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A DIAGNOSTIC STUDY OF AGRICULTURAL LAND USE IN THE SOUTHWEST BRAZILIAN AMAZON *

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Tropical deforestation--a contributor to global warming via release of atmospheric CO_2--is highest in Latin America compared to Africa and Asia. Deforestation rates in the Amazon Basin of Brazil increased from the early 1960s through the mid-1980s due to national policies supporting road building, tax and credit incentives to large corporations and ranches, and colonization projects for the rural poor. Changes in the same policies seem to have contributed to observed declining rates of deforestation. Interviews indicated that settlers in Pedro Peixoto, Acre, cleared about two ha per year per family and settlers in Theobroma, Rondonia, cleared some three ha per year to produce first rice followed by beans, maize, and cassava. Lands were next converted to pasture as farmers took advantage of increasing prices for "improved" lands--i.e., cleared lands with pasture, fencing, corrals and ponds. Analysis of satellite images agreed with farmer-reported data and improved our understanding of the dynamics of deforestation. Development of alternatives to slash-and-burn agriculture which would decrease rates of deforestation, increase sustainability of resource use, and enhance the well-being of settlers would have to combine on-farm and policy research.

Tropical deforestation, due in part to slash-and-burn agriculture, contributes to global warming via burning and release of CO_2 into the atmosphere; and Brazil is now the fourth atmospheric carbon contributor--after the US, ex-Soviet Union, and China (Moran 1993). Deforestation is also leading to losses of genetic (Phillips *et al* 1994) and cultural diversity. Decreasing transpiration and precipitation within and outside of areas cleared may also be a consequence of deforestation (Fearnside 1985, Salati 1989).

Farmer settlers in the government colonization projects of Pedro Peixoto in the Amazonian state of Acre and in Theobroma, Rondonia, were interviewed; satellite images were analysed; and GIS maps prepared as a part of activities to characterize local systems and system dynamics. Funding was provided by the Inter-American Development Bank for a project "A diagnostic study of agricultural land use in the southwest Brazilian Amazon".

Settlement in colonization projects such as Pedro Peixoto and Theobroma has been facilitated by government policies to populate frontier areas in the Amazon, road construction, and direct and indirect subsidies. Data presented

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in this paper addresses the dynamics of deforestation at the farm level, i.e., farmer decision-making in light of constraints and opportunities afforded by the local agroecosystem and within the context of relevant local, regional, national, and international policies.

INTRODUCTION: DEFORESTATION IN THE AMAZON

Rates of Deforestation. Compared to Asia and Africa, deforestation has been highest in Latin America in both absolute area (43,000 km^2/year) and percent of forest area cleared (0.64%/year, Anderson 1990). Of Latin American forests standing in 1850, 370 million ha or 28% were converted by 1985: 44% to pasture, 25% to cropland, 20% degraded, and 10% to shifting cultivation (Houghton *et al* 1991). Recent analysis of satellite data indicates that some 230,000 km^2 of the Brazilian Amazon is deforested (Moran *et al* 1994); and that 588,000 km^2 are affected--if "edge effects" of one km into adjacent areas of forest are considered (Skole and Tucker 1993). Deforestation in the Brazilian Amazon has been highest in Rondonia and Mato Grosso, followed by western Maranhao, Acre, and northern Goias (Anderson 1990). Shifting cultivation (slash-and-burn agriculture) was thought to account for 1.8 million ha or 32% of tropical American deforestation taking place in 1980 (Houghton *et al* 1991). Causes of Amazonian deforestation: 1960-1985. Interlinked factors contributing to deforestation up to a decade ago included road building, land conversion to pasture and cattle ranching (and associated policies), demand for land by the rural poor, credit and tenure policies which equated land improvements with clearing, and land speculation (especially in a highly inflationary economy).

Roads opened the Amazon to settlement and land to deforestation. The Brasilia-Belem highway was completed in 1960. The then military government made the Amazon the focus of growth in 1964. BR364 between Porto Velho in Rondonia and Cuiaba in the south was completed in 1965 and improved in 1969. The government decided to build the Trans-Amazon highway in 1970; and various sections were completed between 1972 and 1976 (Kleinpenning *et al* 1985, Millikin 1991, and Moran 1993). Deforestation in the Amazon has been the heaviest along these roads.

Over 10 million ha of forest were converted to pasture from 1960 to 1990 (Anderson 1990). The Agency for the Development of Amazonia (SUDAM) was established in 1966 largely to facilitate private investments in the Amazon through tax incentives, with most support granted to large ranches and corporations (Binswanger 1989, Kleinpenning *et al* 1985). Ranches now cover 8.4 million ha, average 24,000 ha each; but employ only one cowboy per every 300 ha and were profitable only with full tax advantages (Moran *et al* 1994) and at considerable social costs--of 0.5 ton of rainforest per quarter-pound of hamburger (Uhl and Parker 1986). Beef produced, however, was not for export to the US for its fast-food industry--as Hecht (1984) proposed and as was the case in Central America (Myers 1981, Van der Kamp 1990). Although beef sufficient for the same quarter-pound hamburger cost US $0.26 to produce in the Amazon with $ 0.22 coming from subsidies, the Amazon has barely produced enough beef for its own needs (Browder 1988).

Related policies that contributed to deforestation were exemptions of agricultural incomes from taxation, rules determining security of land claims which encouraged clearing, progressive land taxes encouraging conversion to pasture, credit schemes subsidising corporate livestock ranches, and tax breaks for wood products industries (Binswanger 1989).

The rural poor were pushed to the frontier areas in search of land: 4.5% of Brazil's land owners hold 81% of the country's farmland, while 70% of rural households are landless (Anderson 1990). In the period 1963-73, Brazil shifted from "inward-oriented" import-substitution policies to modified "outward-oriented" export-substitution characterized by area expansion, domestically produced inputs, mechanization through credit, increased output and land concentration, and coffee eradication. The period 1971-80 then saw a high expansion of agricultural exports and wealth concentration aided by high inflation combined with low fixed interest rates for a few borrowers (Graham *et al* 1987). Mechanization of soybean, wheat, and sugar cane production had the effect of driving the rural poor out of Brazil's populous and developed center-south region (Fearnside 1986, Sawyer 1990, 1984). In that area, soybean became a major crop and labor-intensive small scale agriculture was replaced by energy- and machine-intensive cultivation (Skole *et al* 1994).

