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Smallholder Specialization Strategies along the Forest Transition Curve in Southwestern Amazonia

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Summary. — Rural specialization strategies can be examined within the forest transition framework. We compared smallholder livelihood strategies between neighboring southwestern Amazonian sites at different stages along the forest transition curve. Surveys of 243 households in Pando, Bolivia and Acre, Brazil, within and outside of two major protected areas, confirmed a higher reliance on forest-based income in forest-rich Pando than in Acre. In Acre, forest reliance was higher in the protected area than outside, where forest cover was lower and households were more livestock-dependent. Country context and protected area status were critical to explaining different smallholder specialization strategies in similar biophysical environments.

Key words — Brazil, Bolivia, NTFPs, protected areas, livelihoods, deforestation

1. INTRODUCTION

Tropical forests provide distinct, yet often overlooked contributions to rural livelihoods (Angelsen & Wunder, 2003; Sunderlin *et al.*, 2005; Kaimowitz & Sheil, 2007; Chhatre & Agrawal, 2009), which must be analyzed within the broader context of regional economic development. The concept of forest transition provides a framework for understanding the relationship between development and forest cover at large spatial and temporal scales, and is useful in regional or cross-national comparisons. Allegedly, forest cover decreases at an early stage of a country's economic development, through agricultural expansion due to rising commodity demand and better access to forest areas, and eventually increases again at high income levels as part of, *inter alia*, a transition to a service economy; this reforestation is the result of spontaneous regeneration on abandoned lands or purposeful tree-planting activities driven by forest scarcity or environmental concerns (Mather, 1990; Rudel *et al.*, 2005). When used as an organizational framework, forest transition is broad enough to allow for the incorporation of most drivers of land cover change at multiple scales (Angelsen & Rudel, 2013). For instance, in response to forest scarcity, the increased designation of protected areas, which represents a key conservation policy intervention via restricted land use in approximately 27% of tropical forests (Nelson & Chomitz, 2011), will likely affect economic development and forest cover trajectories. Additionally, livelihood specialization strategies of rural smallholders will depend on available natural, human, social, physical, and financial assets (Scoones, 1998), and economic returns associated with different land uses will affect decisions to maintain standing forest or convert it for

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agricultural uses (Kaimowitz & Angelsen, 1998; Lambin *et al.*, 2001; Chomitz, 2007).

In this study, we sought to understand how position along the forest transition curve, together with land use policy conditions, affects smallholder livelihood specialization strategies. To address this question, we conducted a comparative analysis between two neighboring sites at the border of Pando, Bolivia and Acre, Brazil in southwestern Amazonia. This region provides an important contrast, since Bolivia holds the lowest gross domestic product (GDP) of all South American countries (USD 2320 per capita in 2011) and Brazil represents the highest (USD 12576 per capita in 2011) (World Bank, 2012). The jurisdictions of Pando and Acre reflect these national differences, with Acre clearly being situated further along the economic development *x*-axis and further down the forest cover *y*-axis, i.e., having progressed more on the initial downward slope of the forest transition curve than Pando. Acre is more urbanized, with 73% of the state population living in urban areas, as compared to 40% in Pando. Average per capita annual incomes in Pando and Acre are below their national averages, with higher poverty indices in Pando than in Acre (INE, 2005; Government of Acre, 2011). As predicted by forest transition theory, accumulated deforestation in Acre has correspondingly been greater than in Pando; Acre has 87% forest cover while Pando has 95% (INPE, 2012; Marsik, Stevens, & Southworth, 2011). Deforestation in Acre has been largely driven by establishment of cattle ranches (Souza, Veríssimo, da Silva Costa, Reis, Balieiro, & Ribeiro, 2006) and has occurred mostly within a 45-km band along the paved Brazilian BR-317 Highway (Southworth *et al.*, 2011). In Pando, there are no paved roads, and while forest conversion has historically been minimal, a more recent increase in deforestation has occurred close to population centers and along the Brazilian border (Marsik *et al.*, 2011). Despite these differences, on both sides of the border this region is characterized by lowland humid tropical forests that are rich in Brazil nuts (*Bertholletia excelsa*)—the regionally most important non-timber forest product (NTFP) on which thousands of smallholders base their livelihoods (Assies, 1997; Stoian, 2000). Sustainable use protected areas have been implemented in both places as a policy strategy to curb deforestation and promote local forest-based livelihoods. Thus, we were able to compare land use and livelihoods in smallholder-managed forests both within and outside of two major regional protected areas in each country.

Within this context, we pose two specific research questions. The first focuses on the relation between forest transition and household assets: (1) *How is position along the forest transition curve reflected in household natural, human, social, physical and financial asset portfolios?* The second relates to the land use policy conditions that determine household specialization strategies, specifically the mediating effect of sustainable use protected areas on forest-based specialization strategies: (2) *Does the presence of sustainable use protected areas favor forest reliance, and does this vary by forest transition stage?*.

