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Environmental Income and Rural Livelihoods: A Global-Comparative Analysis

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Summary. — This paper presents results from a comparative analysis of environmental income from approximately 8000 households in 24 developing countries collected by research partners in CIFOR's Poverty Environment Network (PEN). Environmental income accounts for 28% of total household income, 77% of which comes from natural forests. Environmental income shares are higher for low-income households, but differences across income quintiles are less pronounced than previously thought. The poor rely more heavily on subsistence products such as wood fuels and wild foods, and on products harvested from natural areas other than forests. In absolute terms environmental income is approximately five times higher in the highest income quintile, compared to the two lowest quintiles.

Key words — forests, household income surveys, inequality, poverty

1. INTRODUCTION

Rural households throughout the developing world use food, fuel, fodder, construction materials, medicine, and other

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products from forests and other natural, non-cultivated environments to meet subsistence needs and generate cash income (Byron & Arnold, 1999; FAO, 2008; Kaimowitz, 2003; Sunderlin *et al.*, 2005; World Bank, 2004). Quantifying the relative and absolute contribution of environmental income to total income portfolios is important for understanding the livelihoods of rural people, the extent and determinants of poverty and inequality, the welfare implications of the degradation of natural resources, and for designing effective development and conservation strategies (Angelsen & Wunder, 2003; Jagger, Luckert, Banana, & Bahati, 2012; Oksanen & Mersmann, 2003; Vedeld, Angelsen, Sjaastad, & Berg, 2004). Overcoming current knowledge gaps in these areas requires moving beyond the current primarily case study-based state of knowledge on the importance of natural resources to overall livelihoods strategies.

This paper presents results from the Poverty Environment Network (PEN) research project, coordinated by the Center for International Forestry Research (CIFOR). PEN used a standardized set of village and household-level questionnaires designed to elicit comprehensive data about the importance and role of environmental income in rural livelihoods. Our sample includes 7978 households from 333 villages in 24 developing, tropical and sub-tropical countries across three continents (Latin America, Asia, and Sub-Saharan Africa). The data collection was done by 33 PhD students and junior scholars; the research design and methods were developed by an interdisciplinary team of scientists. The hallmarks of the data collection effort are detailed questions on all household income sources, using short (1–3 months) recall periods, and quarterly visits to households.

Our analysis addresses three broad questions. First, how much does environmental income contribute to rural households' income portfolios in different study regions? Second, how does reliance on environmental income vary with different levels of income, including its influence on income inequality? Third, what household-level characteristics and contextual variables affect the magnitude and relative importance of environmental income? Our findings have important implications for how we understand rural livelihoods and how we should design interventions that affect access to and use of natural resources.

2. ENVIRONMENTAL INCOME AND RURAL LIVELIHOODS

Seminal studies published over a decade ago (Campbell *et al.*, 2002; Cavendish, 2000) brought our attention to what Scoones, Melnyk, and Pretty (1992) and Campbell and Luckert (2002) refer to as "the hidden harvest"—the diversity of goods provided freely from the environment, i.e., from non-cultivated ecosystems such as natural forests, woodlands, wetlands, lakes, rivers, and grasslands. The literature identifies three primary roles for environmental income in supporting rural livelihoods: (i) supporting current consumption, (ii) providing safety-nets in response to shocks and gap-filling of seasonal shortfalls, and (iii) providing means to accumulate assets and providing a pathway out of poverty (Angelsen & Wunder, 2003). This paper focuses on the first aspect, while Wunder, Börner, Shively, and Wyman (2014) addresses the second. The third aspect is best addressed with panel data, but these are scarce in existing studies (c.f. Jagger, 2010).

During the past 10–15 years, research on environmental income has gained momentum, and a large share of this literature focuses on forests. Studies from Africa,[1] Asia,[2] and Latin America[3] find that forest and non-forest environmental income makes significant contributions to livelihoods in most rural settings. Most of these studies focus on livelihood strategies, forest or overall environmental dependence, non-timber forest products (NTFPs), or conservation and development issues. An early synthesis of 54 studies estimated an average forest income contribution of 22%—the third most important income source after off-farm activities (38%), and agriculture (crops and livestock combined) (37%) (Vedeld, Angelsen, Bojö, Sjaastad, & Berg, 2007; Vedeld *et al.*, 2004). More recent studies[4] estimate forest income shares ranging from 6% to 44% of total income. Conceptual discussions of the role and potential contributions of forests to livelihoods include Angelsen and Wunder (2003), Belcher and Schreckenberg (2007), de Sherbinin *et al.* (2008), Shackleton, Shackleton, and Shanley (2011); and Sunderlin *et al.* (2005).

Despite this growing literature, methodological heterogeneity and bias in study locations make it difficult to generalize about the overall importance of environmental income to rural livelihoods in developing countries. In their meta-analysis of forest income studies, Vedeld *et al.* (2004: p. xiv) noted that "[t]he studies reviewed displayed a high degree of theoretical and methodological pluralism" and "methodological pitfalls and weaknesses [were] observed in many studies." Jagger *et al.* (2012) demonstrate in a methods experiment in Uganda how alternative data collection methods—a quarterly income survey (PEN) and a one-time household-level participatory rural appraisal—in the same study population can yield sectoral income estimates that differed up to 12 percentage points. Specific limitations of forest income studies include: long (e.g., one-year) recall periods underestimating or seasonally biasing estimates (Jagger *et al.*, 2012; Lund *et al.*, 2008), inconsistent operationalization of key variables (e.g., definitions of forest, NTFPs, etc.), incompatibilities in methods (Vedeld *et al.*, 2004), and survey implementation problems (e.g., varying intra-household respondents) (Fisher, Reimer, & Carr, 2010). Finally, most studies are from dry-land sub-Saharan Africa, with Latin America in particular being underrepresented in the literature. The PEN project was designed to address the problems of methodological incompatibility, weak data collection, and lack of representativeness as observed in the literature.

PEN was also designed to address questions of the relative and absolute importance of environmental income across different wealth groups. The literature suggests that absolute environmental income rises with total income, while relative environmental income (i.e., the share of environmental income in total household income) decreases—i.e., household's environmental "dependence" or "reliance" decreases with higher incomes (Cavendish, 2000; Escobal & Aldana, 2003; Mamo *et al.*, 2007; Neumann & Hirsch, 2000; Vedeld *et al.*, 2007).

The forest "safety net"[5] *vs.* "poverty trap" debate focuses on whether high environmental reliance serves as a safety net by preventing poor households from falling into deeper poverty, or whether inferior good characteristics of forest resources keep households trapped in poverty (Angelsen & Wunder, 2003; Barbier, 2010; McSweeney, 2004; Pattanayak & Sills, 2001; Paumgarten, 2005). High dependence on natural resource extraction by the poor is often associated with asset poverty and lack of access to key markets (Barbier, 2010). Factors such as market access are exogenous to the household, suggesting that the "safety net" interpretation is more appropriate than the "poverty trap" interpretation. Angelsen and Wunder (2003) argue that environmental reliance could be justifiably labeled as a "poverty trap" only in cases where alternative livelihoods strategies exist, but where policies, donor projects, or other external interventions seek to maintain people in their low-yield forest extraction activities.

3. METHODS

(a) *The PEN project and surveys*

PEN is the largest quantitative, global-comparative research project on forests and rural livelihoods to date. It used standardized state-of-the-art definitions and methods allowing for systematic comparisons across studies and regions.[6] Socioeconomic data on household-level variables (demographics, assets, income sources, and social capital), and village-level data (demographics, markets, institutions, and natural resource endowments) provide covariates and contextual information.[7] The surveys covered a 12-month period (see Figure 1). Village surveys at the beginning (V1) and end (V2) of the survey period were undertaken. Household surveys included an initial survey (A1), collecting basic household information (demographics, assets, forest access, and collective action), a terminal survey (A2) capturing economic shocks, land-use changes, and other phenomena over the past 12 months, and four quarterly household income surveys (Q1-Q4) using one- or three-month recall periods.[8]

(b) *Site selection and sampling*

Thirty-three PEN partners were recruited internationally, according to the suitability of their study sites to fulfill three criteria: (i) located within tropical or sub-tropical regions of Asia, Africa, or Latin America; (ii) close proximity to forests; and (iii) contributing country or site-level variation to the global data set. However, case selection was to some degree opportunistic, guided by PEN partner interests and opportunities. We assert that our sample is representative of smallholder-dominated tropical and sub-tropical landscapes with moderate-to-good access to forest resources. The representativeness of PEN sites is discussed in detail in Appendix A. The locations of the 33 PEN study areas are given in Figure 2.

