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ANALYSIS

Tropical forests and shifting cultivation: secondary forest fallow dynamics among traditional farmers of the Peruvian Amazon

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Abstract

Tropical secondary forests created by swidden-fallow agriculture cover extensive areas in the humid tropics and yield significant ecological and economic benefits, yet forest fallowing behaviour among swidden cultivators remains poorly understood. This paper reports on a study of forest fallow management among Amazonian peasant farmers in a traditional, riverside community near Iquitos, Peru. Data were gathered through in-depth household interviews ($n = 36$) on farming practices, demographic characteristics, kinship relations and family history, income-expenditures and household wealth. Field visits and interviews allowed the reconstruction of forest fallow histories ($n = 593$ fields) for the period of 1950–1994. These histories were combined with information on household land holding and demographic composition, over time, and incorporated into a panel data set for analysis of fallow dynamics at the plot and household level. Our analyses indicate marked variations among households in the area, number and age of fallow holdings through time. Tobit regressions suggest that households with better access to land and to both in-house (male) and communal labour hold more land in secondary forest fallow with longer fallow periods. Over time, as primary forest lands around the community became increasingly scarce, households increased their holdings of forest fallow but reduced the fallow length. Duration analyses at the plot level indicate that fallow length is influenced primarily by the type of prior crop, field size, and household access to labour as well as primary forest. Land poorer households have significantly shorter forest fallows than better-off households. Our findings point to the importance of intra-community variations in non-market mediated access to land and labour and their implications for secondary forest fallow management among traditional peoples in tropical rain forest regions.

Keywords: Slash-and-burn agriculture; Agroforestry; Land inequality

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1. Introduction

Research on the fate of the world's forests and the global impacts of forest cover change has stimulated considerable interest in the nature, role and dynamics of tropical secondary forests (Brown and Lugo, 1990; Finegan, 1992; Corlett, 1995). In 1980, secondary forests extended over some 618 million hectares, or about 26% of forest lands in the tropics (derived from Brown and Lugo, 1990, p. 2), comprised in large part by forest fallows created by peasant farmers. On closed forest lands, forest fallows extended over some 240 million hectares – increasing at a rate of about 3.4 million hectares per year – with the largest extension (45% by area) found in the tropical Americas (Lanly, 1995, p. 20). Indeed, recent satellite images from the Amazon basin confirm the vast extent of secondary forest, not only along the roads in the colonization and cattle ranching zones of Pará, Amazonas and Rondônia, but also along the main channel of the Amazon River, its tributaries and interfluves where traditional peasant farmers practice shifting cultivation (Steininger, 1996; Alves et al., 1997; Tucker et al., 1998).

Shifting cultivation – increasingly referred to as 'swidden-fallow' agriculture – mimics the natural patch-phase dynamics of the tropical forest and the secondary forest fallows which result from swidden agriculture provide important ecological services as well as economic benefits for the rural poor. Increasingly, swidden-fallow agroforestry systems are considered as potential models for more sustainable rural development among small landholders in the humid tropics (National Research Council, 1993; Brookfield and Padoch, 1994; Kleinmann et al., 1995; Montagnini and Mendelsohn, 1997). Ecologically, forest fallows serve to protect the soil from erosion, restore soil fertility, provide 'habitat islands' for fauna, and sequester carbon from the atmosphere (Lugo and Brown, 1992; Andrade and Rubio-Torgler, 1994; Fearnside and Malheiros Guimarães, 1996; Szott and Palm, 1996; Kotto-Same et al., 1997). For peasant farmers, fallows provide a wide variety of useful economic products including timber, firewood, construction materials, fruit and other non-timber products, game, and even medicinals (Chambers and Leach, 1989; Corlett, 1995; Voeks, 1996). Recognition of such benefits has renewed interest in classical works on shifting cultivation (i.e. Whittlesey, 1937; Conklin, 1957; Watters, 1960; Benneh, 1972; Ruthenberg, 1980) and prompted research that pays particular attention to the fallow phase of shifting cultivation systems (Denevan et al., 1984; Padoch et al., 1985; Denevan and Padoch, 1987; Balée and Gély, 1989; Irvine, 1989; Dubois, 1990; Kass et al., 1993; de Rouw, 1995; Gleave, 1996).

In this paper, we report on a recent study of secondary forest fallow dynamics among peasant farmers in the Peruvian Amazon. Of specific interest is the influence of household and field-level characteristics on forest fallowing around an Amazonian peasant community. Despite the growing corpus of descriptive accounts of swidden-fallow systems in the Amazon, only a few studies analyze secondary forest fallow dynamics among peasant households (see Scatena et al., 1996; Smith et al., 1998). Whereas these later works explore forest fallowing among frontier colonists and rely on cross-sectional data, we worked with traditional farmers (known in Peru as *ribereños* or as *caboclos*/*ribeirinhos* in Brazil, see Wagley, 1953; Chibnik, 1991; Hiraoka, 1992; Nugent, 1993) to develop a panel data set that allows us to consider forest fallow management through time at both the household and plot level. Importantly, we chose for study a traditional community that has experienced a marked decrease in the availability of primary forest land – essentially as the frontier closed around the village – so as to capture the potential effects of falling availability of forest land. Our analytical approach and results are relevant not only to scientists working on swidden-fallow agricultural systems but more broadly to those seeking, for example, to estimate the magnitude of the ecological and economic benefits of anthropogenic secondary forest (e.g. rates of carbon sequestration, habitat renewal, non-timber forest products supply, etc.) or to better understand the process of land use and cover change in rain forest environments.

