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Forest Clearing in Rural Livelihoods: Household-Level Global-Comparative Evidence

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Summary. — This paper examines the factors that influence rural household decisions to clear forestland. We use a large dataset comprising 7172 households from 24 developing countries. Twenty-seven percent of sampled households had converted forest to agriculture during the previous 12 months, clearing on average 1.21 ha. Male-headed households with abundance of male labor, living in recently settled places with high forest cover, unsurprisingly tended to clear more, but regional peculiarities abounded. Households with medium to high asset holdings and higher market orientation were more likely to clear forest than the poorest and market-isolated households, questioning popular policy narratives about poverty-driven forest clearing.

Key words — land-use change, deforestation, poverty, smallholder farmers

1. INTRODUCTION

Tropical forests continue to be converted at alarming rates (Davidar *et al*., 2010), although recent conservation efforts might have slowed down the speed of deforestation (FAO, 2010). The negative environmental effects of deforestation are well documented (Carrero & Fearnside, 2011). The main immediate cause of forest conversion is to create space for commercial or subsistence agriculture (Angelsen & Kaimowitz, 1999; Hersperger, Gennaio, Verburg, & Burgi, 2010; Hosonuma *et al*., 2012). However, the debate on the underlying causes and what drives agents' behavior is more complex. Relations between forest clearing and household and contextual variables have been found to vary depending on the settings (VanWey, Ostrom, & Meretsky, 2005).

To identify robust links, we thus also need global-comparative research, whereby comparable forest and socioeconomic data are collected in multiple locations across continents, to sample the diversity of biophysical and social processes (Moran, 2005). The high costs often impede this undertaking, and authors have instead used aggregated data at large scales (Gaveau *et al*., 2009; Hansen *et al*., 2008), regional or country level data (Hosonuma *et al*., 2012; Myers, 1994; Rudel, 1998; Scrieciu, 2007). To identify global patterns or generalizations, the practice has been to conduct meta-analyses of household-level case studies (e.g., Geist & Lambin, 2001; van Vliet *et al*., 2012) or extensive reviews (Kaimowitz & Angelsen, 1998; Rudel, 2005). Therefore, to the best of our knowledge, there are no truly comparative global household-level studies of the determinants of forest clearing (Hersperger *et al*., 2010).

The present study attempts to fill this gap by analyzing which household and contextual characteristics affect land-use decisions under variable settings in the developing world. Using a livelihoods framework, where the core idea is that the asset status of households is fundamental to understanding their land-use choices, we examine the role of various asset types—at household and community level—in the smallholder's decisions to clear forestland. The key variable analyzed is self-reported forest clearing by households. This includes temporary/cyclical clearing, which is not categorized as deforestation according to the FAO definition (FAO, 2000).

We use a dataset collected by the Center for International Forestry Research (CIFOR's) Poverty and Environment Network (PEN) project (http://www.cifor.org/pen/). Our data comprise 7172 [1] households from 58 sites in 24 countries located in Asia, Africa, and Latin America (see Appendix A). It is a highly diverse sample drawn from predominantly smallholder households residing in the study villages, and so does not include absentee landowners or commercial companies that may also be responsible for land-use changes.

Because the factors affecting forest clearing, the interactions between them, and the magnitude of their effects all vary significantly across locations (Angelsen & Kaimowitz, 1999; Carrero & Fearnside, 2011), the transcontinental coverage may allow us to reach some more generalizable conclusions. In this way, our study addresses a key recommendation in Moran (2005) to use uniform methods and survey tools across different sites.

The rest of the paper is organized as follows. In Section 2, we discuss the livelihoods framework and more specific land-use and agricultural household models to examine forest clearing, and introduce the variables included in the analysis. Section 3 presents our data and methods, and Section 4 the descriptive and econometric results. Section 5 discusses the results, while Section 6 provides concluding remarks.

2. RURAL HOUSEHOLDS AND FOREST CLEARING: A LIVELIHOODS FRAMEWORK

(a) *The livelihoods framework*

The livelihoods framework (LF) (e.g., Ellis, 2000b) is frequently used by conservation and development researchers and practitioners (Campbell *et al*., 2001), including for analyzing rural household economic strategies (Ellis & Bahiigwa, 2003), migration (Ellis, 2003), coastal and fisheries development (Allison & Horemans, 2006), trade (Bacon, Mendez, Gliessman, Goodman, & Fox, 2008), health (VanWey, Hull, & Guedes, 2012) and income diversification (Ellis, 2000a). It has also been integral to poverty reduction strategies and policies of various conservation and development agencies (Sayer *et al*., 2007).

The core idea of the LF is that the *asset* portfolio of households, given a set of *contextual factors* is fundamental to understanding their livelihood *strategies*, which again generate a set of livelihood *outcomes*, including aggregate patterns of environmental resource use (Cundill, Shackelton, & Larsen, 2011; Ellis, 2000b). The livelihood outcomes will in turn determine future household assets (VanWey *et al*., 2012). Forest clearing and agricultural area expansion can be an important component of some households' livelihoods strategies.

The set of asset and context variables relevant to understanding household decision-making includes the following (DFID, 1999; Ellis, 2000b): first, *assets* are classified in five broad categories of capital, namely, natural, physical, human, social, and financial capital. These are the building blocks upon which households are able to undertake production and engage in markets, as well as other reciprocal exchanges. The use of assets is mediated by *processes and context* that inhibit or facilitate the capabilities and choices made by individuals or households, such as: (a) social relations, e.g., gender, caste, class, and ethnicity, (b) institutions, e.g., rules and informal codes of behavior shape access to land and resources, and (c) markets, e.g., their accessibility, transport costs, and relative prices. Lastly, the external environment determines what is referred to as the *vulnerability context* (DFID, 1999), comprising trends, shocks, seasonality of prices, and employment opportunities. [2]

(b) *Specific theories and models*

While there is no unifying theory of land use change yet (Briassoulis, 2000 Hersperger *et al*., 2010; Lambin & Geist, 2006; Lambin, Geist, & Rindfuss, 2006; Turner, Lambin, & Reenberg, 2007; VanWey *et al*., 2005), a number of more-specific models to explain households' land use have been developed and tested. We argue that most of these can be interpreted as specifications of key relations within the LF (although many of these models predate the LF). While the LF provides a general method for thinking about the multiple and interactive influences on livelihoods without overlooking important explanatory factors (Adato & Meinzen-Dick, 2002), these models provide a basis for developing more specific and testable hypotheses and for rigorous theory building.