After study areas were selected, partners were encouraged to select villages with variation in important characteristics, including distance to market, vegetation type, land tenure and local institutions, population density, ethnic composition, sources of risk, and levels of poverty (Cavendish, 2003). Within villages, households were sampled randomly based on household rosters or pre-existing censuses. Larger PEN study area with distinct geographical sub-areas were split into "sites", yielding a total of 58 sites, 333 villages, and 7978 households[9] used in the income analysis in this paper.[10]

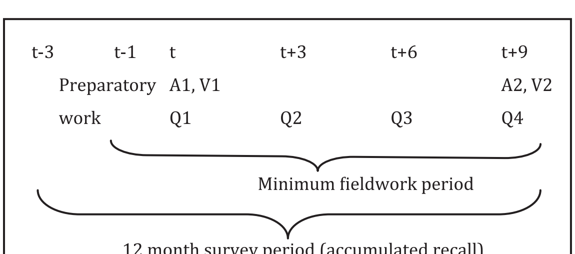

Figure 1. *Timing of village and household surveys in PEN studies. Note: t, start of surveys (month); A1, A2, Annual household surveys; V1, V2, Annual village surveys; Q1–Q4, Quarterly household income surveys).*

(c) *Definitions*

The primary objective of the household survey was to collect detailed data on all income sources, including from forests and non-forest natural environments. Income is defined as the value added of labor and capital (including land). For self-employment (e.g., in agriculture and extractive activities), income was defined as the gross value (quantity produced multiplied by price) minus the costs of purchased inputs (e.g., fertilizers, seeds, tools, hired labor, and marketing costs). The PEN guidelines (CIFOR, 2007) emphasize that households' subsistence extraction and production (i.e., in addition to extraction/production that generates cash income) should be included in total income.

To define "forest income", we use the FAO (2000) definition of a forest: "forests are lands of more than 0.5 ha, with a tree canopy cover of more than 10%, where the trees should be able to reach a minimum height of 5 m *in situ*, and which are not primarily under agricultural land use". This includes both primary and secondary forests, native and exotic species, natural and planted forests, as well as closed and open forests.[11] Products collected from forests were generally defined as forest products if their supply depended on the existence of forest cover. For example, income from minerals extracted within forests was classified as non-forest environmental income, and income from fish caught in rivers or lakes within forests was collectively classified as forest income. Wild fish caught outside the forest is part of non-forest environmental income. Finally, forest income includes direct payments for forest-based environmental services, e.g., carbon credits or profits from community-based forest ecotourism.

"Environmental income" refers to extraction from non-cultivated sources: natural forests, other non-forest wildlands such as grass-, bush- and wetlands, fallows, but also wild plants and animals harvested from croplands. Most forest income is environmentally sourced (i.e., a "subsidy from nature"), but plantation forestry by definition is excluded from environmental income. Forest environmental income (i.e., excluding income from plantations) and non-forest environmental income combined make up total environmental income, i.e., the sum of "incomes (cash or in kind) obtained from the harvesting of resources provided through natural processes not requiring intensive management" (CIFOR, 2007).[12] We define "environmental (forest) reliance" as the share of environmental (forest) income in total household income.

Income from other sectors was treated as follows. Crop income consists of income from cropping on land categorized as agriculture, and agroforestry. Livestock income comes from products (including the sale of live animals) and services (e.g., rented-out horsepower), but excludes non-realized incremental changes in stock values, which are captured in the value of assets. Livestock also includes fish-farming (aquaculture). Three other categories describe non-farm income including wage income from all sectors, income from self-owned businesses, and other income including remittances, pensions, gifts, and other sources not captured above.

For inter-household comparisons we used *adult equivalent units (AEU)*.[13] We compared national currency values using *purchasing power parity (PPP)* rates[14]; thus all income figures are reported as PPP adjusted $US per AEU. Further details on data processing, aggregation, and modifications are presented in Appendix A.

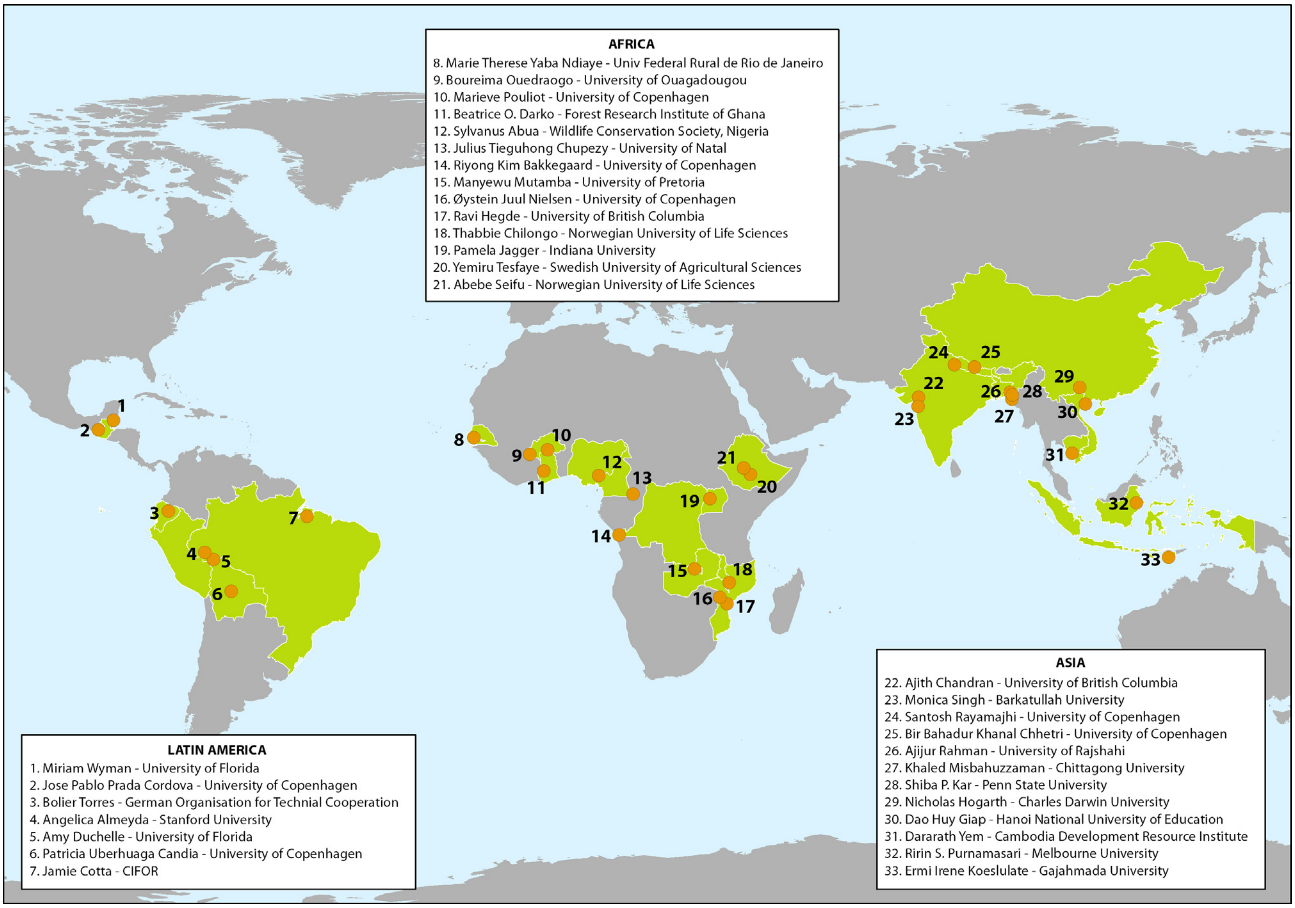

Figure 2. *Location of the PEN study areas.*

(d) *Descriptive analyses*

To understand the relationship between total income and environmental reliance, we calculate the Relative Kuznets Ratio (RKR); i.e., the ratio between the environmental income share of the highest (top 20%) and lowest two income quintiles (bottom 40%) (Vedeld *et al.*, 2004).[15] A value of RKR < 1 indicates that low-income households have a higher environmental income share. We conducted a similar analysis of *absolute* forest and environmental income, referring to this as the Absolute Kuznets Ratio (AKR).

As for different methods of aggregation, environmental (forest) reliance at the site-level can either be calculated as the mean of the environmental (forest) income shares of the sampled households in that site, or as the share of mean environmental (forest) income in mean total income (mean of shares *vs*. share of means). We follow Davis *et al.* (2010) who recommend "mean of shares" if households are the main unit of analysis, as in our case. Next, in calculating means for the full sample, we take the mean of the site-level shares ("triple averages").

(e) *Multilevel regression analyses*

We use regression analysis to test which factors influence household incomes. We treat the PEN data set as a global sample, where households are nested within sites. To leverage the hierarchical data structure we use multilevel (hierarchical) regression, which has the advantage of accounting for highly variable numbers of observations at site-level through partial pooling (Gelman & Hill, 2006).[16] In contrast to a standard cross-sectional regression approach, where varying intercepts or coefficients are introduced through dummy variables and interaction terms, multilevel models allow us to simultaneously and efficiently estimate group-level effects and predictors (Gelman, 2006).[17, 18]

We estimate two-level regression models with varying site-level intercepts for five dependent variables: absolute forest income, relative forest income, absolute environmental income, relative environmental income, and total household income. All absolute income measures are log transformed to account for the non-normal distribution of the income data and reduce the impact of outliers. For relative forest and environmental income (proportions between 0 and 1), we estimate fractional logit models (Papke & Wooldridge, 1996).[19]

Independent variables are either household- or site-level predictors. Household-level variables include indicators of human capital (e.g., household size, age and education of household head, whether the household head is female, and whether the household participates in forest user groups[20]), household endowments of land and financial capital (agricultural land owned, value of tropical livestock units (TLU), and value of assets), shocks experienced by the household (income, asset, and labor shocks), and contextual variables that we expect to influence access to forests products and markets for forest products (distance from the household to the forest, and distance from the household to the village center). Household asset value per AEU measured at the beginning of the survey period is included as a welfare indicator in the models. Separate analyses (not reported) suggest significant correlation between asset values and inter- as well as intra-site differences in income.[21]

To accommodate for effects at different scales, the asset variables (assets, TLU, and agricultural land) enter the regression models in two forms. First, the household-level variables are standardized at the site level using group-mean centering to reduce collinearity and facilitate interpretation of contextual group-level effects (Paccagnella, 2006).[22] Second, the site-level means are included as contextual predictors.[23] The rationale for doing this is that individual and aggregated indicators of site-level well-being may exert different and independent effects on environmental income and reliance outcomes (Enders & Tofighi, 2007).