2. Study area

The study community – referred to here as 'San José' so as to preserve the anonymity of respondents – is situated along the Amazon River near Iquitos, the largest urban centre in northeastern Peru. Perched on the upland, overlooking the Amazon, San José is a small peasant community (60 households, 365 individuals) where residents engage in traditional agriculture, forest product extraction and river fishing for their livelihood. Unlike colonists in frontier areas who clear land for pasture with an eye to raising cattle and/or moving on, local residents have lived for years in San José, in most cases for generations, practising long-cycle swidden-fallow agroforestry. Founded in the mid-19th century as an agricultural estate to serve the burgeoning rubber trade, the lands of San José were transferred in 1971 under the Agrarian Reform to the families of the *peones* that had long worked the estate. Since the early 1970s, the population of San José has remained relatively constant, though somewhat reduced in size (by perhaps 20–30%) from the estate days of the 1950s and 60s. Today, community lands encompass about 2300 hectares, most of which is under crop or forest fallow. San José is bounded inland on all sides by lands belonging to neighboring communities. Whereas 30 years ago primary forest was abundant within San José's boundaries, virtually no unclaimed land remains within community boundaries and less than 1% of the land area is under primary forest.

Swidden-fallow agroforestry is practiced in San José in two areas: on the upland which surrounds the community; and on a remnant river terrace that lies several kilometres inland. The rolling hills of the upland are composed of old Tertiary alluvium, dissected by small perennial streams. Upland soils are typically deeply weathered, nutrient-poor and acidic. In contrast, terrace soils are siltier, less acidic and richer in nutrients (Coomes and Burt, 1997). Unlike the upland which has been cultivated in places for more than a century, the more distant terrace lands were brought under cultivation only in the 1970s.

Local farmers begin the swidden-fallow cycle by slashing and burning a patch of rain forest. Using only machetes and axes (i.e. no chainsaws), and working with kinfolk, farmers open the forest and plant crops in the field, thereby claiming the land. On the upland, the plot is cultivated through a sequence of crop phases, beginning with a swidden phase (one to three years) which is dominated by short cycle subsistence crops such as manioc, yams or plantain (see Coomes and Burt, 1997). A transitional phase (2–6 years) of marketable fruit crops including pineapple, cashew, and guava often follows. Some farmers will continue the cycle with an orchard phase of slower maturing fruit trees such as *umarí* (*Pouraqueiba sericea*), *macambo* (*Theobroma bicolor*), or peach palm which may thrive for 25 years or more. On the terrace, farmers cultivate their plots first in manioc, maize or rice and then plantain/banana (see Coomes and Burt, 1997). At any moment, the farmer may leave the plot in fallow and allow secondary forest to return; some years later, the forest fallow will be cut and the cycle begun anew. Each farmer holds several fields, typically scattered throughout the area, in different phases of cultivation and fallow; this ensures a steady stream of subsistence and cash income for the household, and gives rise to a richly variegated landscape around San José, like many other peasant communities, of swidden and transitional fields among orchards, forest fallows and primary forest.

Residents are economically poor and highly reliant upon local resources for their livelihood. The median market income is about $2000/household per year, earned largely from sales in Iquitos of produce derived from swidden-fallow agroforestry, fishing, small livestock, non-timber forest product extraction, handicraft production and floodplain agriculture along the Amazon river. Although households are integrated into product markets, land and labour are typically allocated by traditional rather than market means. Land – the most important household asset – is held in usufruct and transferred principally by gift and inheritance. Despite outward appearances, marked differences exist within San José in access to land – household land holdings range from 0.42 up to 45.21 hectares with 20% of households possessing 58% of the land; only one in two

Table 1
Characteristics of sample households ($n = 36$), San Jose, Peru, 1994

	Mean	Standard deviation	Range
Household size	5.83	2.94	(1–14)
No. males (15–65 years)	1.66	1.15	(0–6)
No. females (15–65 years)	1.22	0.73	(0–5)
Household age (years)	20.03	13.92	(3–57)
Kin group size	6.47	3.24	(1–12)
No. generations born in San Jose	4.83	1.40	(1–7)
Total land holding (ha)	10.09	9.86	(0.42–45.21)
Upland (ha)	5.73	4.74	(0.42–19.18)
Terrace (ha)	3.11	6.93	(0–33.55)
Lowland (ha)	1.24	1.39	(0–6.0)
No. of fields held	9.22	5.28	(2–26)
Value of non-land assets ($US)	152.46	152.17	(0–583)
Total market income ($US)	2347.74	1534.93	(416–7096)

households holds land on the more fertile terrace, and these tend to be better off households. Households are capital poor with non-land assets valued typically at less than $500, comprising mostly farming and fishing implements as well as small livestock (i.e. chickens and pigs). Labour for agricultural activities is shared communally along kinship lines and local opportunities for wage work are few.

3. Methods

Field data were gathered in San José during the period of June-August of 1994 and 1995. Of the 60 households in the community, 42 were found to be dedicated principally to farming and this group formed our target population. Structured interviews were conducted with heads of households and their spouses to provide data on household demographic composition, kinship relations and family history, land holding, labour use, household income, expenditures, and non-land asset holdings. In addition, respondents were asked to report all live births and deaths since the year of their formation to allow the reconstruction of household demographic history. The key characteristics of households in the sample ($n = 36$) are summarized in Table 1.

Each head of household was accompanied to visit his/her crop and fallowed fields. At each site, the dimensions of the field were estimated by ocular inspection (undertaken by an experienced field assistant; precision verified initially by tape measurement, then checked periodically), and a cropping-fallowing history was reconstructed with the aide of the field owner, beginning with the current crop/fallow cover and working back through time to the year of acquisition. The natural 'programmatic' sequencing of crops in the swidden-fallow agroforestry cycle enabled owners, in some cases, to readily recall field cover back as far as the 1950s (see Coomes and Burt, 1997). A more general history of land holding since household formation also was taken which revealed fields that were once held but since had been abandoned or transferred to others; individual histories of such fields were also reconstructed. After 90 days of interviewing, cropping and fallowing histories were available from 593 fields for the period, 1950–1994. This information was coded and used to construct a panel data set for statistical analyses.