The agricultural household model (Barnum & Squire, 1979; Singh, Squire, & Strauss, 1986b) has served as the workhorse for investigating the economic behavior of households (LaFave, 2011; Taylor & Adelman, 2003). It has also been applied to deforestation/forest clearing (Caviglia-Harris, 2004; Maertens, Zeller, & Birner, 2006; Shively, 2001; Shively & Pagiola, 2004; Vance & Geoghegan, submitted for publication). Two broad classes of agricultural household models are the separable (recursive) and the non-separable model (Singh, Squire, & Strauss, 1986a; Upadhyay, Solberg, & Sankhayan, 2006; Vance & Geoghegan, submitted for publication).

Within recursive models the household operates in a context of well-functioning markets, and production decisions are made independently of consumption decisions. The emphasis is on *market opportunities* of and *economic returns* to different activities and strategies, including those involving forest clearing. These models can also serve as a bridge to the land-use science where, particularly in economics and economic geography, most land-use change studies are informed by the land rent theory of von Thünen (1826). The models typically assume perfect markets and exogenously given prices to the land users, as in the recursive models. Land rent is a function solely of location, with the key attribute being distance from a central marketplace (Van Kooten & Folmer, 2004). von Thünen-inspired scholars have examined how rents of different land uses would be related to location, and how that in turn determines the actual land-use patterns (VanWey *et al*., 2005).

Non-separable household models recognize that local markets are missing or functioning imperfectly, and so decisions on production (including land use) and consumption (including labor supply) are not separable. In these models, often referred to as *Chayanovian models* (Ellis, 1988), family size, composition, stage in the life cycle, and other household characteristics, which are irrelevant for land use decisions in the context of perfect markets, will also determine land-use decisions, in addition to market prices and wages (Kaimowitz & Angelsen, 1998; Mena, Bilsborrow, & McClain, 2006). Empirical tests of this theory have tended to examine the effects on land use of variables such as age of the household head, number of adult males, and migration status (Pacheco, 2009; VanWey, D'Antona, & Brondizio, 2007).

There are several variants of the Chayanovian models. Walker, Perz, Caldas, and Silva (2002) argue a *risk minimization model* better describes the behavior of small producers in their study area of the Brazilian Amazon. Angelsen (1999) argues that much of the policy thinking around deforestation and corresponding conservation strategies are based on a *subsistence ("full belly") model*, where households seek to minimize labor inputs, given a subsistence target that satisfies their basic needs, rather than maximizing their income. Finally, the *life-cycle model* focuses on the accumulation of land over the life cycle, and that particularly young and land poor households are more likely to clear forests (see Walker *et al*., 2002).

Another important body of the land use literature focuses on how the institutions, and more specifically different forest *tenure regimes*, affects forest use, e.g., whether forests managed

by local communities are better protected than others (Chhatre & Agrawal, 2009). Finally, the *forest context* in which households operate matters (VanWey *et al*., 2012), and different deforestation drivers operate along the forest transition curve (Angelsen & Rudel, 2013).

The above models emphasize different factors within the LF, and how these affect forest clearing. The models also have divergent policy implications (Angelsen, 1999). Critical aspects of this can be summarized in what we call the "*means vs. needs*" debate. Are asset poor household clearing *less* forest because they do not have the means, or are they clearing *more* forests because they have the need (and no other opportunities)? We address this question by exploring how the level of different asset holdings impact forest clearing.

(c) *Variables included in the analysis*

The LF and the models discussed above motivate our empirical analysis. In global-comparative research, such as that presented in this paper, the application of particular models presents several challenges. In datasets from diverse contexts, a particular model is likely to have high relevance in some study areas but not in others. For example, in the agricultural household model, knowing whether a household behaves according to separability or non-separability is needed for the correct modeling of production decisions (Vakis, Sadoulet, Janvry, & Cafiero, 2004) and yet Carter and Yao (2002) argue that the prevalent global tests are inappropriate as non-separability should be applicable only to those households whose choices are constrained by the underlying market imperfections. Making these distinctions in a global context is difficult. Finally, a proper application of the model requires data on, for example, land prices and wages, which we only have incomplete data for (in part because proper land markets in many locations do not exist).

The purpose of our global-comparative study is therefore to identify robust global correlations and develop a few broad narratives, rather than testing specific models or theoretical approaches. The latter is better done by testing specific hypotheses (derived from the models) on a context-by-context basis, and summarized in meta-studies.

With these caveats, and guided by the livelihoods framework and the literature on forest clearing, we select a number of variables for inclusion in the analysis under seven broad categories: human, physical, social, natural and financial capital, mediating factors, and vulnerability indicators. Our hypothesized relations between these variables and forest clearing are presented in Table 1. Some variables are observed at the household level, [3] a number of which pertain to the household head, [4] while others are observed at the village level. The review and justification of the variables has a Latin American slant reflecting the prevalence in the literature on household level studies of forest clearing in Latin America. For example, although Cameroon is the central African country that has attracted most attention from researchers and environmentalists, very few econometric studies on the causes of forest clearing are available (Gbetnkom, 2009).

To measure different aspects of households' human capital we use *education*, *age*, and*, sex* of the household head. We also use the *number of adult males*, and *number of adult females*. The education of household head is commonly used as an overall indicator of the household's human capital (Cundill *et al*., 2011; Vanwey, 2003) and as a proxy for the value of time (Dolisca, McDaniel, Teeter, & Jolly, 2007). Higher education levels tend to provide greater opportunities for non-farm based livelihoods, and raise the opportunity cost of labor. At the same time, as Mena *et al*. (2006) point out, educated people might also have better access to agricultural loans, and the basic technology for forest clearing (e.g., chainsaws), which could at the margin lead to increased land clearing. Yet, we hypothesize a negative correlation between the likelihood of a forest clearing and education.

Age can have conflicting effects on forest clearing. As households tend to accumulate land over their lifetime (Coomes, Takasaki, & Rhemtulla, 2011), younger households are likely to be at a land accumulation stage and therefore more likely to clear forest. In addition, these younger households are also likely to be more physically able to clear forest. But, older households may also have better access to assets that facilitate forest clearing (political capital, cash to hire labor, etc.). In aggregate we expect a negative correlation.

Household labor endowment is an important demographic variable in the land clearing process among smallholders (Caldas *et al*., 2007) through its influence on the area of land cultivated (Mitinje, Kessy, & Mombo, 2007). In the absence of significant local labor markets, family members are the main source of labor on frontier farms (Mena *et al*., 2006). Given the labor-intensive nature of forest clearing, we expect the likelihood of forest clearing to be positively correlated with the number of adult males. Female adult labor may also play a role, as these are likely to contribute to farming activities on the cleared land.

With respect to gender, Sunderland *et al*. (in this issue) note that in most cultures, gender clearly differentiates use and access rights to natural resources, including trees. For example, Coulibaly-Lingani, Tigabu, Savadogo, Oden, & Ouadba (2009) find that land inheritance practices and procedures for formalizing land rights often discriminate against women. It could, however, also be argued that because clearing is physically hard labor, female-headed households are less likely to engage. This effect should, however, be controlled for by our inclusion of the number of adult males. The remaining difference between male- and female-headed households (i.e., after having controlled for differences in household characteristics and endowments) is often referred to as gender bias or discrimination (Agarwal, 2003). We hypothesize that female-headed households clear less forest reflecting this bias because they, for example, have less access to forests.

