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Forest Ecology and Management 192 (2004) 161–177
Forest Ecology and Management
www.elsevier.com/locate/foreco

Tropical forest management and silvicultural practices by small farmers in the Brazilian Amazon: recent farm-level evidence from Rondônia

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Received 1 July 2003; received in revised form 1 December 2003; accepted 30 December 2003

Abstract

This paper examines forest management and silvicultural practices of small colonist landholders in the western Brazilian Amazon state of Rondônia. Although recent colonists in the Amazon are widely acknowledged as key agents of tropical forest conversion, relatively little is known of their uses of primary and secondary forest patches and the degree to which these farmers plant trees as part of their land use strategies. Based on longitudinal survey data drawn from three different colonist settlements in 1992 and 2002, this paper explores the range of small farmer's uses of forests and fallows that may indicate future trends in forest management. We also examine the links between forest extraction and tree planting and the factors that may influence these practices. We found that nearly 40% of the farmers surveyed regularly extract useful products from their forests. We examine the types and quantities of timber and non-timber forest products extracted by small farmers over this 10-year study period, and reasons given by them for managing or not managing their forest patches. Forest extractor households were characterized as having a smaller percentage of their land deforested and smaller cattle herds. In addition, we found that roughly 30% of the small farmers surveyed planted trees on their farms during this 10-year study period. Results of statistical analysis (ANOVA and chi square contingency tests) to identify factors that correlate with tree planting behavior indicate that tree planters own larger plots, reside longer on those plots, have a larger number of working age household members, and secure land titles. They were also more likely to participate in social organizations. We conclude that despite ongoing deforestation processes in the region, natural forest use is an important subsistence activity for many small farmers and that many farmers are planting and managing tree species for both short-term products and as long-term investments.

Keywords: Forest extraction; Tree planting; Forest management; Colonist farmers; Amazon; Brazil

1. Introduction

The Amazon basin is believed to have supported large native populations in Pre-Columbian times who managed tropical forests for a wide range of subsistence products and services (Balee, 1989; Roosevelt, 1989; Denevan, 2001; Heckenberger et al., 2003). These forests continue to be managed by many traditional inhabitants, from indigenous

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0378-1127/$ – see front matter © 2004 Published by Elsevier B.V.
doi:10.1016/j.foreco.2003.12.016

people to *riberiños*[1] or *caboclos*[2] living along the region's extensive river banks. A considerable ethnographic research literature on the forest management practices of these traditional forest-dwelling peoples has emerged in the last two decades (Denevan and Padoch, 1987; Posey and Balee, 1989; Redford and Padoch, 1992; Wiersum, 1997). Alternative strategies to promote more sustainable land use systems in the region have taken some of these practices as models that might apply to its more recent inhabitants of the region, e.g. colonists migrating from other regions (Browder, 1989; Gradwohl and Greenberg, 1988; Anderson, 1990). Several donor organizations have sponsored projects that seek to introduce sustainable non-timber forest product extraction from primary forests, sustainable timber management, agroforestry, and management of secondary forest in colonist settlements, with mixed results (Amaral and Amaral Neto, 2000; Browder, 2001; Browder and Pedlowski, 2000; Teixeira, 2001). Despite widespread interest in forest management and silvicultural practices among traditional Amazonian populations, very little is known about such practices in the more recently settled colonist communities.[3]

Following a selective review of the ethnographic literature on forest management and tree planting practices in both traditional and colonist communities of the Amazon, we present the findings of a longitudinal (10-year) household level survey of such practices by colonists in the western Brazilian state of Rondônia. While it is widely recognized that small farmers in the Amazon tend to slash and burn their forests, we also found that roughly 30% of the farmers surveyed have planted native tree species on their farms and nearly 40% regularly extract useful products from their forests. We examine the types and quantities of timber and non-timber forest products extracted by small farmers over this 10-year study period, and reasons given by small farmers for managing or not managing their forests for useful products. We hypothesize that farmers who plant trees as part of their farming system will also be better stewards of remnant primary forests and present the results of statistical analysis (ANOVA and χ^2 contingency tests), seeking to identify factors that may encourage tree planting behavior. Understanding the factors that influence smallholder's participation in extractive and tree planting activities (including agroforestry) throughout the life cycle of the household is important to the larger questions of land use and land cover change, as well as to conservation and development programs and policies.

2. Smallholder forest management and silvicultural practices in the Amazon

Tropical forest management (extraction) for multiple products and small-scale silviculture (tree planting) often in agroforestry contexts, are widely viewed as alternative land use practices that can provide sustainable livelihoods while protecting forests, and potentially generating higher incomes than non-sustainable land uses based on forest conversion (Peters et al., 1989; Padoch and Jong, 1992). Many major environmental non-governmental organizations and development agencies have adopted "sustainable extractivism" and agroforestry in the design and implementation of integrated conservation and development projects (ICDPs). Indeed, the 1980s saw a significant shift in conservation strategies, from a traditional "protected area" and preservationist approach to one that targets local communities (e.g. rubber tappers, other traditional peoples) to use tropical forests sustainably (Browder, 2001).

Whereas research on "sustainable" natural forest management for non-timber products has focused mainly on traditional populations, research on non-

[1] Riberiños: In Spanish speaking countries of South America it refers to detribalized mestizo populations that live along the major waterways of the Amazon basin.

[2] Caboclos: The Portuguese equivalent of riberiños.

[3] Traditional people in the Amazon basin include indigenous native populations as well as riverine and detribalized groups that have mixed with European descendents, especially during the rubber boom era (late 19th century). They live scattered in the main waterways of the Amazon and deep in the forest in old rubber estates connected through social networks of extended families and relying on the forests and rivers for subsistence (e.g. Coomes, 1992). Smallholder farmers are of more recent origin, most of them arriving in the 1970s and 1980s with the opening of roads into the region and through planned settlement projects. They differ from their traditional counterparts in that they live in privately owned parcels of land distributed by the government, and have wider access to markets through existing road systems. Small landholder farmers together with large cattle ranch owners and the timber industry are considered the main agents of deforestation in the region (Fearnside, 1997; Wood, 2002).

traditional rural inhabitants of agricultural frontier areas has concentrated mostly on land use studies and deforestation (e.g. Fearnside, 1993; Dale et al., 1994; Browder, 1994; Scatena et al., 1996; Pinchon, 1997; Marquette, 1998; Walker et al., 2000; Moran et al., 2002; Wood and Porro, 2002). These studies emphasize the agricultural components of small-holder's livelihood, while rarely exploring the other economic activities they are engaged in such as forest product extraction.