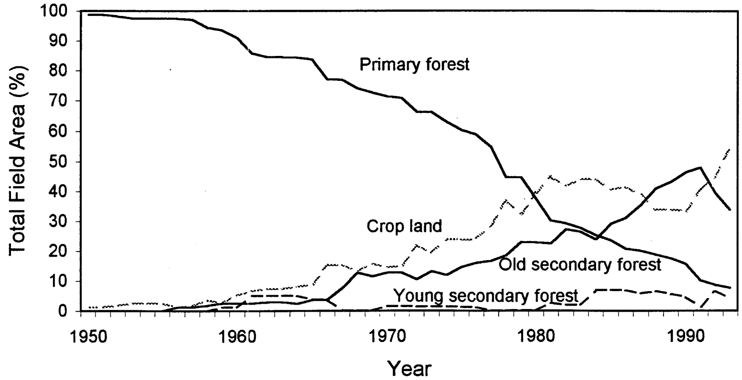

Fig. 1. Land cover change at San José, Peru, 1950–1994.

4. Results

4.1. Land cover change (1950–1994)

According to residents, the extent and type of land cover around San José changed markedly since the 1950s as land became increasingly scarce. In the absence of historical records of land use or sequential aerial photographs, we sought to reconstruct the trajectory of forest cover change based on field histories. From the histories of fields known to have been cut originally in primary forest ($n = 90$), we can track the fate of primary forest over past decades, essentially 'at the margin' (Fig. 1). Since the 1960s, we note a sharp decline in primary forest and the rise of both crop land and secondary forest. The trajectories of older secondary forest (i.e. > 6 years old) and younger secondary forest (i.e. ≤ 6 years) are quite distinct: whereas the stock of younger forest has been relatively constant over time, the area under old fallows rose steadily, essentially replacing primary forest, to a peak in the early 1990s when farmers began cutting into the stock of older fallows. By 1994, primary forest had all but disappeared, replaced by a patchwork of swiddens, transitional fields, orchards and secondary forest fallows that dominate the local landscape.

4.2. Forest fallow characteristics

Households in the sample held in 1994 a total of 96 fields in secondary forest fallow on the upland ($n = 53$) and terrace ($n = 43$), covering an area of 174 ha and representing about 29% of all fields ($n = 332$) in that year. Individual forest fallows vary markedly in size, from 0.01 to 28.3 hectares, with a mean of 1.80 ha (S.D. 3.31), and tend to be larger on average than crop fields (i.e. swiddens: 0.62 ha; transitional fields: 0.67 ha; orchards: 0.80 ha); this difference reflects, in part, the decreased availability of land through time. Most forest fallows are young (mean: 5.6 years, S.D. 6.2) though fallows of up to 33 years are noted. Approximately one-half of the fields currently in fallow are 3 years or less in age and only 25% are older than 8 years (Fig. 2). Although forest fallows on the upland appear to be smaller and younger than fallows on the terrace such differences are not statistically significant.

Forest fallows constitute a major part of most households' agroforestry portfolios (Table 2). At

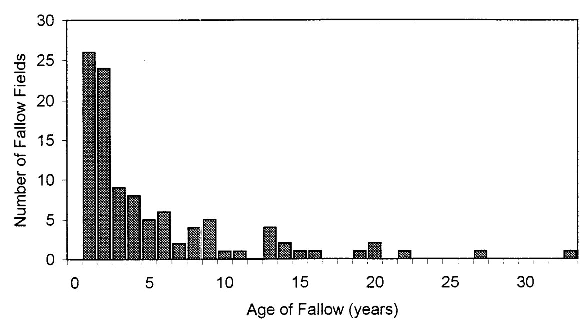

Fig. 2. Age distribution of secondary forest fallows at San José, Peru, 1994.

Table 2
Household holdings of secondary forest fallow, San José, Peru 1994

	Mean	Standard deviation	Range
Total area in fallow (ha)	4.85	7.52	(0–36.4)
No. of fields in fallow	2.67	3.08	(0–13)
Average size of fallow fields (ha)	0.51	0.57	(0–2.6)
% of holdings; in fallow	0.42	0.33	(0–1.0)
Average fallow period (years)	5.63	6.15	(1–33)
% of initial land holdings in forest	0.07	0.17	(0–0.58)
% of initial land holdings in fallow	0.37	0.37	(0–1.0)

the mean, households hold nine fields (i.e. six in crop and three in fallow) with a combined area of about 10 ha; forest fallows typically occupies about one-half of a household's total land holdings. Such fallows lie within about four kilometres of the community, typically scattered as small patches in the hinterland. The mean fallow and cropping periods at the household level for the period 1950–1994 were 5.6 and 8 years, respectively. Most household's holdings today were built up from an initial endowment of land dominated more by forest fallows (mean: 37% of initial land area) than by primary forest (mean: 7% of area).

Marked differences are noted within the sample in the holding of forest fallows. Indeed, nine of the 36 households in 1994 held no land in forest fallow, though four of these households did own umarí orchards. Households with forest fallows possessed between one and 13 fallow fields with a total area in secondary forest of between 0.02 and 36.4 ha (Fig. 3). Fallow land is unevenly distributed among households with the top 20% of households holding about 60% of land under secondary forest. Considerable variance also exists in the duration of the fallow period: the average length of forest fallow, calculated as the mean age of all fallow fields in the household's portfolio in a given year, ranged from 1 to 9 years.