2. STUDY AREA

In the approximately 220,000 km^2 border region of Pando, Bolivia and Acre, Brazil in southwestern Amazonia, communities and smallholders have substantial control over nearly one-third of forests (ZEE, 2006; INRA, 2009). The history of colonization and settlement by smallholders in this border region began in the mid-1800s through the extraction of Peruvian bark (*Cinchona* spp.) and grew during the first boom of natural rubber (*Hevea brasiliensis*) at the end of the 19th century. When the price of rubber fell in 1912, in response to the high productivity of established rubber plantations in Malaysia, Amazonian elite began to abandon their rubber estates and independent rubber tappers began to diversify their livelihood strategies to include agriculture and extraction of Brazil nuts (Barham & Coomes, 1996; Stoian, 2005). During World War II, a second, smaller rubber boom recruited a new wave of Brazilian "rubber soldiers" to Acre (Sobrinho, 1992), and in Bolivia, labor temporarily shifted back to extraction of rubber and Peruvian bark, stimulating a brief economic revival (Stoian, 2000). In the 1990s, the center of Brazil nut processing and commercialization shifted to southwestern Amazonia, and Brazil nuts became the most economically important NTFP in the Bolivian Amazon (Stoian, 2000).

Several contemporary policies in Bolivia and Brazil created different contexts for smallholder management of forests in the study area. In Bolivia, the 1996 Agrarian Reform Law was passed to resolve competing land claims and title undocumented lands. In northern Bolivia, the reform process instigated a struggle over control of forest resources between large landholders, who tried to maintain their privileged position, and peasant and indigenous communities (Stoian, 2000; Ruiz, 2005). In 2000 and 2004, modifications of the Agrarian Reform Law gave forest-dwelling communities legal rights to 500 ha per family, with the ultimate spatial area of a communal title determined by the official number of resident families; the remaining forests were to be granted to large landholders as NTFP concessions of up to 15,000 ha (Cronkleton & Pacheco, 2010).

In the 1970s, the formerly forest-based nature of the Acre state economy changed when the Brazilian military government incentivized landless peasants to colonize the Amazon region, granting 100-ha parcels to settlers who engaged primarily in agricultural activities (Pacheco, 2009). Simultaneously, it implemented federal cattle subsidies (Valentim, Sá, Gomes, & Santos, 2002) and removed national price supports for rubber (Hall, 1997). Countering these federal policies, the 1998 self-proclaimed "Forest Government" of Acre re-stimulated the rubber economy by introducing state-level rubber subsidies in 1999 (Kainer, Schmink, Leite, & Fadell, 2003) and by creating a natural rubber-based condom factory in Xapuri. It also experimented with Ecological-Economic Zoning, payments for environmental services, and sustainable forest management at different scales (Kainer *et al.*, 2003). Nevertheless, and even though federal cattle subsidies were eliminated in 1991, Acre's cattle economy has continued to expand to approximately 2.6 million heads, with one of the highest growth rates in the Brazilian Amazon (IBGE, 2012).

At the border region, each country also designated a massive protected area. In Pando, the 750,000-ha Manuripi National Wildlife Reserve was officially created in 1973 for biodiversity conservation, although it was not officially managed as such until 1999 (Künhe, 2004). The reserve has nine communities, but most land is illegally held by individual landholders in the form of large estates (1,000–80,000 ha), and illegal logging and large-scale cattle ranching are major threats to forest conservation (Künhe, 2004). In Acre, the almost one million ha Chico Mendes Extractive Reserve was created in 1990 from 42 former rubber estates. The extractive reserve designation guarantees usufruct rights to reserve residents who practice subsistence agriculture and NTFP extraction; they must maintain at least 90% of their landholdings in forest cover (Allegretti, 1990; Fearnside, 2003). Resource use is regulated by rules limiting timber harvest and hunting. In both reserves, land is government-owned, with management responsibilities jointly shared by residents and respective country-level environmental agencies.

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3. METHODS

We studied eight communities in Pando and 13 in Acre, with a total of 243 households in the survey (131 in Pando, 112 in Acre; Figure 1). In Pando, we sampled 67 households in four communities in the Manuripi Reserve, and 64 households in four communities outside the Reserve. In Acre, we sampled 58 households in four communities (former rubber estates) within the Chico Mendes Extractive Reserve and 54 households in nine colonist associations outside (hereafter also termed "communities;" Table 1). In communities with less than 20 households, all available households were included; otherwise, random samples were chosen from a list of all households in each community. [1]

To understand the relationship between livelihood systems and forest conservation in these communities, we applied community and household-level questionnaires from June 2006 through October 2007 in collaboration with the Poverty and Environment Network of the Center for International Forestry Research (CIFOR PEN; http://www.cifor.cgiar.org/pen/_ref/home/index.htm). In the first annual household survey, we measured initial household assets. In the second annual household survey, we asked households to self-report the amount (ha) of forest cleared within the previous 5 years, as well as the area of previously cleared lands left in fallow. In addition, we conducted four quarterly household questionnaires for detailed income accounting. Prices for subsistence products were estimated in community meetings where a consensus willingness-to-pay price was determined.

We first generated descriptive statistics for asset and income variables in both countries (Table 2). Natural assets [2] included landholding size, amount of forest cleared, [3] and amount of land abandoned for re-growth. For forest clearing, we calculated three variables from questionnaire data:

1. Annual area (ha) of forest cleared over the past 5 years (2002–07).
2. Forest cover (in %) remaining on the landholding in 2006.
3. Annual forest/land clearing rate (dividing 1. by total landholding size in 2006).

Since these values were derived from *self-reported* and not *observed* forest clearing, and smallholders in this region may face legal ramifications if they exceed deforestation limits, some underreporting may have occurred.