Brazil's National Institute for Colonization and Agrarian Reform (INCRA) instituted a Program for National Integration (PIN) in 1970 to assist the rural poor. High rates of migration to Rondonia--including spontaneous migration and land "invasions" (Mueller *et al* 1992)--resulted in five million ha (21% of the state's land area) given to settlers by 1977 (Mueller 1980). Forest clearing reached 17% of the state by 1987 (Millikin 1991); and farmers with rural credit cleared 25% more forest than those without (Browder 1988). Problems such as lack of all-weather access roads, unsuitable seed, early rains, lack of planting materials for perennial crops, and insecure titles, as well as the oil crisis in 1973, however, led the government to shift from supporting small farmers via colonization schemes to (again) aiding large operators in 1974 (Moran 1984, 1985, 1993). Other factors contributing to Amazonian deforestation have included displacement and resettlement of farmers from earlier-settled areas in the north as soils were depleted or as demands for land by new speculators increased (Mueller *et al* 1992), logging and wood processing (Houghton *et al* 1991, Verissimo *et al* 1992), and mining and use of timber for fuel for smelting (Fearnside 1992, Moran *et al* 1994).

Deforestation since 1985. Some of the major incentives provided to large corporations and cattle ranches were eliminated in 1985 as Brazil suffered from recession and hyperinflation (Moran 1993). Although cause and effect relationships are difficult to establish, recent analysis of remote sensing data shows that rates of Amazonian deforestation have been decreasing: from 8.0 million ha in 1987 to 1.8 million ha in 1989, 1.4 million ha in 1990, and to 1.1 million ha in 1991 (Moran 1993, see also Stone *et al* 1994). On the other hand, two-thirds of deforestation due to ranching has occurred without SUDAM incentives (Browder 1988a, 1988b, Fearnside 1990); and explanatory factors appear to be: a) that new demands for (cleared) frontier lands by urban-based land speculators have appeared as frontier government has strengthened to the extent that it can protect property rights (as opposed to ranchers having to finance private armies to maintain their land claims), and b) that cattle ranching is economically viable under current land prices (World Bank 1993).

The various factors contributing to or tending to diminish deforestation in the Amazon Basin over time are shown in Figure 1.

Optimistic viewpoints in the search for alternatives. Optimistic findings have emerged along with the observed decreasing rates of deforestation. First, forests may be more resiliant and may rebound from disturbances more quickly and completely than previously thought (Buschbacker *et al* 1988, Moran *et al* 1994, Uhl *et al* 1988, Uhl and Buschbacher 1985). Second, secondary forests globally are being formed at about nine million ha per year and now account for 40% of total forest area (Brown and Lugo 1990); and, third, much of currently observed deforestation is of secondary rather than primary growth (Homma *et al* 1993, Skole *et al* 1994). As a result of such resiliance, several researchers have proposed improved management of secondary forests (Brown and Lugo 1990) and encouragement of natural forest regeneration (Anderson 1990, Bierregaard *et al* 1992, Lovejoy *et al* 1980, Nepstad *et al* 1991, and Verissimo *et al* 1992).

Other researchers have described the diversity of environments within the Amazon Basin and suggested land classification and zoning as starting points for improved land use and management (Alvim 1980, Denevan 1984, Fearnside 1983, and Furley 1980).

Although there is evidence that soil fertility under cattle pastures in the Amazon cannot be maintained (Fearnside 1979, 1980, Hecht 1984), research has also suggested that sustainability is possible with improved pasture species (Serrao and Toledo 1990). Contrary to earlier views of ecologists, research also suggested that continuous cropping is possible with fertilizer use (Nicholaides *et al* 1984). Agroforestry has also been suggested as an appropriate land use (Fearnside 1992, Uhl *et al* 1990); and even steam sawmills and stewardship rather than ownership were suggested as appropriate and needed for the Amazon (Goodland 1985).

People also solve their own problems. With deforestation of their parcels, settlers in the Bolivian Amazon were observed to eventually reach a crises stage due to soil nutrient depletion, weeds, decreasing yields, and increasing costs, but then (some) successfully responded by turning to mechanization, cattle, or perennial crops, thereby "escaping" to a "consolidated stage with markedly higher incomes" (Thiele 1993).

THE RESEARCH SITES

Acre and Rondonia. The state of Acre covers 153,000 km^2. The area of Rondonia is 239,000 km^2. Acre is drained by the Rio Purus and Rio Jurua; while Rondonia is drained by the Rio Madeira. Climate is warm and humid tropical with a rainy season spanning from July to October in Acre and from June to August in Rondonia. Mean annual rainfall is approximately 2000 mm and mean temperatures are 22-26°C. Soils in Acre are Oxisols (Latosolo Amarelo Vermelho Distroficos) and in Rondonia are Oxisols (Latisolos), Alfisols (Terra Roxa), and Ultisols (Podzolicos). The population of Acre is 426,000 and that of Rondonia is 1,350,000.

Reported cattle herd size in 1990 was 40,000 in Acre and 1,700,000 in Rondonia. Reported crop production in Acre for 1993 was 32,000 t of rice, 36,000 t of maize, 14,000 t of beans, 20,000 t of cassava, and 12,000 t of oranges. Rondonia produced a reported 275,000 t of rice, 390,000 t of maize, 93,000 t of beans, 650,000 t of cassava, 166,000 t of coffee, and 26,000 t of banana. Forest products for Acre were rubber (12,000 t), Brazil nuts (*Bertholletia excelsa*, locally *castañha*, 18,000 t), and wood (300,000 m^3).

Pedro Peixoto, Acre, and Theobroma, Rondonia. The Pedro Peixoto colonization site covers 370,000 ha divided into 3700 parcels distributed to 3200 families. Lots are located at distances of 50 to 100 km from the state capital of Rio Branco. Theobroma covers 300,000 ha divided into 3000 parcels (reportedly) distributed to 3000 families. The project area is located some 350 km from the state capital of Porto Velho (Marcus Vinicius, personal communication).

METHODS

Farmer-settler Interviews. A draft questionnaire was developed for use in Acre and Rondonia in mid-1994 by researchers from CIAT and the International Food Policy Research Institute (IFPRI). The questionnaire was designed in a way to ensure appropriateness to local conditions, to ensure ease of use in the field, and to facilitate data coding. Booklets to code data from each questionnaire were developed. Open-ended questions were included which were coded after the range of responses were reviewed. Questionnaire and the data coding booklets were finalized after daily modifications and group discussions in an initial week of fieldwork.

Fieldwork took place in late August and early September 1994 as settlers were burning their fields. Participants represented CIAT, IFPRI, EMBRAPA (CPAF-Acre and CPAF-Rondonia) with interviewers from the Grupo de Pesquisa e Extensao em Sistemas Agroflorestais do Acre (PESACRE) a non-government organization contracted by EMBRAPA.

