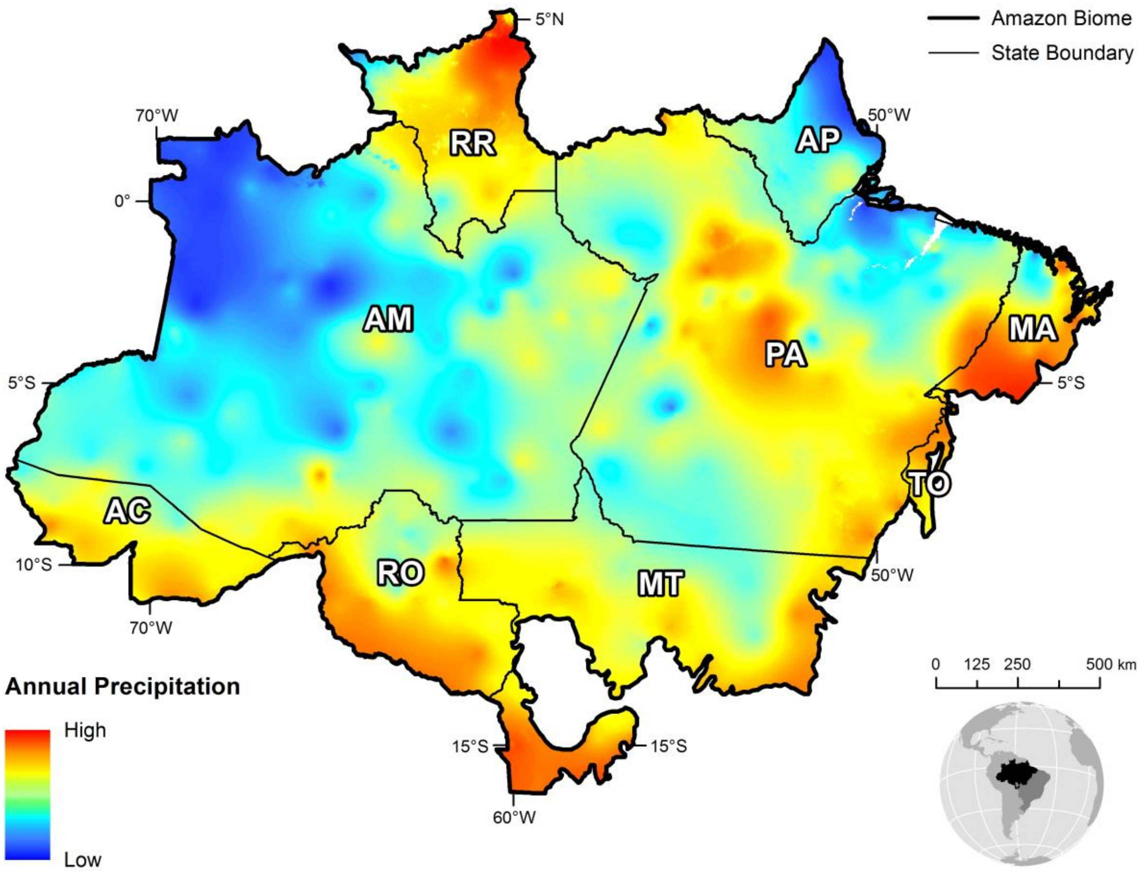
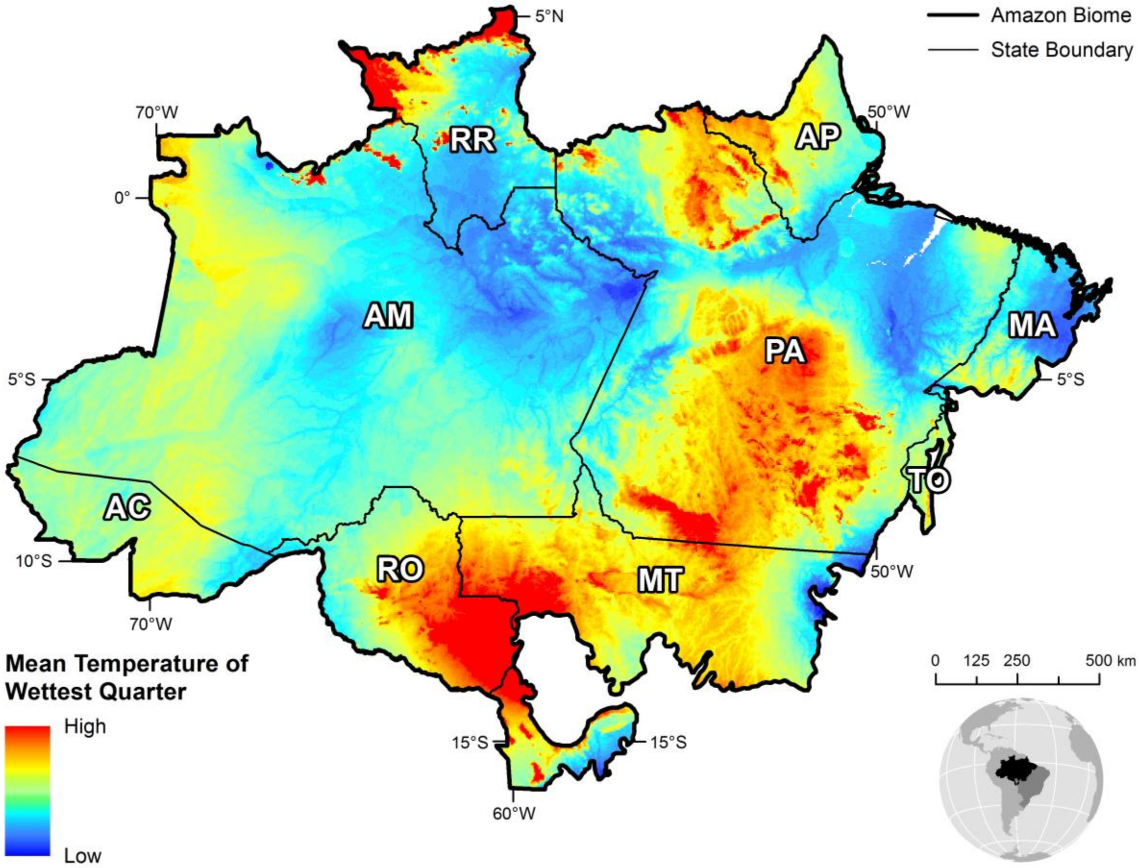