Additional site-level variables include the Gini coefficient to measure income inequality, market integration (i.e., value of cash income/total income), and the share of forested land in the site classified as formally private or community forest (with state-owned forest as the default category). Finally we include regional dummy variables for Africa and Asia (with Latin America as the default). Robust standard errors are estimated for all models. Summary statistics for the variables used are found in Appendix B.

4. RESULTS

(a) *Environmental income*

(i) What is the size and relative importance of forest and non-forest environmental income?

We present absolute and relative forest and non-forest income environmental income in Table 1. The average share of forest income in total household income across all sites is 22.2%.[24] In absolute terms, annual forest income averages $US 440 (i.e., $US 422 from natural forests and $US18 from plantation forests) for the global sample (99.6% forest product, 0.4% forest service incomes), but we observe large and systematic regional variation. For example, in the 10 Latin American sites, forest income constitutes 28.6% of average household income, whereas in Asia and Africa forest income shares are 20.1% and 21.4%, respectively. Income from forest plantations is very low, accounting for only 1% of total income in the global sample and ranging from 0.1% in Latin America to 1.8% in Asia. Forest income shares vary widely across the sites. The highest forest reliance is found in one Bolivian site, where 63% of household income is derived from forest products, mainly Brazil nut (*Bertholletia excels*) (see Duchelle, Zambrano, Wunder, Börner, & Kainer, 2014). We also find a forest income share above 59% in Cameroon, attributed to the collection of bushmeat and high-value wild fruits. At the low end, two sites in East Kalimantan, Indonesia, have relative forest shares of approximately 5.5%. A third site in East Kalimantan has a forest income share of 32.6%, illustrating the wide variation observed even within a single province.

We estimate non-forest environmental income of $US 86 or 6.4% of total household income for the full sample. The Africa sites stand out with higher shares of non-forest environmental income, averaging 9.6%, or roughly half of forest income, reflecting the value and diversity of products collected from open savannahs, bushlands, and other non-forest wildlands.

The global average environmental income share—forest (excluding plantations) and non-forest environmental income—is 27.5% of total household income ($US 508), only marginally less than crop income (28.7%). This finding highlights the overall importance of forests and non-agricultural areas to rural livelihoods. Again, we note considerable

Table 1. *Absolute and relative incomes*[a,b]

Income category	Absolute income ($US PPP)				Relative income (percent of total)			
	Global	Latin America	Asia	Africa	Global	Latin America	Asia	Africa
Forest (natural)	422.0	1353.8	262.6	200.7	21.1	28.5	18.4	20.5
	(650.6)	(1104.9)	(179.6)	(274.5)	(13.1)	(16.4)	(9.1)	(13.8)
Forest (plantation)	18.3	0.63	29.0	16.4	1.0	0.1	1.8	0.8
	(44.6)	(2.0)	(54.9)	(42.8)	(2.4)	(0.1)	(3.3)	(1.8)
Forest (natural & plantation)	*440.3*	*1354.4*	*291.7*	*217.2*	*22.2*	*28.6*	*20.1*	*21.4*
	(651.8)	*(1104.3)*	*(182.4)*	*(304.7)*	*(13.0)*	*(16.3)*	*(9.3)*	*(13.8)*
Non-forest environmental	85.7	119.1	47.1	103.4	6.4	3.6	3.7	9.6
	(127.5)	(85.4)	(37.5)	(173.3)	(5.8)	(2.8)	(3.0)	(6.7)
Environmental (natural forest & non-forest environmental)	*507.7*	*1472.9*	*309.7*	*304.1*	*27.5*	*32.1*	*22.0*	*30.1*
	(693.3)	*(11121.8)*	*(195.9)*	*(394.7)*	*(12.4)*	*(16.5)*	*(9.4)*	*(11.6)*
Crop	432.0	786.8	425.7	305.4	28.7	18.5	29.1	32.2
	(405.4)	(642.3)	(232.1)	(333.2)	(13.3)	(12.7)	(13.2)	(12.0)
Livestock	235.4	578.0	249.6	97.5	12.3	11.7	13.2	11.7
	(355.5)	(695.4)	(218.9)	(88.4)	(9.2)	(10.4)	(8.4)	(9.5)
Wage	325.5	1154.9	237.5	86.8	15.2	22.6	17.6	10.7
	(749.4)	(1589.8)	(150.3)	(94.9)	(10.7)	(12.4)	(6.4)	(8.6)
Business	179.8	328.2	180.6	124.1	7.4	4.5	6.3	10.6
	(269.6)	(362.7)	(314.9)	(160.9)	(6.3)	(4.0)	(6.4)	(6.5)
Other	153.5	424.3	169.4	40.7	7.8	10.7	9.9	5.0
	(254.2)	(402.7)	(233.6)	(43.9)	(7.5)	(8.6)	(9.8)	(3.1)
Total[c]	1852.2	4745.8	1601.7	975.1	100	100	100	100
	(1889.1)	(2793.0)	(652.2)	(852.3)				
N	58	10	21	27	58	10	21	27

[a] Standard deviations in parentheses.
[b] All values are per adult equivalent in purchasing power parity (PPP) adjusted $US.
[c] Total income is sum of forest (natural & plantation), non-forest environmental income, crop, livestock, wage, business, and other income.

regional variation, with Latin America's share (32.1%) led by high-value cash products, Africa's (30.1%) environmental income from diverse and largely subsistence use of forest and other environmental products, and Asia's mostly forest-based share (22.0%).

Generally, we find higher absolute incomes in the Latin America sample (averaging income of $US 4746 per AEU/year), compared to $US 975 in Africa and $US 1602 in Asia. Active labor markets generate higher wage incomes in the Latin American (22.6%) and Asian samples (17.6%) than in Africa (10.7%). Livestock income is relatively homogeneous across regions (11.7–13.2%). Perhaps surprisingly, the largest share of income from business is observed in the African sites (9.4%). The income shares for crops (28.7%) and livestock (12.3%) in the PEN sample are close to the shares of 16 country-level rural income surveys presented in Davis *et al.* (2010; 30.0% and 10.3%, respectively). The total wage share in the PEN sample is lower (15.2% compared to 25.3%) than in the Davis *et al.* (2010) sample, possibly because our sites tend to be located in more remote areas with lower market integration.

(ii) *What is the composition of forest and environmental income?*

Forests and natural environments yield a diversity of products (Table 2). Wood fuels (i.e., fuel wood/firewood and charcoal) are the dominant category accounting for 35.2% of forest income, and representing about 7.8% of total household income. Most of this is fuel wood, while charcoal makes up roughly 11%. The second-most important category is food (30.3%), which includes fish and bush meat, an important source of protein for rural households in many of our sites, as well as wild fruits, vegetables, and mushrooms. Finally, structural and fiber products make up 24.9% of the forest income, split between wood (e.g., poles and sawn wood) and non-wood products (e.g., leaves, thatching grass, and bamboo). Wooden products also include a range of processed products, such as locally made furniture and utensils, and non-wood products including baskets and mats, brooms, vines for construction, etc.

The basket of goods contributing to non-forest environmental income is different than for forests. Food is by far the most important product category (48.9%), followed by wood fuel (20.6%). We note that fodder, often considered an important forest product (Vedeld *et al.*, 2004), is commonly sourced from non-forest environments making up a large share of that category for the global sample (11.6%).

Regional variation is noteworthy. In Latin America, some specialty high-value food products (e.g., Brazil nuts, Açai fruits) raise the food share in forest products to 53%, and make the wood fuel share low relative to Africa and Asia. Non-forest environmental income plays a particularly important role in the African sites (9.6%), where reliance is strongly negatively correlated with forest reliance (site-level Pearson correlation coefficient = −0.38), indicating some substitutability; in forest scarce locations, collecting food, fuel wood, and other products from non-forest environments is relatively more important.