A team of some 15 interviewers was assembled; and interviewers worked individually (native speakers of Portuguese) or in pairs (where the additional person was not a Portuguese native speaker). Pedro Peixoto and Theobroma were divided into areas which are relatively "accessible" or "inaccessible" during the rainy season. The group selected and worked in different areas in each site each day; and farmers were selected at random in the field--by distributing interviewers at considerable distances from one another and then, if appropriate, by using an "every third parcel" approach. Eighty-one farmers in Pedro Peixoto and 74 farmers in Theobroma were interviewed, with either or both male and female heads of household included.

Completed questionnaires were reviewed and data passed to codebooks each evening. There were considerable difficulties in obtaining complete interviews due to inexperience of some of the contracted interviewers. The group moved to Theobroma after farmer interviews in Pedro Peixoto, and lastly worked together in Porto Velho to make sure that data coding was as complete and readible as possible.

Copies of completed questionnaires were left with EMBRAPA for their data analysis and publication. CIAT also retained copies of the interviews and has reviewed and cross-checked data, revised the coding system as needed, set up data archives, and entered and tabulated data. This paper presents and discusses descriptive findings (simple frequencies and means) from this tablulated data.

GIS and remote sensing. The CIAT team assembled available maps and secondary data from various sources and digitized data in order to present simple overlays of, for example, project roads and parcels by access in the wet season and roads and parcels by soil type. Satellite images of the Pedro Peixoto site for 1984, 1987, and 1992 were obtained in order to analyse rates of deforestation over time. An overlay of the parcellary or cadastral maps on the images allowed analysis of deforestation by parcel, as functions of distances from roads (both primary and secondary) and wet season accessibility, parcel tenure, and other variables.

RESULTS

Migration and settlement. Theobroma settlers were geographically mobile prior to settlement in Theobroma. They moved: a) away from the Northeast, b) to and then from the Southeast, c) and from the South. Theobroma heads-of-household were born in the Northeast (47%), South (38%), and Center-West (12%); raised in the Southeast (48%), Northeast (22%), and South (20%); and prior to arrival in Theobroma lived in the Southeast

(40%), South (31%), and Northeast (16%). Few Theobroma settlers were born, raised, or lived previously in the North.

More of the Pedro Peixoto settlers came from the North itself. Almost half were born (45%), raised (41%), and last lived (50%) in the North. Approximately a third were born and raised in Acre itself; and a third, although not born or raised there, lived in Rondonia prior to settlement in Pedro Peixoto. Other main points of origin for Pedro Peixoto settlers were the South and the Northeast (Table 1). Settlers left previous places of residence largely in search of land (52% in Pedro Peixoto and 58% in Theobroma) and "a better life" (Table 2).

Although Theobroma was initiated as a colonization project earlier than Pedro Peixoto, settlers had lived in the former a mean six years and in the latter a mean eight years, possibly indicating either arrival of a second "generation" of settlers in Theobroma or inclusion in Pedro Peixoto of early spontaneous settlers who remained in the project area. For Pedro Peixoto, almost a third arrived prior to 1975; and two-thirds arrived in the 1980s. For Theobroma, arrival was mainly in the 1970s (36%) and 1980s (58%, Table 3).

Land holdings, deforestation, and land use. Settlers have large parcels of forested land which they steadily clear for conversion to agricultural uses. Mean sizes of respondents' parcels were 88 ha in Pedro Peixoto and 76 ha in Theobroma. By 1993-94, settlers reported that they had cleared a mean 27 ha (31%) of these lands in Pedro Peixoto and a significantly higher 35 ha (46%, Table 4).

Most cleared land was eventually converted to pasture. Farmers reported that at the time of the survey, the 31% of total cleared lands in Pedro Peixoto were divided into a mean 20% of the total in pasture, 6% in fallow, and 4% in annual crops. The 46% of lands converted from forest in Theobroma were divided into an even greater area (26% of the total) of pasture, 8% in fallow, 7% in annual crops, and significantly more perennial crops (4.4 ha or 5%) than in Pedro Peixoto (Table 4).

Changes in land use from 1993-94 to 1994-95 could be calculated because interviews were conducted in late 1994 after field clearing and burning as farmers prepared for the 1994-95 cropping season: deforested portions of the settlers' parcels increased a mean 2.0 ha and from 31% to 34% in Pedro Peixoto and a mean 2.7 ha and from 46% to 50% in Theobroma. Overall, some 40% of the settlers' land in the two colonies has been deforested, with more than half of the cleared area converted to pasture. Only 7% of settlers' lands were in fallow (Table 4).

Table 1. Origins of heads-of-household (% of respondents), Pedro Peixoto, Acre (n = 81), & Theobroma, Rondonia (n = 74), Brazil, 1994

	Pedro Peixoto			Theobroma		
	Born	Raised	Last	Born	Raised	Last
North (Amazonia)	**45**	**41**	**50**	3	4	1
Rondonia	0	3	34	3	4	1
Acre	**35**	**35**	**10**	0	0	0
Other	10	3	6	0	0	0
Northeast	**25**	12	14	**47**	22	16
Southeast	0	20	12	0	**48**	**40**
South	**27**	**22**	**20**	**38**	20	31
Center-West	3	4	4	12	5	12

Table 2. Reported reasons (% of respondents) for leaving previous residence, Pedro Peixoto (n = 60) and Theobroma (n = 67)

Reasons for leaving	Pedro Peixoto	Theobroma
No land	52	58
Search for better life	18	25
Work on rubber plantation	10	-
Others	20	17

Table 3. Year of arrival (% of respondents) in Pedro Peixoto (n = 81) and Theobroma (n = 74)

Year	Pedro Peixoto	Theobroma
1990-94	3	3
1985-89	**40**	**24**
1980-84	**23**	**34**
1975-79	5	**21**
1970-74	13	15
< 1970	16	3
Total	100	100
Mean years at site	**9**	**8**

Table 4. Land use (mean areas), Pedro Peixoto, Acre (n = 81) & Theobroma, Rondonia (n = 74), 1993/94 & 1994/95

	Pedro Peixoto				Theobroma				
	93/94		94/95	Dif	93/94		94/95	Dif	
	ha	%	%	%	ha	%	%	%	Total
Forest	61	**69**	66	-5	41	**54**	50	-7	**61**
Cleared	27	**31**	34	+11	35	**46**	50	+8	**39**
Pasture	**17**	**20**	**25**	**+30**	**20**	**26**	**29**	**+10**	**23**
Fallow	5	6	2	- 60	6	8	4	-50	7
Annual crops	4	4	7	+50	5	7	9	+40	6
Perennials	1	1	0	-	4	5	8	+50	3
TOTAL	**88**	100	100		**76**	100	100		100