Human assets included household size and composition (number of adults, children, and elders), [4] age of household head, length of residency in the community, and average years of education among household members. Social assets included membership in a local Brazil nut cooperative, the self-stated degree of trust in neighbors, and the perceived ability to ask for help from neighbors in times of need. Physical assets included material goods and livestock assets. Financial assets included savings in banks or credit associations and non-productive assets, such as gold or jewelry, from which we deducted any outstanding household debt (including agricultural credit and any unpaid advances for the Brazil

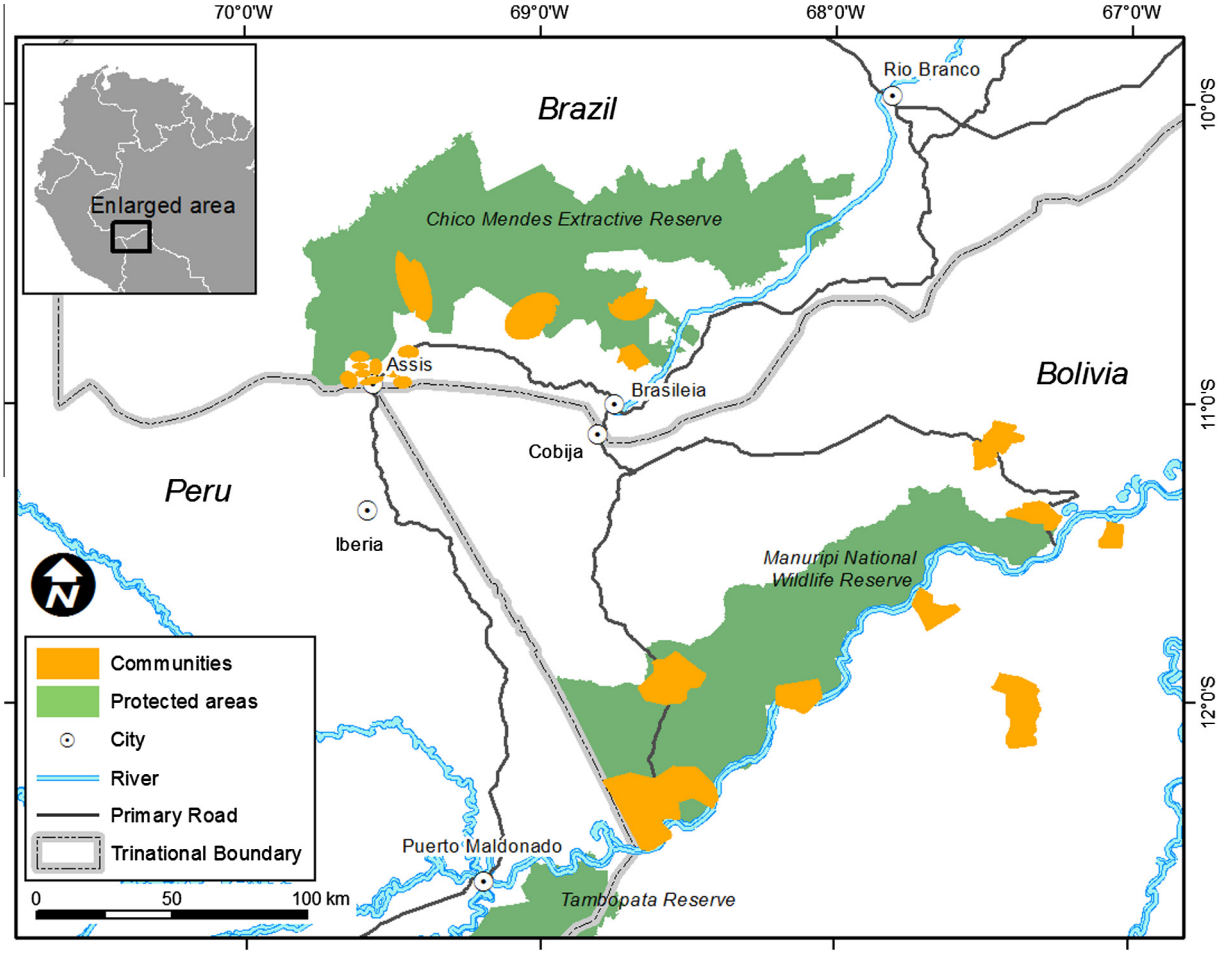

Figure 1. *Map of communities sampled in Pando, Bolivia, and Acre, Brazil.*

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Table 1. *Basic information on communities sampled in Pando, Bolivia, and Acre, Brazil*

Community name	Protected area status[a]	# households total (2006)	# households sampled
Pando, Bolivia			
La Cruz	Manuripi Reserve	14	10
El Chivé	Manuripi Reserve	80	26
Irak	Manuripi Reserve	15	13
Curichón	Manuripi Reserve	46	20
Turi Carretera	None	14	14
Santa Rosa de Manuparé	None	32	17
Palma Real	None	28	17
Abaroa	None	19	14
Acre Brazil			
Chico Mendes	Chico Mendes Extractive Reserve	28	11
Terra Alta	Chico Mendes Extractive Reserve	24	16
Wilson Pinheiro	Chico Mendes Extractive Reserve	27	15
Guanabara	Chico Mendes Extractive Reserve	16	16
Novo Progresso	None	~10	4
Cristo Rei	None	~10	2
Iracema	None	~10	8
Bacia	None	~10	10
São Félix	None	~10	8
Agronorte	None	~10	7
Estrela Brilhante	None	~10	4
Beija Flor	None	~10	6
Livramento	None	~10	4
Fortaleza	None	~10	1

[a] Location within a given protected area, or outside of it ("None").

nut harvest). Household income, as a livelihood outcome, included annual net cash and subsistence income derived from different land uses in 2006–07. We also included the distance to nearest municipal center (in hours by the most common form of transport) from each community center as a measure of market accessibility.