2.1. Non-timber forest product (NTFP) extraction

Much of the recent interest in tropical forest management focuses on non-timber forest products (Nepstad and Schwartzman, 1992; Panayatou and Ashton, 1992; Plotkin and Famolare, 1992; Peters, 1996). The economic potential of sustainable NTFP extraction was found, in some studies, to compete favorably with the financial performance of non-sustainable land uses (Peters et al., 1989; Clay, 1992). Such analyses spawned a lively debate in the early 1990s about the potential and limits of extractivism as a development model for the region (Browder, 1992a,b,c; Coomes and Barham, 1997).

In the main, the NTFP research suggests that the extraction of non-timber forest products can be sustainable where human population densities are low, or where its principal use is for subsistence. Where market demand for forest products increases, over-harvesting and local extinction of the commercial species can occur (Browder, 1992a; Coomes, 1992). Also, where forests are treated as common property, as opposed to open access resources, community governance and norms can provide a structure for continual forest management (Western and Wright, 1994; Gibson et al., 2000). Despite the high initial interest in the economic potential, income actually obtained from the extraction of non-timber products, with a few exceptions, continues to be very low and its importance is still primarily linked to the subsistence livelihoods of traditional peoples (Southgate, 1998).

The relationship between non-timber forest product extraction and biodiversity conservation appears to be ambiguous. The literature abounds with examples of biodiversity loss due to over-harvesting of non-timber products (Coomes and Barham, 1997; Alvard et al., 1997). Other studies suggest that non-timber forest product extraction enhances biodiversity of useful tree species. In the lower Tambopata River, Peru, Phillips et al. (2000) found that the extraction of non-timber forest products had little effect on overall botanical diversity and, in fact, those areas subjected to greater human use, correlated with higher biodiversity levels than those that were less impacted. Summers et al. (2001) found similar results within the Amazonian community of Infierno, Peru, where although human pressure was high on some target species, little correlation was found with biodiversity levels. Yet, in many cases, humans were inadvertently enhancing rather than reducing overall biodiversity in areas of higher impact extraction.

The extremely high biodiversity of tropical forests also accounts for the low species densities, of both timber and non-timber forest products, limiting the capacity of many species to be managed or extracted commercially unless access to large areas are available (e.g. extractive reserves, communal reserves). Browder (1992a,b,c) and Crook and Clapp (1998) note that the sustainable harvest of forest products on a commercial scale requires that the resource be concentrated in high densities that favor agricultural alternatives, and be located within a close geographic range of viable urban markets. As such, the prospects for sustainable commercial extraction of a wide range of NTFPs appears to be bleak.

2.2. Timber extraction

Timber continues to be the most important economic resource to come from natural tropical forests. Research on commercial timber extraction has identified complex relationships between the opening of roads, the timber industry and agricultural and pasture expansion (Uhl et al., 1991; Verissimo et al., 1992; Brown and Ekoko, 2001). These studies confirm that small farmers play a crucial role in providing roundwood for the lumber industry and that timber extraction often subsidizes the expansion of small-scale agriculture and pasture. However, by focusing on small farmers as if they constituted a homogeneous social group these studies often fail to recognize and address the differences among them, how timber extraction fits into the broader range of household economic strategies, and the household level factors that might influence and explain different timber extraction practices.

On the other hand, research on "sustainable" timber management has been concentrated on low impact harvesting methods suitable for large scale industry operations or for community cooperatives (Hartshorn, 1990; De Graff and Poels, 1990; Heinrich, 1995; Johns et al., 1996; Barreto et al., 1998). Although these are important areas of research, "sustainable" timber management models ignore the fact that most of the tropical timber in the Brazilian Amazon continues to come from the expanding agricultural frontier areas. Suitable models for integrating existing timber harvesting practices of small landholders to more sustainable forest use strategies are still poorly explored.

Forest policies and laws in the Brazilian Amazon have sought to promote large scale forestry operations, while NGOs and development agencies have tried to support smaller scale social forestry programs among traditional forest peoples. These efforts, although important in their own context, have little effect on the conventional logging patterns, and the tropical timber trade from the Amazon basin continues to be almost entirely unsustainable (Johnson and Cabarle, 1993; Angelsen and Kaimowitz, 1999; Putz et al., 2000). As long as there is a continuous supply of cheap timber from areas of frontier expansion, the models of private and community sustainable timber management systems will have little impact over the overall timber trade since they cannot compete with cheaper timber coming from the agricultural frontier areas. Current programs to expand and pave the existing road system by the Brazilian government in the Amazon (Nepstad et al., 2001; Laurance et al., 2001) and the inability of the state agencies to control illegal logging, suggests these trends will probably continue in the foreseeable future. Brazilian forest policy has yet to effectively integrate smallholders and informal logging practices into more sustainable forest use practices.

2.3. *Tree planting*

Tree planting, whether as part of an agricultural system (e.g. agroforestry), tree plantations, or as the enrichment of secondary growth areas, is found in many places to offer substantial environmental and economic benefits for rural people (Winterbottom and Hazelwood, 1987). Most tree planting research has focused on timber and fuel-wood species, but there is growing interest in the production of NTFPs as well as in environmental services such as carbon sequestration, erosion control and soil productivity enhancement (Nair, 1993; Smith et al., 1996; Fischer and Vasseur, 2002). While much of this research literature focuses on the factors that motivate small farmers to plant trees, considerably less has been written about the conditions influencing successful silvicultural outcomes (Browder and Pedlowski, 2000). The literature on tree planting and agroforestry has shifted somewhat in the last decade from an emphasis on the agricultural and biological aspects of tree planting, to the social and economic dimension of these practices (Fischer and Vasseur, 2002).

An economic incentive (e.g. higher perceived income) is usually listed as one of the major factors encouraging the adoption of tree planting among small producers in developing countries (Sullivan et al., 1992). Yet, there is little evidence that tree planting actually leads to higher incomes. Fischer and Vasseur (2002) claim that 84% of farmers in Panama had no change in their income level as a result of participating in tree planting projects. Yamada and Gholz (2002) estimated that the mean *per hectare* annual income of rural farmers in Tome Açu, Pará (Brazilian Amazon) is higher for mixed agroforestry crops than pastures, but still ranching is becoming an increasingly attractive investment. In Costa Rica, a financial analysis of agroforestry systems in experimental stations was estimated to yield higher financial returns in the long run than their monocultural counterparts (Ramirez et al., 2001). Differences in the financial models make decisive conclusions problematic. Inconclusive accounts of financial performance suggest that farmers may value tree planting for non-economic reasons.

