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FOREST DISAPPEARANCE BY FIREWOOD CONSUMPTION IN THE AMAZON ESTUARY

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ABSTRACT

Deforestation of flooded (várzea) and non-flooded (terra firme) forests caused by firewood consumption at tile factories (olaria) was investigated in Abaetetuba Island at the Amazon estuary. Várzea is spatially limited, the area is only 3% of the whole Amazon, however, it is heavily influenced by human activities, especially by the cultivation of açaí palm (Euterpe oleracea Mart.). The trees are cut down for the olarias. The number of tree species are small, and they have less wood density than terra firme tree species because the várzea is flooded twice a day throughout the year. Terra firme forests, which are also secondary forests, receive less human impact, and have more tree species and more individual trees with a growth extension that exceeds the species in the várzea forests. The deforestation was examined by comparing forest biomass in a unit area to firewood consumption at olarias. The annual area of deforestation was estimated by using the combination of tree species in the firewood and human impact in the várzea forests. Then the estimation was extended to the whole island, assuming that the forests were rotatively cleared every 25 to 30 years. The results indicated that the area of deforestation was 6,870ha/25 years to 8,337ha/30 years, and that it was smaller than the island. However, logging is not only for fuel at olarias. If Belém's economic influence becomes stronger, and electric energy is not diffused throughout the island, the lumber consumption will accelerate and the increase might make the forest disappear faster than estimated.

Key words: Amazon estuary, tile factory (olaria), firewood, forest biomass, deforestation area

INTRODUCTION

It has been a long time since illegal logging and the associated decrease of the tropical rain forest attracted considerable attention in Amazon. Particularly, in western Amazon with the small population, there is still no end to absentee

landowners who speculatively purchase huge parcels of land for pasture development. Deforestation and forest burning have brought about the decrease of forested area (Fearnside, 1996). Satellite data analysis evaluated that the annual mean deforestation was 21,218km2 from 1978 to 1989 (Fearnside et al., 1990). Also, INPE, Instituto Nacional de Pesquisas Espaciais (1992) estimated that the annual deforestated area was 17,860km2 in 1989, 13,810km2 in 1990 and 11,130km2 in 1991. Further, SUDAM/PNUD, Superintendência do Desenvolvimento da Amazônia / Programa das Nações Unidas para o Desenvolvimento (1994) reported that the deforestated area exceeded more than 20% in Rondônia and Mato Grosso, and reached 10% in the legal Amazon.

In the mouth region of the Amazon, on the other hand, local inhabitants are mostly involved in secondary forests which repeats felling and regeneration. These forests are different from natural forests in western Amazon, and are not targeted for monitoring to evaluate forest resources or deforested areas. The flooded forest (várzea forest) is predominant in the lower course. The forest structure and floristic composition are different from those of non-flooded forest (terra firme forest) because low lands are flooded twice a day by the tidal activities. Not only the main course but also all tributaries and small streams are flooded in the Amazon estuary (Sioli, 1984, Soares, 1991). Terra firme forest also exists on a hill 7-8m higher in altitude just like the forests in western Amazon.

People move through rivers in the estuary floodplain where land transportation is not developed. Goods also come and go over the rivers. In the past, people have made a living by collecting forest products and fish. Mandioca and feijão were cultivated for domestic use in terra firme forests, camarão (shrimp) was collected by a traditional method, and engenho de cana (sugarcane company), which produced sugar and aguardente (distilled liquor), was only a local industry in the estuary (Anderson, 1991). After 1975, however, the self-sufficient economy collapsed because of the influence of a monetary economy and the population growth of the Belém metropolitan area. The agroforestry of açaí palm (Euterpe oleracea Mart.) and tropical fruits, the ceramic industry and the palm resin extraction industry are growing rapidly (Hiraoka, 1993). The cultivation of açai palm and tile production at ceramic factories (olarias) deserve special mention (Hiraoka, 1995). It is thought that trees of várzea are cut down for açaí palms and wood consumption is increasing for fuel at olarias. Tsuchiya (1996) investigated tree rings of várzea and terra firme species in Abaetetuba Island near Belém, and pointed out that the trees of várzea did not have clear tree-ring boundaries and the wood density was smaller than that of terra firme tree species because of the special environment of flooding.

The purpose of this study is to compare the firewood consumption at olarias to forest biomass in order to examine the balance between wood utilization and forest regeneration in the Amazon estuary.