4.3. Inter-household variations in forest fallow holding

What factors account for the marked variations observed among households in the holding of secondary forest fallows? To answer this question, we defined four aggregate features of fallow holding at the household level for analysis: total area in fallow; percent of land holdings in forest fallow; number of fallows held; and, the average length of fallow among fallowed fields in the portfolio. 'Household-year' is used as the unit of observation (i.e. we analyze the total area in fallow on both the upland and terrace for each year of the household's existence, using household characteristics in each year) and, for this reason, the total number of observations used in the analyses exceeds the number of households in the sample. Because some households, during certain years, may not have any fields in forest fallow (i.e. data are censored at zero), tobit rather than OLS estimations were used for regression analyses. Standard errors were corrected to account for the fact that the panel is 'unbalanced' (i.e. fallows included of households formed in different years). Given the paucity of prior theoretical work on the determinants of fallow holdings and the complexity of the problem, we tested a wide range of independent variables – drawn from microeconomic theory, field experience and relevant litera-

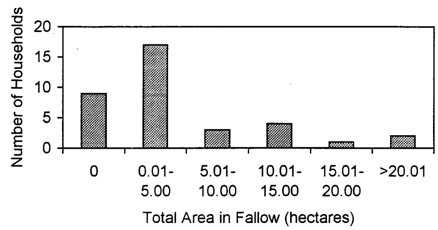

Fig. 3. Size distribution of secondary forest fallow holdings at San José, Peru, 1994.

ture – in developing tobit models to explain the observed variance for each dependent variable.

Our final tobit models include nine independent variables which reflect household and local characteristics that are expected to influence forest fallow management. Three variables relate to the household's access to *labour*: number of male's of working age (i.e. 15–65 years old) in each given year; number of females of working age (in each given year); and kin group size (in 1994). In San José, households rely upon in-house labour (male and female) and communal labour to do agricultural work, and differential access to such labour may well influence households' decisions on fallowing (Staver, 1989; Dvořàk, 1992). Households belonging to larger kin groups in San José are expected to have greater access to communal labour than households with fewer kinfolk; as such, 'kin group size' (determined as the frequency of shared paternal and maternal surnames among heads of households in San José) serves as a proxy for communal labour. Access to *land* is also expected to be influential (see Gleave, 1996) and three variables are included: total land holdings (hectares) in each given year, percentage of the household's initial endowment of land in primary forest (in year of household formation); and percentage of initial endowment in forest fallow (year of household formation). Three additional variables capture *historical features* that may influence fallow management: the age of the household (i.e. number of years since formation) in each year; the number of generations of the household's family that were born in San José (1994) and the percentage of primary forest remaining around the community for each year between 1950 and 1994. Fallow management is expected to be associated with the household lifecycle, i.e. households build up a stock of fallow land over time and then later in life transfer forest fallows to their heirs and kin (à la Chayanov, see Walker and Homma, 1996). Households whose forebearers established themselves earlier in San José (i.e. several generations prior) may have certain advantages conferred by longer residency (e.g. first claims on better quality land, greater depth of local environmental knowledge, more experience with fallowing) which would affect fallow management. The portion of land remaining in primary forest around San José serves as a proxy for the availability of forest land which has decreased substantially through time (Fig. 1); households formed when primary forest was abundant have distinct prospects for land accumulation and forest fallow holding than households that arrived recently in San José. As such, the tobit models include both time variant variables (e.g. land holdings, labour supply, household age) and time invariant variables (e.g. initial endowment of fallow land/primary forest land, kin group size, number of generations). By including both types of variables, which are potentially influential in secondary forest dynamics, our models account for inter-household variations but do not control for unobservable household effects.

Tobit analyses account for a significant amount of observed variance in fallow holding among households in the sample (Table 3). Five of the nine independent variables contributed consistently and significantly across the regression models. Households with better access to male and communal labour, larger land holdings and more of their initial endowment of land in fallow tend to hold more land in fallow, more forest fallows, and a larger percentage of their holdings in fallow. Longer family residency in San José (i.e. number of generations) is associated with less area in fallow and a lower percent of holdings in fallow. As access to primary forest around the community has fallen, households appear to dedicate more land to forest fallow. Fallow holdings, however, are not generally related to the age of the household or the proportion of the household's initial land endowment in primary forest. Average fallow lengths (i.e. over the household's portfolio of fallowed fields) are longer when held by older households (but with shorter family residence in the community), households with better access to in-house male and communal labour, larger land holdings, and a higher portion of the initial land endowment in forest fallow.

Our results indicate that households in San José tend to increase their holdings of forest fallows as prospects for land accumulation diminish over time with the closing of the frontier around the community. The increase in fallow area and per-

Table 3
Tobit analyses of key features of forest fallows at household level, San José, Peru

Variables	Area in fallow		Holdings in fallow (%)		No. of fields in fallow		Average length of fallow	
Constant	−3.60	(0.87)***	0.04	(0.06)	−0.48	(0.52)	−2.17	(0.92)**
No. Male workers	0.68	(0.19)***	0.06	(0.01)***	0.62	(0.12)***	0.61	(0.21)***
No. Female workers	−1.04	(0.26)***	−0.03	(0.02)*	0.78	(0.16)***	0.06	(0.28)
Kin group size (1994)	0.20	(0.07)***	0.02	(0.005)***	0.26	(0.04)***	0.36	(0.08)***
Age of household (years)	−0.02	(0.02)	−0.001	(0.001)	−0.01	(0.01)	0.11	(0.02)***
No. of generations (1994)	−0.66	(0.14)***	−0.06	(0.01)***	−0.84	(0.09)***	−0.83	(0.15)***
Total land holdings (ha)[a]	0.63	(0.02)***	0.01	(0.002)***	0.18	(0.01)***	0.16	(0.03)***
% of initial holding in fallow	4.89	(0.62)***	0.48	(0.04)***	4.58	(0.38)***	6.20	(0.66)***
% of initial holding in forest	2.03	(1.32)	0.08	(0.09)	−0.44	(0.79)	−1.70	(1.42)
% of primary forest remaining	−1.76	(0.68)***	−0.17	(0.05)***	−1.67	(0.41)***	−0.19	(0.72)
Log likelihood	−1322.73		−188.34		−1135.88		−1403.82	
No. of observations	655		651		655		655	
χ^2	703.13		294.39		480.68		254.91	
$(P>\chi^2)$	(<0.01)		(<0.01)		(<0.01)		(<0.01)	
Pseudo R^2	0.21		0.44		0.18		0.08	

[a] Hausman procedure used to test for endogeneity with dependent variables. Tests fail to reject exogeneity at $P \leq 0.01$. S.E. inside parens.