The environmental benefits of farmer tree planting behavior are also somewhat controversial. Many development agencies and NGOs have sponsored tree planting and agroforestry systems as part of ICDPs hoping that such initiatives will help relieve the pressure on native forests by providing alternative sources of income and similar forest products. Murniati et al. (2001) found that farmers who diversified their agricultural crop systems to include timber species, use native forests less intensively than neighboring farmers who only planted rice. But they attributed this to labor constraints ("intensive" labor requirements for mixed crops as opposed to only temporary labor required for rice planting and harvesting). However, other studies have shown how ICDPs projects have few positive effects on adjacent protected forested areas (Browder, 2001; Fischer and Vasseur, 2002).

Some studies have tried to systematically determine the factors that influence farmers' decisions to adopt tree planting strategies. Among the statistically significant factors, land size had a positive correlation with tree planting (Salam et al., 2000; Simmons et al., 2002; Murniati et al., 2001). Land tenure has traditionally been considered important factor in affecting adoption of tree planting practices (Fortmann, 1985; Walters et al., 1999). Household level factors such as availability of labor have also been found to be a significant factor influencing agroforestry adoption in Rondônia, Brazil (Browder and Pedlowski, 2000) and in Bangladesh (Salam et al., 2000), but not in a study that examined farmers in Pará and Panama (Simmons et al., 2002). A recurrent significant factor across studies was the presence of outside agents, governmental or non-governmental, in supporting tree planting activities (Salam et al., 2000; Simmons et al., 2002; Fischer and Vasseur, 2002).

Environmental and ecological characteristics of the site have also been recognized to affect the land use decisions and practices among colonist households (Pinchon, 1997; Wood and Porro, 2002). Traditional populations have long been recognized to have a highly accurate knowledge for selecting soils and lands for different uses depending on existing vegetation and other ecological site characteristics (Behrens, 1989; Moran, 1974). In contrast, newly arrived colonists lack this knowledge, but acquire it through trial and error and social networks.

On the whole, then, the literature on Amazonian forest management has been dominated by an interest in large-scale forest tract management for timber production and by small-scale NTFP extraction by traditional populations. With some important exceptions, what has eluded widespread analysis is the role of forest products and tree planting in small farmer land use strategies. The present study of the forest management and silvicultural practices of small farmers in Rondônia, Brazil, addresses some of these gaps in our knowledge, as reviewed above.

3. Study sites

The three study sites are located in the Brazilian Amazon State of Rondônia (Fig. 1). Rondônia (243,000 km^2) was a major destination for landless rural workers from the Southeast and South of Brazil during the 1970s and 1980s. Aided by the Northwest Region Development Program (POLONOROESTE; 1980–1985), co-financed by the World Bank, over 60,000 families settled on forest lands in Rondônia largely during the 1980s (Browder, 1989, 2001). These farmers brought with them their own specific knowledge about farming based on the mixed crop–coffee systems prevalent in Brazil's agricultural heartland. The result was an enormous increase in deforestation, accompanied by invasion of protected areas and indigenous reserves. The social and environmental problems that accompanied the program produced strong international pressures and triggered the temporary suspension of the World Bank's funding in 1986. While in 1978 only 2% of the state's primary forests had been deforested, by 1998 deforestation had eliminated 23% of the state's natural forest cover (IBAMA, 1999 in Browder, 2001).

The three study sites—the municipios of Rolim de Moura, Nova União, and Alto Paraiso—were all established as a result of the second second of this colonization program (1982–1986), although the first settlers arrived in the former two sites in the late 1970s. Despite certain local differences in soil profiles and social history, they all share common characteristics of the region's settlement programs (Table 1). In this respect they were planned colonization areas with 100 ha plots distributed throughout the landscape in a grid-type fashion with parallel main roads and perpendicular feeder roads serving as main lines of access to the plots.

4. Methods

The data for this analysis were generated as part of a larger 10-year (1992–2002) household survey research project on land use strategies among small landholders in these agricultural settlement projects.[4]

[4] NSF project: John O. Browder, Robert T. Walker, and Randolph H. Wynne, Patterns and processes of landscape change in the Brazilian Amazon: a longitudinal comparative analysis of smallholder land use decision-making, NSF grant #BCS-0136965.

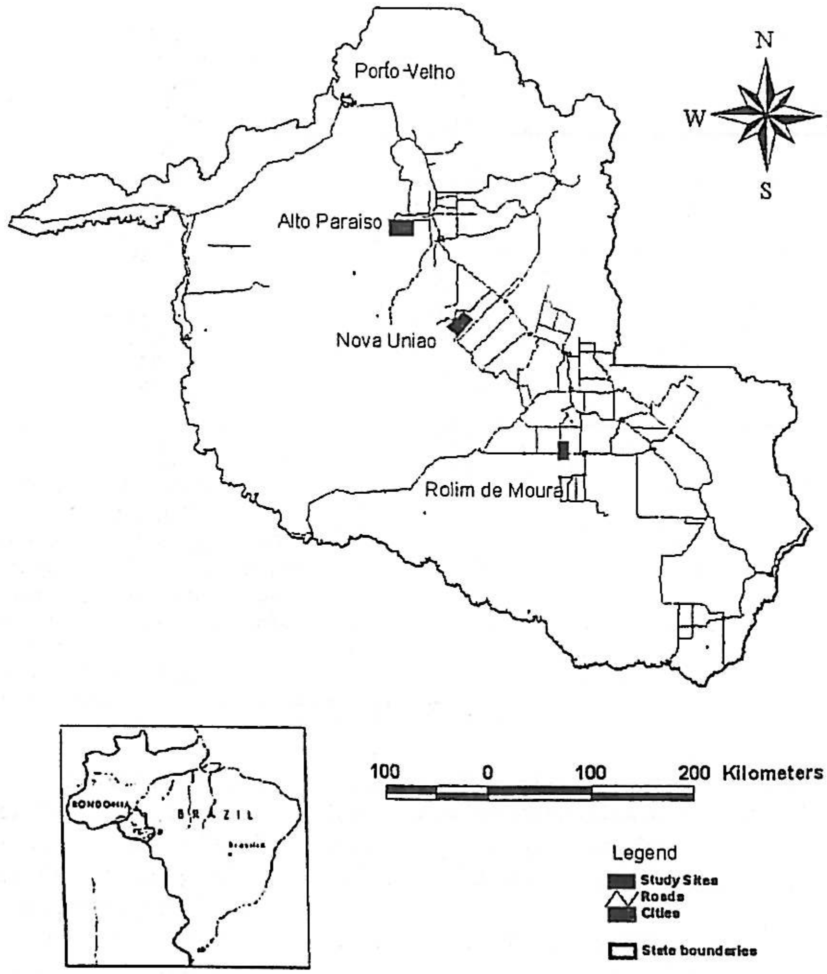

Fig. 1. Location of study sites.