STUDY AREA AND STUDY METHODS

Study area

The location of Abaetetuba Island where the fieldwork was carried out is shown in Figure 1. Abaetetuba Island is located 60km south-westward from Belém, the capital of Pará State, and 3km northwest of Abaetetuba City. The island, including Marajó Island, was made from alluvial deposit transported through Pará River and Tocantins River. There are numerous small tributaries called furo or igarape inside the island, and the water level rises and falls by the tidal activities. The whole island is a typical example of the tidal floodplain. Although the seasonal fluctuation of water level between rainy and dry season is not large (about 1 to 2m), the tidal changing component which is repeated every 6 hour reaches about 3m. An additional 3m is added in the spring tide. The annual rainfall is about 2,800mm, and this region belongs to Af climate according to Köppen's climatic classification, however, the seasonal difference is quite evident between the rainy (December to June) and dry seasons (July to November) (SUDAM/PHCA, 1984). Therefore, the water condition of terra firme is largely different, especially in the dry season, from that of the várzea which is under the influence of flooding. According to Thornthwaite and Mather's water balance calculation, a water deficit of 300mm appears during the dry season. It is thought the terra firme is directly influenced by this amount of water stress. Vegetation is also dependent upon the different water conditions. Two types of forests coexist in this region, one is várzea forest distributed in the floodplain, and another one is called terra firme forest which is predominant on a hill. The floodplain is generally seen on both sides of the river and is 100 to 200 meters wide. Beyond that the interior highlands becomes the terra firme area with the transitional zone called ica. The floodplain is wider in northern half of the island because the altitude is lower than 10m, while the non-flooded area is dominant in the southern interior and along Pará River with a large sedimentary velocity.

Study methods

A questionnaire survey of the olarias was conducted along Maracapucu Miri River and Furo Maracapucu River in July, 1995 (Fig.1). The number of olarias surveyed was 10. Monthly, seasonal and annual tile production, the amount of clay used and the price, how to obtain clay, how to process the clay, how to get

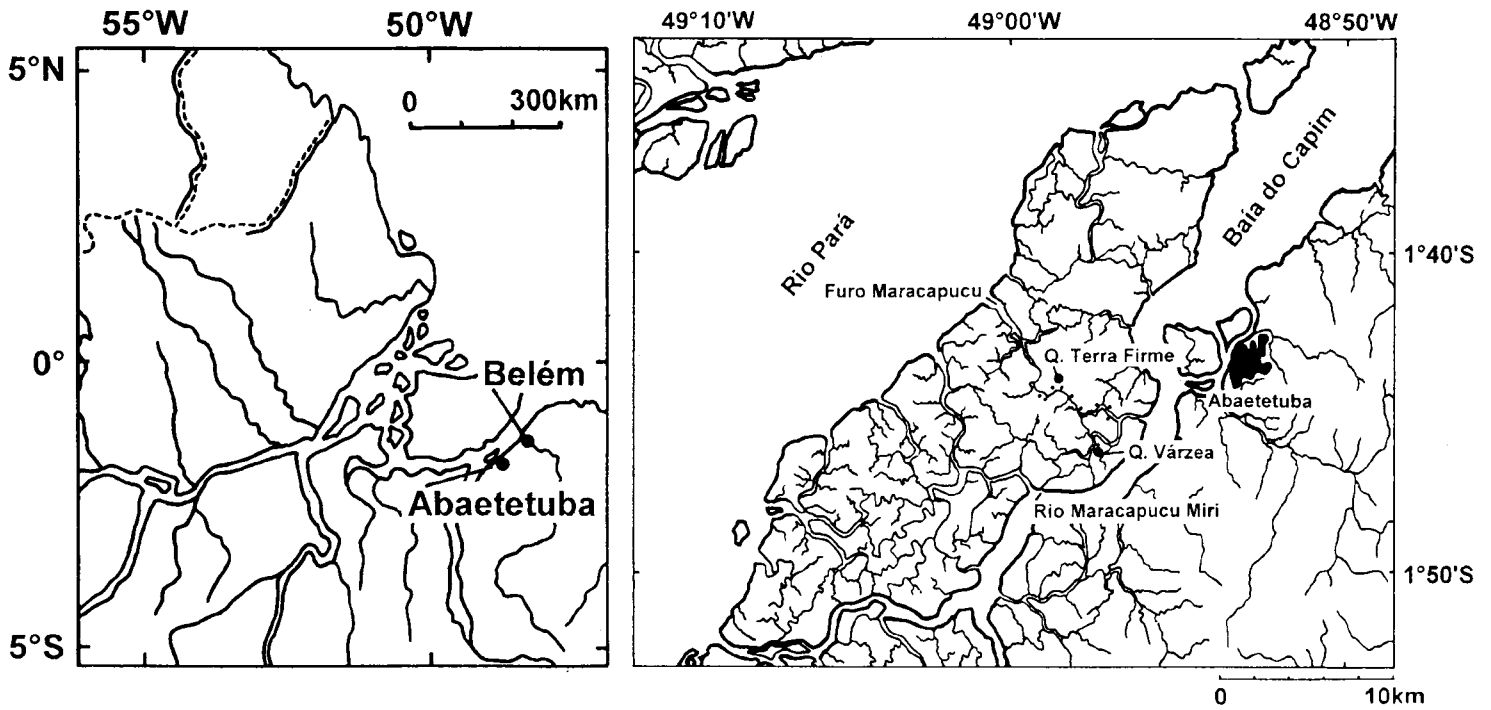

Fig. 1. Location of research site. Large circles are the location of várzea and terra firme quadrats. Small dots are the location of olarias.

firewood, tree species in the firewood, the burning procedure, the amount of firewood used, the price of tile, genuine profit, work force, foundation year, etc. were investigated. The size and the number of trunks and branches in each unit of firewood were also measured at the olarias.