Physical capital is measured in terms of the *value of household assets*, and the *quality of housing.* The impact of these asset and wealth variables is ambiguous, depending on whether need- or opportunity-driven strategies are dominant (see above).

We use *ethnicity* (whether or the household belonged to largest ethnic group/caste in the village) and *membership of a local forest user group (FUG)* [5] as indicators of social capital. Membership in the largest ethnic group could imply privileged access to communal resources (Coulibaly-Lingani *et al*., 2009), thus we expect this variable to be positively correlated with forest clearing. The meaning and role of FUG's will vary across regions. Our definition required a minimum level of organization, including regular meetings of the group. We hypothesize that members of FUGs will be less likely to clear forest as members are more likely to adhere to local rules of forest management. For example, Hayes (2006) found a strong correlation between vegetation density and the presence of forest product rules and the ability of users to make rules.

The actual extent and quality of natural resources ("natural capital") will, quite obviously, co-determine strategies of forest use (Cundill *et al*., 2011). We use two variables to proxy forest supply: the *share of forestland in the village* and *distance from the household to the forest margin*. At the household level, we

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Table 1. *List of variables, expected relationship to forest clearing and summary statistics*

Variable	Definition	Unit	Expected sign	Mean	Standard deviation
Dependent variables					
Cleared	Whether or not a household cleared forest in last 12 months	0/1		.27	.45
Area	How much forest was cleared	ha		1.21	1.5
Independent variables					
Human capital					
Males	Number of males aged 15+	People	+	1.78	1.19
Females	Number of females aged 15+	People	+/–	1.74	1.17
Age	Age of household head	Years	–	45.8	14.447
Female	Female-headed household	0/1	–	0.12	0.32
Education	Years of schooling of household head	Years	–	4.1	4.22
Physical capital					
Assets	Value of household implements and other large items	USD PPP	–	1149.5	3987.04
Housing	Household has tiled or iron-sheet roof house	0/1	–	0.45	0.5
Social capital					
Forest user group	Membership of local forest user group	0/1	–	0.26	0.44
Ethnicity	Membership of the largest ethnic group	0/1	+	0.75	0.43
Natural capital					
Land	Agricultural land owned by household	ha	–	3.86	8.1
Forest cover	The percentage of land under forest cover (village level)	%	+	42.2	33.8
Distance to forest	Household distance to forest edge	Hours	–	0.56	0.75
Financial capital					
Livestock	Tropical livestock units	tlu	+	4.86	17.76
Mediating factors					
Roads	At least one road useable by cars during all seasons (village level)	0/1	+	0.70	0.46
Market orientation	Crop production sold/total crop production	Ratio	+	0.34	0.6
Input use intensity	Crop input costs/gross value of crop production	Ratio	+/–	.20	.26
Electricity	Share of households with electricity (village level)	%	–	23.18	36.86
Vulnerability context					
Shock	Household experienced a shock during past 12 months	0/1	+	0.24	0.42
Forest cover decline	Household reporting that forest cover has declined during past 5 years (village level)	0/1	–	0.62	0.49

use agricultural landholding, [6] an indicator of the households need for land (Chibwana, Jumbe, & Shively, 2013). Typically we will expect larger forest (abundance) and smaller landholdings to go along with higher clearing.

Livestock holdings are liquid assets, and therefore often in the LF categorized as part a household's financial capital (DFID, 1999). They often play a critical role as a store of wealth and buffer against income fluctuations and shocks (Ellis, 2000b). While the deforestation impact of especially cattle varies across production systems (Faminow & Vosti, 1998), we expect more livestock to be associated with more forest clearing for pasture.

Roads have been found to increase the likelihood of forest clearing through their effect on reducing transportation costs, providing market access, and thereby making deforesting activities more profitable (Angelsen, 2010; Chomitz & Gray, 1995; Pfaff, 1999; Weinhold & Reis, 2008). We test whether this holds in our data set. Further, as additional controls, we include *market orientation*, defined as the share of cash in total household income, and the intensity of use of crop inputs. Our hypothesis is that households close to or integrated in markets will be more likely to clear forestland for agricultural purposes. However, as noted in subsistence models, intensification of agriculture and higher yield could also sometimes reduce forest clearing, as a given income target can be met by cultivating less land (Angelsen & Kaimowitz, 2001). Finally, we include village-level *electrification* as a contextual proxy for village-level physical infrastructure, which often will reflect established rather than frontier settlements. The latter expectedly goes hand in hand with more aggressive forest clearing.

Last, we test whether households clear more forest in response to *shocks* to compensate for income shortfalls or higher consumption needs. In terms of households' self-stated shock responses, increased harvesting of forest or agricultural products did not rank among the primary coping strategies for households experiencing shocks (Wunder *et al.*, in this issue), but this does not preclude the possibility that some post-shock forest clearing response would be detected in our data.

3. DATA AND METHODS

(a) *Data set*

Our global-comparative dataset is drawn from 24 countries in Asia, Africa, and Latin America. The data were collected by the Poverty and Environment Network (PEN) of the Center for International Forestry Research (CIFOR). The core of the PEN project was a detailed recording of all income sources, collected through four quarterly surveys. More

general household surveys were also conducted at the beginning and at the end of the fieldwork period. The surveys were conducted by 33 PEN researchers, mainly PhD students, who stayed in the field for 1–2 years. Details of the survey, sampling, and other related issues are reported in Angelsen *et al.* (in this issue).

During the last interview, households were asked whether or not in the last year they had cleared any forest—we followed FAO's forest definition (FAO, 2000)[7]—and if yes, we also asked how much, what forest type, where (distance from house), under what tenure, and for what purpose it was cleared (e.g., main crops grown afterward). Forest-clearing questions were placed in the final survey because of the likelihood of greater trust between enumerators and respondents after several visits which would be important in places where forest clearing was illegal.

(b) *Estimation strategy*

A key characteristic of the livelihoods framework is that individual households are nested within communities. The PEN data were collected with this nested structure in mind, with household- and village-level surveys. The analysis thus also needs to employ multi-level statistical methods. We use a *random effects Logit model* for the binary decision to clear forest or not and a *random effects Tobit model* for area cleared. These models permit both individual and village-level variables. We considered alternative models, such as two-part or hurdle models that would allow the censoring mechanism and the outcome (area cleared) to be modeled as separate processes, however, these models require exclusion restrictions/instruments, i.e., a variable that can generate non-trivial variation in the selection variable but does not affect the outcome directly (Cameron & Trivedi, 2010). Yet, we were not able to identify instrument variables with the necessary properties (e.g., only affecting the clearing decision and not the area decision) and sample wide validity.