On-farm rates of deforestation calculated from interview data. Rates of on-farm deforestation were calculated from interview data and from analysis of satellite images. Rates calculated from the interviews used the simple equation:

$$r_1 = \frac{\text{area currently cleared - area cleared at time of arrival}}{\text{years occupying the parcel}}$$

Farmers had converted a mean 19 ha in Pedro Peixoto and 30 ha in Theobroma of primary forest at the time of the interviews. A mean 3.3 ha in Pedro Peixoto and 8.5 ha in Theobroma had already been cleared at the time of arrival and parcel occupation. As shown in Table 3, farmers had occupied parcels in Pedro Peixoto a mean 9 years and Theobroma a mean 8 years. The rate of primary forest clearing was thus calculated as 1.8 ha per year in Pedro Peixoto and 2.8 ha per year in Theobroma.

The interview data also show that in both Pedro Peixoto and Theobroma, roughly half of the settlers cleared less than two ha per year; and half cleared more than two ha per year. Comparing the two groups, those cutting more forest have greater areas of their parcels deforested, more pasture, larger areas of food crops, and sell more rice. On the other hand, the two groups did not differ in areas of fallow, area of perennial crops, and quantities of all other crops and forest products sold.

In both Pedro Peixoto and Theobroma individual farmers' areas cleared and area in pasture were correlated to overall parcel size; and area in pasture was highly correlated to area cleared. Comparing Theobroma farmers who cleared and who did not clear forest land in late 1994, those not clearing had significantly (at the 5% level) more fallow land (8.6 ha) than those clearing (4.0 ha). Although Pedro Peixoto farmers clearing forest in late 1994 also had less fallow land (5.6 ha) than those not clearing (4.5 ha), the difference was not significant. Farmers clearing and not clearing forest lands in 1994 at both sites did not differ: a) in areas of perennial crops (i.e., farmers with more perennial crops were equally likely to clear forest land as those with smaller areas of perennial crops), b) in amounts of Brazil nuts gathered and sold (i.e., those relying and those not relying on this NTFP were equally likely to clear forest), c) in area planted to rice in 1993-94, and d) in rice production in 1993-94.

Deforestation in Pedro Peixoto calculated from satellite images. Analysis of satellite images from 1984, 1987, and 1992 of Pedro Peixoto tends to confirm rates calculated from farmer-reported data. Each image covers an area of 357,000 ha, of which there are 276,000 ha of colonists' parcels, 22,000 ha of haciendas, and 56,000 ha of "other" (the officially reported 370,000 ha of the Pedro Peixoto project appears to include haciendas and land uses besides settlers' parcels).

Overall, the percent area cleared within the area covered by the images of Pedro Peixoto was 8.8% in 1984, 12.1% in 1987, and 25.0% in 1992. Colonists' cleared areas increased from 8.1% in 1984, to 13.1% in 1987 and 26.4% cleared in 1992 (Table 5, Figures 3, 4, and 5). This latter figure and the cleared area calculated from farmer interviews of 31% in 1993-94 are mutually supporting: both analysis provide annual rates of about 3% and total deforestation in Pedro Peixoto colonists' lots at about 30% in 1993.

The haciendas increased cleared area from 16.8% to 32.4% from 1984 to 1992. The area cleared on the haciendas approximiately doubled over the eight year period (1984-92); while clearing on the colonists' parcels increased by more than 300% for the same period (Table 5).

For per parcel deforestation in Pedro Peixoto, images show that there was an increase from 22,388 ha cleared in 1984 to 72,970 ha cleared in 1992 for 3,141 farmer's parcels. That is, a total of 6,323 ha were cleared per year over the eight year period, or a rate of 2.0 ha cleared per parcel per year. This rate again corresponds quite well to the calculation based on farmer-reported data.

Deforestation range and distribution in Pedro Peixoto. Satellite image analysis was used to determine the range and distribution of deforestation by percentiles (i.e., frequency of lots showing 0-9.9%, 10-19.9%, ... 90-100% deforestation for 1984, 1987, and 1992) in Pedro Peixoto. In 1984, 70% of the settlers' parcels were less than 10% deforested; and only 3% of the parcels were 40% or more cleared. By 1992 only 22% of the parcels remained less than 10% deforested; while another 22% were 40% or more deforested (Table 6, Figure 6). The obvious and expected trend is that settlers' lots will steadily "move" towards the higher deforestation percentiles and away from the lower. Modelling a date when, for example, no lots would remain in the less than 10% deforested and 10% of the parcels would be deforested at the 90-100% level is complicated, however, by differential rates of forest clearing as a function of distances from roads and of access.

Table 5. Forest clearing (satellite image analysis), Pedro Peixoto, 1994, 1987, and 1992.

	Total ha	% area cleared		
		1984	1987	1992
Total (ha x 000)	356.7	8.8	12.1	25.0
Colonists' parcels	276.4	8.1	13.1	26.4
Haciendas	21.8	16.8	17.2	32.4
Other	58.5	9.1	6.2	16.1
Accessible parcels	79.5	9.3	13.7	27.1
Inaccessible parcels	169.9	5.3	11.7	24.6

Table 6. Deforestation ranges and distribution by percentiles, Pedro Peixoto; analysis of 1984, 1987, and 1994 satellite images

Percent clearing	Percent of Parcels		
	1984	1987	1992
90 -100	0.0	0.1	1.1
80 - 89.9	0.1	0.3	1.8
70 - 79.9	0.1	0.7	1.9
60 - 69.9	0.3	0.7	3.7
50 - 59.9	0.9	1.8	5.4
40 - 49.9	1.4	2.5	7.8
30 - 39.9	2.9	5.0	12.7
20 - 29.9	7.6	10.2	19.0
10 - 19.9	17.1	24.3	24.3
0 - 9.9	69.6	54.4	22.3

Deforestation as a function of distance from roads and as a function of wet-season accessibility. Analysis of satellite images confimed that deforestation has not only increased steadily over time in the colonies, but has been uniformly greater: a) nearer to roads and b) nearer to primary vs secondary roads. Forest clearing as a function of distance from roads was analysed for sampled areas of the 1984, 1987, and 1992 Pedro Peixoto satellite images. From 1984 to 1992, deforestation increased: a) from 58% to 84% for areas up to 250 m away from the main roads; b) from 25% to 48% at distances of between two and three km from the main roads; and c) at intermediate levels for the intermediate distances. For secondary roads, deforestation similarly increased over the 1984-1992 period from 10% to 51% for the area up to 250 m from the road; and from 4% to 13% over the same period and at two to three km from the same secondary roads. Intermediate distances (and the intermediate 1987 image) from the secondary roads again provided intermediate values (Table 7, Figure 7).