Forest inventory was carried out in 1993 and 1994. The várzea site was set up in a forest along Maracapucu Miri River, and the terra firme site was set up 500m interior from Furo Maracapucu River. The distance between the two sites was about 4km. Four 400m2 quadrats were set up in each site. They are called VQ1, VQ2, VQ3, VQ4 in várzea, and TQ1, TQ2, TQ3, TQ4 in terra firme. Tree height and diameter at breast height (DBH) were measured. However, trees whose DBH was smaller than 5cm were excluded. Tree disks were obtained from all the trees in VQ4 and TQ4 in order to count the number of tree rings. The number of individual palms was also counted in the várzea site.

RESULTS

Tile production

There are 50 olarias in the study site. There are a total of 260 olarias on the whole Abaetetuba Island. The main ceramic products such as tile (telha), brick (tijolo), dishes (agidá), water pots (tina) and cooking ranges (fogão) are different by rivers, but tile production is predominant in every olaria. Recently, tile production is becoming one of the main local industries because (1) alluvial soil necessary for tile accumulates in the depth of 2m below the riverbeds, (2) abundant trees can be utilized as fuel, (3) açai palm is transplanted after cutting the trees, and (4) the demand of ceramic products, especially of roof tile, is increasing due to the population growth of Belém. Tile production is the second income resource next to açai palm in the Amazonian estuary.

The production procedure begins from purchasing clay (barro) and firewood (lenha). Both of them are traded by a unit of corda. In case of firewood, one unit of firewood is 18 (horizontal) x 9 (vertical) as measured by the length of the thumb to the middle finger when a man opens his hand (about 3.6m x 1.8m). Mean wood length is 1.5m. The total volume is about 9.72m3, and each corda is transported by boat. The firewood is kept out of the rain within the olaria, and is used after it is fully dry. One corda of clay is 1m3. Although dependent upon the size of the tile, about 3,000 pieces of tile are made from 4m3 if it is a standard type (comum) with a length of 46cm. Olaria's laborers sometime provide firewood by themselves, while clay is usually supplied by the specialist.

Clay is generally kneaded by hands and legs, but some olarias with a large amount of capital use a machine worked by diesel engine (marumba). A tile pattern is cut out from the clay by a simple hand-operated machine (maquina de prensa) after painting the resin of andiroba (Carapa guianensis) and diesel oil. Beside comum, there is another type of tile called colonial which is slightly bigger than comum (50cm in length). The traded price of comum to brokerage is about 50 cents, and the colonial is 70 cents. After cutting a pattern, the tile are dried on a shelf made from the trunk of jupati (Raphia vinfer), a palmaceous species. Drying takes 3 to 4 days during dry season, but 5 days to two weeks during rainy season.

There are three procedures when burning tile. The first is to burn at a low temperature for 2 nights using várzea tree species as fuel (esquentar), the next step is to burn at a high temperature for 12 hours using terra firme tree species as fuel (queimar). The tile are then cooled for one night to four days in the kiln (formada) after burning is stopped, and finally, they are taken out to cool again for three days (esfriar). Trunks and leaves of açaí and miriti (Mauritia flexuosa) palms are frequently used when making a fire. When the trees of terra firme are not available, várzea tree species are used in the process of high temperature burning as well. The completed tiles are sold to brokerages, and they are transported to the markets in Abaetetuba and Belém.

The annual tile production at 10 olarias is shown in Figure 2. The production depends upon the drying time of raw tile as mentioned above, more tile is produced in the dry season than in the rainy season with its high humidity. The reason the production is different among olarias is because the scale of the olaria and the work force are different. For example, olaria of No.7 was built 40 years ago, and the owner employs four laborers. He has a marumba, four maquinas de prensa to cut a tile pattern and two formadas. Tile is produced two or three times a month in the dry season, and once a month in the rainy season. The number of tiles produced at one time is 6,500 to 10,000. The genuine profit is relatively larger (about $250/month) after paying the cost of materials such as $25 for firewood, $5 for clay and $35 for transportation. Totally, 1,333,500 tiles are annually produced in 10 olarias.