(b) *What is the relationship between environmental reliance, total income, and inequality?*

Having a large data set permits both inter- and intra-site analyses of the relationship between both forest reliance and overall environmental reliance and total income. The inter-site analysis examines patterns across different locations, to explore how broad economic development can change forest and

Table 2. *Main products providing forest and non-forest environmental incomes (percent of income category)*

Product	Forest income[a]				Non-forest environmental income			
	Global	Latin America	Asia	Africa	Global	Latin America	Asia	Africa
Food	30.3	53.0	27.3	24.2	48.9	41.6	60.0	43.8
Plant products	16.6	30.9	14.9	12.7	18.1	17.4	10.8	23.5
Animal products	11.9	21.8	10.5	9.3	28.4	24.0	48.9	15.6
Mushroom	1.7	0.3	1.9	2.1	2.4	0.2	0.3	4.6
Fuel	35.2	13.2	37.3	41.7	20.6	39.2	14.5	18.0
Firewood	31.2	11.7	32.9	37.2	19.6	38.3	11.9	18.0
Charcoal	4.0	1.5	4.5	4.5	1.1	0.9	2.6	0.0
Structural & fiber	24.9	25.4	25.0	24.7	9.9	4.4	9.5	12.3
Sawn wood	7.7	19.1	7.7	3.5	1.1	1.7	1.2	0.8
Poles & construction materials	3.8	0.9	1.8	6.4	0.8	0.2	0.0	1.5
Other wooden products	2.4	1.4	2.0	3.0	0.0	0.0	0.0	0.1
Non-wood products[b]	11.0	4.0	13.4	11.8	8.1	2.5	8.3	10.0
Medicine, resins, and dyes	5.5	5.2	5.1	5.9	4.0	5.3	1.2	5.6
Fodder	3.0	0.6	4.4	2.9	11.6	9.6	10.7	13.0
Manure	0.8	2.5	0.8	0.1	0.8	0.0	0.4	1.3
Other	0.2	0.0	0.0	0.5	4.1	–	3.6	6.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Absolute value ($US)[c]	433	1342	281	215	86	119	47	103
Pct. of total income	21.8	28.3	19.5	21.2	6.4	3.6	3.7	9.6

Note: Subcategories may not add up to main category due to rounding-off with one decimal.
[a] Forest income includes income from natural and plantation forests but does not include payments for forest services, which make up 0.36% of total income in the global sample.
[b] Includes leaves, thatch, and bamboo.
[c] All values are per adult equivalent in purchasing power parity (PPP) adjusted $US.

environmental reliance and use. The intra-site analysis reflects how environmental reliance is linked to household-level poverty, inequality, and social differentiation at a local level.

(i) *Inter-site forest and environmental income*

Figure 3 illustrates the correlation between mean forest reliance and total household income (a) and mean environmental reliance and total household income (b) at the level of the 58 PEN sites. The correlation between forest reliance and site income (log) is weak (a). The fitted quadratic regression line yields a weak U-shaped relationship, but none of the coefficients (linear and squared) are significant and the fit of the model is poor ($R^2 = 0.049$). Environmental reliance and mean site income have an even weaker relationship (b). These results are robust when each of the three regions is analyzed separately.

Absolute forest and environmental income (log) were also regressed on total income (log) at the site level (not reported) to obtain elasticities (i.e., the percentage increase of forest or environmental income when total income increases by 1%).[25] The elasticity for forest income is 1.09 and 1.00 for environmental income. There is, however, a notable difference between cash and subsistence sources. A 1% increase in total income is associated with an increase of 1.23% in forest *cash* income and a 1.17% increase in *cash* environmental income, while *subsistence* forest income increases by 0.97% and *subsistence* environmental income by 0.85%. For non-forest environmental income, the elasticities are much lower: 0.74 (total), 0.70 (cash), and 0.50 (subsistence). In short, *relative* forest and environmental incomes do not vary systematically with income at the site level. However, *absolute* forest and environmental incomes tend to be higher at the high-income

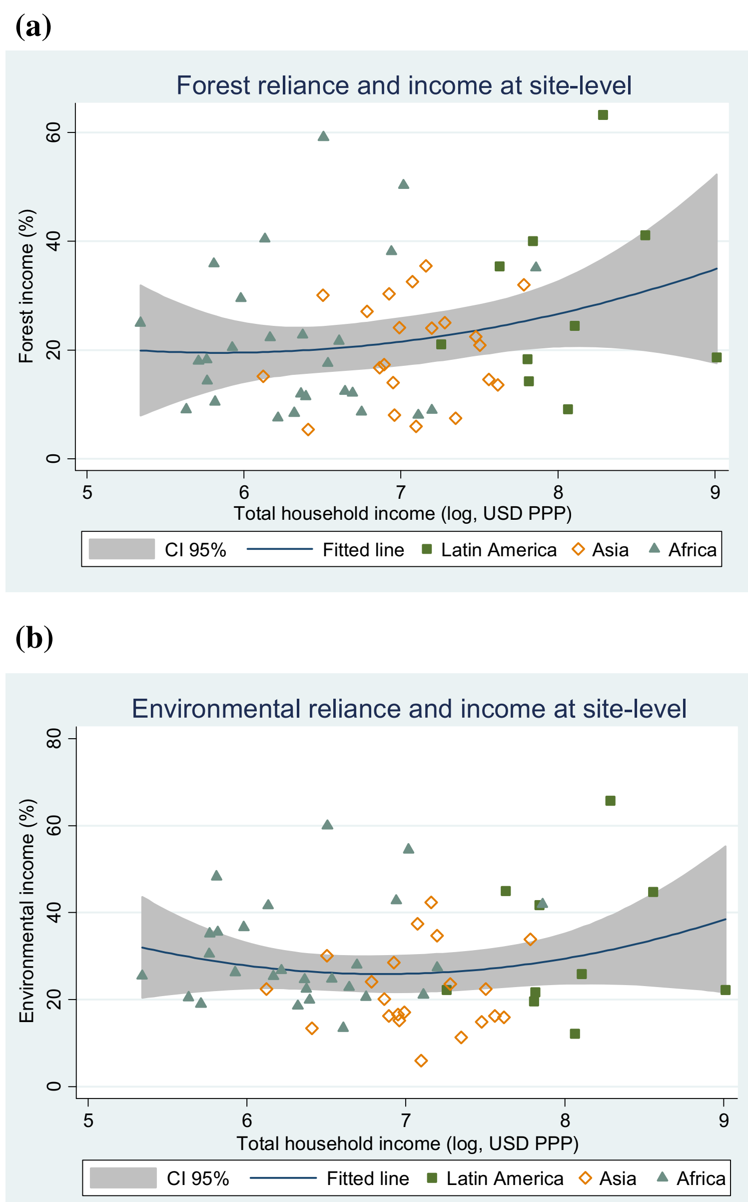

Figure 3. *The relationship between forest reliance (income share) and total income (a); and environmental reliance and total income (b). Note: CI = confidence interval.*

sites, but with a shift from subsistence to cash forest/environmental incomes.

A common finding among case-studies presented in the literature is that poor households rely more on forest and environmental income sources than better-off households, with reliance measured in relative terms as its share in total household income (e.g., Campbell & Luckert, 2002; Cavendish, 2000; Yemiru *et al.*, 2010). We also expected a negative relationship between environmental reliance and total income at the site level, but we do not observe this pattern when comparing the 58 sites. This may, in part, be explained by the sites included in the PEN sample: several of the high-income sites in Latin America have valuable commercial forest products, and some of the poorer African sites have limited access to forests.

(ii) *Intra-site forest and environmental income*

We analyzed forest and environmental income distributions using the Relative Kuznets Ratio (RKR) (Table 3). For the global sample of PEN sites the mean forest RKR is 0.88, which suggests that forest income plays a more important role in the livelihoods of the poorest households. More nuanced patterns emerge when decomposing the results by region. Sites in Asia have RKRs that suggest that forest income plays a *relatively* more important role in the lower income quintiles (0.75). In Latin America, forest income shares are slightly higher for the top income quintile, with an overall RKR of 1.07.

Disaggregating again on subsistence and cash incomes, subsistence income is more aligned with lower quintiles (RKR = 0.65). This is not surprising, given diminishing marginal utility to most subsistence uses (food, firewood, construction material, etc.). Conversely, forest cash income is very clearly associated with greater prosperity, with the global sample average RKR of 1.63, and the pattern is similar across the regions.

For non-forest environmental income, the association with the low-income quintile households is similar to that of forest income (RKR = 0.90), but the difference between cash and subsistence incomes is much more pronounced. For subsistence uses only, the ratio is 0.58. Interestingly, we observe that the cash component of non-forest environmental income strongly favors high-income quintile households in Asia (5.06) and Africa (2.78), although we should keep in mind that this represents only a very small share of the total household income in Latin America (see Table 1). Comparing absolute income from forests and non-forest environments (the Absolute Kuznets Ratio—AKR), the picture looks very different. High-income households generate much higher absolute forest and non-forest environmental incomes.[26] Overall, the richest 20% have about five times more forest and environmental incomes compared with the poorest 40%, while the Kuznets ratio for total income is close to six (5.76).

Table 4 presents the results of a simulation exercise that illustrates the influence of environmental income on income inequality. Subtracting environmental income when calculating the Gini coefficient increases income inequality by an average of 4.7 percentage points, suggesting that access to natural resources plays an important equalizing role in our study sites. A complete Gini-decomposition (not reported) confirmed this overall result.