An independent samples *t*-test was conducted to compare asset and income variables between smallholders in Pando and Acre. Since this initial descriptive analysis indicated a stark contrast in livelihoods focus between households in Pando and Acre (Brazil nut *versus* livestock specialization, respectively), we used a multinomial fractional logit model to explore how selected factors influenced smallholders' degree of reliance on Brazil nut and livestock (*versus* other) income sources. Reliance was measured in terms of the share in total income for each of the three sources (Brazil nut, livestock, and other), resulting in dependent variables that were bounded between 0 and 1. Much correlation between these proportions thus existed by construction, and non-standard regression techniques were needed to account for the variance structure of fractional dependent variables (Papke & Wooldridge, 1996). Hence, we used a multinomial fractional logit model to simultaneously estimate the parameters of the same set of predictors for each share.

4. COMPARISON OF ASSETS AND INCOME

Our analysis revealed important differences in smallholder livelihoods between Pando, Bolivia and Acre, Brazil (Table 2) in terms of assets and income.

(a) *Comparison of assets*

Landholding size and remaining forest area were significantly lower in Acre than in Pando ($p < 0.001$; Table 2). The extremely high level of forest cover in Pando reflects large areas of communal forestlands allocated to individual households. The amount of land left annually in fallow was also significantly greater in Pando than in Acre ($p < 0.001$; Table 2), suggesting in the latter case more permanent forest conversion (e.g., for pastures) and possibly shorter swidden agriculture cycles. Importantly, when we disaggregated the natural assets data by protected area status, the unprotected are in Acre became quite distinct from the other areas. For instance, mean household landholding size in the Chico Mendes Reserve (603 ha) was similarly large to that of the protected and unprotected areas in Pando (566 ha and 546 ha, respectively); in the unprotected area in Acre, it was much lower at 114 ha. Additionally, remaining forest cover on household lands in the Chico Mendes Extractive Reserve was 95% in contrast to the unprotected area in Acre where it was only 60%. Residents of the Chico Mendes Reserve reported the greatest amount of forest cleared annually (1.33 ha), followed by those in the unprotected and protected areas in Pando (0.99 ha and 0.79 ha, respectively), and finally, smallholders in the unprotected area in Acre (0.41 ha).

In analyzing differences in human and social assets, we found that households in Acre were smaller than in Pando ($p = 0.004$), with fewer children ($p < 0.001$) and had resided on their landholdings for a significantly longer period of time ($p < 0.001$). These results reflect generally older settlements in Acre when compared to Pando.[5] While 38% of households in Pando belonged to Brazil nut cooperatives, compared with only 19% in Acre, there was a greater degree of self-reported trust among neighbors in Acre ($p = 0.006$), along with a higher perceived ability to obtain help from neighbors when in need ($p = 0.001$). This finding may be linked to the rubber tapper movement in Acre, which was based on close social ties, possibly reflecting higher social capital in this group (Pretty & Ward, 2001), as well as the more clearly defined land tenure among smallholders in the Chico Mendes Extractive Reserve

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Table 2. *Means comparison of household assets and income between smallholders in sites in Pando and Acre*[a]

Variable	Pando, Bolivia Mean (Std. Error)	Acre, Brazil Mean (Std. Error)	*t*-stat (df)	*p* value
Natural assets[b]				
Total land per household (ha)	639 (43)	379 (42)	4.35 (220)	<0.001
Amount forest cleared annually (ha)	0.93 (0.08)	0.88 (0.09)	0.42 (205)	0.679
Remaining forest cover (%)	99.6 (0.08)	81.0 (2.2)	8.91 (222)	<0.001
Annual rate of forest/land clearing (%)	0.014 (0.011)	0.004 (0.13)	0.88 (220)	0.378
Amount land left in fallow annually (ha)	0.41 (0.04)	0.24 (0.03)	3.54 (220)	<0.001
Human assets				
Size (# of household members)	6.0 (0.2)	5.0 (0.2)	2.88 (239)	0.004
Number of adults (age 15–65)	2.8 (0.1)	3.1 (0.1)	−1.38 (239)	0.168
Number of children (age < 15)	3.0 (0.2)	1.8 (0.2)	4.76 (239)	<0.001
Number of elders (age > 66)	0.15 (0.04)	0.07 (0.02)	1.54 (239)	0.126
Age of household head (years)	42.9 (1.2)	43.4 (1.2)	−0.26 (239)	0.797
Length of residency (years)	16.7 (1.3)	24.9 (1.8)	−3.82 (237)	<0.001
Education (sum years/capita)	3.9 (0.2)	3.6 (0.3)	0.68 (239)	0.497
Social assets				
Brazil nut cooperative member (0 = no; 1 = yes)	0.38 (0.04)	0.19 (0.04)	3.30 (239)	0.001
Trust neighbors (1 = no; 2 = partly; 3 = yes)	2.3 (0.06)	2.5 (0.5)	−2.8 (219)	0.006
Help from neighbors (1 = no; 2 = partly; 3 = yes)	2.3 (0.07)	2.7 (0.06)	−3.36 (217)	0.001
Physical assets				
Material goods (USD/capita)	334 (84)	735 (118)	−2.77 (218)	0.006
Livestock herd (USD/capita)	52 (16)	4527 (745)	−6.0 (218)	<0.001
Financial assets (USD/capita)				
Savings minus debt	−68 (15)	−331 (95)	2.99 (239)	0.003
Income 2006–07 (USD/capita)[c]				
Forest income	669 (83)	351 (35)	3.42 (208)	0.001
Brazil nut income	475 (53)	74 (16)	6.98 (208)	<0.001
Crop income	105 (20)	312 (56)	−3.62 (208)	<0.001
Livestock income	26 (4)	817 (164)	−5.06 (208)	<0.001
Aquaculture income	0 (0)	47 (37)	−1.33 (208)	0.186
Wage income	111 (20)	254 (63)	−2.27 (208)	0.025
Business income	90 (29)	61 (26)	0.74 (208)	0.459
Other income	45 (8)	283 (43)	−5.68 (208)	<0.001
Total income	1046 (102)	2126 (218)	−4.62 (208)	<0.001
Location				
Distance to city (hours[d])	6.5 (0.5)	3.5 (0.2)	5.13 (238)	<0.001