Firewood consumption

The annual firewood consumption at 10 olarias is 530.6 cordas (5157.83m3). This means that a piece of tile is produced by burning about 3,000 to 4,000cm3 (3,616cm3 on average). The number of tree species used in olarias are 24 in várzea and 16 in terra firme forests. The reason the várzea tree speices is used more is because it is easier to carry the trees in várzea along rivers than those

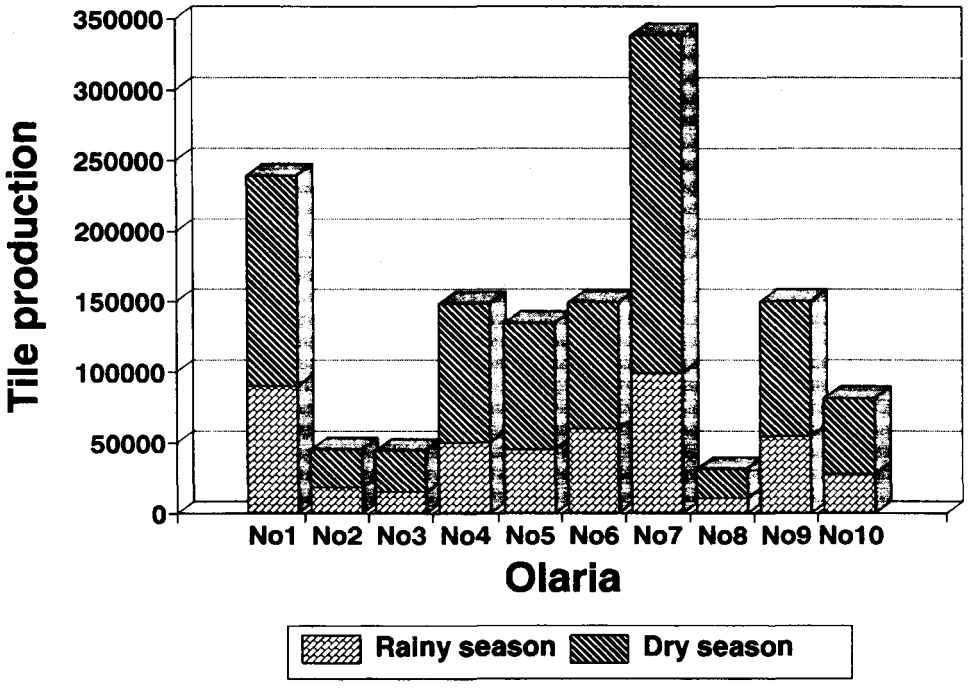

Fig. 2. The annual tile production at 10 olarias

in terra firme growing in the interior. The combination between várzea and terra firme species in a corda is, in general, 80-85% of a corda's wood volume is várzea species, and the remaining 15-20% is terra firme species. Trees are usually cut down by professional lumbermen (cortador) at the landowner's request. Forests with the age of 25 to 30 are opened for tree felling, but the area which is opened does not exceed 1ha at a time. In most cases, the owner transplants açaí after the cortador fells the trees in várzea, and cultivates mandioca in terra firme. The cultivation is small because the cultivation of mandioca is only for domestic use (Moran, 1995).

The mean radius of trees packed as a corda was 8.45cm in large sized logs, 5.60cm in medium size, and 2.79cm in small size. Also, logs with a radius of 11.0 to 15.0cm which were unable to be packed were found in some cases. The number of logs in a corda was 227 if the corda was composed of only large sized logs, 518 in medium sized logs, 2,080 in small sized logs, and 26 to 130 in case of irregularly big trunks. The length of the logs was almost uniformly the same length (1.5m). Each corda contains a number of trees.

The annual firewood consumption was estimated in dry weight from the fact that 80 to 85% of a corda were trees of várzea, the mean wood density of

várzea tree species was 0.60g/cm3, and that of terra firme tree species was 0.71g/cm3 (Fig.3). As for the measurement of wood density, refer to Tsuchiya (1996). In the figure, the firewood consumption was estimated in four cases by changing the composition of tree species between várzea and terra firme from V0T100 of which all the trees were made of terra firme tree species to V100T0 of which all the trees were made of várzea tree species. The difference between the both cases becomes more than 300t because wood density is different in each forest.