Deforestation in Pedro Peixoto was slightly lower in less accessible compared to more accessible areas. Areas blocked by rivers, flooding, and poor or non-existent roads and bridges during the wet season were identified on the cadastral map by EMBRAPA researchers. The overlay of the cadastral map on the satellite images allowed for analysis of deforestation as a function of wet season accessability. In 1984, 5% of the inaccessible compared to 9% of accessible areas were deforested. By 1992, however, the gap had narrowed from 25% of inaccessible vs 27% of accessible parcels (Table 5, Figure 8).

More on forest clearing. Farmers in Pedro Peixoto needed 23 days/ha to clear primary forest and 16 days/ha to clear fallowed land. Theobroma farmers spent less time clearing land, but needed the same amount of labor to clear forest and fallow (14 days/ha, Table 8). Reasons for differences between sites were not apparent. Farmers used chainsaws, axes, and machetes to clear primary forest, and axes and machetes to clear secondary forest. Labor was mainly family followed by hired labor, often for chainsaw operation (Table 8).

Burning of slash followed cutting and a period of drying. Most farmers reported that the function of burning was to make space for the crops; and only a few at each site mentioned that ash improved soil fertility or that fire decreased the incidence of weeds and other pests (Table 9). This result highlights differences between such settlers and traditional slash-and-burn agriculturalists who universally perceive burning in terms of nutrient management and pest control.

Table 7. Forest clearing (% area cleared) as a function of distance from roads of different classes, Pedro Peixoto, 1984, 1987, and 1992

Distance from road (m)	Class I Road			Class II Road		
	1984	1987	1992	1984	1987	1992
0 - 250	58	80	84	10	27	51
251 - 500	53	71	81	7	18	37
501 - 750	47	63	77	5	13	29
751 - 1000	41	55	71	5	11	23
1001 - 2000	30	38	57	4	7	15
2001 - 3000	25	30	48	4	7	13

Table 8. Respondents' reported labor use (type and days/ha) for cutting & slashing forest and fallow prior to burning (days/ha), Pedro Peixoto and Theobroma

	Pedro Peixoto		Theobroma	
	Forest	Fallow	Forest	Fallow
Labor use (days/ha)	22.6	16.4	13.5	13.6
Labor type (% respondents)				
Family	72	81	92	85
Hired	30	12	56	25
Exchange	8	2	10	4
Use chainsaw (% respondents)	90	1	89	6

Table 9. Respondents' reported reasons (% of respondents) for burning slash, Pedro Peixoto and Theobroma

	Pedro Peixoto	Theobroma
Clear land/make space	81	79
Ash/fire improves soil fertility	11	10
Remove weeds/pests	11	6

Food crop production. Rice is the major crop at both sites. Farmers (92% in Pedro Peixoto and 70% in Theobroma) planted rice in the first year of cultivation of what was primary forest; and cultivated maize, cassava (in Pedro Peixoto), and pasture in the second year. Rice, the most important crop for both consumption and sales of surpluses, was not grown in the second or subsequent years of plot use (Table 10).

Farmers' reported crop yields were quite good given local conditions and farmers' resource levels. Farmers were asked about their 1993, and their "normal", "low", and "high" yields for rice, maize, and beans in terms of ratios of yield to seed sown. Yields in 1993 were somewhat below average, with "normal" yields at the two sites being about 70-75:1 for rice, 95:1 for maize, and 27:1 for beans (Table 11). Mean reported yields at the two sites did not differ. Because they sowed a mean of about 21 kg rice seed/ha (although this varied from 7-60kg), farmers' "normal" rice yields would then be in the 1.5 to 1.6 t/ha range.

Most farmers at the two sites reported problems (defined as factors which led to decreased yields) with rice and beans. Stink bug, stemborer, and birds in Pedro Peixoto and birds and storage weevils in Theobroma were problems of rice (Table 12). Web blight (*Thanathephorus cucumeris*) and beetles (*Diabrotica* spp) were the major problems of beans at both sites. Few farmers reported problems with maize, although problems mentioned included birds, wild animals, and spittle bug (*Deois flavopicta*).

Table 10. Respondents' reported land use, first & second years (% respondents) after clearing, Pedro Peixoto (n = 70) & Theobroma (n = 67)

	Pedro Peixoto		Theobroma	
	1st	2nd	1st	2nd
Rice/rice+maize(-beans)	92	0	70	0
Maize	0	42	0	44
Cassava	0	26	0	0
Pasture	1	17	13	25
Fallow	0	8	0	8
Other	7	7	17	23
Total	100	100	100	100

Table 11. Respondents' reported mean "normal", "low" and "high" crop yields (ratio of production to seed sown), Pedro Peixoto and Theobroma

	Pedro Peixoto				Theobroma			
Crop	1993	Normal	Low	High	1993	Normal	Low	High
Rice	63*	70	34	103	69	75	42	96
Maize	88	94	56	118	76	96	59	154
Beans	19	28	14	52	10	26	10	41

* At a mean 21 kg seed sown per ha, "normal" rice yields would be approximately 1.5 to 1.6 t/ha

Table 12. Reported crop problems (% of respondents), Pedro Peixoto (n = 71) & Theobroma (n = 72)

Problem	Local: Scientific names	Pedro Peixoto	Theobroma
	RICE		
Has problem		78	65
Stink bug	*Percevejo*: *Tibraca* spp, *Oebalus* spp	45	5
Birds	*Pasarim/Grauna*	14	34
Stemborer	*Panicula branca*: *Diatrea* spp	17	5
Diseases	Symptoms referred to as *quema*	7	2
Storage weevils	*Gorgulho*	6	15
Miscellaneous		31	28
	MAIZE		
Has problem		41	28
Birds	*Pasarim*	5	8
Wild animals		0	5
Spittle bug	*Cigarinha*: *Deois flavopicta*	5	2
Storage weevils	*Gorgulho*	14	5
Miscellaneous		23	18
	BEANS		
Has Problem		78	96
Web blight	*Mela*: *Thanathephorus cucumeris*	58	58
Chrysomelides	*Vaquinha*: *Diabrotica* spp	30	40
Miscellaneous		29	28

More on land use cycle. Farmers cultivated lands cleared from primary forest for a mean period of 2.1 (Pedro Peixoto) to 2.5 years (Theoborma). Sixty percent in Pedro Peixoto cultivated such plots for two years; while Theobroma farmers used their newly cleared lands for from one to more than three years in somewhat equal proportions (Table 13). Again, reasons for differences between sites were not apparent and warrent further investigation. Farmers reported that discontinuation of annual cropping on lands cleared from forest was due to the not mutually exclusive reasons of lower productivity, weeds--especially *Imperata* sp (locally *sape*), and insects and diseases (Table 14).