The three study sites (settlement areas) selected were established at roughly the same time, located equidistant from the main highway bisecting the State (BR 364), and represent a range of settlement conditions (especially soil types) found across the State. In 1992, each study area was divided into equal-size road sections containing between 20 and 30 property lots. Then three road sections were randomly chosen from all possible road sections within each study site. All property owners within each road segment selected were interviewed. The same properties were revisited in 2002. The sample size was 240 farms in 1992, increasing to 281 in 2002, due to property fragmentation.

In both surveys, the male and female household heads were interviewed by trained Brazilian researchers using a standardized 18-page questionnaire.[5] By 2002, 30.4% of the original owners had moved and 16.8% had subdivided their plots.

[5] The original 1992 questionnaire instrument was elaborated on the basis of earlier questionnaires designed by co-author John Browder as part of his ongoing survey research in the region since 1984. The survey instrument was pretested and revised in June 1992 prior to the execution of the base-line survey. The 2002 questionnaire was based on the 1992 instrument, with several questions added to reflect changes in conditions occurring since 1992 (e.g. the increasing trend in property fragmentation).

Table 1
Characteristics of project study sites in Rondonia (1992)

Characteristic	Nova União	Alto Paraiso	Rolim de Moura
Location	62°35′W, 10°50′S	63°20′W, 9°35′S	62°47′W, 11°40′S
Altitude[a]	100–225	110–369	250
Average annual rainfall (mm)	1600–1700	2000–2100	2000–2250
Main soil type[b]	PE 3/Re[c]	Pva 13/Rd 3[d]	PE 9/Ce 23[e]
Vegetation cover	TTSMF[f]	TTSMF	TTSMF
Sample size (farms)	97	82	61
Average farm size (ha)	73.5	88.7	80.0
Mean year of farm start	1981	1982	1979
Legal land title (%)	69.0	75.9	63.9
Persons per farm	11.2	9.3	7.6
Workers per farm[g]	6.8	6.05	5.4
Rural credit use (%)	1.0	0	3.3
Labor organization (%)[h]	31.2	20.7	6.7

Note: All "%" refer to percentage of farms in each site's example.
[a] Meters above sea level (IBGE, Elevation maps, 1974).
[b] Projeto Radambrasil. Mapa Exploratório de Solos, 1:1,000,000, 1979.
[c] Eutrophic yellow-red podsols with patches of eutrophic litolic soils.
[d] Alic yellow-red podsols with patches of distrophic litolic soils.
[e] Eutrophic yellow-red podsols and non-hydromorphic cambisols.
[f] Transitional tropical seasonal moist forest.
[g] Worker: persons age 11–65 years for Rondonia sites.
[h] Percentage of farms with members participating in local rural workers organization.

In addition to a wide range of information on land use, household composition, and household socio-economic characteristics, the survey instrument collected farmer responses to questions about primary forest product extraction and tree planting during the 10-year study period. The results of a descriptive statistical analysis of these data for 1991 and 2001 are presented below. In addition, the results of ANOVA tests and chi square contingency tests identified factors that are associated with forest management and tree planting practices of small farmers in our samples. Those results are also presented below.

5. Results

Most farmers in our sample do not systematically manage their primary forest patches for either timber or non-timber forest products. Many, however, do recognize and regularly extract specific forest resources. Although forest extraction is rarely a basis of livelihood for farmers, our data indicate that forest products (both non-timber and timber) were regularly extracted by farmers on nearly 43 and 40% of the farm properties surveyed in 1991 and 2001, respectively (Fig. 2), despite the reduction in primary forest area as a percentage of total mean farm area, from 57% in 1992 to 31% in 2002 (Browder et al., 2004).

5.1. Non-timber forest product extraction

The number of farmers extracting *non-timber* forest products declined during the 10-year study period. In 1991 farmers on 30% of the lots extracted at least one NTFP compared to 23% in 2001 (Fig. 3). Only two non-timber forest products were extracted with any regularity by colonist farmers in the study sites: Brazil nuts (*Bertholletia excelsa*) and palm hearts (*Euterpe* spp.). Overall there was a dramatic decline in the number of farm properties from which Brazil nuts were extracted (from 21.2% to 10.5%), although the median quantity (weight) extracted was relatively stable over this study period (30 kg/property in 1991 and 35 kg/property in 2001; Table 2), suggesting that extraction became specialized by a diminishing number of farms over time. This diminishing trend was found to be similar between study sites.

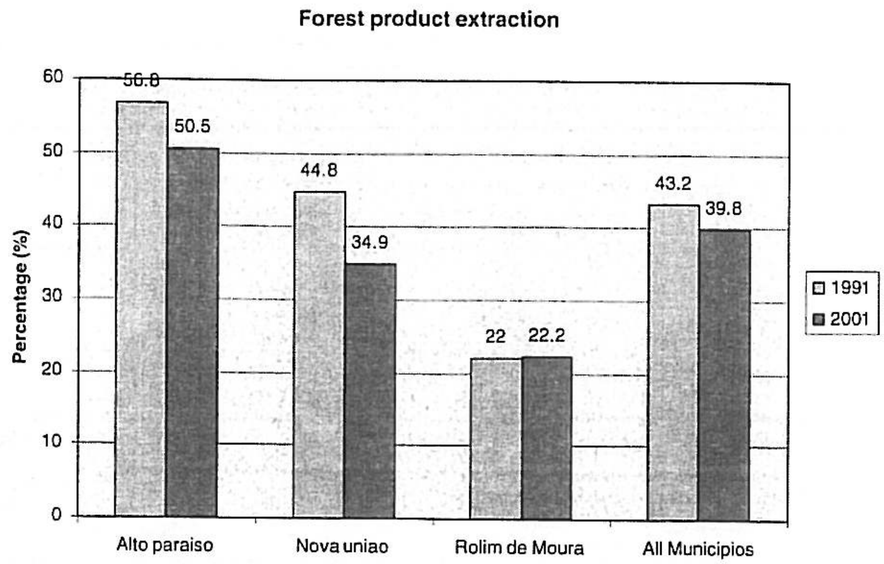

Fig. 2. Forest product extraction (percentage of households extracting).