Random-effects models assume the random intercept is not correlated with the observable explanatory variables. A way to relax this restrictive assumption, by allowing for correlation between unobserved heterogeneity and observable characteristics while still identifying the contribution of the latter, is to use the Mundlak–Chamberlain approach (Chamberlain, 1980; Mundlak, 1978) of parameterizing the unobservable effects as functions of the means of the household level regressors (Poel, O'Donnell, & Doorslaer, 2009; Rabe-Hesketh & Skrondal, 2012). We therefore included the village level means for all household-level variables in our regressions.[8] We also tested and rejected endogeneity of agricultural land as an explanatory variable.[9]

4. RESULTS

(a) *Descriptive characteristics of households that cleared forests*

Overall, 27% of the respondents in our sample reported that they cleared forest in the year leading up to the interview. These households were, on average, younger, smaller, and had more years of schooling ($p < 0.01$). The average value of assets (excluding land and livestock), was USD 1074 (PPP adjusted) for all households, 1448 for households that cleared forests and 935 for those that did not clear (difference statistically significant ($p < 0.01$)). Households that cleared forests were closer to the forest ($p < 0.01$) and came from villages with higher forest cover (Figure 1).

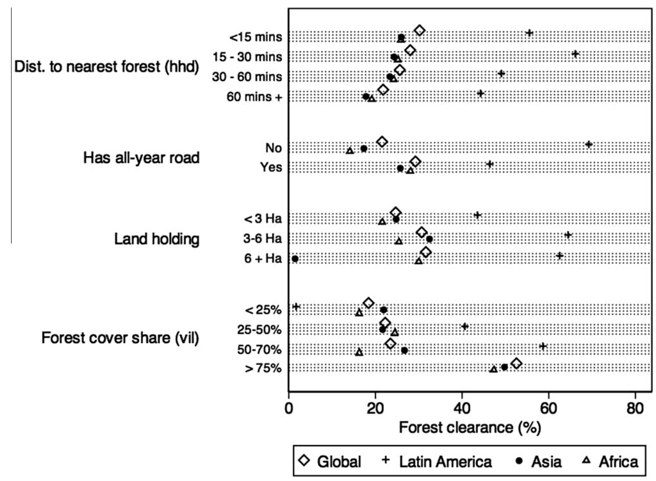

Figure 1. *Forest clearance rates by natural and physical capital.*

We generally found higher incidence of forest clearing among households with larger land holdings: the average forest clearing rate within the group of households with 6 ha or more was about 30% higher than the rate within the group of households with less than 3 ha of land. Not surprisingly, we find higher incidence of forest clearing among households closest to forests (within 15 min walking distance).

For human and social capital we find higher forest clearing incidence in younger cohorts, even though there are no differences in the Latin American cases. Households with more education had a higher incidence of forest clearance, a result that is fairly consistent across continents (Figure 2).

With respect to the *household size* and *forest clearance*, again patterns in the Latin America sites differ from those in other regions. In Latin America, household size appears to be positively correlated with forest clearing, with a 20% higher forest clearance incidence among the largest households (10+ members) compared to the smallest (up to four members).

We had expected lower instances of forest clearing among households that belonged to FUG's, given greater emphasis on sustainable forest use. This negative correlation indeed holds globally and for the cases in Africa and Asia; however, in the Latin American studies, we find the reverse.

Figure 2. *Forest clearance rates by human and social capital.*

(b) *Characteristics of cleared forest*

Respondents were asked what type and the ownership status of forest they cleared. The results are presented in Table 2. Two thirds of the households (67%) reported clearing primary, natural forest, while almost one quarter (24%) reported that they cleared secondary forests (generally defined as natural forest younger than 15 years). We note a very high share of natural forest clearing for the Asia sub-sample, where most of the forest clearing occurred in a few PEN sites in Bangladesh, Cambodia, and Indonesia.

With respect to the ownership status, 45.4% said the forest cleared was on private land, 43.4% on state land, and 11.1% on community land. The cleared forest was, on average, located about 3 km from the household. When we look at the location by forest type, we find cleared plantations were the furthest (16 km), followed by managed forests (8 km), natural forests (2.4 km). Secondary forests cleared were, perhaps not surprisingly, the nearest to the households (2 km).

(c) *Use of cleared forest land*

Table 3 shows the use of the land immediately after clearing. Across the board, the main immediate use is growing crops. For the cases in Africa and Latin America, crops are, by and large, the only immediate use of cleared land. There are, however, many places especially in Latin America where cleared land later goes more permanently into pastures (not registered in our survey).

In Asian cases, we find slightly more diversity in the use of cleared land. 21%—the highest reported household share—cleared forests to grow trees. The principal crops grown post-clearing were cereals and roots and tubers, as presented in Figure 3. Maize, rice, cassava, and banana are the four principal crops cultivated on freshly cleared forestland.

(d) *Econometric results*

The results of the multivariate, multilevel econometric analysis are presented in Table 4 for the decision to clear or not (logit model), and Table 5 for how much was cleared (tobit model). The effects in the logit model are shown in terms of odds ratios. [10]

(i) *Human capital*
Higher availability of male labor within the household increases, as expected, the likelihood of forest clearing in the global model and the Asian model (Table 4). Male labor is also conducive to more land being cleared, but only in the Latin America model (Table 5). Age of household head, which is split into two groups (below/above 35 years), is only significant in the clearing decision model for Africa and the area model for Asia. In these models, households clear less with higher age until the age of 35, after which the age effect is insignificant. Finally, the length of education is not significant in any of the models, in spite of the systematic differences in the bivariate analysis above.

Household headship has a significant impact on the likelihood of clearing forest. Specifically we find that the odds that female-headed households clear forests is 30% lower than for male-headed households, after having controlled for other factors. Household headship is not significant for the area decision (Table 5).

(ii) *Physical capital*
Our aggregate measure of assets is significant in the global model on forest clearing, i.e., households with more assets up to 100 USD PPP are more likely to clear forests, after which there is no significant impact on forest clearing. This indicates that a certain minimum level of physical asset wealth may facilitate an engagement in forest clearing. This asset variable is not significant in the area model.

(iii) *Social capital*
We find that neither membership of forest user group (FUG) nor ethnicity (belonging to the largest ethnic group) is significant in any of the models, with the exception of ethnicity in the Latin America model on how much to clear (those belonging to the dominant ethnic group clearing smaller areas, where the opposite was hypothesized above).

