Natural resource extraction and household welfare in rural Laos

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Abstract:

Human induced degradation of land due to over-extraction of water and forest resources is a threat to sustainable development in many developing countries. Solving this requires an understanding of the factors affecting the extraction and its impacts on rural welfare. In this study, we determine the factors affecting the extraction of and dependence on forest and water resources and examine the impacts of the extraction on rural household welfare in Laos. We address our research questions with an econometric framework that models the extraction and its implications simultaneously. We use the data of 430 rural households from a survey undertaken in 2013 in 38 villages of Savannakhet province. Our findings show that extraction is a shock-coping strategy of rural households but contributes to reducing household income inequality. For extracting households, extraction increases household income, consumption and food security. However, for non-extracting households, although extraction would increase food security, it would reduce their income and consumption. We suggest that promoting rural education and off-farm employment opportunities, enhancing investments in physical infrastructure, and developing livestock rearing would reduce the extraction of and the dependence on the resources of extractors and prevent non-extractors from being forced to extract the resources.

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ABSTRACT

Human induced degradation of land due to over-extraction of water and forest resources is a threat to sustainable development in many developing countries. Solving this requires an understanding of the factors affecting the extraction and its impacts on rural welfare. In this study, we determine the factors affecting the extraction of and dependence on forest and water resources and examine the impacts of the extraction on rural household welfare in Laos. We address our research questions with an econometric framework that models the extraction and its implications simultaneously. We use the data of 430 rural households from a survey undertaken in 2013 in 38 villages of Savannakhet province. Our findings show that extraction is a shock-coping strategy of rural households but contributes to reducing household income inequality. For extracting households, extraction increases household income, consumption and food security. However, for non-extracting households, although extraction would increase food security, it would reduce their income and consumption. We suggest that promoting rural education and off-farm employment opportunities, enhancing investments in physical infrastructure, and developing livestock rearing would reduce the extraction of and the dependence on the resources of extractors and prevent non-extractors from being forced to extract the resources.

KEY WORDS: Sustainable Livelihoods Framework, environmental income, endogenous switching regression, counterfactual analysis, Laos

INTRODUCTION

Poverty, food insecurity and natural resource degradation remain central development challenges (Bansel, 2008). According to the Food and Agriculture Organization (FAO, 2013), about 842 million people (or about 12% of the world's population) were experiencing chronic hunger in 2011; and the majority of these people reside in rural areas of developing countries, where many of their essential goods are derived from water and forest resources. The extraction of the resources in these rural areas is often considered a means of livelihoods (Wunder et al., 2014). There is evidence that the poor depend more on the resources than the non-poor (Kaburo-Mariara, 2013). As the resources are increasingly degraded (Angelsen et al., 2014), it is likely that the poor are hurt more. In addition, rural residents in the developing world are exposed and vulnerable to various types of shocks due to their inadequate shock coping capacity (Barrett & Santos, 2014). This leads to an increase in the extraction of and in the dependence on the resources. Over-extraction of forest and water resources brings serious consequences regarding degradation of land, forest, and water as well as deterioration of rural livelihoods. Thus, a deep understanding of the roles of the resources to rural livelihoods, the factors affecting the extraction and dependence, and the impacts on rural welfare is relevant for successful rural development and conservation initiatives.

Lao People's Democratic Republic (hereafter as Laos) is characterized by a low Gross Domestic Product (GDP), a high poverty incidence, and a high dependence on forest and water resources (Martin & Lorenzen, 2016). The national forests have declined dramatically (Forest Trends, 2014). In terms of water resources, 80% of the country's area lies within the Mekong River Basin. Forestland and water tenure is extremely insecure as forestland and water surface are claimed as state-owned property (Lund, 2011). While the government does not have sufficient human power for effective management of these resources, the rural residents who depend on the resources for much of their livelihoods have no legal access to the resources. As a consequence, they simply exploit the resources for survival, in contravention of the prevailing regulations (WWF, 2015; Parvathi & Nguyen, 2018).