[a] List of communities sampled in Table 1.
[b] These variables reported only for households with >5 ha of land.
[c] Income reported in USD per capita for 2006–07. Forest income includes all raw and processed products collected in forests, including wild plants, fruits, seeds, game (mammals, fish, and insects), fuelwood, and timber. Crop income includes grains, fruits, and vegetables cultivated in swidden-agriculture plots and home gardens. Wage income includes payments for both on- and off-farm labor. Livestock income includes all animals (chickens, pigs, sheep, and cattle) slaughtered or sold alive; animals owned but not sold are not counted as income, but as assets. Business income is earnings from on- and off-farm businesses, including transport of forest products. Aquaculture income represents fish raised in ponds. "Other income" includes remittances, government payments (e.g., pensions and other cash transfers), non-governmental donations, and generally negligible non-forest environmental incomes.
[d] By the most common form of transportation.

in Acre when compared to Pando (Duchelle, Cronkleton, Kainer, Guanacoma, & Gezan, 2011).

Finally, in terms of physical and financial assets, the value of livestock assets was dramatically higher in Acre ($p < 0.001$), and even the value of material goods was higher among the Brazilian households ($p = 0.006$). There was greater debt in Acre ($p = 0.003$), likely based on easier access to credit and suggesting that savings is mostly in the form of livestock assets as opposed to in non-productive assets.

(b) *Comparison of income*

Total income per household was twice as high in Acre (2126 USD) as in Pando (1046 USD; Table 2), and income sources varied widely. We observed extremely high forest income reliance among communities in Pando, deriving 45% of their total income from Brazil nuts compared to 2% in Acre. In Pando, forest income made up 64% of the total household income, compared to just 12% in Acre. In Acre, the dominant income source was livestock (817 USD), 31 times higher than in Pando (26 USD). Incomes derived from crops and other sources (mainly government aid) were also significantly higher in Acre than in Pando ($p < 0.001$). In other words, along with their higher value livestock assets, households in Acre were wealthier than their Bolivian counterparts, the latter being much more forest-reliant, and particularly specialized on Brazil nut collection.

As in these descriptive statistics, the regression model highlighted that the country in which households were located largely determined their livelihood strategies. Households in

Brazil derived a significantly lower share of their income from Brazil nuts and a higher share from livestock, when compared to households across the border in Bolivia (Table 3). It also provided some additional nuance to the comparison. For instance, location within or outside of a protected area in Brazil had an influence on household specialization strategy. In Brazil, households located within the Chico Mendes Extractive Reserve were more likely to specialize in Brazil nuts than those outside that were more likely to specialize in livestock (Table 3). Finally households in Acre had easier access to markets, due to their significantly closer proximity to towns ($p < 0.001$; Table 2). Distance to market was a significant predictor of livelihood specialization strategy based on livestock; households closer to markets were more intensively engaged in livestock specialization (Table 3).

Select natural, human, social, physical, and financial assets were also important explanatory variables for the Brazil nut income share in both countries (Table 3). Results of the Brazil nut income model showed that households with higher forest cover in both countries derived greater income from Brazil nuts, reflecting the fundamental natural resource base for this product. Yet, higher annual forest cleared was also associated with more Brazil nut income, suggesting a diversification of livelihood strategies among nut collectors. In terms of human assets, households that had younger heads, along with more children and elders, derived more income from labor-intensive Brazil nut collection, as did those who had lived for longer periods on their landholdings. A longer residence may solidify earlier established rights to nut trees and enhance long-standing business relations with local intermediaries; additionally, more recent migrants may be less NTFP-reliant. Finally, households with fewer accumulated material assets and savings were more likely to garner income from Brazil nut collection. These findings support understandings of NFTPs as products for the poor (Angelsen & Wunder, 2003); indeed certainly fewer material inputs are required for nut collection when compared with other land uses.