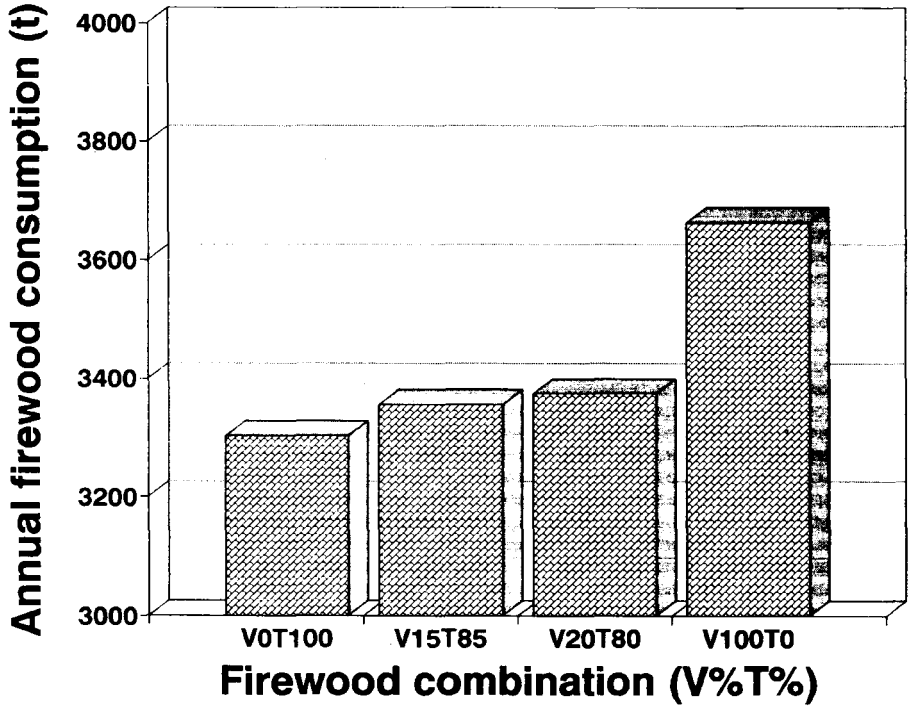

Fig. 3. The annual firewood weight consumned at 10 olrias estimated infour cases, considering the combination of firewood between várzea and terra firme tree species and their wood density.

DISCUSSION

Human impact and forest biomass

In order to estimate forest age, the number of tree rings was counted in the tree disks sampled in three várzea and three terra firme quadrats. As a result, 3 to 8% of trees had more than 30 tree rings in every forest. This means the forest was ready for clear cutting because in this region the forests are rotatively developed every 25 to 30 years. Table 1 shows the species and the number of trees in each quadrat. The várzea quadrats have small number of species, and

the number of trees is also small except for a couple of species such as Pterocarpus amazonicus, while in terra firme quadrats both the number of species and trees are larger. This shows that the species which is adaptable to the special water condition of inundation is restricted in várzea. The total number of trees at VQ3 is 38, while the number of açaí and miriti palms is more than double. There is a tendency that more palms are in várzea, smaller number of trees appears there. Figure 4 shows tree height class distribution of VQ1 and VQ3. The number of trees lower than 10m is small in the latter quadrat. This is due to forest management. Many stumps are found within the forest. In case of terra firme quadrats, the canopy height reaches almost 30m, and many understory individulas are also found in the forest floor. Because the terra firme spreads in the interior, it escapes excessive utilization by inhabitants.

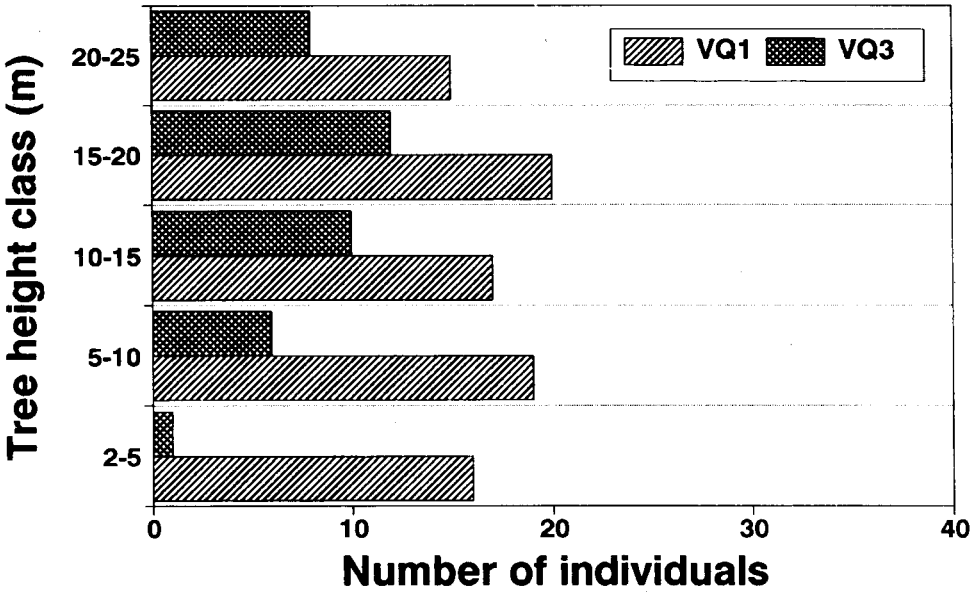

Fig. 4. Comparison of tree height class distribuion between VQ1 and VQ3.