(iv) *Natural capital*
In the global decision model (Table 4), one hectare increase in owned land increases the odds of forest clearing by a factor of 1.2 if land area remains below 3 ha, but the effect is insignificant beyond that level, indicating as for physical capital a more complex relation between asset holding and forest clearing. There are interesting regional differences for the land variable. In both the Asia and Latin America sub-samples, the propensity to clear is reduced when landholdings increase beyond 3 ha. However, in the global area model (Table 5), the coefficient for land area beyond 3 ha is positive and significant, suggesting that the extent of clearing is also correlated to higher land area owned by the household. This pattern is significant also for African cases, while the patterns are more mixed in the two other regional models.

Table 2. *Type and ownership status of the cleared forest*

	Geographical region			
	Latin America	Asia	Africa	Global
Type of forest (%)				
Primary, natural	60.1	93.0	59.4	67.4
Primary, managed	4.5	2.6	9.9	6.7
Secondary	34.8	2.9	28.2	24.1
Plantation	0.6	1.5	2.5	1.8
Total	100	100	100	100
Tenure status of cleared forest (%)				
State	58.5	39.7	37.4	43.4
Community	12	5	14.2	11.1
Private	29.5	55.3	48.4	45.5
Total	100	100	100	100
Sample size	525	562	988	2075

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Table 3. *Immediate land use after forest clearing (by household categories)*

	N[a]	Crops	Trees	Pasture	Non-cultivated
Global	2019	73.4	15.8	5.9	4.8
Region					
Latin America	550	80.6	6.2	8.5	4.7
Asia	466	58	20.7	10.2	11
Africa	1033	78.8	17.9	2	1.3
Agricultural land holding					
No land	111	73.3	17	3	6.7
<3 Ha	1094	71.9	15.3	6.1	6.7
3–6 Ha	384	79.4	16.1	3	1.5
6+ Ha	430	72.3	16.5	8.5	2.7
Tropical Livestock Units					
0–5	1702	73.3	16.6	5	5.2
5–10	147	76.5	15.8	4.9	2.7
10–15	64	65.5	12.6	18.4	3.4
15+	106	77.5	5.4	14.7	2.3
Sex of head					
Male	1843	73.7	15.3	5.9	5.1
Female	176	71.2	21	5.7	2.2
Household size					
1–4 Members	688	69.4	15.4	8.1	7.1
5–9 Members	1132	75.1	16.2	5	3.7
10+ members	199	78.9	15	2.8	3.3
Head age					
14–34 years	535	74.8	13.8	5.7	5.7
35–64 years	1271	72.7	16.7	5.9	4.7
65+ years	187	75.9	14.2	6.5	3.4

[a] *N* represents the number of households, however, some households reported more than one use of the cleared land and as such the reported percentages show the frequency among the responses. In some cases (e.g., age of the household head), *N* does not add up to 2019, this is because of missing values on some grouping variables (e.g., the date of birth was unknown for 26 household heads). Lastly, we test differences in the proportions of the various responses and find them all to be statistically significant.

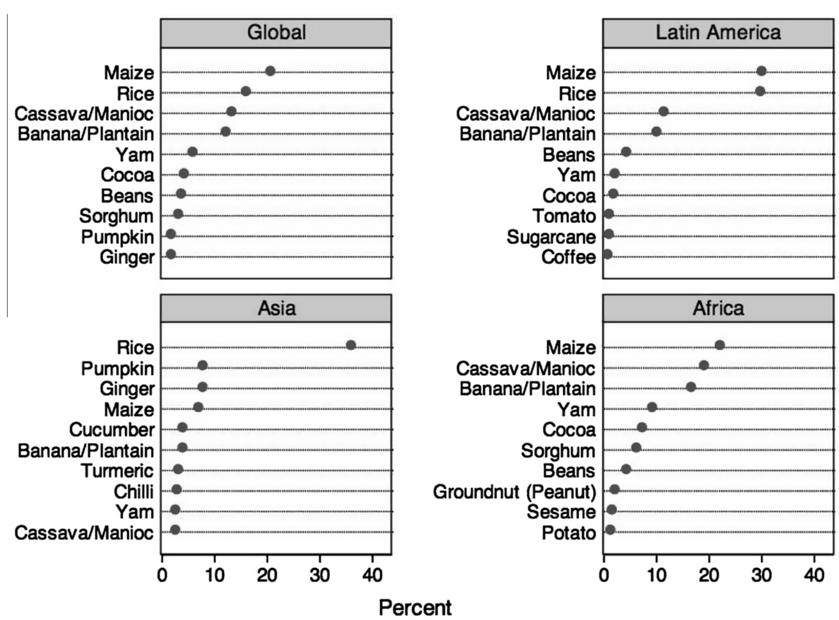

Figure 3. *Principal crops grown (among households that cleared to grow crops).*

We also find that the higher the share of forest cover in a village, the more likely are households to clear forests (Asian sites being an exception). In the area model, this relationship is not significant in the global model, while it is in positive and significant in the Latin American and negative in the Asian sites. Within a forest transition framework, the link between forest

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Table 4. *Logit regression models for the decision to clear forests*