High reliance on livestock income was explained by select natural, human, and physical asset variables (Table 3). The natural asset of more land left annually in fallow was associated with more income from livestock, which represents the abandonment of degraded pastures. In terms of human assets, household education was negatively related to livestock income share, suggesting that more educated households were engaged in livelihood strategies focusing on off-farm labor or business activities. Finally material assets and savings were positively correlated to livestock specialization, reflecting the higher inputs needed for engagement in this production strategy.

5. SMALLHOLDER SPECIALIZATION TYPOLOGIES

Both the descriptive statistics and the interpretation of the regression results support three typologies of smallholder specialization in southwestern Amazonia largely based on geographic location, i.e., country context (Brazil *versus* Bolivia) and protected area status (inside or outside). To allow for direct comparison, the typologies discussed below assume that Acre and Pando are following the same forest transition curve.

Table 3. *Explaining household reliance on Brazil nut and livestock incomes, respectively*

Variables	Brazil nut income share Coefficients (Std. Err.)[a]		Livestock income share Coefficients (Std. Err.)	
(Intercept)	0.704 (0.680)		−0.641 (0.727)	
Natural assets				
Total land per household (km^2)	0.023 (0.024)		0.020 (0.027)	
Remaining forest cover	0.805 (0.384)	*	−0.465 (0.354)	
Annual rate of forest/land clearing	0.013 (0.003)	***	0.009 (0.005)	
Area left in fallow	−0.061 (0.232)		0.640 (0.223)	**
Human assets				
Age of household head	−0.024 (0.007)	***	0.000 (0.008)	
Length of residency	0.017 (0.005)	**	−0.007 (0.006)	
Education	−0.068 (0.041)		−0.135 (0.043)	**
Number of dependents (children + elderly)	−0.155 (0.045)	**	−0.012 (0.067)	
Social assets				
Cooperative membership	0.244 (0.184)		−0.096 (0.254)	
Trust in neighbors	−0.129 (0.190)		−0.431 (0.182)	*
Physical and financial assets				
Material assets + savings (minus debt)	−0.056 (0.020)	**	0.009 (0.002)	***
Location variables				
Brazil	−5.166 (0.677)	***	2.743 (0.358)	***
Protected area	−1.381 (0.662)	*	−2.786 (0.755)	***
Distance to town	−0.000 (0.017)		−0.059 (0.025)	*
Interaction term				
Protected area × Brazil	3.179 (0.724)	***	−2.547 (0.507)	***
Trust × protected area	0.598 (0.271)	*	1.003 (0.316)	**
Chi-square goodness of fit	*694.14*			
BIC	*489.07*			

[a] Significance levels *, **, *** are 90%, 95%, and 99%, respectively.

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(a) *Modest livelihoods and forest cover maintenance under Brazil nut specialization*

The household characteristics and adaptation in Pando reflect a context at a relatively early stage on the forest transition curve where there is very high forest cover and high forest reliance, but also the beginnings of forest clearing. The forest reliance observed in Pando was unrelated to protected area status, suggesting that the Manuripi Reserve does not currently affect land use in this remote area, likely due to a general lack of pressure on forests in Pando at this juncture. Indeed, although households in Pando were relatively strongly endowed in natural and human assets (labor and education), they had less physical (material and livestock) and financial assets available. Thus, average household incomes in Pando were only about half those obtained in Acre.

(b) *Livelihood gains and sustained forest loss from long-term cattle specialization*

The households sampled in the unprotected area in Acre reflect a context toward the bottom of the forest transition curve, with lower forest cover, less forest reliance, smaller landholdings, and higher income and wealth among smallholders. Current forest clearing was lowest among these households, since they were past the point of actively clearing forests to support their livestock-based livelihood strategy. Indeed, the average percentage of forest cover on these landholdings was 60%, a share not compliant with the current Brazilian Forest Code, which requires a minimum of 80% forest cover on Amazonian landholdings outside of reserves. Hence, the comparatively high physical and financial asset values of this group of households likely also resulted from the past mining and conversion of natural resources (forests).

(c) *Entrenched Brazil nut specialization with emerging cattle opportunities*

The situation in the Chico Mendes Extractive Reserve can be considered a hybrid between the Pando context and that in the unprotected area in Acre, where rural livelihoods include both a continuous Brazil nut reliance and emerging livestock income opportunities. In the reserve, there was a similar positive relationship between forest reliance and forest cover as in the communities in Pando. That said, the absolute amount of forest cleared annually in the reserve by each household was higher than the other groups. This finding reflects a recent adoption of cattle by reserve households, even among rubber tappers who initially fought against cattle ranchers to maintain access to their forested landholdings (Gomes, 2009; Vadjunec, Gomes, & Ludewigs, 2009), incrementally catching up with the specialization pattern outside of the reserve.

Despite some recent depletion of natural assets in the Chico Mendes Extractive Reserve, there may be benefits associated with this mixed livelihood strategy. First of all, even though reserve residents were clearing more land for cattle, forest was still the primary land cover on these landholdings (95%); these households had not yet reached the 10% deforestation maximum that is allowed within extractive reserves. These households had more physical assets than their counterparts in Pando, especially livestock. In the reserve, cattle at this stage are not yet consumed or sold regularly, but rather used as a form of savings. Livestock is also a source of milk and cheese, which diversify rural diets. Brazil nut producers in the reserve also use livestock to help transport nuts more efficiently out of the forest. While income from Brazil nuts was lower than in Pando, households gleaned income from a greater variety of forest products, including natural rubber (*H. brasiliensis*), for which Acre's state government has provided subsidies and promoted private investment (Sills & Saha, 2010). There was also higher household income derived from crops and government subsidies when compared to Pando. Finally, this group, like that in Pando, had more natural assets—namely forests.