In the case of palm hearts (*Euterpe precatoria*) there are no major differences in the overall percentage of properties extracting, around 15% in 1991 and 14% in 2001. Despite the slight reduction in the percentages of properties extracting palm hearts, the median quantity extracted per household did remain constant (10.0 kg/households in 1991 and 2001; Table 3). Between study sites we found an increase in Alto Paraiso (which also shows larger areas of disturbed remnant forests that might account for this), while it declines in the other two municipios.

Both of these NTFPs are extracted primarily for domestic consumption; less than 1% of the respondents extracting these products exchanged (sold/traded)

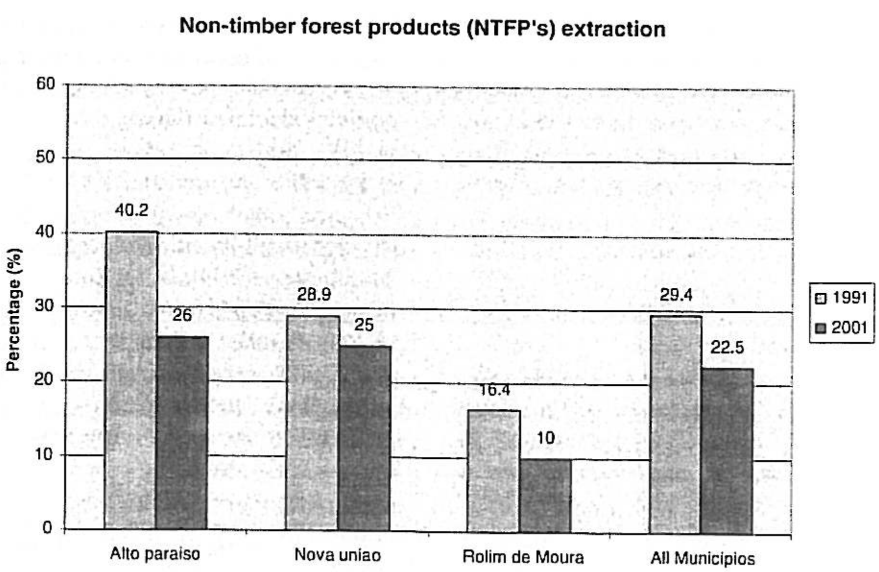

Fig. 3. Non-timber product extraction (percentage of households extracting).

Table 2
Brazil nut (*B. excelsa*) extraction. Mean, standard deviation and median extracted by household (kg/year)

Brazil nut	Alto Paraiso		Nova União		Rolim de Moura		All	
	1991	2001	1991	2001	1991	2001	1991	2001
Mean	112 ± 59	50 ± 8	55 ± 26	18 ± 6	44 ± 38	0	88 ± 36	44 ± 7
Median	50	50	20	20	10	0	30	35
Count	30	15	17	4	3	0	50	18

Table 3
Palmito (*Euterpe* spp.) extraction. Mean, standard deviation and median extracted by household across municipios (kg/year)

Palmito	Alto Paraiso		Nova União		Rolim de Moura		All	
	1991	2001	1991	2001	1991	2001	1991	2001
Mean	35 ± 19	33 ± 13	12.4 ± 3	9 ± 1	211 ± 131	60 ± 40	71 ± 38	22 ± 6
Median	20	20	10	10	20	60	10	10
Count	7	8	17	13	9	20	33	23

Table 4
Timber extraction. Mean, standard deviation and median (m^3) extracted by household

	AP		NU		RM		All	
	1991	2001	1991	2001	1991	2001	1991	2001
Timber extracted (m^3)								
Mean	47 ± 12	43 ± 13	95 ± 12	12 ± 4	78 ± 42	11 ± 4	71 ± 15	28 ± 8
Median	20	28	55	5	80	11	30	10
Count	20	18	20	10	3	4	43	33

any of their harvests. Those that marketed Brazil nut in 1991, reported receiving a producer unit price of CR$ 100.00 kg^{-1} (US$ 0.25[6]) and R$ 1.00 in 2001 (US$ 0.42). In 1991 the producer price paid for palmito was CR$ 200.00 kg^{-1} (US$ 0.67[7]). Using these market prices, we conclude that the financial value of NTFP extraction for households is generally negligible. However, those six farmers selling NTFPs in 1991 had extracted those products on a much larger scale, ranging from 800 to 1000 kg of palmito, with a corresponding value of extraction of CR$ 160,000.00 to CR$ 200,000.00 (US$ 533 to US$ 667), and 60–80 kg of Brazil nut, with a market value of CR$ 6000.00 to CR$ 8000.00 (US$ 26.00–35.00), representing a significant income supplement. Clearly, NTFP extraction is not an economic solution for any larger number of rural producers in a given market area, but may provide some opportunity for specialized commercialized extraction on properties with large forest reserves.

5.2. Smallholder timber extraction trends

During the 10-year study period the percentage of households surveyed harvesting timber remained stable (20%). However, the median volume of timber harvested from the sample overall declined by two-thirds, from 30 to 10 m^3 over the study period as remnant forest areas were progressively high-graded for timber then converted into other land uses (Table 4). Overall, the number of farms from which timber was sold dropped by 62%, from 37 to 14 farms (Fig. 4). However, between sites, the Alto Paraiso study site showed an increase in the median of timber

[6] Price was obtained using the mean exchange rate of cruzeiros to dollars between February and April 1991 when Brazil nuts are harvested.

[7] Based on exchange rate in June 1991: CR$300 = $ 1.00.