	Global		Latin America		Asia		Africa	
	O.R	C.I	O.R.	C.I	O.R.	C.I.	O.R.	C.I.
Human capital								
Males	1.070*	[0.993,1.153]	1.052	[0.881,1.257]	1.189**	[1.009,1.400]	1.054	[0.955,1.163]
Females	1.023	[0.949,1.104]	0.904	[0.749,1.090]	1.130	[0.952,1.341]	1.028	[0.933,1.134]
Female headed	0.709**	[0.545,0.924]	0.664	[0.330,1.338]	0.545**	[0.308,0.964]	0.815	[0.581,1.144]
Age (14–35)	0.836	[0.665,1.052]	1.098	[0.632,1.907]	1.355	[0.829,2.215]	0.647***	[0.481,0.871]
Age (35+)	1.003	[0.933,1.078]	1.089	[0.904,1.311]	0.891	[0.764,1.039]	1.022	[0.930,1.124]
Education	0.995	[0.973,1.018]	0.978	[0.924,1.035]	1.010	[0.963,1.059]	1.002	[0.973,1.032]
Physical capital								
Assets (10s, 0–100$)	1.026**	[1.002,1.051]	1.021	[0.940,1.109]	1.031	[0.980,1.086]	1.023	[0.993,1.054]
Assets (10s, 100$+)	1.000	[1.000,1.000]	1.000	[1.000,1.000]	1.000	[0.999,1.001]	1.000*	[1.000,1.001]
Housing	0.936	[0.774,1.130]	0.875	[0.538,1.424]	0.970	[0.700,1.342]	0.919	[0.698,1.210]
Social capital								
Forest user group	0.991	[0.758,1.297]	1.031	[0.520,2.043]	1.032	[0.623,1.711]	0.916	[0.630,1.334]
Ethnicity	1.157	[0.957,1.398]	1.199	[0.722,1.990]	1.222	[0.712,2.097]	1.149	[0.919,1.435]
Natural capital								
Land (upto 3 ha)	1.207***	[1.100,1.324]	1.626***	[1.290,2.050]	1.155	[0.945,1.411]	1.170**	[1.034,1.325]
Land (3 ha +)	1.001	[0.988,1.013]	0.980*	[0.958,1.002]	0.629***	[0.465,0.851]	1.007	[0.990,1.024]
Forest cover	1.014***	[1.005,1.023]	1.014**	[1.003,1.024]	0.976**	[0.957,0.997]	1.023***	[1.011,1.035]
Distance to forest	0.989	[0.869,1.125]	1.114	[0.886,1.402]	1.347	[0.847,2.142]	0.890	[0.751,1.054]
Financial capital								
Livestock (<5 TLU's)	1.136***	[1.074,1.201]	1.167**	[1.030,1.321]	1.202***	[1.070,1.350]	1.063	[0.982,1.151]
Livestock (>5 TLU's)	0.997	[0.989,1.005]	1.003	[0.991,1.015]	1.039	[0.953,1.133]	0.991	[0.976,1.006]
Mediating factors								
Roads	1.183	[0.658,2.126]	0.703	[0.367,1.348]	0.993	[0.286,3.448]	1.046	[0.508,2.153]
Market orientation	1.236*	[0.998,1.531]	2.370***	[1.255,4.475]	0.943	[0.721,1.232]	1.301*	[0.993,1.704]
Input use intensity	0.965	[0.679,1.371]	1.064	[0.549,2.062]	2.060*	[0.991,4.282]	0.573**	[0.341,0.962]
Electricity (0–50%)	1.001	[0.980,1.023]	1.012	[0.991,1.033]	1.000	[0.958,1.044]	0.985	[0.955,1.017]
Electricity (>50%)	0.957***	[0.932,0.983]	0.971**	[0.947,0.995]	0.956*	[0.914,1.001]	1.002	[0.953,1.053]
Vulnerability context								
Shock	0.980	[0.821,1.170]	1.228	[0.677,2.229]	1.200	[0.843,1.707]	0.860	[0.689,1.074]
Forest decline	0.987	[0.830,1.173]	1.159	[0.775,1.733]	0.982	[0.673,1.432]	0.917	[0.731,1.150]
Other controls								
Asia = 1	0.700	[0.284,1.728]						
Africa = 1	0.167***	[0.067,0.416]						
Constant	1.311	[0.107,16.12]	0.196	[0.009,4.291]	0.00720*	[0.000,2.440]	0.348	[0.013,9.250]
Random effects SD (vil)	3.260***	[2.507,4.237]	0.426*	[0.163,1.115]	2.010***	[1.196,3.378]	1.482*	[0.949,2.316]
Observations	7172		833		2379		3960	

O.R. = odds ratio; C.I. = 95% confidence intervals.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

cover and forest clearing is not linear, and a more nuanced story could be developed by studying these non-linearities in more details (which is beyond the scope of this paper).

Distance from household residences to forest is not significant for the clearing decision, but seems to affect the area cleared negatively. This may be explained by the fact that most households in the sample are living quite close to the forests, e.g., approx. 80% are within one hour of walking.

(v) *Financial capital*

The pattern regarding the impact of livestock follows that of agricultural land. More livestock up to a certain level (5 Tropical Livestock Units—TLUs) increases the odds of clearing forests, but the impact is insignificant after that. In the global area model, the area cleared tends to increase also beyond the 5-TLU threshold. The coefficient for the above 5-TLU variable is also positive and significant in the Latin America model, where we expected to find the clearest positive relationship between livestock holdings and forest clearing.

(vi) *Mediating factors*

We find, surprisingly, that the road variable is not significant in any of the models, except for the area model on the Latin America sample (positive and significant). A possible explanation is that the effects of roads on forest cover are strongest immediately after their establishment. Many roads might have been in place for a long time and the clearing they stimulate has already been done. As we did not have data on when roads were established, we cannot control for this.

The variable for market orientation (share of agricultural income being cash) has the expected positive sign and is significant in all logit models, except the Asian one. The coefficient is particularly large in the Latin America subsample, with an odds ratio of 2.4.

Table 5. *Tobit regression models for how much forest was cleared (ha)*

	Pooled (global)		Latin America		Asia		Africa	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Human capital								
Males	0.0110	(0.011)	0.1044***	(0.038)	0.0129	(0.011)	−0.0019	(0.016)
Females	−0.0150	(0.011)	−0.0599	(0.040)	−0.0054	(0.012)	−0.0117	(0.015)
Female headed	−0.0405	(0.036)	−0.0287	(0.150)	−0.0369	(0.036)	−0.0386	(0.054)
Age (14–35)	0.0165	(0.036)	0.0621	(0.120)	0.0959**	(0.041)	−0.0289	(0.053)
Age (35+)	−0.0122	(0.010)	−0.0386	(0.040)	−0.0103	(0.010)	−0.0075	(0.016)
Education	0.0017	(0.003)	−0.0122	(0.012)	0.0034	(0.003)	0.0040	(0.005)
Female	−0.0405	(0.036)	−0.0287	(0.150)	−0.0369	(0.036)	−0.0386	(0.054)
Physical capital								
Assets (10s, up to 100$)	0.0018	(0.004)	0.0056	(0.018)	0.0032	(0.004)	0.0019	(0.005)
Assets (10s, 100$+)	0.0000	(0.000)	0.0000	(0.000)	−0.0000	(0.000)	0.0001	(0.000)
Housing	0.0308	(0.029)	0.1222	(0.105)	0.0044	(0.027)	0.0255	(0.047)
Social capital								
Forest user group	−0.0459	(0.041)	−0.0309	(0.147)	0.0073	(0.038)	−0.0892	(0.066)
Ethnicity	−0.0229	(0.029)	−0.2201*	(0.113)	0.0006	(0.034)	0.0019	(0.040)
Natural capital								
Forest cover	0.0015	(0.001)	0.0047***	(0.002)	−0.0036***	(0.001)	−0.0001	(0.001)
Land (up to 3 ha)	0.0668***	(0.014)	0.2424***	(0.051)	0.0007	(0.015)	0.0684***	(0.021)
Land (3 ha +)	0.0068***	(0.002)	−0.0031	(0.005)	−0.0029	(0.003)	0.0098***	(0.004)
Forest cover	0.0015	(0.001)	0.0047***	(0.002)	−0.0036***	(0.001)	−0.0001	(0.001)
Distance to forest	−0.0448**	(0.019)	0.0056	(0.045)	−0.0071	(0.033)	−0.0747***	(0.027)
Financial capital								
Livestock (<5 tlu's)	0.0165**	(0.008)	0.0119	(0.026)	0.0131*	(0.008)	0.0192	(0.014)
Livestock (>5 tlu's)	0.0030**	(0.001)	0.0080***	(0.003)	−0.0002	(0.002)	0.0015	(0.002)
Mediating factors								
Roads	0.0468	(0.060)	0.2166**	(0.101)	0.0150	(0.088)	−0.0416	(0.084)
Market integration	0.0171	(0.019)	−0.0509	(0.092)	0.0095	(0.028)	0.0250	(0.025)
Input use intensity	−0.0479	(0.050)	0.1219	(0.141)	0.0426	(0.051)	−0.1992**	(0.079)
Electricity (up to 50%)	0.0069***	(0.002)	0.0040	(0.004)	−0.0013	(0.003)	0.0099**	(0.004)
Electricity (50% +)	−0.0113***	(0.003)	−0.0071*	(0.004)	−0.0046	(0.003)	−0.0185***	(0.006)
Vulnerability context								
Shock	0.0282	(0.028)	0.0610	(0.126)	0.0102	(0.030)	0.0364	(0.041)
Forest decline	−0.0102	(0.027)	−0.0736	(0.085)	−0.0141	(0.029)	−0.0027	(0.041)
Other controls								
Asia = 1	−0.0286	(0.097)						
Africa = 1	−0.1388	(0.098)						
Random effect SD (vill)	0.3497***	(0.020)	0.0000	(0.095)	0.2068***	(0.021)	0.3056***	(0.028)
Observations	7172		833		2379		3960	