Açaí palm is widely cultivated/managed in várzea forests. Although the açaí agroforest (açaizal) is commonly located around the dwellings along rivers, the area is limited (0.5 to 3.0ha). Açaí is raised by protection of the naturally regenerating açaí or by planting seedlings. The seedlings have 4 to 6 stems after 10 years, and their height reaches 10 to 15m. When reaching maximum growth, old trunks are removed to promote the growth of juvenile stems. Palm hearts (palmito) and fruit are harvested for sale. Palm hearts are processed for export and the fruit is sold in the region. The juice (vinho do açaí) is one of the main

Tabla 1

Floristic composition and the number of trees appeared in three várzea and three terra firme quadrats (/400m²)

Scientific name	Local name	Number of individuals (400m²)					
		VQ1	VQ2	VQ3	TQ1	TQ2	TQ3
Trees							
Pterocarpus amazonicus	Mututi da varzea	54	27	23	–	–	–
Pachira acuatica	Mamorana	8	11	2	–	1	3
Vatairea guiamensis	Faveira	7	8	–	–	–	–
Virola surinamensis	ucuuba de varzea	7	1	4	–	–	–
Avicennia nitida	Ciriuba	4	1	–	–	–	–
Magnifera indica	Mangeira	3	2	–	–	–	–
Margaritaria nobilis	Indrinha	3	1	1	–	–	–
Caryocar villosum	Piquia	1	–	–	–	–	–
Symphonia gloulifera	Anani	–	2	–	–	–	–
Duroia macrophylla	Purui da mata	–	1	–	1	1	–
Zygia sp.	Jarandeua	–	1	–	–	–	–
Heve brasiliensis	Seringeira	–	–	7	–	–	–
Pentaclethra macroloba	Pracaxi	–	–	1	–	–	–
Vochysia vismiafolia	Quaruba cedro	–	–	–	26	12	13
Goupia glabra	Cupiuba	–	–	–	13	1	–
Gustavia augusta	Jeniparana	–	–	–	8	4	3
Tapirira guianensis	Tatapiririca	–	–	–	5	1	–
Eschweilera amazonica	Matamata	–	–	–	4	3	22
Triplaris surinamensis	Tachi	–	–	–	4	4	3
Emmotum tagifolium	Muiraximbe	–	–	–	3	–	–
Manilkara amazonica	Maparajuba	–	–	–	2	3	–
Acacia polyphyila	Paicarana	–	–	–	1	1	–
Apeiba burchelli	Pente de macaco	–	–	–	1	–	–
Aspidosperma eteatum	Araracanga	–	–	–	1	–	–
Duguettia cauriflora	Envira	–	–	–	1	1	6
Iryanthera sagotiana	Ucuubarana	–	–	–	1	–	1
Sagotia racemosa	Arataciu	–	–	–	1	–	–
Sterculia pilosa	Capoteiro	–	–	–	1	1	–
Sterculia elata	Arara	–	–	–	1	1	–
Buchenauia sp.	Cinzeira	–	–	–	1	1	–
Undefined	Jeneira	–	–	–	1	–	–
Erisma uncinatum	Podemastro	–	–	–	1	2	–
Hymenaea intermedia	Jutai	–	–	–	–	22	5
Platonia insignis	Bacuri	–	–	–	–	5	–
Clidemia hirta	Catininga	–	–	–	–	3	1
Poragueiba guianensis	Marirana	–	–	–	–	3	–
Ormosia coutinhoi	Buiucu	–	–	–	–	2	–
Swartzia racemosa	Pacapeua	–	–	–	–	2	–
Didymopanax morototoni	Morototo	–	–	–	–	1	–
Guarea kunthiana	atauba	–	–	–	–	1	1
Mora paraensis	Pracuuba	–	–	–	–	1	–
Simaruba amara	Marupa	–	–	–	–	1	1
Tovomita cephalostigma	Manguerana	–	–	–	–	1	–
Vouacapoua americana	Acapu	–	–	–	–	1	–
Myrcia falax	Murta	–	–	–	–	–	8
Undefined	Cama	–	–	–	–	–	4
Humiria balsamitera	Miri	–	–	–	–	–	4
Duguetia tlagelaris	Caatinga de cutia	–	–	–	–	–	2
Britoa acida	Golabarana	–	–	–	–	–	1
Pipthecellobium decandrum	Saboeiro amarelo	–	–	–	–	–	1
Undefined	Azulzinho	–	–	–	–	–	1
Total		87	55	38	77	80	82
Palms							
Euterpe oleracea	Acai	11	42	83	–	–	–
Mauritia flexuosa	Miriti	1	8	11	–	–	–

components of the diet of the regional people. For this reason, açaí has become the most important cash crop in the estuary (Pollak et al., 1995). Therefore, unnecessary trees and branches are removed. The number of açaí is 11 in VQ1, 42 in VQ2, and 83 in VQ3. Forest management is the largest in VQ3, and is the least in VQ1.

Aboveground biomass estimate was referred to an allometric equation suggested by Higuchi et al. (1994). The coefficients are divided into two patterns according to DBH: ln(WF) = -2.4768 + 2.2301ln(D) + 0.6518ln(TH) (5 =< DBH < 20cm) and ln(WF) = -3.8102 + 1.4631ln(D) + 1.8190ln(TH) (DBH >= 20cm) Here, ln: natural log, WF: fresh weight, D: DBH, and TH: tree height. Allometric equation was tried to find in the Amazon estuary, for example, by Auer (1993), however, it is not an equation to cover all tree species in the site. Different methematical models used by researchers have raised a lot of questions and controversies when estimating biomass from forested area or when estimating carbon dioxide released by forest burning, but Higuchi et al. recommend to use their model as a result of careful examination between actual biomass and estimated one in several places in Amazon.