* $P \leq 0.10$.

** $P \leq 0.05$.

*** $P \leq 0.01$.

cent of holdings in fallow is due to an increase both in the number of fallow fields and in the average size of fallows relative to crop fields. Moreover, although the area under forest fallow has increased, the length of fallowing has decreased, especially at the plot level (Fig. 4). The decline in fallow length reflects several changes: the fallow length of older fields has shortened through time; new fields have shorter fallows than older fields; and, the fallow length of newer fields has also fallen through time. Thus, as land has become increasingly scarce, households devote more land to forest fallow, essentially through the conversion of primary forest, but shorten the fallow period. The result at the community level is an increase in the area under secondary forest but an overall reduction in the age of the forest.

Given the observed inequality in land holdings within the community and differences observed in agroforestry practices between land rich and poor households (see Coomes and Burt, 1997), we tested for differences in fallowing that might be attributable specifically to uneven access to land. The sample was split at the mean land holding in 1994, with households holding less than 10 ha as ‘land poorer’ and those with more land as ‘land richer’; this division marks a natural break in the bimodal distribution of land and ensures a similar and sufficient number of observations in each category. By dividing the sample in two and taking into account the initial as well as changing household conditions, the likelihood of selectivity bias is reduced. Results of tobit analyses on each sub-sample reveal that the initial endowment in fallow, total land holdings and kin residency have a similar effects across land poorer and land richer households (Table 4). Households with a higher initial area in fallow, higher total land holdings and shorter residency tend to have more land in fallow, a higher proportion of their holdings in fallow, more fallow fields, and longer fallows.

Two sets of key variables, however, affect fallow holding distinctly between land richer and

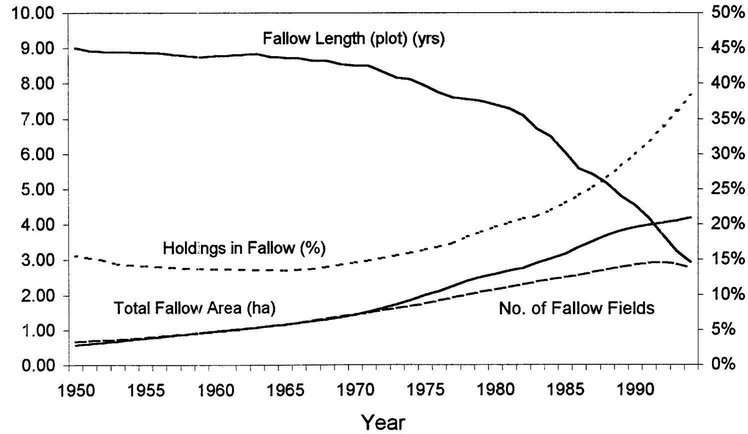

Fig. 4. Mean characteristics of forest fallow holdings at household level, San José, Peru, 1950–1994.

poorer households. First, forest fallowing is related to the availability of primary forest for both groups of households, but in a distinct manner. As the availability in primary forest has declined, land poorer households tend to increase their holdings of fallow, the portion of their land in fallow, and the average length of fallow. Among the land richer, however, the area and length of fallow among better off-households has actually fallen with the decline of primary forest. Second, households are distinguished by a 'labour effect'. Land richer households with more male workers and better access to communal labour tend to hold more land in forest fallow. In contrast, land poorer households are not to be subject to the labour effect; in fact, it appears that the presence of more female members of working age tends to decrease the total fallow area and the percentage of land held in fallow.

Our findings suggest that forest fallowing at the household level is profoundly affected by changing access through time to both land and labour. If a household possesses only limited land, then the potential influence of access to intra-household and extra-household (communal) labour on forest fallowing is muted and 'land factors' (i.e. percent of initial holdings in fallow; availability of primary forest) dominate. Once a household accumulates land beyond a certain minimum area, then labour access becomes more influential (i.e. number of males of working age and kin group size). For many households, however, prospects for augmenting their land holdings are limited and access to land rather than labour is the primary factor that conditions their decisions over forest fallow management.

4.4. Predictors of forest fallow length at plot level

Whereas tobit analyses provide insight into the factors that influence the average length of fallow in households' portfolios, a distinct approach is required to explore for predictors of fallow length at the plot level. As Gleave (1996) points out, swidden farmers often manage their fields distinctly from one field to another with the result that fallow lengths may vary significantly within a household's portfolio; such indeed is the case in San José. Moreover, households clear and cultivate new fields that may be managed differently from older plots in their portfolio. As such, fallow management behavior can be masked by 'portfolio averages'. Analysis at the plot level is necessary therefore to identify the factors that induce households to leave a field in fallow longer or to cut the forest fallow and initiate the cultivation cycle, taking into account not only the household level characteristics but also the particular characteristics of each plot.