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

The variable for input use intensity is also related to the degree of market orientation and commercialization of agricultural production. In Asia, higher input use intensity tends to increase forest clearing, while higher intensity reduces forest clearing in the African sample. Access to electricity in the village is typically gained after some consolidation of settlement, so a low share is expected in recent, frontier settlements. The factor is also important, in the expected direction. When the share of household with electricity exceeds 50%, then increasing the share further by 1% leads to a strong decrease in the odds of clearing forests by 2.4%. A similar result appears in the area model (Table 5).

(vii) *Vulnerability context*

The shock variable is not significant in any of the models. This suggests that shock patterns are not affecting forest clearing notably. First, many shocks are in the form of labor loss, and forest clearing (and cultivation) is labor intensive. Second, the time lag between clearing and harvesting makes forest clearing less attractive for immediate food or cash needs. The variable for self-reported forest decline is also insignificant in all models.

5. DISCUSSION

(a) *The role of assets: needs* **vs.** *means?*

A focus of this paper was how assets affect the likelihood and extent of forest clearing, as part of household livelihoods strategies. As hypothesized, the number of adult males available in the household is an important determinant of whether forests are cleared. For other assets, namely land, livestock and physical assets, we find a non-linear pattern: as these as-

sets increase, the likelihood of the household being involved in forest clearing increases, up to a certain level. Above that threshold, increases in asset holdings cease to have significant impacts on forest clearing decisions.

In the analysis of the area cleared (Table 5), we do not find a similar plateau-like relationship between the two main agricultural assets: land and livestock. Rather, there is a tendency of the extent of forest clearing to be positively correlated with more land and livestock owned, also among the asset-rich households. To further illustrate the difference between the two decisions and their relationship to land ownership, Figure 4 displays the quadratic fit between the variables. The figure shows that forest area cleared continues to increase with higher land holdings.

What do these results mean for the aforementioned debate about needs *vs.* means-driven forest-clearing, i.e., a subsistence-target, Chayanovian-type household behavior by poor households, as compared to a market-, profit- and opportunity-driven land expansion? Our results tell a nuanced story. The asset-poorest, most needy households tend to clear less forest, whereas those in a middle range aspiring for improved livelihoods, with the minimum assets needed to expand cultivation, are more land-use expansive. There is little difference between households with medium- and high-level asset holdings when it comes to the forest clearing decision. One possible explanation is that the more asset-rich among our smallholder households may have other means and opportunities of acquiring higher income (e.g., off-farm options), or they may already have established sufficiently large farm areas. However, among households clearing forests, those with high asset (land and livestock) levels seem to be clearing larger areas. Thus for asset-rich households involved in agriculture, higher asset positions go hand in hand with larger forest areas converted to agriculture.

(b) *The role of markets*

We find that higher market orientation increases the odds of forest clearing, other things being equal. The presence of all-year roads is significant for explaining how much forest is cleared, but only in the Latin America model. Agricultural intensification, measured by value of inputs to outputs, was insignificant in the global regression, but the negative value for the African sub-sample (only) might suggest that the African households followed more of a subsistence logic (e.g., due to more limited market access): higher yields (as proxied in our model by input intensity) can substitute for expansion of agricultural area. Conversely, in the Asian subsample our intensification measure was significantly correlated with *more* forest clearing, indicating that farmers may have expanded some more profitable intensive technologies into the forest, defying at least locally what has been denominated the Borlaug hypothesis—in line with the case-study literature on agricultural technologies and deforestation (Angelsen & Kaimowitz, 2001).

Our results appear to fit well with what is proposed by the von Thünen model, and are contrary to the popular development paradigm that market orientation is a catalyst for agricultural intensification with lower pressure on forests (Pendleton & Howe, 2002). Our results fit the claim that during the early stages of forest transition, better access to markets (e.g., through road building) tends to increase the pressures on forests (Angelsen & Rudel, 2013).

(c) *The life-cycle hypothesis*

The bivariate analysis showed higher forest clearing incidence among younger and smaller households, a result that would be consistent with the life-cycle theory. The effect of age on the intensity of forest clearing does not, however, hold when we control for other factors in the global regression model (Table 4), nor in the area decision (Table 5). The exceptions are the decision model for Africa and the area model for Asia, where we find that younger households are more likely to clear forests and to clear a larger area. Thus, there is somewhat scattered support for the life-cycle hypothesis of more forest clearing among the youngest households. One possible explanation for the regionally diverse results could be less developed land markets in some regions (e.g., in Africa), making land purchase less (and forest clearing more) of an option for young households to accumulate the desired agricultural land area.