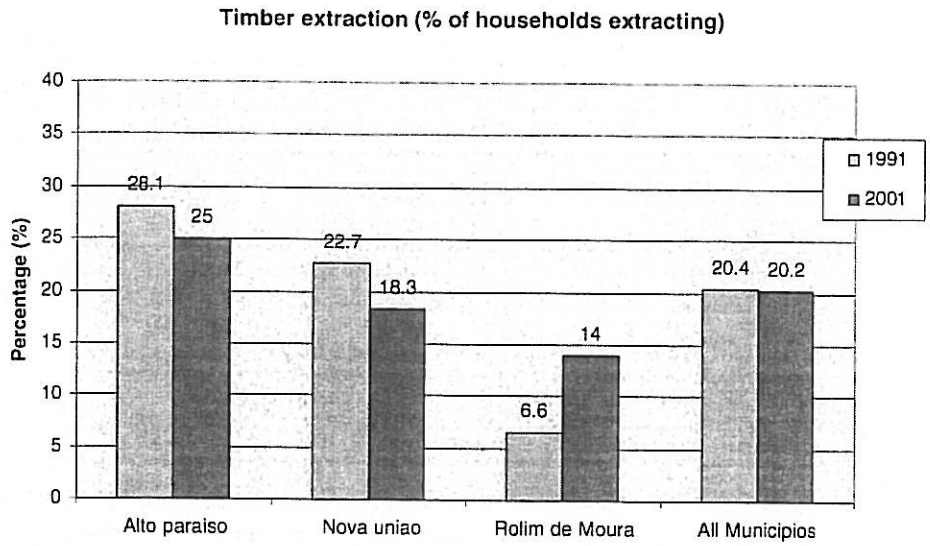

Fig. 4. Timber extraction (percentage of households extracting).

extracted while it declined considerably in the two other study sites. We attribute this to the larger areas of remnant forests in this site as opposed to the other ones.

In 2001, farmers extracted timber of 26 different species, 16 (52%) of which were sold for cash, the others traded for finished wood products (especially fence posts, construction lumber). Of the 14 farmers selling timber, the average volume sold was 28 m^3 and the average price received per sale was the R$ 8.1 m^{-3} (US$ 3.4), generating an average annual income supplement of R$ 183.00 (US$ 76.3). This does not represent a very significant "subsidy from nature" and certainly provided farmers with little incentive to sustainably manage their forest patches for timber. This does not necessarily mean that all farmers are uninterested in silviculture as examined below.

5.3. Tree planting

Our analysis indicates that there were no major changes in the level of interest for planting among colonist farmers, remaining at around 50% for all households over the 10-year study period. The percentage of properties whose owners actually planted tree species also remained fairly stable going from 29.7% (66 farms) in 1992 to 30.0% (81 farms) in 2002. The rate of increase in farms planting trees is highest in those study sites where deforestation has left the smallest areas in remnant primary forests intact (Rolim de Moura and Nova União, respectively).

Reasons given for planting trees reveal wide-ranging interests in silviculture, from aesthetic to economic (Table 5). For example 42.9% of the farmers surveyed indicated that they replanted in order to help

Table 5
Reasons for planting tree and palm species (%)

Municipio	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)
Alto Paraiso	47.2	0.0	8.3	0.0	27.8	0.0	16.7
Nova União	32.4	23.5	2.9	2.9	29.4	2.9	5.9
Rolim de Moura	71.4	28.6	0.0	0.0	0.0	0.0	0.0
Total	42.9	13.0	5.2	1.3	26.0	1.3	10.4

Code: 1, reforestation; 2, aesthetics; 3, for sons and daughters; 4, association support; 5, commercial interests; 6, its the law; 7, ecological values—shelter, river protection.

Table 6
Reasons for not planting tree species (%)

Municipio	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)	7 (%)	8 (%)	9 (%)	10 (%)	11 (%)	12 (%)	13 (%)
Alto Paraiso	21.2	9.1	0.0	6.1	12.1	33.3	0.0	9.1	3.0	3.0	0.0	3.0	0.0
Nova União	21.6	17.6	0.0	11.8	2.0	7.8	7.8	9.8	0.0	3.9	11.8	3.9	2.0
Rolim de Moura	46.2	15.4	15.4	7.7	7.7	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	24.7	14.4	2.1	9.3	6.2	16.5	4.1	8.2	1.0	3.1	6.2	3.1	1.0

Code: 1, only pasture/no area to plant; 2, not productive; 3, no financial resources; 4, too old; 5, planning to move; 6, no incentive; 7, does not need too many trees around and in forest reserves; 8, not interested; 9, fire hazard; 10, does not know how—no information; 11, not good soil for trees; 12, other.

reforest their properties. Another 26.0% indicated economic values associated with (timber) tree planting. Another 13.0% declared that they planted trees for aesthetic reasons, while 10.4% cited ecological motives for their action (e.g. riparian corridor protection, shelter for livestock, buildings and fields).

Table 7
Number of farms planting tree seedlings by species and year

Species		Total	
		1992	2002
Acai	*Euterpe precatoria*	1	2
Andiroba	*Carapa guianensis*		1
Aroeira	*Astronium lecointei*		1
Bandarra	*Schizolobium amazonicum*	3	14
Caroba	*Jacaranda copaia*		2
Castanha	*Betholettia excelsa*	10	13
Caxeta	*S. amara*	1	1
Cedro	*C. odorata*	7	9
Cereijeira ou Imburana	*T. cearensis*	3	7
Eucalipto	*Eucalyptus* spp.	2	1
Freijo	*Cordia* sp.	12	25
Garrote	*Bagassa guianensis*		1
Ipe	*Tabebuia* spp.	4	4
Itauba	*Mezilarus* sp.	1	1
Jatoba	*Hymenaea courbaril*	2	2
			1
Mogno	*S. macrophylla*	11	16
Munguba	*Pseudobombax munguba*		1
Pinho Cuaibano	*Schizolobium parahyba*	1	1
Pupunha	*Bactris gasipaes*	2	5
Seringa	*H. brasiliensis*	39	22
			1
Sucupira	*Diplotropsis* sp.	1	1
Sumauma	*Ceiba pentandra*		1
Tamboril	*Enterelobium* sp.		1
Teca	*Tectona grandis*		18
Count		16	24

The principal reasons given for not planting trees ranged from "no available land" (24.7%), "no outside incentive", e.g. credits (16.5%), "not productive" (14.4%), to "too old to take on new work" (9.3%). Interestingly, only one percent of the farmers surveyed indicated that they did not plant trees because of possible "fire hazards" (Table 6).