Table 13. Respondents' reported normal years of cultivation of lands cleared from forest (% of respondents), Pedro Peixoto & Theobroma

Years cultivated	Pedro Peixoto	Theobroma
1	13	26
2	60	24
3	16	31
>3	11	19
Total	100	100
Mean years	2.1	2.5

Table 14. Respondents' reported reasons for discontinuation of annual cropping in what were newly cleared lands (% of respondents), Pedro Peixoto & Theobroma

Reason	Pedro Peixoto	Theobroma
Lower productivity	36	68
Weeds	51	34
Weeds - *sapé*	43	5
Diseases & pests	25	12
Other	31	40

After food crops, two-thirds of Pedro Peixoto farmers and nearly half of Theobroma farmers converted their lands to pasture. About a third in both areas left some land in fallow (although much of such land may also be used as unimproved pasture). Theobroma (20%) but not Pedro Peixoto farmers also converted some land from annual to perennial crop use (Table 15). Farmers at both sites "normally" left any fields which they fallowed for a mean 2.5 years, although they thought that 3.0-3.5 years of fallow would be ideal. Rice followed by maize and beans were the main crops planted in the re-opened fallows (Table 16).

Table 15. Respondents' reported general or "normal" use of lands after annual cropping (% of respondents), Pedro Peixoto (n = 70) & Theobroma (n = 67)

Land use	Pedro Peixoto	Theobroma
Pasture	64	44
Fallow	36	36
Perennials	0	20
Total	100	100

Table 16. Respondents' reported use of fallow (years & % of respondents), Pedro Peixoto and Theobroma

	Pedro Peixoto	Theobroma
Years of last fallow	2.4	2.7
Years ideally fallowed	3.4	3.1
Years "normally" fallowed	2.4	2.4
Crop planted after fallow (%)		
Rice	62	72
Maize	23	13
Beans	12	8
Cassava	3	0
Pasture	0	2
Other	0	5

Perennial crops. The role of perennial crops in the systems studied is important to the degree that research seeks agroforestry-based innovations. For perennial crops, 35% of Pedro Peixoto farmers reported problems of low prices or poor markets; 29% reported no problems; and 40% had not grown perennials. In Theobroma, only 20% had not grown perennials; 43% reported "production problems" (i.e., insects and diseases); and 45% reported having had no problems (Table 17).

The role of cattle and pasture. Cattle and pasture formation are perhaps the major driving force behind deforestation in the settlements. Most settlers (91% in Pedro Peixoto and 81% in Theobroma) had cattle. Herd size was a mean 18 head (with 6 giving milk) in Pedro Peixoto and 26 (4 giving milk) in Theobroma (Table 18). Milk production ranged from a mean two to three liters per head in the dry season and four to five liters in the wet. Farmers' number of cattle were not (inversely) correlated to area of perennial crops (although there was of course a high correlation between number of cattle and area of pasture).

Table 17. Respondents' reported problems (% of respondents) with perennial crops, Pedro Peixoto (n = 17) and Theobroma (n = 49)

Problem	Pedro Peixoto	Theobroma
"Production problems"	6	43
Low prices/poor markets	35	10
Lack of transport	18	0
Too much labor required	3	1
Fire during burning season	12	2
No problem	29	45
Has not grown perennials	40	20

Table 18. Respondents' reported livestock holdings (head), Pedro Peixoto and Theobroma

	Pedro Peixoto	Theobroma
Percent of settlers with cattle	91	81
Number of cattle		
Maximum number in last year *	18	26
Number sold in past year	4	2
Current number *	23	30
Milk		
Mean number giving milk (head)	6	4
Mean liters/head/day, dry season	2	3
Mean liters/head/day, wet season	4	5

* Difference in maximum number last year and current number reflects cattle born, deaths, and purchases

The predominant pasture species used at both sites were *Brachiaria brizanta, B. decumbens*, and *B. humidicola*. Some Pedro Peixoto farmers also had *Pueraria phaseoloides* or mixes of *P. phaseoloides* and brachiaria. Theobroma settlers also had pastures of *Panicum maximum* (Table 19). In terms of pasture management, a mean 70-75% of farmers burned fields yearly, and 70% of farmers at both sites rotated cattle to different pastures at a mean of every 2.0-2.5 months (Table 20). Settlers reported stocking 2.2 head per ha in Pedro Peixoto and 1.6 head per ha in Theobroma, with roughly equal numbers of respondents at both sites reporting stocking: a) less than one, b) one to two, and c) more than two head per ha (Table 21).

Table 19. Respondents' reported types and areas (% & ha) of pasture, Pedro Peixoto & Theobroma

	Pedro Peixoto			Theobroma		
	% of respondents	mean area (ha)	% of area	% of respondents	mean area (ha)	% of area
Brachiaria brizanta	80	12	57	78	15	51
Brachiaria decumbens	60	7	24	36	9	13
Brachiaria humidicola	11	3	2	32	5	5
Pueraria phaseoloides	7	4	1	-	-	-
Panicum maximum	-	-	-	12	7	3
P. phaseoloides + B. decumbens	7	22	10	-	-	-
Other mixtures	4	7	2	8	20	7
Native pasture	7	8	3	-	-	-
Other	12	2	1	37	11	21

Table 20. Pasture management practices (% of respondents and frecuency over time), Pedro Peixoto & Theobroma

	Pedro Peixoto	Theobroma
Use fire for regeneration (%)	75	71
Frequency of fire use (years)	1.3	1.1
Rotate cattle to different pastures (%)	70	70
Frequency of rotation (months)	2.6	2.1

Table 21. Current number of animals per ha (% respondents), Pedro Peixoto and Theobroma

Animals per ha	Pedro Peixoto	Theobroma
< 1	33	37
1 - 2	38	37
> 2	29	26

In a sense it appears that farmers' main "income" source is the appreciation of the value of their lands due to conversion to pasture: 93% of Pedro Peixoto and 97% of Theobroma settlers perceived their land values as having risen (values were discussed in terms of equivalent numbers of cattle), at annual rates of 74% in the former and 157% in the latter site.Farmers reported total increases since occupying their parcels in value of about 800% in Pedro Peixoto and 950% in Theobroma, with reasons for increases attributed to addition of pasture or cleared areas, fencing, ponds or other water sources, corrals, houses, perennial crops, and improved access (Table 22).