6. DISCUSSION

Smallholders in different localities, even in roughly the same biophysical environment, develop diverse livelihood specialization patterns based on different development options, infrastructure levels, cultural preferences, and externally-induced land use restrictions. While select household characteristics influenced specialization in Brazil nuts *versus* livestock, geographic location—in terms of combined country and protected area status—was clearly important in determining smallholder specialization strategies (Table 3). Location not only determines institutional opportunities and constraints (McLennan & Garvin, 2012), including access to roads (Stoian & Henkemans, 2000), but also shapes smallholders' asset portfolios, which influence their specialization strategies (Chowdhury, 2010).

Despite their close proximity, Pando, Bolivia and Acre, Brazil represent very distinct contexts. First, the major market center of Rio Branco in Acre is substantially larger than the smaller markets of Cobija and Riberalta that are accessed by residents of Pando. Second, there has been massive state investment in Acre when compared with Pando, which is reflected in the paved roads and other basic infrastructure that are present in Acre and absent from Pando. Third, the social movement legacy in Acre resulted in the creation of the Chico Mendes Extractive Reserve, which gained broad national and international support (Ehringhaus, 2006), and where many residents—but not all—are oriented toward forest conservation. Strong local recognition of the Chico Mendes Extractive Reserve in Acre contrasts with a lack of local recognition of the Manuripi Reserve in Pando. While community-based residents interviewed in our study reported high levels of natural assets, other larger private landowners within the reserve practice illegal logging and cattle ranching (Künhe, 2004), partially a consequence of not recognizing reserve norms when created in 1973.

In Pando, smallholder specialization on Brazil nuts is likely due to two main factors. First, the Brazil nut economy in northern Bolivia includes a well-developed system of advance payments (Bojanic, 2001), which fuels the chain of middlemen, Brazil nut cooperatives, and Brazil nut processing plants (Stoian, 2000; Cronkleton & Albornoz, 2009), and facilitates the transport of urban-based Brazil nut collectors to, and nuts from, even the most isolated forests. Second, given the relative remoteness of the communities in Pando, there are few other income-generating opportunities available for rural people. In fact, the Brazil nut harvest period is much longer in Pando than in Acre due to such a lack of other livelihood options (Duchelle *et al.*, 2011).

While forest cover remains high and there is currently moderate forest clearing among households in Pando, especially given their larger landholding sizes, a move further along the downward slope of the forest transition curve is likely. Such a move would be precipitated by more lucrative agricultural opportunities becoming available to rural people through road building, increased migration to the area, and general regional

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economic development. Correspondingly, livelihood specialization on Brazil nuts may thus also decrease. For instance, in farm-level scenario modeling in a colonist site in the western Brazilian Amazon, adding value to forests through Brazil nut income was not considered a viable way to dissuade producers from incrementally converting Brazil nut-rich forests to pasture. Instead, a subsidized quadrupling of nut prices suggested *increased* pressure on forests; this huge price increase was not enough to render forest conservation more lucrative than continuous pasture expansion. Instead, households invested the marginally higher income from Brazil nut subsidies in accelerated deforestation: capitalization impacts dominated over relative price effects (Vosti, Muñoz Braz, Carpentier, & D'Oliveira, 2003). A real-world example where a foreign cosmetics company paid indigenous groups in the eastern Brazilian Amazon "fair" (higher) prices for their Brazil nuts also resulted locally in *greater* environmental pressures, as households reallocated assets to clear more land for agriculture and to intensify their hunting practices (Morsello, 2002). Such a scenario in Pando would depend on substantial development of roads and markets, which could very well happen through state-led plans for regional integration, since opportunities for remote communities to engage in commercial agricultural activities are currently quite limited.

In Acre, households specialized in livestock, as both an increasingly valuable physical asset and an income source, did so largely based on greater access to markets and national and state policies that incentivized the adoption of cattle by colonist farmers (Valentim *et al.*, 2002). As households build capital over time, purchase of cattle has been considered an important way to buffer against risks (Faminow, 1998; Mertens, Poccard-Chapuis, Piketty, Lacques, & Venturieri, 2002; Perz, Walker, & Caldas, 2006). Cultural aspects of the Brazilian cattle ranching lifestyle, including country music, cowboy imagery, and notions of power, also attract smallholders in Acre to adopt this livelihood specialization strategy (Hoelle, 2011). This livelihood strategy has obvious environmental implications, and accumulation of cattle has been positively correlated with forest clearing in southwestern Amazonia (Vosti *et al.*, 2003; Caviglia-Harris & Sills, 2005).