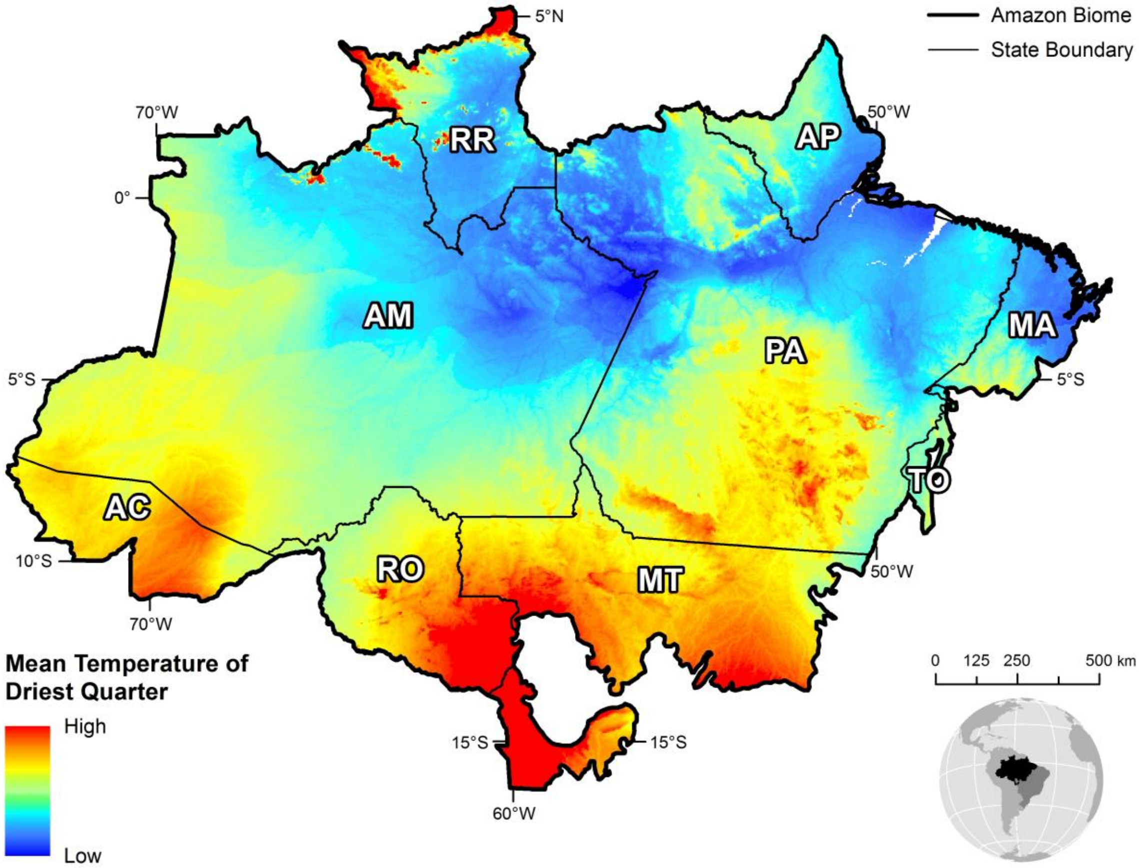
TO
15°S
60°W
0 125 250 500 km
Hydrography