(c) *What household and contextual factors determine environmental income and reliance?*

While the above analyses have clarified how forest and environmental incomes are related to overall income, our regression analysis explores the influence of several covariates and controls. Table 5 presents the results of five regression models—with dependent variables: absolute (log) and relative forest income, absolute (log) and relative environmental income, and total (log) income.[27]

Table 3. *Relative and absolute Kuznets ratios*

		Global	Latin America	Asia	Africa
Relative Kuznets ratios					
Forest income	Subsistence	0.65	0.77	0.58	0.67
	Cash	1.63	1.87	1.59	1.56
	Total	0.88	1.07	0.75	0.91
Non-forest environmental income	Subsistence	0.58	0.65	0.53	0.58
	Cash	3.36	1.27	5.06	2.78
	Total	0.90	0.72	0.95	0.92
Environmental income	Subsistence	0.57	0.69	0.51	0.56
	Cash	1.63	2.21	1.49	1.53
	Total	0.77	0.99	0.66	0.77
Absolute Kuznets ratios					
Forest income	Subsistence	3.65	4.63	2.34	4.30
	Cash	9.15	12.48	6.48	9.98
	Total	5.21	7.05	3.34	5.98
Non-forest environmental income	Subsistence	3.68	5.67	2.25	3.99
	Cash	16.80	9.97	20.18	16.57
	Total	5.30	6.17	3.94	5.98
Environmental income	Subsistence	3.17	4.27	2.09	3.61
	Cash	9.21	14.26	6.06	9.80
	Total	4.56	6.59	2.87	5.12
Total income		5.76	6.31	4.81	6.30

Table 4. *Gini coefficients with and without environmental income*

Index	Global	Latin America	Africa	Asia
Gini without environmental income	0.426	0.456	0.439	0.394
Gini with environmental income	0.379	0.408	0.395	0.346
Mean difference	−0.047	−0.048	−0.044	−0.048
N	58	10	27	21

(i) *Household characteristics*

We included four household characteristics: household size, age, gender of the household head, and education of household head. Larger households tend to have lower absolute income in all three models (i.e., forest, environmental, and total income), which is in part a function of income being measured per adult equivalent unit (AEU). Large households are also likely to have higher consumer to worker ratios, and income per adult equivalent is therefore likely to be lower. However, larger households have higher relative forest and environmental incomes (although not significant for the latter), possibly because the high-labor intensity of many extractive activities make these relatively more attractive to large households.

All else being equal, increasing age of the household head reduces total income as well as absolute forest and environmental income (and relative forest income). A simple analysis of correlations suggests that older households have accumulated more assets and tend to have higher reliance on crop and livestock income. In addition, older people may be less able physically to access forest and wild resources.

Female-headed households (about 11% of our sample) have lower absolute incomes, and also lower forest reliance. Although significant, the magnitude of the variable is rather small: all things being equal, female-headed households have 0.9 percentage points lower forest reliance compared to male-headed households. We note, however, that the negative effect is higher for forest income than for environmental income (and the coefficient is not significant for environmental reliance), suggesting that non-forest environmental income is relatively more accessible and/or attractive to female-headed households, as compared to forest income. The question of gender differences in forest use in the PEN sample is elaborated further in the article by Sunderland, Achdiawan, Angelsen, Babimigura, Ikowitz, Paumgarten, *et al.* (2014).

As expected, households with more years of education tend to have higher total income, and lower forest and environmental income (the impact on income shares are negative but not significant). This might reflect better opportunities for the households in the off-farm labor market.

(ii) *Assets*

Three assets were included in the regression models: agricultural land, tropical livestock units (TLU), [28] and value of other assets (furniture, bicycles, motorbikes, equipment, etc.). While all are measures of household wealth, land and livestock are key productive assets for farm households. Ownership of agricultural land and livestock increases as expected absolute incomes (forest, environmental, and total). The impact on relative forest income is insignificant, suggesting that possible crowding-in effects (e.g., part of the same livelihoods strategies) balance crowding-out effects (e.g., substitute agricultural income with forest income due to competition for family labor). Surprisingly, agricultural land ownership is positively correlated with higher environmental reliance.

The variable for other assets displays a different pattern. While the coefficient is highly significant in the total income regression, it is insignificantly correlated with forest and environmental absolute incomes. Thus we find a pattern where asset-poor households are relatively more reliant on forest and environmental resources (i.e., higher income shares), complementing our earlier findings of higher forest and environmental reliance among the income-poor. We also note the much larger negative coefficient for environmental reliance than for forest reliance, confirming the more pro-poor pattern for non-forest environmental income than for forest income.

(iii) *Shocks*

All households were asked if they experienced a severe shock during the 12-month period covered by the survey. We classified these as direct income shock (e.g., crop failure or lost wage employment), labor shock (e.g., illness or death of productive adult) and asset shock (e.g., loss of land or livestock), [29] as the impacts may differ. By definition, an income shock should affect total income negatively, and this is confirmed in the total income regression. We find that income shocks have a (weakly) significant and positive impact on absolute forest and environmental incomes (and on forest and environmental reliance), indicating some role of forests as a "shock-absorber". Households experiencing income shocks had—all other things being equal—1.3 percentage points higher environmental reliance, both a result of higher (0.16%) absolute environmental income and lower (−0.15%) total income.

We found no significant impact of assets or labor shocks. One reason could be that asset shocks have more medium-to long-term effects on incomes compared to other shocks. Labor shocks probably impede the households from engaging more in labor-intensive coping strategies such as forest extraction. The role of forests for insurance and gap-filling among households in the PEN sample is explored in depth in Wunder *et al.* (2014).

(iv) *Institutions*

Fully capturing the institutional complexity of forest use is challenging. We included two variables: membership in forest user groups (FUG) and formal ownership of forests (share of land at site level under private, communal, and state ownership, respectively). FUG membership could have contradictory effects on forest use: privileged access to forest resources as well as self-selected membership by active forest users may cause a positive correlation, while membership can also restrain participants from overly intensive (and unsustainable) uses. We do not find any significant association between FUG membership and absolute or relative forest or environmental income. There is a weakly significant and positive association between total income and FUG membership, probably indicating a tendency of higher income households to join FUGs.

A high share of forest being privately or community owned is associated with higher absolute forest and environmental income, as compared to state-owned forests. These findings are, however, open to different interpretations and call for more detailed analysis, as the tenure regime is likely associated with other characteristics. The role of forest tenure and its characteristics are explored further in Jagger, Luckert, Duchelle, Lund, and Sunderlin (2014).

Table 5. *Multilevel regression models*[a,b]

	Forest income		Environmental income		Total income
	Absolute	Relative	Absolute	Relative	
Household-level variables					
Household size, adult equivalents	−0.073***	0.084***	−0.104***	0.114	−0.093***
	(−4.84)	(2.73)	(−10.53)	(1.43)	(−10.38)
Age of household head, years	−0.012***	−0.025***	−0.008***	−0.017	−0.002***
	(−5.63)	(−6.35)	(−5.96)	(−1.40)	(−2.81)
Female-headed household	−0.491***	−0.872***	−0.352***	−0.599	−0.108***
0 = No; 1 = Yes	(−7.61)	(−3.69)	(−6.38)	(−1.32)	(−4.00)
Education of head, years	−0.025***	−0.019	−0.022***	−0.034	0.016***
	(−4.56)	(−0.76)	(−4.03)	(−0.52)	(5.16)
Agricultural land owned, hectares (log and centered at site level)	0.090***	0.064	0.094***	0.167**	0.071***
	(2.83)	(0.69)	(4.45)	(2.03)	(4.77)
Tropical livestock units (TLU) owned (log and centered at site level)	0.133***	0.021	0.126***	0.111	0.151***
	(5.07)	(0.26)	(4.58)	(0.87)	(7.79)
Value of assets, $US (log and centered at site level)	0.012	−0.193**	−0.008	−0.436***	0.193***
	(0.39)	(−2.41)	(−0.32)	(−3.96)	(12.35)
Household experienced income shock	0.154**	0.385***	0.156*	1.324***	−0.145***
0 = No; 1 = Yes	(2.51)	(2.63)	(1.74)	(10.47)	(−3.44)
Household experienced asset shock	0.02	−0.158	0.056	−0.241	0.049
0 = No; 1 = Yes	(0.3)	(−0.69)	(0.78)	(−0.31)	(1.31)
Household experienced labor shock	0.112	0.278	0.038	0.189	0.043
0 = No; 1 = Yes	(1.52)	(1.19)	(0.71)	(0.47)	(1.48)
Household member of forest user group	0.051	0.161	0.067	0.317	0.061*
0 = No; 1 = Yes	(0.88)	(1.03)	(1.26)	(0.76)	(1.72)
Distance to forest, hours walking	−0.056	−0.079	−0.035	−0.022	−0.048***
	(−1.07)	(−0.89)	(−0.81)	(−0.07)	(−2.63)
Distance to village center, hours walking	0.075**	−0.082	0.079***	−0.041	−0.003
	(2.25)	(−0.57)	(2.82)	(−0.24)	(−0.15)
Site-level variables					
Site-level average agricultural land owned, hectares (log)	−0.050*	−0.340***	−0.033*	0.322***	0.059***
	(−1.91)	(−3.05)	(−1.75)	(2.75)	(3.72)
Site-level average tropical livestock units (TLU) owned (log)	0.05	1.642***	−0.133***	−1.057***	−0.036**
	(1.29)	(10.72)	(−7.16)	(−4.24)	(−2.54)
Site-level average assets, $US (log)	0.380***	1.236***	0.375***	0.498***	0.349***
	(23.97)	(7.96)	(24.02)	(4.94)	(29.62)
Site-level Gini coefficient	−0.051***	−0.264***	−0.023***	−0.077***	0.005***
	(−19.15)	(−11.04)	(−12.97)	(−5.32)	(2.89)
Site-level degree of market integration (% of cash/total income)	−0.008***	0.01	−0.010***	−0.105***	0.003***
	(−3.71)	(1.6)	(−6.69)	(−6.17)	(2.73)
Share of forest land in village privately owned (c.f. state owned)	0.224*	0.628	1.283***	2.232**	0.419***
	(−1.79)	(−1.19)	(−20.17)	(−2.48)	(−8.87)
Share of forest land in village	0.207***	0.364	0.494***	2.570***	−0.128***
	(2.65)	(0.74)	(10.81)	(5.52)	(−3.16)
Asia (c.f. Latin America)	−1.169***	1.138*	−0.959***	1.013*	−0.562***
	(−12.51)	(1.94)	(−16.41)	(1.67)	(−10.99)
Africa (c.f. Latin America)	−1.006***	2.248***	−0.623***	2.123***	−0.735***
	(−11.77)	(6.42)	(−10.54)	(6.02)	(−13.01)
Constant	7.237***	10.305***	5.621***	12.509***	5.995***
	(36.93)	(10.33)	(30.7)	(9.39)	(51.76)
LNS 1 constant	0.365***		0.151**		−0.441***
	(5.59)		(2.01)		(−8.00)
Site 1 constant	0.626***	1.764***	0.485***	−0.948***	0.393***
	(34.31)	(9.8)	(40.97)	(−8.00)	(25.9)
Log-likelihood	−13,229	−3,473.43	−11,658.4	−1440.69	−7271.17
AIC	26,508.02	6994.86	23,366.85	2929.38	14,592.34