'Duration analysis' – a technique used elsewhere by health scientists (see Hamilton et al., 1996) and economists (see Kiefer, 1988) studying,

Table 4
Tobit analyses of selected features of forest fallows held by land richer and poorer households, San José, Peru[a]

Variables	Area in fallow		Holdings in fallow (%)		Average length of fallow	
	Land richer households	Land poorer households	Land richer households	Land poorer households	Land richcr households	Land poorer households
Constant	−15.89 (2.35)***	−0.78 (0.46)*	−0.41 (0.12) ***	−0.05 (0.10)	−9.60 (1.55) ***	−1.59 (1.64)
No. male workers	0.83 (0.28)***	0.15 (0.10)	0.06 (0.01)***	0.03 (0.02)	0.88 (0.18)***	0.09 (0.36)
No. female workers	−0.29 (0.40)	−0.64 (0.17)***	0.04 (0.02) **	−0.08 (0.04)**	−0.23 (0.26)	0.21 (0.60)
Kin group size (1994)	1.01 (0.15)***	−0.05 (0.03) *	0.08 (0.008) ***	−0.004 (0.006)	1.47 (0.10) ***	0.05 (0.11)
Age of household (years)	0.03 (0.07)	0.02 (0.009)**	−0.002 (0.003)	0.005 (0.002) ***	0.27 (0.04) ***	0.04 (0 03)
No. of generations (1994)	−1.57 (0.28)***	−0.09 (0.07)	−0.11 (0.01) ***	−0.02 (0.01)*	−2.03 (0.19) ***	−0.81 (0.24)***
Total land holdings (ha)	0.77 (0.04) ***	0.35 (0.03) ***	0.01 (0.002) ***	0.03 (0.006) ***	0.06 (0.02)**	0.88 (0.10) ***
% of initial holding in fellow	11.89 (1.21)***	2.09 (0.36) ***	0.71 (0.06) ***	0.64 (0.08) ***	11.37 (0.82)***	4.69 (1.28)***
% of initial holding in forest	−2.79 (2.67)	1.15 (0.53) **	−0.10 (0.14)	0.01 (0.11)	-9.49 (1.77)***	−1.6 (1.92)
% of primary forest remaining	4.39 (2.27)*	−1.31 (0.40)***	0.0009 (0.11)	−0.22 (0.08) ***	3.04 (1.49)**	2.63 (1.37)*
Log likelihood	53.78	−375.27	−25.93	−82.94	−670.71	−623
No. of observations	340	315	339	312	340	315
χ^2	461.3	218.9	286.2	152.4	329.8	124.3
$(P>\chi^2)$	(<0.01)	(0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.0 1)
Pseudo R^2	0.23	0.23	0.85	0.48	0.20	0.09

[a] S.E. in parens.
* $P \leq 0.10$.
** $P \leq 0.05$.
*** $P \leq 0.01$.

for example, the duration of illness and unemployment – is employed to assess the factors that may influence fallow length at the plot level. We define the length of fallow for each field as the 'fallow spell' and then assess the contribution of a range of independent variables in conditioning the probability that the forest fallow will end. Duration analysis is particularly useful in studying fallow length because of an intrinsic problem of data censoring. Included in the panel data set are fields for which the fallow period is 'complete' (i.e. between two cropping periods) but also those fields for which the fallow is 'incomplete'(i.e. the field was still in fallow in 1994 when the survey was conducted). A field left in fallow in 1993, for example, would appear in the record to have a fallow length of 2 years, even though the owner may intend to leave the plot in fallow for a full 5 years; as such the fallow period of this plot is artificially truncated or 'censored'. Censoring could contribute in part, therefore, to the apparent fall in the length of fallow over time (Fig. 4), as recent fallows are less likely to be complete than fields fallowed years ago. Unlike with OLS or tobit estimations, duration analysis allows us to take account of fallow spells that are 'in progress' at the moment of data collection and to analyse the length of fallow controlling for the potential influence of censoring. Because soil fertility differences between the upland and terrace may influence fallow length, we focus here only on forest fallows found on the upland, the dominant landscape unit around San José and other *terra firme* communities elsewhere in the amazon.

We begin our analysis by examining the 'survival rates' for upland plots held by land richer and land poorer households. To determine whether plots owned by households with distinct endowments of land have different fallow durations, we compute from the panel data the Kaplan-Meier survival rate for fallowed fields; that is, the probability that a plot continues in fallow for another year, given the number of years that it has been in fallow. Fallow plots among land richer households are found to have a higher survival rate than plots held by land poorer households (Fig. 5). A 10-year-old fallow, for example, belonging to a land richer household has

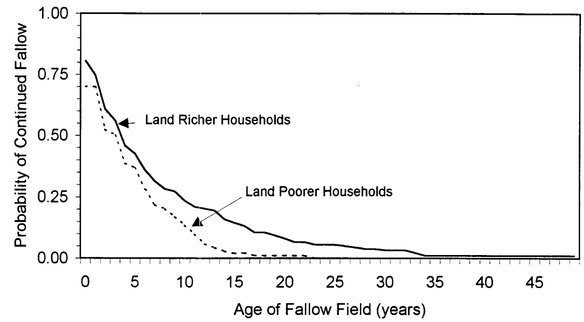

Fig. 5. Kaplan-Meier survival rate curves for forest fallows held by land richer and land poorer households, San José, Peru.

a 27% chance of staying in fallow for the next year whereas the same field only has a 17% probability of remaining in fallow for another year among land poorer households; the survival functions of the two land groups are statistically different ($P \leq 0.01$) by a test of equality functions, suggesting that the fate of fallows held by land richer and land poorer households is quite distinct.