During the 10-year study period the number of farms on which trees were planted and the range of tree species planted increased substantially, from 16 to 24 species, a 50% increase (Table 7). The 10-year difference for both figures shows an increasing interest and planting of *madeira branca* (light density, commercial soft-wood) tree species such as caxeta (*Simaruba amara*), bandarra (*Schizolobium* sp.), freijo (*Cordia alliadora*), and pinho cuiabano (*Schizolobium* sp.). The traditionally high-value hardwoods such as cedro (*Cedrela odorata*), mahogany (*Swietenia macrophylla*) and cerejeira (*Torresia cearensis*), also continue to score high on planting preference. When discriminating timber species from non-timber species we find that only the rubber tree (*Hevea brasiliensis*) was planted by any significant proportion of the farmers surveyed, and both the proportion planting and interested in planting fell-off sharply during the 10-year study period. Brazil nut (*B. excelsa*) was the second most significant NTFP species planted (13% of farmers reported planting Brazil nut trees).

6. Factors influencing forest management and silvicultural practices

To identify the factors that might influence the forest management and silvicultural practices of small farmers in rural Rondônia colonist settlements, we

Table 8
Comparison of descriptive variables for two sub-populations: forest extractors and non-forest extractors

Variable	Forest extractors (n = 100)	Non-forest extractors (n = 150)	P
Lot size (alqueires)	26.9 ± 16.3	27.1 ± 12.8	0.938
Percentage deforested	66.3 ± 22.5	76.7 ± 23.9	0.001***
Amount deforested	17.1 ± 9.5	20.2 ± 15.2	0.075*
Number of years in lot	16.9 ± 7.0	16.3 ± 8.3	0.618
Number of working age household members	3.9 ± 2.6	4.2 ± 2.9	0.581
Number of dependents	2.2 ± 2.1	1.8 ± 2.2	0.224
Number of working off-farms	0.51 ± 0.79	0.66 ± 1.1	0.283
Cattle (own)	45.0 ± 62.3	80.9 ± 114.6	0.005***
Cattle (third party)	21.6 ± 40.7	11.7 ± 29.9	0.031**
Weighted wealth	6.8 ± 4.8	6.9 ± 4.8	0.876
Total cattle	66.8 ± 86.6	94.2 ± 119.5	0.054*
Mutual help association	57.1%	45.7%	0.101
Participated in syndicate	65.9%	58.4%	0.321
Participated in cooperative	8.9%	8.0%	0.807
Living in lot (percentage of property owners)	73%	64%	0.168
Family living in close rural zone	14%	16.7%	0.599
Other rural properties	31.9%	28.9%	0.656
Definitive land title	55.1%	55%	1.000
Credit	25.8%	23.1%	0.648
Lived in urban area for >1 year	43.5%	47.6%	0.584
Family currently living in urban area	77.2%	77.1%	1.000
Owns urban properties	20.6%	18.1%	0.728

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

tested the characteristics of four farm subgroups; forest extractors versus non-extractors and tree planters versus non-planters (Tables 8 and 9).

We hypothesized that property size would be directly related to the intensity of forest extraction and inversely related to tree planting efforts for the following reasons. First, larger properties may have a larger proportion of their land in remnant forest from which to extract forest products. Second, larger plot owners having larger areas of natural forest will see less need for tree planting. Our analysis rejects the first of these two hypotheses. We found no significant differences in lot sizes between forest product extractors (26.9 alqueires) and non-extractors (27.1 alqueires). However, as hypothesized, we did find significantly different lot sizes between the tree planting group and those farmers not planting trees.

Although we hypothesize that demographic variables (numbers of working household members, dependents and off-farm workers) might have a positive effect on such activities as forest extraction and tree planting, we did not find any significant differences for forest extraction. In the case of tree planting, we did find, as expected, that households that had engaged in tree planting during the 10-year study period had more available working age members in residence, but the number of dependents and off-farm workers was not significantly different. Our finding that labor availability positively correlates with tree planting supports the literature and theories that suggest that household level labor allocation decisions are more likely to be based more on welfare satisfaction and drudgery minimization than on strictly financial motives, e.g. profit maximization (Walker et al., 2002).

Cattle is rarely considered a variable related to forest extraction and tree planting. We hypothesized that households specializing in cattle (ranchers) would be less likely to plant trees and use forests since cattle raising in this region is pasture-extensive, demanding large tracts of land, giving ranchers little incentive to maintain forest remnants or plant trees. Although forage tree species are well established in the agro-silvipastoral literature, we did not find any relationship between tree planters and cattle ownership or pasture

Table 9
Comparison of descriptive variables for two sub-populations: tree planters and non-tree planters

Variable	Tree planters (n = 77)	Non-tree planters (n = 170)	P
Lot size (alqueires)	29.3 ± 12.9	25.3 ± 15.9	0.049**
Percentage deforested	65.6 ± 21.7	72.3 ± 24.5	0.004***
Amount deforested	18.5 ± 9.9	18.8 ± 14.9	0.876
Number of years in lot	18.9 ± 6.2	14.3 ± 8.5	0.000***
Number of working age household members	4.7 ± 2.9	3.8 ± 2.7	0.020**
Number of dependents	2.2 ± 2.5	1.8 ± 2.0	0.127
Number of working off-farm	0.49 ± 0.78	0.6 ± 1.1	0.308
Cattle (own)	58.4 ± 84.3	74.3 ± 106.3	0.252
Cattle (third party cattle)	15.7 ± 33.2	14.7 ± 34.4	0.829
Weighted wealth	7.1 ± 4.8	6.9 ± 4.7	0.792
Total cattle	74.1 ± 95.1	89.7 ± 114.2	0.301
Mutual help association	64.5%	39.8%	0.001***
Participated in syndicate	84.2%	46.9%	0.000***
Participated in cooperative	13.5%	6.3%	0.126
Living in lot (percentage of property owners)	76.6%	61.8%	0.029**
Family living in close rural zone			
Other rural properties	31.6%	29.2%	0.758
Definitive land title	73.7%	46.7%	0.000***
Credit	27.6%	22.1%	0.415
Lived in urban area for >1 year	43.4%	50.6%	0.324
Family currently living in urban area	75%	77.8%	0.737
Owns urban properties	22.4%	19.3%	0.602

** Significant at 5% level.
*** Significant at 1% level.

formation, but we did find some interesting differences for cattle ownership between forest extractors and non-forest extractors. Forest extractors had significantly smaller cattle herds, almost half of what is owned by non-forest extractors. However, they also stock double the number of cattle that they do not themselves own, renting their own pasture-land to neighbors.