(*continued on next page*)

Table 5. *(continued)*

	Forest income		Environmental income		Total income
	Absolute	Relative	Absolute	Relative	
BIC	26,680.62	7160.55	23,539.45	3095.07	14,764.94
N (households)	7360	7360	7360	7360	7360
N (sites)	56	56	56	56	56

[a] *t*-values in parentheses.
[b] All models estimated as generalized linear and latent mixed models (gllamm) in Stata 12.1. Relative forest and environmental income are estimated as fractional logit multilevel models.
[*] Indicates level of significance at the 10% level.
[**] Indicates level of significance at the 5% level.
[***] Indicates level of significance at the 1% level.

(v) *Location*

We included two variables related to the location of households: distance to the forest, and to the village center, both measured in hours of walking. Surprisingly, households located close to forests do not have significantly higher absolute or relative forest income. However, the simple Pearson correlation coefficient between distance to forest and both forest income and forest reliance are −0.12. This suggests that households living close to forest have higher absolute and relative forest income, but that this effect disappears once controlling for differences in other characteristics that change with location.

Households located close to the village center tend to have higher absolute forest and environmental incomes, possibly reflecting better market access and higher prices of forest products. The simple correlation between total income and distance to village center is close to zero, and also by controlling for other factors in the regression analysis the coefficient for distance to village center in the model with total income as the dependent variable is insignificant.

(vi) *Site-level economic factors*

To mirror intra-site level asset effects, we included site level means for major assets to control for structural differences in development across sites. More agricultural land at the site-level is—all else being equal—associated with higher total income, and lower absolute and relative forest income. We observe the opposite pattern for livestock; more livestock is associated with lower income and higher relative forest income. Absolute environmental income tends to decline with more agricultural assets. “Other assets”, which is a good proxy for the wealth of the site, are associated with higher forest, environmental and total income, as well as higher environmental and forest income shares. This may reflect the influence of high-value forest products in some sites, and is in line with the earlier findings of a strong positive correlation between total income and absolute forest and environmental income.

We find that inequality as measured by the Gini coefficient is negatively correlated with forest and environmental incomes (both absolute and relative ones), but positively correlated with total income. In other words, sites with high use and reliance on environmental resources, including forests, tend to have lower inequality. The intra-site income equalizing effect of environmental income discussed earlier thus also seems to hold when comparing sites. A similar pattern of significance is observed for market integration: sites with high degrees of market integration (share of cash income in total income) tend to have lower use and reliance on the natural environment.[30] As expected, we observe a positive and significant relationship between market integration and total income.

5. DISCUSSION

Our findings underscore the significant role played by natural environments in the livelihoods of rural households in developing countries. Forests provide an average annual household income of $US 440 at our sample sites, representing 22.2% (21.1% from forest environmental income, 1.1% from forest plantations) of total household income. Non-forest environmental income adds another $US 86 (6.4%) bringing the total environmental income contribution to $US 508 or 27.5% (i.e., not including forest plantation income). While forest income is the primary contributor to total environmental income, non-forest environmental income also plays an important role in rural livelihoods confirming the findings of seminal environmental income studies (e.g., Cavendish, 2000; Metz, 1989). The households in our sample use a wide variety of products, many of which are “non-timber forest products” (NTFPs) that are likely to help meet nutritional, medicinal, utilitarian, and ritual needs (Belcher, 2003). However, in value terms, wood fuel and structural and fiber products (timber, poles, building materials, etc.) are the dominant forest products, accounting for about 60% of all forest products in value terms. Food accounts for another 30%.

Several nuanced stories emerge when we consider intra-site income relations with the data disaggregated by income quintile. First, we observe significantly higher differentiation among income groups in the reliance on forest and environmental income when we look at the sites in Africa and Asia. Second, subsistence forest reliance is much higher among the two lowest income quintiles households, compared to the highest; for cash income the pattern is the opposite. We note that causality may run both ways. High (cash) income of any kind also implies that the household is more likely to be in the top-income quintiles. But, better-off households are also more likely to have the financial capital required to produce and market high-value products (e.g., chainsaws, woodworking tools, trucks, and hired labor). Third, we find notable differences between forest and non-forest environmental incomes. For the average household in the sample, 86% of the non-forest environmental income is in the form of subsistence uses, and the Relative Kuznets Ratio for this category is 0.58 (i.e., this income share is almost twice as high for the two bottom quintiles compared to the top quintile). Thus most non-forest environmental resources appear to be more accessible for the poor as compared to forest resources. This pattern is exemplified in Pouliot and Treue (2012) for PEN sites in Ghana and Burkina Faso.[31]

Environmental and forest reliance, as measured by the relative income share, provide good indicators of the importance of that income source for a household, irrespective of the absolute income level of the household. However, it is not high-income *shares* that lift households above the poverty line, but higher *absolute* incomes. The top-income quintile has an absolute environmental income which is approximately five times higher than the environmental income of the bottom quintile. Thus, in an absolute sense the better-off households in the study sites use more environmental resources.

The distinction between absolute and relative incomes becomes critical when studies demonstrating high environmental reliance are taken further to argue that the poor are putting high pressure on the environment. To the extent that degradation of forest and other environments are the result of local forest use, it is the absolute volumes of environmental goods that are of interest. It may thus be misguided to hold the poorest households responsible for degradation that may occur, as their forest use is just a fraction of those of the wealthier households. Likewise, it would be naïve to assume that policies or project investments in forestry will necessarily benefit the poorest disproportionately.

The regression analyses yielded a number of insights as to the determinants of environmental income. In general, we find support for environmental income being more important to households with young household heads (c.f. McElwee, 2008), to large households (in contrast to Mamo *et al*., 2007 who found the opposite in their case study), and to less-educated households (e.g., Babulo *et al*., 2008; Mamo *et al*., 2007; Vedeld *et al*., 2007). We do not find support for the claim that environmental income is more important to households that are female headed (c.f. Babulo *et al*. (2008); see also Sunderland *et al*. (2014) for further discussion).

Assets play a key role in the choice of livelihood strategies (Ellis, 2000). Agricultural land and livestock are productive assets (as wells as indictors of accumulated wealth), while "other assets" are primarily wealth indicators. Within sites, productive assets are positively correlated with forest and environmental incomes, suggesting that these crop and livestock activities at the site level are largely complementary livelihood strategies (as compared to off-farm activities). "Other assets" shows a different pattern, and is closely correlated with lower forest and environmental reliance.

At the site level, this broad pattern is almost reversed. More agricultural land go hand in hand with lower relative and absolute forest income. This suggests that at the site (or landscape) level agriculture and forestry are alternative development and specialization pathway patterns and bring hard land-use trade-offs much more to the forefront than when we look at intra-site household differences: agricultural expansion takes place at the expense of forest cover in the area, which reduces forest income (as most of the income is from forest land accessible to all in the community). This reduction is an aggregate effect of individual household expansion, and will therefore only be observed at higher levels of aggregation. Also, agricultural expansion and development happens in conjunction with development of transport and market infrastructure. Intensively managed perennial crops are a better investment for a household if the context supports it.