In Acre, location within a sustainable use protected area seems key to balancing smallholders' livelihoods between forest- and livestock-based specialization strategies. This finding underscores the importance of this policy tool in promoting forest reliance at sites farther along the downward slope of the forest transition curve. There is ample evidence for the conservation effectiveness of protected areas in tropical countries, particularly strict protected areas (Bruner, Gullison, Rice, & Fonseca, 2001; Nolte, Agrawal, Silvius, & Soares-Filho, 2013), but also that of community- or co-managed sustainable use forest areas including indigenous lands (Nepstad *et al.*, 2006; Porter-Bolland *et al.*, 2012; Nelson & Chomitz, 2011). In fact, sustainable use protected areas in Acre, including the Chico Mendes Extractive Reserve, were found to be under much higher threat than strict protected areas, highlighting their critical role in mitigating deforestation (Pfaff, Robalino, Lima, Sandoval, & Herrera, 2013). Recent research has demonstrated that people may not necessarily become worse off by being located within a protected area and that there may be certain welfare benefits associated with spatial proximity to protected areas, including protection of local resources from outsiders (Clements, Suon, An, Wilkie, & Milner-Gulland, 2014), access to forests for subsistence uses (Naughton-Treves, Alix-Garcia, & Chapman, 2011) and poverty alleviation, possibly through tourism opportunities, outside investments in human and physical capital, and maintenance of ecosystem services (Andam, Ferraro, Sims, Healy, & Holland, 2010). The unique aspect of the Chico Mendes Extractive Reserve is that official land tenure reflects customary use of forest resources (Ankersen & Barnes, 2005). Security of rights for local people and relatively large landholdings within the reserve may explain its currently positive conservation outcomes (Chhatre & Agrawal, 2009), along with the fact that many residents are the descendants of rubber tappers. This context contrasts with the smallholder settlements outside of the reserve, which while also representing clear property rights, were the product of state-sponsored colonization on smaller landholdings with a heavy agricultural focus. As opportunities change, however, smallholders who were previously identified with conservation-friendly land uses may change their specialization patterns, such as is beginning to be seen in the Chico Mendes Extractive Reserve. How far these land use and livelihood changes will reach remains to be seen, including when forest clearing begins to approximate the legal limits.

7. CONCLUSION

Our comparative study between neighboring sites in two countries provides various insights into what determines two of the main smallholder specialization strategies in southwestern Amazonia: Brazil nuts and livestock.[6] It brings detailed, comparative land use and livelihood data to the forest transition framework to better understand environmental and development trajectories in the border region of Pando, Bolivia, and Acre, Brazil. It highlights the important role of country context and protected area status in influencing different smallholder specialization strategies in similar biophysical environments. While location-specific path dependencies may persist over time, increasing regional integration through highway development in southwestern Amazonia is likely to also expand the forest and non-forest based land use options for all smallholders. Such change would imply new livelihood opportunities that increase incomes and development levels, and could also trigger higher pressures on forests.

In this dynamic context, a mix of regulatory and incentive-based policies, which account for current and changing smallholder specialization strategies, are needed. As one innovative policy strategy, in October 2010 the Government of Acre passed the State System of Incentives for Environmental Services (SISA) to increase the value of standing forests and recuperate degraded lands across the state. Under the SISA umbrella, small colonist farmers, such as those sampled in the unprotected area in Acre, are the target of technical assistance and direct cash payments for adoption of more sustainable agricultural practices through the Certification of Smallholder Properties Program. Additionally, SISA can support residents of the Chico Mendes Extractive Reserve in initiatives to commercialize a diversity of NTFPs, including Brazil nuts, and engage in sustainable timber management. In Pando, where effective regulatory or compensation policies for conservation are largely absent, maintaining forest cover and forest-based livelihoods is likely contingent on its continued remoteness. Cross-border collaboration to promote regional environmental governance, such as the Madre de Dios-Acre-Pando (MAP) Initiative—an effort between local governments, non-governmental organizations, academics, and producers in Acre and Pando (and including neighboring Madre de Dios, Peru)—may be key to helping mitigate the effects of infrastructural expansion through linking scientific information to public decision-making (Perz *et al.*, 2008).

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Despite inherent implementation challenges, improved enforcement of existing use-right restrictions, strengthening and creation of protected areas (national parks or sustainable use areas), and/or provision of direct and conditional conservation incentives are likely important if forest conservation and forest-based livelihoods are to remain viable in the southwestern Amazon and in other tropical forest frontiers.

NOTES

1. This sampling method differed slightly in the unprotected area in Acre. While households in each community were selected randomly to represent 50% of the total, in several, many households were unavailable or unwilling to participate in the study, resulting in very small sample sizes. To account for this low participation, more households were randomly selected in other communities (>50% of total) to increase the overall sample size in this area.

2. Brazil nut tree density information was not included in the natural assets category as these data were unavailable for the majority of communities studied.

3. Forest cleared included mature and secondary regrowth (>15 years old), since annual forest cleared was derived from forest clearing over a 5-year period, in which different forests types were not differentiated nor use of the cleared land indicated.

4. Household members were those residing in the household at the start of the research (dry season). Importantly, this did not account for seasonal migrants who could have arrived during the course of the year, especially during the Brazil nut harvest.

5. In both Pando and Acre, older children often leave home to study in nearby towns, so this factor would likely not explain the observed difference in household size.

6. Although we focus on the stark difference between Brazil nut *versus* livestock reliance in Pando and Acre, respectively, we recognize the importance of other income sources to regional rural livelihoods. For instance, crop income, largely for subsistence purposes, is fundamental to food security and health. Additionally, government-sponsored subsidies in Acre are an important source of cash, as are off-farm income activities (wage labor, business), in both places.

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