Some authors have suggested that there is an inverse relationship between wealth and forest extraction, as households become wealthier they rely less on forest extraction (Godoy et al., 2000), while other studies found a positive association between wealth and resource extraction (Takasaki et al., 2001). Cattle has also been considered an accurate wealth indicator, suggesting that households that own fewer cattle, or are forced to rent land to other owners to pasture their cattle, might be poorer and more reliant on the extraction of forest products for subsistence or commercial reasons. Unlike cattle, our weighted wealth indicator (based on more than 15 wealth endowments) did not prove to be significantly different in either comparison group.

Participation in different social organizations is recognized in the literature as an important medium through which farmers can learn better farming practices, as well as disseminating conservation and environmental knowledge (Bebbington, 1996; Reardon and Vosti, 1992; Ellis, 2000). Thus, we hypothesized that those that participated in social organizations (mutual help associations, rural labor unions, or co-operatives) will be more inclined to extract forest products and plant trees. As hypothesized, forest extractors and tree planters both scored higher on each of the three social participation variables, but were more important for tree planting than for forest extraction. In the case of forest extraction we did find a larger proportion of forest extractors participating in informal "mutual help assistance" groups as opposed to non-extractors. In the case of tree planting, a significantly larger proportion of tree planters were members of both mutual help associations and the politically influential rural worker syndicates. These results agree with those found for successful agroforestry adopters (Browder and Pedlowski, 2000). Results suggest social organizations might be an efficient means through which tree planting has been encouraged.

Land tenure and property variables (years living on plot, multiple rural property ownership, definitive land title) were also compared statistically between sub-group populations. We did not find any significant differences among the different groups of forest extractors and non-extractors for tenure and multiple property variables. On the other hand, we did find a significant larger number of tree planters who resided on their plots (77% as opposed to 61%) and that they possessed definitive land titles (74% as opposed to 47%). Other rural properties and family members living in adjacent rural areas were not significantly different between planters and non-planters. However, the number of years the household had resided on the plot was also significantly higher for the sub-population of tree planters as opposed to those that did not plant trees. Thus a profile of land owners that have a secure title, physically live on the lots, and have been there for a significant length of time is also the profile of farmers who are more likely to plant trees.

Urban connections have recently received some attention in the tropical land use and deforestation literature due to the strong urbanization processes in place in the Amazon. The growing links between the rural and urban populations are thought to affect land use decisions (Browder and Godfrey, 1997; Browder, 2002). We examined three variables that indirectly relate to urban linkages of these households (household members living in an urban area for more than 1 year, family members currently living in urban area, and household/family ownership of urban properties). We did not find significant statistical differences between the two sets of groups in relation to urban connections, but acknowledge that this may be related to an inadequately specified analytical conception of the relationship of urbanization and rural land use (Browder, 2002).

The analysis of regional sub-populations of farmers classified by their forest extractive strategies or by their tree planting practices, gives insights into household level characteristics that can help explain these activities. These differences suggest that forest extractors correlate with low income farmers, still relying heavily on forest extraction and practicing less intensive land use practices on their land. In the case of tree planters, they were characterized by being significantly more active in social groups, having a definitive land title, living in the plot for a significantly longer time period, having more labor availability within the household unit, and having larger areas of remnant forests on their farms.

7. Conclusions

Forest management and silvicultural activities of small farmers in settlement projects in Rondônia, Brazil, were explored using household level survey data for a representative 10-year (1992–2002) sample of households. The results of these surveys show some interesting trends and patterns. First, although small farmers do not systematically manage their forest patches, a significant proportion (40%) extract products from them, although median quantities of both timber and non-timber forest products have decreased considerably during the study period. Two NTFPs—palm heart and Brazil nuts—are the principal NTFPs extracted. Second, while about one-half of the farmers surveyed indicated an interest in planting trees, the percentage of the rural population actually doing so declined from 30 to 22% during the study period. Still, a greater number of different species were planted, reflecting changes in market demand for lesser known timber species. The discrepancy between interest and actual tree planting suggests that most farmers face barriers to tree planting. About 30% of those farmers not planting trees cited lack of economic incentives to do so, while 21% simply did not have any available land left to plant. Nearly 50% of the farmers surveyed acknowledged the need to reforest degraded areas of their farms as the primary reason for planting trees, followed by "commercial reasons" cited by 26% of the sample. For those planting trees, economic motives are not the predominant reason. Although tree planting has been promoted as a strategy to curb deforestation, perceptions of high initial costs (seed acquisition and seedling generation) may explain much of the difference between interest and actual planting of trees.

Third, farmers extracting forest products are different from non-extractors in three ways: they tend to clear less forest, own smaller cattle herds and participate more frequently in mutual aid associations than non-extractors. Farmers extract forest products mainly for subsistence consumption, not for commercial use. Only 1% of farmers extracting forest products sold any of their harvest, and the income obtained from such transactions is negligible.

Fourth, farmers planting trees during the study period are significantly different from non-planters in several respects: They tend to own larger lots, retain larger areas in primary forest, have resided on their lots for longer periods of time, are more active in social organizations, and are more likely to possess secure land title than farmers not planting trees. Over time, farmers may appreciate the non-economic values of forest and plant trees to help restore their woodlands, possibly reflecting the emergence of a "land ethic" that favors primary forest patch conservation, as well as tree planting. Moreover, it appears that social participation encourages tree planting. Indeed, many farmers in the sample belong to associations that actively promote agroforestry and silvicultural practices among their membership. Finally, consistent with much of the literature, secure land tenure appears to be a factor positively correlating with tree planting behavior.

Given that nearly half of the rural population in the three study sites is interested in tree planting suggests an opportunity for policy focused on ecological restoration. Half of the households with sufficient working age members in residence appear willing to use their labor to plant and maintain seedlings, if the seedling stock can be provided, thereby eliminating the major capital constraint to tree planting. On the other hand, forest conservation policies based on promotion of NTFP extraction appear to be of limited utility when applied to rural colonist populations.

Acknowledgements

We thank Eliane Siqueira Pedlowski, Crisanto Lopes de Oliveira, Keila Souza Aires, Ivoni Holz Seidel, Galvanda Queiroz Galvan, Leonardo de Sousa Cavadas, Miguel Raul Mazissa Zinga and Raimundo Cajueiro for assistance during fieldwork.

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