6. CONCLUDING REMARKS

This study represents a global overview of a large dataset that promises to yield much more nuanced findings, as the data are disaggregated geographically and by substantive topic. Our analysis confirms that the environment—i.e., natural forests and other natural areas, play a critical role in rural livelihoods, with more than one quarter of household income in our sample coming from these sources. Failing to account for this contribution would give a misleading picture of rural livelihoods, and provide an inadequate basis for policy design. In terms of rural areas in developing countries, with similar characteristics to those included in the PEN study, ignoring environmental income in socioeconomic surveys and in rural development planning is quantitatively analogous to ignoring the fact that rural people grow crops.

Previous studies have highlighted the important role of forest and environmental incomes for the poor and vulnerable. Overall, we find that environmental income shares are higher for the poorest households; more so when we look at subsistence uses and incomes from non-forest environments. The income profile differs between specific forest and environmental products, pointing to the need for more disaggregated analysis to capture important differences in settings. Further, we have argued that only considering relative environmental incomes ("environmental dependency" or "reliance") can be misleading, both when considering poverty dynamics and any unsustainable local uses. The higher environmental reliance among the poor has often been used to blame the poor for environmental degradation. Our results do not distinguish detailed products and their context-specific sustainability of extraction, but broadly households in the highest income quintile have absolute environmental and forest incomes that are about five times higher than the two bottom quintiles. This implies that local income growth and poverty alleviation probably do not automatically take pressure off natural resources.

Agricultural area expansion into forests and other vegetation types may increase household incomes. Yet, while we have not gathered any geo-referenced data on extraction densities from specific areas, the corresponding forest income losses could in some cases be larger than previously assumed. In the current debate on the role of forests in climate mitigation, our findings suggest that there are important local benefits of maintaining forest cover and that the potential for both climate mitigation and livelihood benefits might be larger than often assumed. But the type of policy intervention clearly matters. Limiting the poor's access to natural resources through exclusionary conservation policies could jeopardize the livelihoods of local people considerably.

NOTES

1. Ambrose-Oji (2003), Appiah et al. (2009), Babulo et al. (2008), Babulo et al. (2009), Campbell and Luckert (2002), Cavendish (2000), Fisher (2004); Homewood (2005), Jagger (2010), Jagger (2012), Kaimowitz (2003), Kamanga, Vedeld, and Sjaastad (2009), Mamo, Sjaastad, and Vedeld (2007), Paumgarten (2005), Pouliot and Treue (2012), Pouliot, Treue, Darko Obiri, and Ouedraogo (2012), Shackleton, Shackleton, Buiten, and Bird (2007), Tieguhong and Nkamgnia (2012),and Yemiru, Roos, Campbell, and Bohlin (2010).

2. Adhikari, Di Falco, and Lovett (2004), Dewi, Belcher, and Puntodewo (2005), Fu et al. (2009), Illukpitiya and Yanagida (2008), McElwee (2008), Narain, Gupta, and Van't Veld (2008), Rayamajhi, Smith-Hall, and Helles (2012), Reddy and Chakravarty (1999), Soltani, Angelsen, Eid, Naieni, and Shamekhi (2012), and Viet Quang and Nam Anh (2006).

3. Coomes, Barham, and Takasaki (2004), Escobal and Aldana (2003), Gavin and Anderson (2007), Godoy et al. (2002), McSweeney (2002),

McSweeney (2004), Pattanayak and Sills (2001), Takasaki, Barham, and Coomes (2001), and Uberhuaga, Smith-Hall, and Helles (2012).

4. Babulo et al. (2009), Jagger (2010), Kamanga et al. (2009), McElwee (2008), Narain, Gupta, and Van't Veld (2008), Rayamajhi et al. (2012), Tieguhong and Nkamgnia (2012), Uberhuaga et al. (2012), and Yemiru et al. (2010).

5. The term "safety net" refers to a mechanism preventing poor households from falling into even deeper poverty.

6. The PEN research tools (the prototype questionnaires and the associated technical guidelines; the template for data entry; the code book; and the data cleaning procedures) can be downloaded from the PEN web site (http://www.cifor.org/pen/). Prototype questionnaires are available in English, French, Spanish, Portuguese (Brazilian and Mozambican), Chinese (Mandarin), Nepalese, and Khmer. Students and researchers are encouraged to use these tools, with proper acknowledgment to PEN and CIFOR.

7. A comprehensive guide to fieldwork and research methods based on the PEN experience is published in Angelsen, Larsen, Lund, Smith-Hall, and Wunder (2011).

8. Quarterly income surveys with short recall periods were designed to yield improved precision and accuracy, and to account for seasonal variation in income generating activities as compared to one-off income surveys with one-year recall (Jagger et al., 2012). The recall period for forest, other environmental, wage and business income was one month, which we then extrapolated to a three-month period. For agricultural income (i.e., income from cropping and livestock) and "other income" (remittances, pensions, etc.), three-month recall was used. These are typically larger, distinctly defined, and more regular income sources, making them easier to remember (Campbell et al., 2002; Rayamajhi & Olsen, 2008).

9. Our sample originally included 8305 households. Due to attrition during the course of the quarterly data collection, our sample was reduced to 7978 households. Households left the sample for a variety of reasons including marriage, death or illness, division or formation of new households, and temporary or permanent migration. We find no systematic bias in our sample among those households that we dropped from the sample.

10. This is the number of households for which we have complete income data. The sample size in the regressions models is lower, due to missing data for some explanatory variables.

11. To facilitate data collection we distinguished between *direct* (raw or unprocessed) and *derived* (processed products) forest income depending on whether value addition was involved (Sjaastad, Angelsen, Vedeld, & Bojö, 2005).

12. Overall, 4.1% of forest income is from tree plantations.

13. There is a range of methods for calculating adult equivalents (Deaton, 1997), but most analyses are robust to different AE formulas (Haughton & Khandker, 2009). We therefore follow the rather simple formula used in many World Bank analyses, and as a variant of the OECD scales (Atkinson, Rainwater, & Smeeding, 1995): children below 15 years and adults above 65 years are assigned a weight of 0.5, while all other household members (15–65 years) are assigned a weight of 1.

14. See PENN World Tables, ver. 7.0 http://pwt.econ.upenn.edu/php_site/pwt_index.php.

15. The term Kuznets ratio is named after Simon Kuznets (1953), who compared the ratio of *total* income of the top 20% to total income of the bottom 40% as a measure of income inequality. Our measure therefore differs from the original Kuznets ratio in two ways: we use income from only one sector, and we use it also for income shares.

16. We chose to estimate a two-level model with households nested within sites. Estimating a three-level model with households, villages, and sites would have been ideal but we were limited by small sample sizes for some villages.

17. Large numbers of predictors and multiple group levels limits the complexity of a multilevel model, such that not all potentially relevant relationships are explored using the global data set. Separate estimation of regression models for each PEN site may enrich the lessons learned from a global analysis, but the global focus of the paper limits presentation of such analyses.

18. Potential pitfalls for causal inference from multilevel models arise from possible correlations between individual-level predictors and group-level errors (Wooldridge, 2001). To allow for such correlation, group level averages of individual predictors can be used as additional group level predictors, but the group level coefficient of this new "contextual predictor" may then be misinterpreted as a causal relationship (see, for example, Wakefield (2003) or Hox (2010) on the "ecological fallacy").

19. All models were estimated using the "gllamm" command in Stata v. 12 (Gelman & Hill, 2006; Rabe-Hesketh & Skrondal, 2008).

20. A forest user group (FUG) is defined as an organized group of people who use and maintain a forest, and who share the same rights and duties to products and services from the forest. The definition presupposes some forest with collective property rights, i.e., a FUG cannot exist—according to our definition—if all forests are privately owned. The group may or may not be formally organized, but a minimum level of organization is required, including regular meetings. It may have originated through customary law, or may have been established through outside interventions, e.g., by NGO or government. Examples of FUGs are groups specifically designed for community forest management, producer organizations that include forest products in their portfolio, grazing associations, and natural resources committees within a formal village structure (CIFOR, 2007).

21. The three asset variables included (agricultural land, livestock and other assets) explain 57% of the variation in mean site income (using a simple OLS regression model). Within sites, the three asset variables are still highly significant, but explain less of the income variation observed (19%).

22. For example, the agricultural land area of a household is subtracted the site mean and divided by the standard deviation, such that variable for a particular site has a (0, 1) distribution.

23. Similar to income, all asset variables (except education) are per adult equivalent units, and are also log of PPP adjusted values at the site-level.

24. As noted, these shares are calculated as "triple averages". The simple mean of forest income shares for the full sample is slightly lower (20.6%), which suggest that the smaller site-samples tend to have higher forest reliance.

25. An elasticity for absolute forest (environmental) income of one implies an elasticity of relative income of zero.

26. The ratio for total income is included as a point of reference; at the average site the top 20% has a PPP-adjusted income per AE that is 7.6 times higher the bottom 20% of the households.

27. The models should be interpreted simultaneously. For example, relative forest income is total forest income divided by total income; hence it is useful to investigate if an impact of a particular variable on relative forest income is due to a change in absolute forest income or in total income.