Our study addresses the following questions: (i) what are the factors affecting forest and water resource extraction and dependence of rural households? and (ii) what are the impacts of forest and water resource extraction on rural household welfare? Our contributions to the current literature are: (i) Although the importance of forest and water resources to rural households in many other developing countries has been documented (see Angelsen et al., 2014), this remains unknown in Laos (Lestrelin & Giordano, 2007); (ii) most of previous studies ignore the fact that some rural households do not often need to extract natural resources for their livelihoods. Yet, they might be forced to do so in specific circumstances (e.g., when they are facing an unexpected income loss due to shocks). Thus, understanding the factors forcing these households to extract and their welfare changes would be useful in designing effective rural development and conservation strategies; and (iii) methodologically, most welfare impact studies account only for observable selection bias. In this study, we use a Heckman regression model and an endogenous switching model to control for both unobservable and observable selection bias. In addition, we also conduct a counterfactual analysis to examine the impacts of the extraction on household income, consumption and food security as welfare indicators of both resource extractors and non-extractors. To our understanding, this is one of the first efforts to account for both observable and unobservable selection bias in determining the welfare impacts of natural resource extraction. In this regard, we address our research questions with an econometric framework that models the extraction and its implications simultaneously.

CONCEPTUAL FRAMEWORK AND DATA COLLECTION

Conceptual framework

We use the Sustainable Livelihoods Framework (Ashley & Carney, 1999) to describe the livelihoods of a rural household. The framework includes three components: platforms, strategies and outcomes (Figure 1). The livelihood platforms consist of natural capital (e.g., land), physical capital (e.g., equipment), human capital (e.g., education), financial capital (e.g., assets), and social capital (e.g., social networks). These different types of capital are the platforms for a household to choose its livelihood strategies, which include different activities such as natural resource extraction (e.g., collecting forest products and fishing), farming (e.g., crop production), non-farm self-employment (e.g., cottage industry or small-scale trade), and off-farm wage employment. The selected livelihood strategies lead to a specific set of livelihood outcomes (e.g., income, consumption, and food security).

(Insert Figure 1 here)

Figure 1. Conceptual framework for the study

As noted by Dokken and Angelsen (2015) and Nguyen et al. (2015), the contributions of natural resources to rural livelihoods can be classified into three major channels: (i) supporting consumption and subsistence needs of the rural population (Kaburo-Mariara, 2013), (ii) serving as a safety net to overcome an unexpected income loss or high expenditure (Debela et al., 2012), and (iii) providing a pathway out of poverty via regular cash income provision (Shackleton et al., 2007). Two well-established patterns regarding natural resource extraction in developing countries are: (i) rural households depend to a certain extent on the resources (Cavendish, 2000), and (ii) the poor depend more on the resources than the non-poor (Kaburo-Mariara, 2013). Yet, there is evidence that some households extract the resources only in certain circumstances (Barbier, 2010). Thus, understanding under which circumstances these households must extract the resources (e.g., facing shocks as in Figure 1) and their welfare changes would also be useful, as we know when rural households switch on and off natural resource extraction and its implications.

Study site and data collection

Our field work was conducted in Savannakhet province of Laos (Figure 2). This province was selected because the majority of the rural population depends on agriculture and extraction of forest and water resources for their livelihoods (Parvathi & Nguyen, 2018). Savannakhet has a total land area of 21,774 km^2 and is rich forests and rivers. The forest cover of the province is about 52% of the total land area, a reduction from 60% in 2005 (IUCN, 2011). In addition, many rivers flow across the province and provide important habitat for aquatic species. The province can be divided into three regions: the Mekong in the west, the Lowland between the east and the west, and the Mountain in the east. Economically, the Mekong region is better-off since it borders Thailand whereas the Mountain region is worse-off.

(Insert Figure 2 here)

Figure 2. Laos (left) and of Savannakhet province (right), where the study villages are indicated

Our data collection follows the guidelines of the United Nations Department of Economic and Social Affairs (UN, 2005). In the first step, 46 villages in all three regions of the province (Mekong, Lowland, and Mountain) were selected with selection probability proportional to size measured as the number of households in the village. In the second step, 15 households in each selected village of the Mekong and Lowland regions, and 10 households in each selected village of the Mountain region were randomly sampled because the village size of the Mountain region is smaller than that of the other two regions.