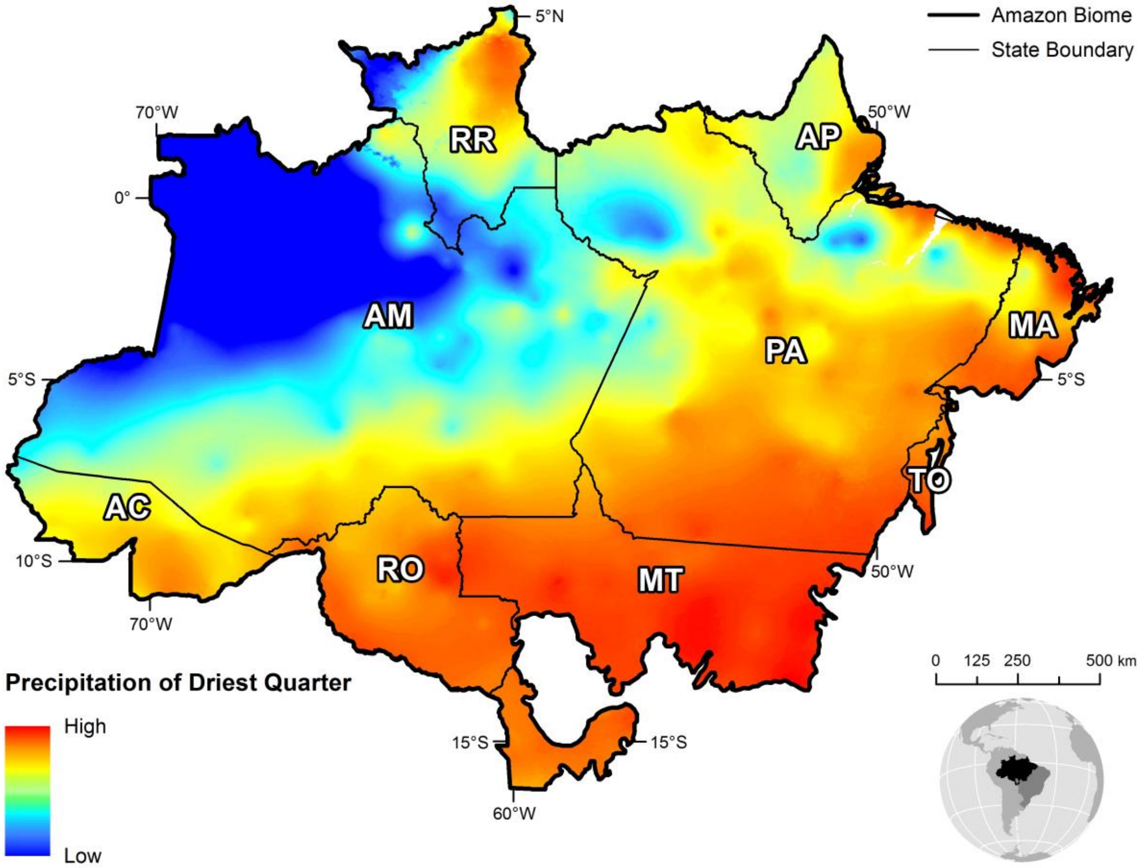
Bioclimatic



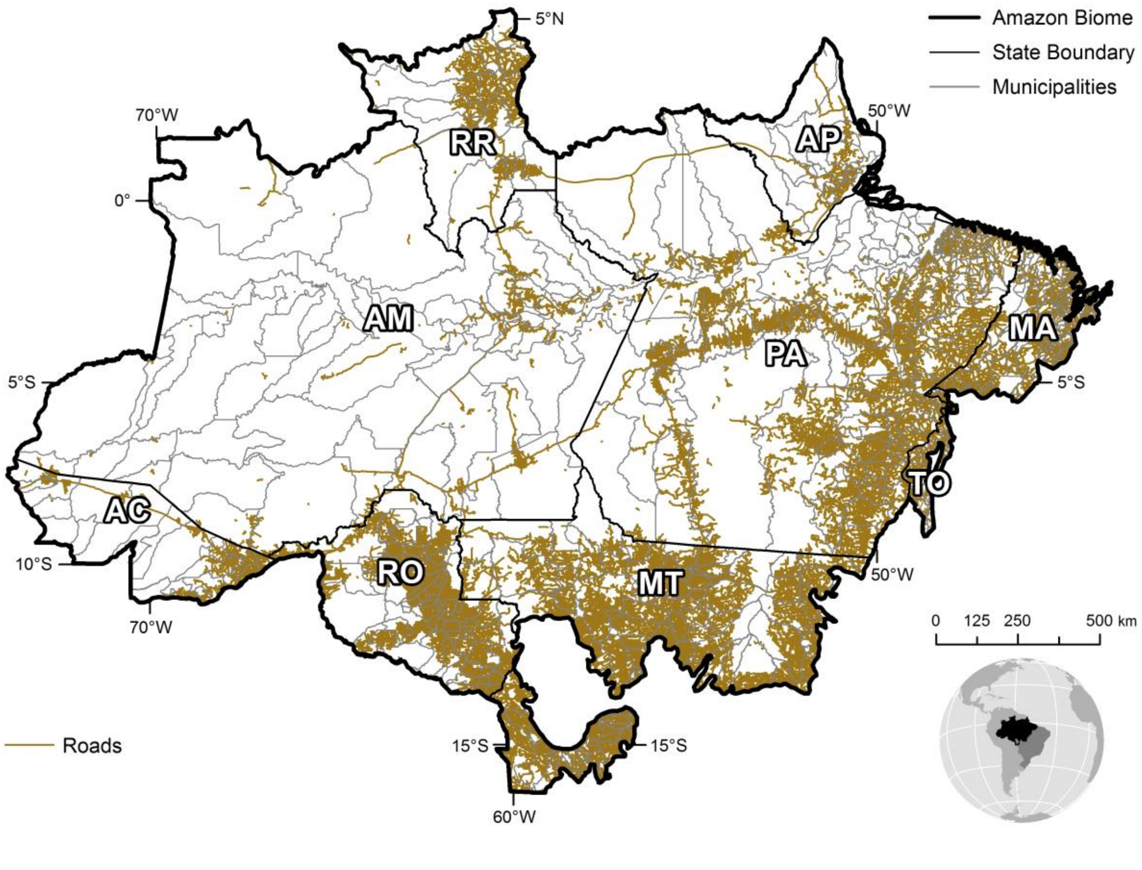



5°N
Amazon Biome
State Boundary
70°W
50°W
0°
RR
AP
AM
PA
MA
5°S
5°S
AC
TO
10°S
RO
MT
50°W
70°W
Mean Temperature of
Wettest Quarter
0 125 250 500 km
High
15°S
15°S
60°W
Low