Dry weight biomass of each quadrat was estimated as shown in Figure 5 from the description that the dry weight represented an average of 60.4% of the fresh weight. The biomass at three terra firme quadrats showed almost the same value, while the biomass was greatly different in várzea quadrats such as 20.43t/400m2 at VQ1 and 6.01t/400m2 at VQ3. It is thought that this difference was dependent on the different degrees of human intervention by the cultivation of açaí. However, the mean biomass of várzea was slightly larger than that of terra firme. This result makes us estimate that the biomass of várzea would exceed the terra firme if the várzea is left without human intervention.

Deforestation area

The mean forest biomass of várzea quadrats was 12.30t/400m2, and the mean biomass of terra firme was 11.56t/400m2; these varied widely among várzea quadrats. Using these data and the data for annual firewood consumption, forest area which will disappear because of fuel use at olarias was evaluated. Converting the firewood (5,157.83m3) into weight by making the firewood combination change from V0T100 to V100T0, and setting up three levels of várzea forests from HIMin (human impact: minimum) to HIMax (human impact: maximum), the area was estimated in a total of 12 cases. The result is shown in Figure 6. When the trees are brought from an almost undisturbed várzea forest, forests of 6.16 to 12.49ha disappears in one year. Also, when the trees are

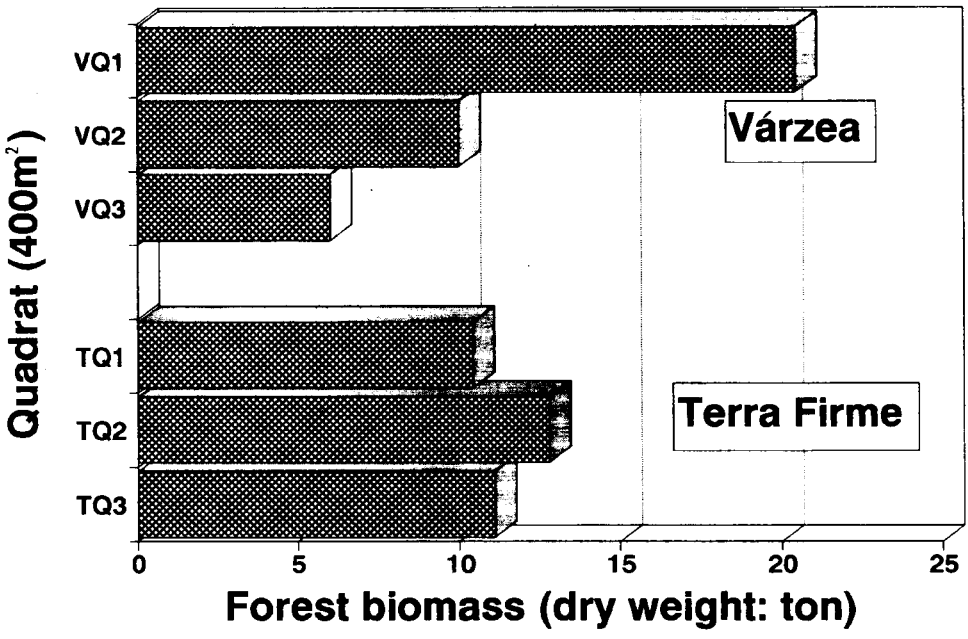

Fig. 5. Forest biomass (t) in three várzea and three terra firme quadrats.

supplied from a normal várzea with an average density of individual, the area becomes 10.23 to 12.49ha. Further, when the trees are cut down from a heavily used várzea such as the cultivation of açaí palm, the deforestation area increases to 20.94 to 12.49ha. However, açaí palm is not necessarily cultivated in the whole várzea, and all várzea forests experience human intervention because people also live along the same riversides. Considering that every várzea forest is influenced by human activities to some degree, the level HIMed is thought to be the most likely. Further, it hardly happens that all firewood is composed only from várzea or terra firme tree species. Therefore, it is concluded that the forest disappearance area caused by 10 olarias' activity is between 10.57 to 10.69ha/year.

The area of Abaetetuba Island is 36,200ha, and 260 olarias exist as described in the above. By calculating 80 to 85% of firewood as várzea tree species, estimating the human impact to várzea at a medium degree, and assuming all the other olarias to have the same scale of tile production as 10 olarias surveyed, the above mentioned estimates were extended to the whole island. Table 2 shows the results in which the logging rotation of forest was regarded to be every 25 to 30 years. In the former estimate (rotation: 25 years), the forest disappearance is 6,870 to 6,948ha, and in the latter case (rotation: 30 years), it is 8,244 to 8,337ha. Firewood for olarias is never provided from the outside of island.