We used two questionnaires with structured interviews for data collection. The household questionnaire contains sections on education and health status of household members, on income generating activities; and on household consumption. A separate section is on resource extraction (fishing, hunting, collecting, and logging). These extraction activities were recorded along with information on types of products, places of extraction, distance to home and markets, intensity and cost of extraction (e.g., fuels and materials), the quantity and value of total outputs for sales and for home consumption. Furthermore, a comprehensive food security section measuring household dietary diversity and calorie intake using one-week recall method was applied. In addition, a shock section recorded all shocks that the households faced during the last three years that led to an increase in household expenditure or a decrease in household income. These shocks include weather shocks (floods, droughts, unusually heavy rains, and storms), health shocks (illness of household members), market shocks (output price decrease or input price increase), and other shocks (theft, job loss). The village questionnaire captures village data on population, physical infrastructure, and public transport to the village. The data collection was conducted in April and May 2013. Our sampling procedure resulted in a sample of both rural and peri-urban villages. For this study, we excluded all of eight peri-urban villages. The residents of these peri-urban villages mainly work either as staff of governmental institutions or as traders of various types of goods. Thus, our final sample includes 430 households in 38 rural villages.

METHODS

Determining the factors affecting the extraction and dependence

Two regression models are used to assess the factors affecting (i) the extraction, and (ii) the dependence. We divide our sample into two groups based on whether the households participate in the extraction of wild or uncultivated forest and water resources, namely the extracting group and non-extracting group. We follow Sjaastad et al. (2005) and Angelsen et al. (2014) to define the income from these extraction activities as "environmental income". Thus, the absolute environmental income is the net income from these extraction activities and represents the level of extraction; the relative environmental income is the share of the environmental income in total household income (in %) and represents the level of dependence. These are the dependent variables in these two regression models. As the non-extracting group does not have environmental income, the absolute environmental income of the sampled households is continuous and greater than or equal to 0, whereas the relative environmental income is between 0 and 100%. This specific characteristic of the data is appropriate for the Heckman model (Heckman, 1979). Therefore, these two models are run in a two-step procedure. In the first step, the decision to participate in the extraction is explained in a Probit model. Let S^* be the variable that indicates whether a household participates in the extraction (selection model):

$$S_i^* = \alpha Z_i + u_i \qquad \text{with } S_i = 1 \text{ if } S_i^* > 0 \text{, and } S_i = 0 \text{ otherwise} \qquad (1)$$

In the second step, the environmental income is modelled only for the extracting households (outcome model):

$$E_i = \beta Z_i + \varepsilon_i \qquad \text{only if } S_i = 1 \qquad (2)$$

where E_i is either the absolute or relative environmental income of household i. Z represents the variables that affect the selection and income of the extraction.

The independent variables (Z) are identified based on the Livelihoods Framework (Figure 1). Natural capital is represented by the average distance to the extracting grounds, and agricultural landholding of the household. Human capital is represented by household dependency ratio, education level, gender, and age of the household head. Physical capital includes the number of Tropical Livestock Units (TLU). TLU is a measure to convert different types of livestock into one standardized unit based on cattle equivalent with a body weight of 250kg. Financial capital is represented by the value of durable assets and whether the household has off-farm income. Social capital is represented by whether the household uses a mobile phone. Finally, most of our interviewees responded that they needed three years to recover from shocks. Thus, the number of shocks experienced by the household during the last three years is included as it can be a factor that forces rural households to extract forest and water resources. At the village level, two dummy variables are included: a dummy variable of whether a river runs through the residential area of the village, and another dummy variable if the village is physically accessible with motorbikes during the whole year. As the province consists of three regions, two additional dummies are used to take into account other regional heterogeneities that are not included by these household and village variables (see Table S1 in the Supporting Information (SI) section). Our independent variables are thus at the household, village, and regional levels. Equations (1) and (2) are estimated simultaneously using the maximum likelihood estimation and account for a correlation of u_i and ε_i (see Tables S1, S2, S3 for multicollinearity, normality, and homoscedasticity tests). Taking into account the potential problem of spatial correlation, the standard errors are clustered at the village level.