Parametric duration analysis is used to assess the influence of independent variables upon upland fallow length at the plot level. The conditional probability that the forest fallow will end in period t, given that the plot has been in fallow $t-1$ periods, is estimated and expressed as a 'hazard rate'. A Cox proportional hazard model (non-time-varying) is employed to assess the role of household and community characteristics (as for the tobit analyses) but also plot level features (i.e. size of the plot and the type of crop just prior to fallow) in conditioning the probability that the fallow period for a given plot will end without specifying a parametric form of the baseline hazard rate (Greene, 1997). Values for most independent variables in the analysis are taken at the beginning of each fallow spell. Dummy variables are included to represent the time period when the spell started, in five-year increments. The analysis is performed with all plots in the sample, and then for plots held by land richer and poorer households.

Our results indicate that fallow length at the plot level is strongly related to the type of crop grown prior to fallow commencement, the size of the field, the number of female workers in the household, and household access to communal labour (Table 5). The coefficients presented in Table 5 indicate the effect of each of 16 independent variables on the hazard rate. For example, field size has a negative (significant) coefficient which suggests that larger forest fallow fields tend to stay longer in fallow (i.e. have a lower probability of going out of fallow). For all households, a field remains longer in forest fallow if the plot is larger and was previously cultivated in manioc, pineapple or plantain if the household owning the plot has better access to labour (i.e. female workers and communal labour); and if primary forest is increasingly scarce. Plots left in fallow during the period of 1985-1990 have, according to the dummy variables for time, a much higher probability of leaving fallow than those begun in the pre-1970 period.

Results of duration analyses contrasting the influence of independent variables on fallow management among land richer and poorer households are consistent with those found by the tobit analyses with respect to the relative effects of land and labour availability. Among land richer households, fallow length is associated most strongly with the type of prior crop, land holdings and labour access. Households with larger plot sizes, better access to communal labour and more female labour tend to have longer fallows at the field level. More male workers and larger land holdings of the household contribute to shortening the length of fallow. In contrast, fallow length among land poorer households is influenced not by labour access or the type of prior crop (except for pineapple) but rather by the availability of primary forest, the time dummy variables and land holdings. As land poorer households add to their holdings, the fallow spell tends to be ex-

Table 5
Duration analyses of forest fallow length for upland fields at plot level, San José, Peru, 1950–1994[a]

Variables	All households	Land richer households	Land poorer households
No. Male workers [b]	0.02 (0.16)	0.47 (0.24)*	−0.30 (0.30)
No. Female workers [b]	−0.26 (0.14)*	−0.65 (0.28)**	−0.19 (0.64)
Kin group size (1994)	−0.09 (0.03)***	−0.21 (0.07)***	−0.10 (0.10)
Age of household (years)[b]	0.03 (0.01)*	0.03 (0.05)	0.09 (0.03)***
Size of plot (ha)[b]	−0.58 (0.19)***	−0.65 (0.26)**	−0.66 (0.52)
Total land holdings (ha)[b]	−0.004 (0.009)	0.04 (0.02)***	−0.17 (0.06)***
% Of initial holdings in fallow	−0.34 (0.23)	−0.10 (0.52)	−0.75 (0.59)
% Of initial holdings in forest	0.12 (0.74)	−0.18 (1.95)	1.64 (1.00)
% Of primary forest remaining	2.90 (1.54)*	3.63 (2.31)	11.12 (5.88)*
Prior crop was manioc (1 = yes, 0 = no)	−1.00 (0.34)**	−2.25 (0.63)***	−0.83 (0.73)
Prior crop was pineapple (1 = yes, 0 = no)	−1.72 (0.25)***	−3.08 (0.43)***	−2.40 (0.83)***
Prior crop was plantain (l = yes, 0 = no)	−1.81 (0.43)***	−3.71 (0.64)***	-1.57 (1.15)
Dummy for period 1970–80	0.28 (0.39)	0.65 (0.56)	1.39 (1.69)
Dummy for period 1980–85	1.43 (0.95)	1.23 (1.10)	5.97 (3.13)*
Dummy for period 1985–90	2.06 (1.02)**	1.11 (1.14)	7.65 (3.65)**
Dummy for period after 1990	1.84 (1.17)	0.52 (1.44)	7.73 (4.08)*
Log likelihood	−392.28	−203.53	−98.95
χ^2	114.27	86.65	131.37
$P>\chi^2$	(<0.01)	(<0.01)	(<0.01)

[a] Note: non-time varying Cox model. A negative coefficient indicates that the independent variable will reduce the hazard rate, effectively lengthening the fallow. A positive coefficient indicates an effect to shorten the fallow period.

[b] At beginning of fallow spell. S.E in parens.

* $P \leq 0.10$.

** $P \leq 0.05$.

*** $P \leq 0.01$.

tended; however, over time as the supply of primary forest contracts, the fallow spell falls sharply on plots held by poor households. Indeed, we note large significant coefficients both for primary forest and the time dummy variables (which also rise by period) for land poorer but not for land richer households (Table 5). Thus, even when accounting for censoring and the differential effects of independent variables on the hazard rates between the two groups of households, we find that plots held by land poorer households have a notably higher probability of ending fallow after 1980 (and increasingly so over time) than by better-off households who appear to be 'insulated' by their larger land holdings from the effects of growing land scarcity.

5. Discussion

In this study of swidden-fallow agriculture in the Peruvian Amazon, we find that secondary forest fallows constitute a major component of the forest landscape around traditional riverine communities and within the agricultural portfolios of Amazonian peasant households. Considerable diversity exists in forest fallow holding within a given community – both across households and through time – in terms of the area held in forest fallow, the proportion of total land holdings in fallow, the number of fallows, and in the average length of forest fallow. Such variations found in forest fallow holding at the household level are explained largely by differential access to land and labour (i.e. in-house male and communal labour), kin residency in the community, the initial endowment in forest fallow, and access to primary forest. At the plot level, the length of forest fallow is influenced primarily by the type of prior crop, the size of the field, and household access to labour (i.e. in-house female and communal labour) as well as primary forest. Overall, forest fallow holding and field management are contingent upon the relative constraints faced by peasant households – poorer households clearly respond differently in their fallowing behavior under conditions of changing access to land and labour than better-off households.