Income sources. Farmers' cash income sources (Table 23) in Theobroma were from sales of labor or pensions (63%) and sales of rice (50% sold a mean 2.3 t/year), maize (47%, 1.8 tons), beans (41%, 1.3 tons), Brazil nut (44%, 1.0 tons), and cattle (26%). More farmers (57%) sold more rice (3.1 tons) in Theobroma in addition to having incomes from labor and pensions (53%), coffee (36%, 3.3 tons), milk (30%), cacao (25%, 1.6 tons), and cattle (22%).

Table 22. Respondents' evaluation of and reasons for (% of respondents) changing land values, Pedro Peixoto (n = 69) and Theobroma (n = 70)

	Pedro Peixoto	Theobroma
Reported increased value (%)	93	97
Total mean increment in cattle (%)	778	952
Mean annual increment in cattle (%)	74	157
Reasons for increase		
More pasture	60	50
Fencing	56	36
Pond/water	30	13
More cleared area	12	26
Corral	12	16
House	26	16
Access/roads	25	27
Perennial crops	12	35
School	10	5
Timber	8	1
Title	7	3
Good soils	4	5

Table 23. Respondents' (%) sources of cash income and approximate quantities sold (tons/year), Pedro Peixoto (n = 68)* and Theobroma (n = 63)*

Source	Pedro Peixoto	Quantity	Theobroma	Quantity
Crops				
Rice	50	2.3	57	3.1
Maize	47	1.8	16	2.7
Beans	41	1.3	9	0.2
Cassava	4	1.5	0	-
Farinha	7	4.1	0	-
Cotton	1	0.6	9	0.4
Coffee	3	1.3	36	3.3
Cacao	0	-	25	1.6
Cattle (head)	26	23	22	5
Milk	7	-	30	-
Poultry/pigs	9	-	0	-
Rubber	7	1.6	0	137
Castana	44	1.0	6	-
Wood	0	-	9	-
Other	9	-	8	-
Labor and pensions	63	-	53	-
Agriculture, male	11	-	26	-
Agriculture, female	3	-	0	-
Non agr., males	15	-	8	-
Non agr., female	16	-	1	-
Pensions	19	-	16	-

* Fewer respondents provided quantities of each product

An attempt was made to identify differences between the roughly half of the settlers producing and the half not producing surpluses of rice for cash sales. The two groups did not differ in terms of total farm size, available family labor, area in perennial crops, total area cleared, area cleared in 1994 (for which sales were reported), or area planted to food crops. The data suggest (difference of means was not significant at the 5% level), however, that farmers not selling rice dedicated more effort to cattle. Rice sellers had an average herd size of 19 head; and non-rice sellers had 27 head in Pedro Peixoto. Those selling rice in Theobroma had 20 head and those not selling had 45 head in Theobroma.

Settlers exploited their forest lands for Brazil nut (although substantially more in Pedro Peixoto), wood, hunting, palm hearts (more in Theobroma), and fish (Table 24). Although an attempt was made, quantities of these products were very difficult to elicit or calculate.

Negative factors associated with the colonies were poor roads or access, malaria, and lack of health posts, schools, and potable water (Table 25).

Table 24. Respondents' (%) use of forest products, Pedro Peixoto and Theobroma

Forest Product	Pedro Peixoto	Theobroma
Brazil nut	90	36
Wood	33	50
Hunting	18	29
Palmito	5	17
Fish	6	13
Rubber	11	0
Medicinal plants	5	6
Acai (another palm)	0	6
Jatoba (a tree legume)	0	6
Other	11	4

Table 25. Respondents' (% of respondents) reported negative factors associated with living in Pedro Peixoto or Theobroma

	Pedro Peixoto	Theobroma
Poor roads/access	51	27
Malaria	25	35
Lack of transport	24	9
" health post	22	30
" schools	14	22
" potable water	10	4
" electricity	4	8
" credit	10	1
Other	23	21
None	4	11

Additional GIS analysis. Overlaying the Theobroma parcel map on a Brazilian soils map shows about 1400 parcels and 114,000 ha of more favorable Alfisols (Podzolico Vermelho Amarelo Eutroficos), 2200 parcels and 124,000 ha of "medium" quality Oxisols and Ultisols, and 250 parcels and 14,000 ha of poor Distropepts (Liticos distroficos, Table 26, Figure 9). This mapped data will permit follow-up studies to determine if there are differences in land use, productivity, and forest species (and diversity) relative to soil quality. The same overlay of cadastral maps and soils in Pedro Peixoto showed that soils throughout that site are essentially similar in terms of agricultural potential.

Parcels in Pedro Peixoto with titles and with titles pending were mapped for Pedro Peixoto (Table 27) and will be overlayed on satellite images in order to determine the role of tenure on rates of deforestation.

Table 26. Number of parcels and area (ha) by soil quality, Theobroma

	Parcels		Area (ha)		Soil Type
	Number	%	ha	%	
"Good"	1392	37	113,524	45	Alfisols
"Medium"	2172	57	123,689	49	Oxisols, Ultisols
"Poor"	241	6	14,120	6	Distropepts

Table 27. Number and area (ha) of lots with titles and with pending titles, Pedro Peixoto

	Parcels		Area (ha)	
	Number	%	ha	%
With titles	1103	74	75,253	74
Title pending	379	26	26,021	26

DISCUSSION

Deforestation at the farm level averaged two ha per year per family in Pedro Peixoto and three ha per year in Theobroma. Reasons for the significantly higher rate of deforestation in Theobroma were not determined, although the contrasting possibilities that clearing accelerates as the settlements age (Theobroma having been settled earlier) or that colonists decrease rates over time (the interviewed settlers in Theobroma had lived in that settlement for less time than had the Pedro Peixoto settlers) is to be investigated in the future.

The interviews included several cross-checking questions for which settlers' responses were not always internally consistent. As a result, deforestation rates could be calculated from the interviews using different formulas, with the differences in results methodologically instructive. A method similar to the one used above again uses data from the number of years of parcel occupation (Table 3) and deforestation at time of arrival, but calculates current deforestation from the sum of farmer-reported areas under different land uses (Table 4):

$$r_2 = \frac{(a1 + a2 + a3 + a4) - \text{area cleared at time of arrival}}{\text{years occupying the parcel}}$$

where:
- a1 = current area of perennial crops
- a2 = current area of fallow
- a3 = current area of pasture
- a4 = current area of annual/food crops

Mean per parcel cleared areas summed for different land uses were 27 ha in Pedro Peixoto and 35 ha in Theobroma; and resulting rates of primary forest deforestation were 2.6 ha per year in Pedro Peixoto and 3.4 ha per year in Theobroma. Farmers appeared to overestimate areas allocated to the individual land uses with the result that overall forest conversion was overestimated.