28. Although aquaculture is included in livestock income, we made no attempt to include the fish stock in the livestock asset variable (TLU).

29. Labor shocks often also imply an immediate income loss and/or higher expenditures, while asset shocks can be seen as a loss of long-term income loss.

30. The Pearson correlation between the Gini coefficient and market integration is 0.12.

31. The dominant environmental product in Burkina Faso, shea nuts, is almost exclusively collected outside forests in parklands and is readily available.

32. This analysis was restricted to the tropical zone; PEN cases from outside the tropics were excluded.

33. For a household not participating in, for example, the second quarter survey, the formula is: $h_2 = ((h_1 + h_3 + h_4)/3) * ((V_2 * 3)/(V_1 + V_3 + V_4))$, with h_i being the household income in quarter *i*, and V_i the average village (or site) income in quarter *i*. We also experimented with more sophisticated imputation methods, but results were close to the simple formula used. For villages with few sampled households, we used site averages instead of village averages.

34. Subsistence fuel wood unit prices are difficult to estimate (Wunder et al., 2011) and are typically not reported in the literature or standard databases such as FAOSTAT.

35. Subsistence fuel wood consumption is highest in areas with high forest cover, fuel wood access, lack of alternative energy sources, cold climatic seasons, use of open fires, and culturally determined uses of fuel wood, e.g., for religious celebrations. In such locations, for example, in the Himalayas (Metz, 1994) or Northern China (Démurger & Fournier, 2011), annual subsistence fuel wood consumption per capita may approach 2000 kg dry weight. This was used as the upper limit in the PEN global database.

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APPENDIX A. SUPPLEMENTAL INFORMATION ON THE POVERTY ENVIRONMENT NETWORK (PEN) GLOBAL DATA

A.1 *PEN study areas and their representativeness*

We assessed the overall representativeness of the PEN study sites at two scales. We first compared the regions from which cases were selected using administrative jurisdictions equivalent to the "province" level (Dewi, Belcher, & Puntodewo, 2011). Forest cover and population density are useful indicators of development and have a strong correlations with forest use. Areas with higher forest cover tend to have higher forest resource availability, lower agricultural production, and limited access to off-farm employment. Areas with higher population density tend to have more developed markets and more off-farm employment. We used global population and forest cover data to map provinces from throughout the tropics along these two dimensions: forest cover and population density (Figure 4). As expected, we observe a negative correlation between forest cover and population density. The PEN study areas are located along the full range of forest cover in the countries where PEN studies were carried out, and to a large extent also along the population density distribution, though the PEN sample does not include cases from provinces with extremely high population density. Overall, the PEN study areas are fairly well distributed, but as expected, there is some bias toward areas with relatively high forest cover.

Provinces are much larger than the PEN study sites, so we did a more detailed analysis of representativeness (Dewi & Belcher, 2012). We compared PEN villages, defined as 10,000-ha circles centered on each PEN village, with 15,000 pseudo-villages, defined as 10,000-ha circles centered on randomly generated points from throughout the tropics.[32] Mean population density was not significantly different between the PEN villages and pseudo-villages. However, PEN villages tend to be located closer to protected areas, and have higher mean forest cover than the random villages.

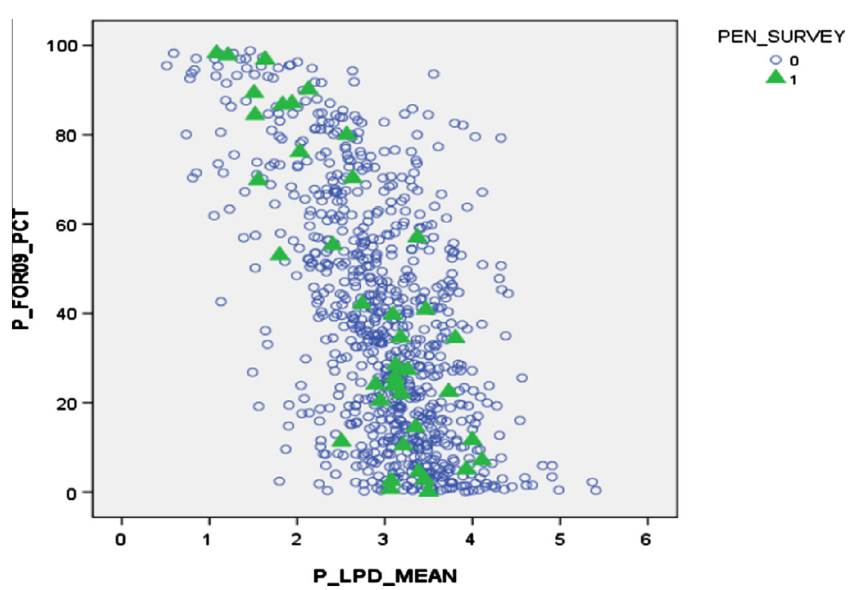

Figure 4. *PEN study areas located by forest cover and population density. (Source: Dewi & Belcher, 2012)*

A.2 *Data cleaning and aggregation*

Cleaning and aggregating data for the global dataset was a significant endeavor. Data submitted by PEN partners underwent centralized data cleaning and quality control processes to identify missing data, inconsistencies, and outliers. Three datasets that did not meet the quality criteria were rejected. We refer to Babigumira (2011) and Lund, Shackleton, and Luckert (2011) to describe the efforts that were made before, during, and after data collection to minimize data defects in terms of accuracy, completeness, and consistency. The resultant dataset was a major project output. For the approved datasets a number of data issues were addressed. We highlight the three most important below:

Missing quarters: Households that missed two or more quarterly surveys were dropped from the dataset. For households participating in three out of the four quarterly surveys, we used a simple formula to impute income from the missing quarter: income is the product of the average household income in the three sampled quarters and a seasonal adjustment factor (based on the seasonal variation found among other households in that particular village or site).[33] The imputation was done for sectoral income (split by cash and subsistence), but not for individual crops or forest products.

Missing prices: Some products were consumed directly with no market exchange by the household, making pricing challenging (Wunder, Luckert, & Smith-Hall, 2011). Based on the PEN guidelines (CIFOR, 2007), partners were encouraged to use the following methods (in rough order of priority): local market prices; barter values (if products were exchanged with market products); price of substitutes; asking about willingness to pay; distant market prices (adjusted to deduct transport costs); and, valuation of time. If prices were still missing, average village prices were used, calculated on a quarterly basis to accommodate any seasonal variation. In cases where there were less than five data points at the village-level, site-level price data were used.

Fuel wood prices and quantities: Fuel wood emerged as the most important forest product (in value terms) for most sites, so we took extra care in the quality checking of those data and identifying outliers. A first challenge was to apply homogenous units and correct conversion factors, done in close consultation with partners. We then identified remaining suspicious cases where prices were either high or low, and quantities for subsistence use high. After reviewing the literature and similar studies (e.g., Bandyopadhyay & Shyamsundar, 2004; Kituyi *et al.*, 2001; Rayamajhi & Olsen, 2008) the rural fuel wood price band was set to PPP $US 0.01—0.15 per kg dry wood in the PEN global database.[34] A ceiling for subsistence consumption of fuel wood was set to 2000 kg dry wood per year per adult equivalent, or about 5.5 kg per day.[35] Overall, these adjustments reduced fuel wood income by approximately 11%. For other forest and agricultural products, we systematically checked for outliers and held consultations with PEN partners to identify the reasons, and made necessary corrections.

APPENDIX B. DESCRIPTIVE STATISTICS FOR REGRESSION MODELS

Table 6. Summary statistics for variables used in regression models

Variable name	Mean	Standard deviation	Min	Max
Household-level variables ($N = 7360$)				
Household size, adult equivalents	4.08	1.95	1	20
Age of household head, years	45.67	14.46	14	111
Female-headed household, share	0.12	0.32	0	1
Education of household head, years	4.06	4.02	0	18
Agricultural land owned, hectares	1.23	3.04	0	106
Tropical livestock unit owned, TLUs	0.99	2.33	0	62
Value of assets, $US PPP	488.68	2171.62	0	79,713
Household experienced income shock, share	0.11	0.31	0	1
Household experienced asset shock, share	0.05	0.23	0	1
Household experienced labor shock, share	0.12	0.33	0	1
Member of forest user group, share	0.27	0.44	0	1
Distance to forest, hours walking	0.57	0.71	0	5
Distance to village center, hours walking	0.38	0.53	0	5
Site-level variables ($N = 55$)				
Agricultural land owned, hectares	1.25	1.32	0.06	6.58
Value of tropical livestock unit owned, TLUs	1.06	1.13	0.03	6.26
Value of assets, $US PPP	556.63	915.03	1.35	5029
Gini coefficient	37.88	9.60	16.45	62.29
Market integration, % of cash/total income	59.66	16.08	25.83	91.47
Village forest privately owned, share (c.f. state)	0.13	0.24	0	0.94
Village forest community owned, share (c.f. state)	0.38	0.40	0	1
Africa, % (c.f. Latin America)	0.38	0.49	0	1
Asia, % (c.f. Latin America)	0.49	0.50	0	1