Our findings allow us to address three general questions. First, what factors enable certain peasant farmers to keep more land in secondary forest fallow, for longer? Such farmers are of particular interest because their decisions shape the local landscape around traditional communities and essentially determine the extent of ecological benefits associated with secondary forest. Generally, households with access to more labour power, from in-house males and/or kinsmen, are able to open more land for swidden-fallow cultivation. In doing so, households increase their land holdings (through usufruct) and ultimately the area under secondary forest fallow. Households whose initial endowment of land included a higher proportion of forest fallow also tend to hold more land in forest fallow than those beginning with more primary forest on their land. Overtime, households add new fields to their swidden-fallow agroforestry portfolio and, as their holdings expand, households can afford to leave more land in forest fallow. With many plots at their disposal, households with abundant land holdings also can wait longer before returning to cut and cultivate any given plot. Similarly, the proportion of holdings in fallow also tends to rise among households with expanding land holdings and good labour access. Such findings suggest that researchers seeking to better understand differential fallowing practices among traditional peoples should pay particular attention to the issue of how households come to accumulate more land than others and, concomitantly, to gain access to more labour – particularly through kinship ties – in the absence of formal markets for these factors. Among colonists along the agricultural frontier, where land and labour markets are more developed, we expect to encounter distinct forest fallowing 'logics' and behaviours; indeed, a potentially fruitful comparison remains to be undertaken of fallow management practices between ribereño and colonist households.

Second, how do forest fallowing practices change as the frontier closes around a traditional community and primary forest land becomes increasingly scarce? With expanding populations and increased local competition for land, traditional communities in Amazonia will face increasingly a shortage of land, and how swidden-fallow agroforestry practices change will determine, in part, the promise of traditional agriculture as an alternate path for more sustainable development. Our results from San José indicate that households, faced with diminishing prospects for land accumulation tended, on average, to increase their holdings in forest fallow but decrease the length of fallow; the result is a forest landscape increasingly dominated by progressively younger secondary forest. Important differences exist, however, in the fallowing behaviour between land richer and poorer households. With abundant land holdings as the frontier closes, fallowing practices among richer households are influenced more by access to intra- and extra-household labour than by the availability of new forest land: those households with access to more labour power tend to increase their holdings of secondary forest fallow. Land poorer households, however, respond principally to the growing scarcity of land, tending to increase their fallow holdings but reducing sharply the fallow length of their plots over time to the point that few of the restorative ecological benefits typically associated with older secondary forest are realized. Unlike for land richer households, access to labour does not significantly affect fallow length among land poorer households. Indeed, land poorer households face two significant barriers to the expansion of their forest fallow holdings: first, less and less new land is available to add to their holdings and thus ultimately to be cycled through a fallow phase; and because land poor households also tend to be labour poor (relative to the land richer), they often face a significant labour constraint.

Frontier closure could, of course, give rise to new labour-land arrangements as land scarcity becomes increasingly constraining. Land poor households, for example, might seek to exchange their labour for access to land belonging to land richer households, through sharecropping, rental or other arrangements. Currently in San José, however, land poor households – in the face of sharply falling fallow periods – are resorting to alternate income generating activities, including handicraft and charcoal production, to offset falling productivity in agroforestry (Coomes and Burt, 1997, 1999). Unlike richer households that are able to leave more land in fallow for longer periods, even as the frontier closes, land poor households must use their land more intensively and they lack sufficient household and extra-household labour to make the investments that would allow them to do so in a sustainable manner. Indeed, several land poor households have left the community recently as others are considering leaving to join communities elsewhere where land is more abundant. When a family leaves the community, the household's land holdings typically are granted to relatives or, infrequently, 'sold' for the value only of the standing crop. The 'exit option' in San José appears to reduce pressure that might otherwise induce the transformation of local labour relations. Should land become more generally scarce, then new labour-land relations may arise which, in turn, would differentially influence forest fallowing practices.

Finally, how can the area in secondary forest fallow be expanded around communities where peasant households practice swidden-fallow agroforestry? This question is most salient where – as in the case of San José – land is becoming increasingly scarce and primary forest is all but exhausted. Indeed, NGOs are working with communities throughout the Amazon basin to find new ways to improve swidden-fallow agriculture that would enhance environmental benefits while reducing rural poverty. In such cases, additions to the stock of secondary forest will come, not from conversion of primary forest as would likely occur where usufructuary rights dominate and land is abundant, but rather from initiatives aimed at, for example, reducing the area under crop (or pasture), introducing a lucrative, non-land-based economic activity and/or increasing remittance flows to local households from external sources (i.e., urban-based, extra-regional, etc.). To reduce the area of cropland around the community – perhaps the most practical option – the productivity of land must be raised by improving forest fallows and/or adding inputs during the cropping phase (e.g. fertilizers, labour, etc.). Given that much of the land under crop is held by land richer households, the greatest environmental gains – from the expansion of secondary forest fallow land and the prolongation of forest fallows – are likely to be realised by working with the land richer, rather than land poorer, households. In doing so, however, land richer households also would benefit materially more than land poor households.

This trade-off poses a troubling dilemma for NGOs and policy makers who assume that the dual aims of forest conservation and poverty alleviation are concordant: assist the better-off households with crop/fallow land management and thereby realize potentially significant ecological gains (albeit at the cost of overlooking the poorest households), or work with the poorest so as to improve their material condition but essentially forego the greater ecological benefits that may come from working with better-off households. Indeed, the promotion of forest fallowing among the poorest of peasant households represents a formidable challenge, in part because significant changes may be required not only in the underlying distribution of land and labour, but also in local land-labour relations which rely upon traditional rather than market mechanisms for their allocation.

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