Rates of on-farm deforestation could also be calculated based on simple questions asking settlers how often they cleared forest lands and how much they cleared each time (Table 28), where:

r_3 = frequency of clearing x area cleared each time

Two-thirds of Pedro Peixoto farmers reported clearing primary forest every other year; and, overall, they cleared a mean 2.5 ha of new land once every 2.1 years. Most Theobroma farmers reported clearing new forest other year (46%) or every three years (25%) for means of 2.8 ha of forest cleared every 2.5 years. The result was that settlers thereby cleared a mean of slightly more than one ha of primary forest per year at both sites. These lower figures appear to represent farmers' under-reporting of frequency of forest clearing, in turn probably reflecting farmers' reluctance to "admit" to frequent clearing.

In any case, settlers still had more than half of their lands in forest and, for the most part, can and probably will continue to slash, burn, and cultivate more primary forest as their currently most (economically) viable option. Two main factors driving land clearing at the farm level were the need to produce food crops and incentives to convert land into pasture. In terms of food production, farmers consumed and sold rice, and to a lesser extent, beans, maize, and cassava (or cassava meal). Rice cultivation may "drive" some deforestation in that although farmers usually planted a cleared field for two or three years, they could not--for technical reasons--sow rice other than in the first year after clearing. As such, a research priority of the ASB project may be to determine if and under which management alternatives could rice production be made more sustainable (acknowledging the *caveat* that any improvement in productivity may lead to greater economic attractiveness of the respective enterprise and thereby invite more deforestation or other forms of resource over-exploitation).

Farmers were clearly motivated to convert cleared lands into pasture because of real or at least perceived resulting increases in land values. Farmers not only maintained cattle as standing "bank accounts" and obtained cash from sales of animals and milk, but built savings by investing time and resources in fencing, corrals, ponds, and other ranching necessities. As observed throughout the two sites, local ranchers and urban-based specultors have purchased continuous blocks of colonists' parcels to form new ranches or to expand the size of adjacent ranches; and payments were reportely much higher for cleared vs forested portions of parcels.

Farmers' pasture management practices consisted of introducing mainly *Brachiaria* spp, annual pasture burning, and rotation of annimals to different pastures. In spite of generally low stocking rates, there were substantial areas of poor and degraded pastures and pasture lands at both sites. Although construction of new cheese processing plants near Theobroma may result in intensification at that site, extensive and low-input cattle and pasture management appear to be the current norm for both sites. Whether or not improved pasture technologies are possible and would be appropriate to farmers' current conditions is another researchable issue.

Conversion of cleared forest land to pasture has meant that--at least in the colonies studied--that there was relatively little land placed in fallow with resulting secondary regrowth and forest regeneration. An implication is that research on improved fallows may **either** result in making fallows more attractive to farmers (as is hoped) because of more rapid regeneration and better maintenance of soil organic matter; **or** farmers may be uninterested in improved fallows because conversion to pasture is by far the preferred land use after cultivation. Factors appearing to drive forest clearing at the on-farm level are diagrammed in Figure 10.

Theobroma farmers practiced agroforestry in the sense that they had significant areas of perennial crops, mainly coffee and cacao. Pedro Peixoto settlers have had less favorable experiences regarding perennials, citing poor prices and/or markets as major constraints. Some Pedro Peixoto farmers had been encouraged (provided with credit) to plant *urucu (Bixa orellana*, used to produce red dye). When the trees started to produce, prices for the product fell to the point that farmers could not afford to harvest and lost their investements. Currently, settlers in Theobroma were being provided credit to grow *acerola (Malpighia punicifolia)*. Although they were promised a future market for all that they produce, schemes to introduce or encourage perennial crops or agroforestry remain risky.

A resource that was largely not available in the systems examined is indigenous technical knowledge of the type usually associated with shifting cultivators (Fujisaka 1989, 1991). Farmers were asked about their soil and land classification and corresponding use systems. Although they distinguished soils by color and texture and called attention to lands either having a sub-surface compacted layer or low waterlogged areas, they did not employ such distinctions in choosing areas to clear and cultivate. Farmers simply cleared land in steady sequence from the areas closest to the roads and houses and towards the rear of their parcels. Although a few named plant species which indicated soil impoverishment and others which indicated fallow regeneration, most farmers appeared to have little concept of use of fallows for biomass (and subesequent soil fertility) regeneration or of (as mentioned) the use of fire to release nutrients for crops use. Only a few Theobroma farmers mentioned that there were medicinal plants that could be harvested from the forest.

CONCLUSIONS

The heartening news is that rates of deforestation in the Amazon Basin appear to be decreasing, due to fewer incentives to large corporations to invest in cattle ranching, a virtual end to a period of road building to "open-up" the Amazon and to protect frontier areas, and a decline in government-assisted colonization programs for the rural poor. Secondary forests have shown relatively high rates of regeneration--both after slash-and-burn agriculture and after abandonment of degraded pastures; and a significant proportion of deforestation for shifting cultivation in other areas of the Amazon basin is now of secondary rather than primary forest.

On the other hand, deforestation and/or consolidation of colonists' parcels to form or expand ranches has continued, with ranches now being formed less by frontier risk-takers and more by urban speculators in areas where land prices have risen and where govenment can protect such investment. The evidence presented suggests that deforestation on colonists' parcels continues at an apparent steady pace--driven by food production needs and by incentives similar to those now pushing formation of larger ranches.

To some extent, the characterization data suggest the need for on-farm research to develop alternatives to slash-and-burn agriculture. Such research--already underway or planned--needs to examine the possibility of making rice production more sustainable (and thereby **hopefully** reducing demand for newly cleared forest), improving (i.e., intensifying to the degree appropriate) pasture and cattle management, introducing or encouraging more perennial cropping and agroforestry, and improving fallows.

At the same time and equally or more importantly, this analysis recognizes the importance to deforestation of what are essential macro-economic forces; national policies regarding road construction, credit, tax incentives, frontier settlement, land tenure, and the rural poor; and perhaps international pressures regarding deforestation, maintenance of biodiversity, and protection of indigenous cultures. Certainly, any development of "alternatives" to slash-and-burn will need to include continued assessment of both the dynamics of deforestation and the results and returns possible from local-level technical innovations vs the importance of policies and future policy options.

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