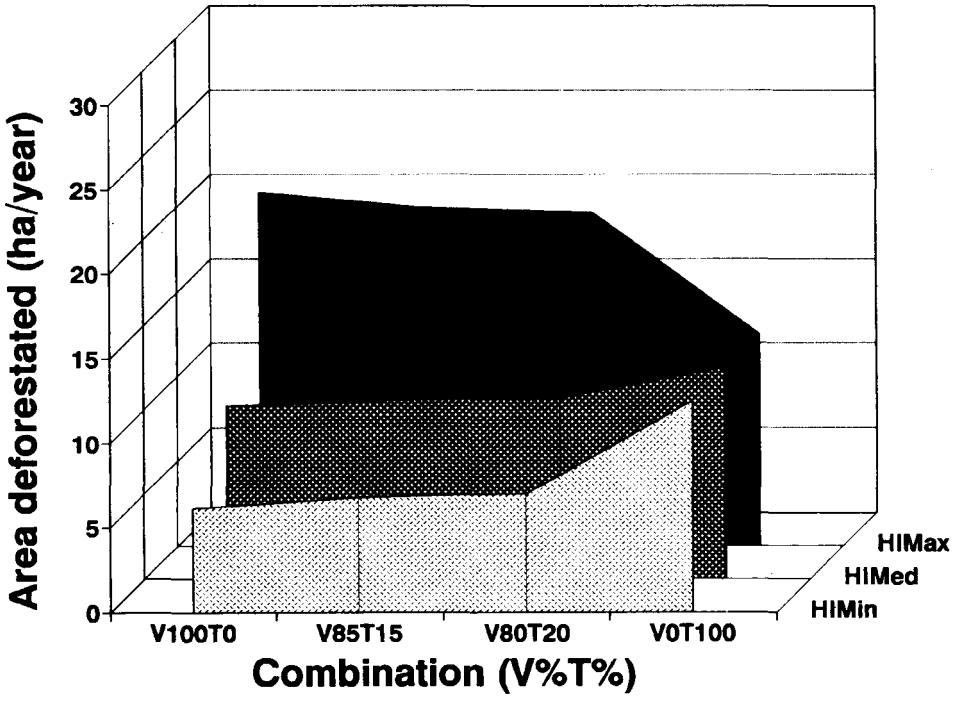

Fig. 6. Anual area of deforestation (ha) estimated from firewood consumption at 10 olarias. HIMin means that the forest management is small, HIMed is a normal várzea, and HIMax is a várzea to which srong human impact is added.

However, the estimated area is smaller than the island. Therefore, it is concluded that forest regeneration and utilization are well balanced at present, and forest resources are not exhausted in this region although the cause of deforestation and the scale are different from western Amazon. However, wood utilization is not only for the fuel at olarias. Terra firme tree species are selectively cut down as construction materials and várzea tree species are also used everyday as the fuel for cooking. The population of Belém is now 1.6 million, it is more than five times the number of 40 years ago. Abaetetuba's population has also grown to 100,000, and that of Abaetetuba Island itself also exceeded 35,000. If the Belém's economic influence grows, and increases the demand for tiles and wood, the balance between forest growth and utilization will be lost unless electric energy is supplied. Another problem is the excessive use of várzea forests. Logging and the switch to açaizal might make the biodiversity of várzea with a small area under special environment decrease further. Although it may difficult to carry out, more use of terra firme trees for fuel by local people would be a help to prevent the excessive use of várzea.

Tabla 2

Forest disappearance area (ha) in the whole Abaetetuba Island with 260 olarias. The upper case is the area inwhich the rottionof forest development is every 25 years, and the lower is the same but for every 30 years

Rotation	V85T15	V80T20
25 years	6,870ha	6,948ha
30 years	8,244ha	8,337ha

CONCLUSION

In this study, the balance between the aboveground biomass of secondary forests and wood utilization at tile factories was examined in the Amazon estuary. Várzea forests are widely utilized due to logging and açaí cultivation, while the degree of human impact is comparatively smaller in terra firme forests. For this reason, the várzea tree species is more frequently used in firewood (80 to 85%), and the utilization of terra firme species with a larger wood density is limited. The area of forest disappearance for making firewood, considering the rotation of forest development as 25 to 30 years, was estimated as 6,870ha/25 years to 8,337ha/30 years. Since the estimate fell short of the area of the whole island (36,200ha), there is no fear of exhausting the forest resources of this island at present.

A future prospect is to investigate the distribution of várzea forests where açaí palms are cultivated according to the degree of cultivation because the wood biomass changes according to the population of açaí palms. When the authors examined by an image analysis of aerial photos, not only the deforestated area but also açaizal were clearly distinguishable from other components in the reflected brightness spectrum. This image analysis will be extended to the whole island in order to increase the precision in the estimate of wood biomass.

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