(d) *Social capital and institutions*

Membership in forest user groups (FUGs) was expected to reduce forest clearing, by improving management of and income from the standing forest. Yet, their popularity varies

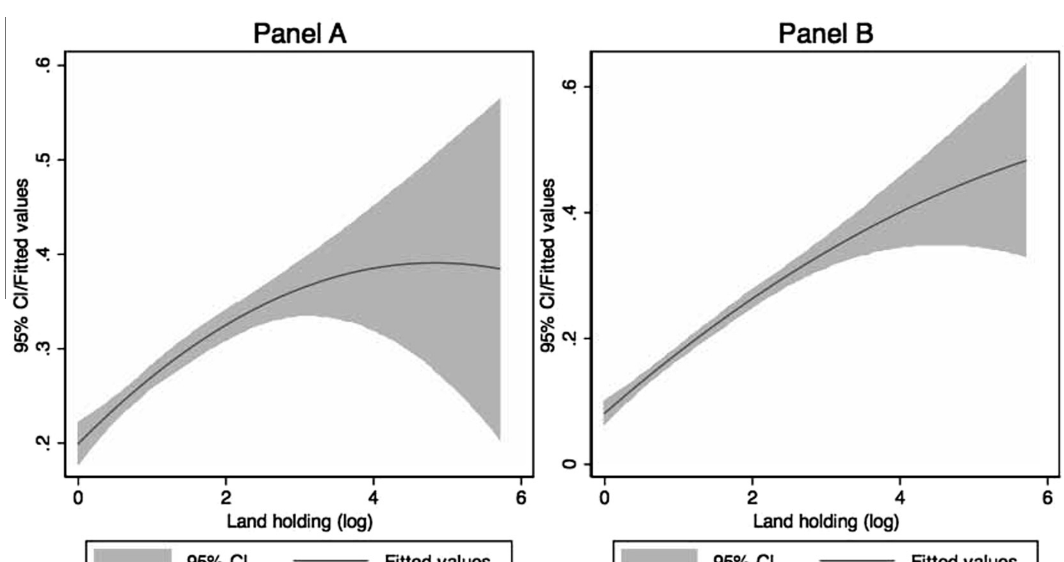

Figure 4. *The bivariate relationship between forest clearing incidence and land holding (panel a) and forest area cleared and land holding (panel b).*

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much across the PEN sample: in 54% of PEN villages globally (in Latin America, 70.2%), no FUGs at all were present. The variable proves insignificant throughout the analyses. One plausible interpretation is that FUGs permit clearing of forest for modestly sized subsistence cropping, but are more restrictive for larger-scale expansion of land for commercial crops.

In Figure 3 and in the regression models, we are also unable to find significant relationships between forestland clearing and membership to the largest ethnic group, apart from the area decisions in Asia (where the coefficient had the unexpected sign). There is thus hardly any difference in forest clearance rates between members and non-members of dominating ethnic groups.

6. CONCLUDING REMARKS

The purpose of this article has been to identify links between rural smallholder households, site contextual characteristics, and their forest clearing decisions, using comparable data from cases in 24 developing countries. Testing general patterns is a valuable exercise, but many links prove highly context-dependent. As such, overview cross-section analyses like ours should be complemented by localized case studies, including time-series analyses exploring forest-livelihood dynamics. Recent livelihoods analyses (VanWey *et al.*, 2012) have argued that asset importance will depend on positioning vis-a-vis forest frontiers and forest transition stages. These hypotheses indicate a promising direction for future research.

Our analysis relates to current narratives and policy debates on causes and impacts of deforestation. Two findings are worth highlighting. First, within our sample of small- to medium-sized farmers (large commercial farmers excluded), we find little support for forest clearing being driven by extreme asset poverty. Rather, households with moderate or high asset holdings are more land-use expansionary. Thus, local forest clearing is not a simple needs-based story, but rather one where more assets often provide the means for smallholders to engage in forest clearing and thereby further improve their livelihoods.

Second, providing better market access and integration is often seen as an integral remedy for poverty alleviation and—eventually—a way to contain deforestation through a forest transition process. Our results suggest that this strategy may backfire on forest conservation, at least in the short run. Rather than pulling farmers away from forest activities, our results—consistent with the bulk of the recent literature on markets and deforestation—suggest that increased market orientation will likely stimulate forest clearance, if forests are accessible and farmers have the means to do so. In fact, an increase in assets and income of rural households could eliminate the capital constraints that previously have kept them from clearing forests. Thus, such development policies alone may not achieve the hoped-for win–win outcomes.

NOTES

1. The full project dataset comprise about 8000 households, however, in this paper we use a subsample for which we have data on forest clearing. Forest clearing questions were asked at the end of the one year survey and so the sub-sample is a result of attrition in the course of the survey.

2. Whether a factor is categorized as part of “mediating processes” or “vulnerability context” is debatable, e.g., specific market characteristics could be in either.

3. We defined a household as a group of people (normally family members but also including members who are not blood relatives) living under the same roof, and pooling resources (labor and income). We also accounted for difficult cases such as polygamy, several families living together in one house, family members living away parts of the time and single person households.

4. To identify the household head, respondents were directly asked “who is the head of the household?” is. We think their response to this question adequately identifies the household head even in complicated situations such as if several generations are living together in the same household.

5. We defined a forest user group (FUG) as a group of people who use and maintain a forest, and who share the same rights and duties to products and services from the forest. Our definition presupposed some forest with collective property rights, i.e., a FUG cannot exist—according to our definition—if all forests are privately owned. Further, we required a minimum level of organization including regular meetings for the group to qualify as a FUG. Lastly, we recognized that FUGs may not exist in all our sites; in particular in the Neotropics they are less common than in Africa and Asia. We recognize that at a finer scale, FUG’s will mean different things in different regions, however, we are believe that as it is defined, the variable is useful.

6. Agricultural land is defined as the sum of cropland, pasture, agroforestry, and silvipasture land that the household owns. It does not include land under fallow.

7. Forest were defined as *lands of more than 0.5 hectares, with a tree canopy cover of more than 10%, where the trees should be able to reach a minimum height of 5 meters in situ, and which are not primarily under agricultural land use.* Further, our definition included both primary and secondary forest, native and exotic forests, as well as closed and open forest (e.g., woodlands).

8. For space reasons, these regressors are not reported here.

9. Agricultural land might be endogenous in a model explaining forest clearing as the same factors that affect how much agricultural land a household holds (e.g., household food needs) may also affect the propensity to clear forest. Such confounding would be highly likely if data on the two variables were collected simultaneously. Yet, this was not the case in our survey. We collected the data on land holding at the beginning of the survey while the module with questions on forest clearing was administered close to a year later. Nonetheless, we followed Papke and Wooldridge (2008) and tested for endogeneity. Specifically, we estimated a reduced form model for agricultural land and obtained residuals from the estimation. We then included the residuals from this model in the forest-clearing model. The coefficient on the residuals was not statistically significant.

10. These are the ratios by which odds change for a unit change in the corresponding independent variable. The odds of clearing forest are related but not the same as the probability of clearing forest; the odds is the expected number of families clearing forest for every family that does not clear.

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APPENDIX A. LIST OF COUNTRIES WITH SITES INCLUDED IN THE STUDY

Latin America	Asia	Africa
Belize (1)	Bangladesh (4)	Burkina Faso (3)
Bolivia (3)	Cambodia (3)	Cameroon (1)
Brazil (3)	China (3)	Democratic Republic of Congo (2)
Ecuador (1)	India (2)	Ethiopia (4)
Guatemala (1)	Indonesia (4)	Ghana (2)
Peru (1)	Nepal (4)	Malawi (2)
	Vietnam (1)	Mozambique (4)
		Nigeria (2)
		Senegal (2)
		Uganda (3)

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