5°N
Amazon Biome
State Boundary
70°W
50°W
0°
RR
AP
AM
PA
MA
5°S
5°S
AC
TO
10°S
RO
MT
50°W
70°W
Mean Temperature of
Driest Quarter
0 125 250 500 km
High
15°S
15°S
60°W
Low



Infrastructures



Interview sheet

UFMG

MAPPING VALUE OF TIMBER AND NON TIMBER PRODUCTS IN ACRE STATE/ AMAZON

SEMI STRUCTURED INTERVIEWS

Presentation:

Hi, my name is Elaine/Sonia/Isabela/Edivan (select) and I'm a student/ consultant of Federal University of Minas Gerais, Centro Sensoriamento Remoto/ Master´s degree in Analysis and Modeling of environmental systems. We are doing a scientific work about timber and non timber products in Acre State/ Amazon.

1. Do you work with non timber products NTFP? **SHOW PICTURES TO INTERVIEWED**

Brazil Nuts ☐ **Rubber** ☐ **Açaí** ☐ **Copaiba** ☐ **OTHER? Which**? ____

2. Show us in the map the exact localization of your production**. MARK WITH "P" IN THE MAP (specify area in hectares)** – how many rubber tree in hectares / number of Brazil nut in hectares (In case of Cooperative/ ONG with COUNTIES / COMMUNITY do you work with (MARK IN THE MAP -AREA in hectares)

3. How important this economic resource is for your financial situation in ha/year (try to make an average of the last 4 years)? Explain (try to reach concrete values **per ha/YEAR -** fill in Table 1)

4. What are the main difficulties faced by extractive in Acre State and what needs improvement? (this question intend to "break the ice" and then try to realise if are losses in their financial situation/ bottleneck) specify what can improve the value of non timber products NTFP **in REAL/ha (indicate how many they can win per ha if improvements were made)**

TABLE 1 NON TIMBER PRODUCTS	< 500 **REAL/ha/YEAR**	500 > 800 **REAL/ha/YEAR**	800 - 1100 **REAL/ha/YEAR**	1100 > 1600 **REAL/ha/YEAR**	> 1600 **REAL/ha/YEAR**	Specify
Brazil nuts						
Rubber						
Açaí						
Copaíba						

TABLE 2

5. DESCRIPTION COST IN CHAIN OF NON-TIMBER PRODUCTS IN ACRE STATE / AMAZON

Processes	**NON TIMBER PRODUCTS**				**Periodicity in activity**	**Cost (real per ha)**		**Income *(real/ha)***
	Brazil Nuts		**Rubber****	**Açaí**		**N° working days**	**Material / Used method (manual, mechanical, fire)**	
	Shelled*	**Unshelled**						
Track opening								
Cleaning tree pane**								
Potting**								
Cut**								
How the bowl is made ** *(Specify – plastic or brass)*								
Anticoagulant application in the bowl**								
Collect			☐ Liquid Latex ☐ Clot					
Production/tree								
Selecting Brazil nut								

Washing/drying *(identify type of drying, outdoors or in greenhouses)*								
Storage								
Transport								
Road								
Boat								
Animal								
Polish * (*remove harsh*)								
Weighing								
Autoclaving *(thermal shock under pressure)*								
Shelling								
Select/Classify								
Transformation								

Packing								
Commercialization								
COMMENT BRAZIL NUTS PHOTOS - SHELLED AND UNSHELLED Differences between cost/income?								
COMMENT TREE PANE PHOTO (cut type)								
COMMENT LIQUID LATEX PHOTO who made/ profitability								
COMMENT LATEX CLOTTED PHOTO who made/ profitability								

TABLE 3. INFLUENCE OF FIRE IN THE DEPRECIATION OF NTFP PRODUCTS

6. Which places had occurrence of "fire" in the last two years? (Mark “F” in the map). How often?
7. What was the fire damage? EXPLAIN FOR RUBBER AND BRAZIL NUT.
8. How much would you be willing to pay so there is no fire? DIFFERENCES FOR RUBBER AND BRAZIL NUT.
NOTES:

Interviewed name:			
Institution:			
Interviewer:		Date: / 07 / 2015	Nº questionnaire:
GPS point:	Map		

NOTES

TRANSCRIPT OF INTERVIEW

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CENTRO DE SENSORIAMENTO REMOTO

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