Examining the impacts of extraction on household welfare

We use daily per capita household income and consumption and food consumption score to represent household welfare. Household income is net income from crop production, livestock rearing, off-farm employment, self-employment, resource extraction (environmental income), financial transfers, and capital income. Household consumption includes the expenditures for food, non-food items, health care, education, transport and communication, and social activities. All values are in 2005 PPP$. For household food security, we consider only the Food Consumption Score (FCS). FCS is a composite score based on dietary diversity, food frequency, and relative nutritional importance of different food groups (WFP, 2008). We also use three Foster-Greer-Thorbecke (FGT) indices to determine the poverty status of a household, namely the headcount index, poverty gap, and poverty severity (threshold value of 2 PPP$ per day). Income inequality is examined using the Gini coefficient and Lorenz curve method.

Similar to the Heckman model in Equations (1) and (2), the participation in the extraction and its implication in terms of household welfare are modelled in a two-stage procedure. In the first stage, we use a Probit (selection) model for the participation 1:

$$I_i^* = \theta Z_i + \varphi_i, \qquad I_i = 1 \text{ if } I_i^* > 0, \text{ and } I_i = 0 \text{ otherwise} \tag{3}$$

that is household *i* chooses to participate in the extraction if $I_i^* > 0$, and 0 otherwise.

In the second stage, we model the impacts of the extraction on the welfare indicators. The simplest approach would be to include in the welfare equations a dummy variable equal to one if the household extracts forest or water resources, and then apply the Ordinary Least Squares (OLS) estimation. This approach, however, might yield biased estimates because it assumes that participation in the extraction is exogenously determined while it is potentially endogenous as shown in Equations (1) and (3). This endogeneity of the extraction is accounted for by estimating a simultaneous equation model. Assume that a household faces two regimes: (1) to extract, or (2) not to extract defined as follows:

$$\text{Regime 1: } y_{1i} = \gamma_1 X_{1i} + \epsilon_{1i} \qquad \text{if } I_i = 1 \tag{4a}$$

$$\text{Regime 2: } y_{2i} = \gamma_2 X_{2i} + \epsilon_{2i} \qquad \text{if } I_i = 0 \tag{4b}$$

where y_i is one of the welfare indicators and *X* represents a vector of variables included in *Z* defined in Equations (1) and (3).

For this model to be identified, a selection instrument needs to be included. Di Falco et al. (2011) note that a variable can be used as a valid exclusion restriction, if it affects the selection of a particular strategy in the Probit equation (extraction or not), but does not affect the welfare outcome equation of those households who do not extract. Thus, we include the average distance to the extracting ground (variable *envidist* in Table S1) as our exclusion restriction (see Table S4 for our test). This endogenous switching regression model allows us to compare the expected welfare of the households that extract (a) with respect to the households that do not extract (b), and to investigate the expected welfare in the counterfactual cases (c) that the extracting households would not extract, and (d) that the non-extracting households would extract (households switch on and off). The conditional expectations for household welfare in the four cases are:

$$\mathrm{E}(y_{1i}|\mathrm{I}_i = 1) = \gamma_1 X_{1i} + \sigma_{1\varphi} \frac{f(\theta Z_i)}{F(\theta Z_i)} \tag{5a}$$

$$\mathrm{E}(y_{2i}|\mathrm{I}_i = 0) = \gamma_2 X_{2i} - \sigma_{2\varphi} \frac{f(\theta Z_i)}{\{1-F(\theta Z_i)\}} \tag{5b}$$

$$\mathrm{E}(y_{2i}|\mathrm{I}_i = 1) = \gamma_2 X_{1i} + \sigma_{2\varphi} \frac{f(\theta Z_i)}{F(\theta Z_i)} \tag{5c}$$

$$\mathrm{E}(y_{1i}|\mathrm{I}_i = 0) = \gamma_1 X_{2i} - \sigma_{1\varphi} \frac{f(\theta Z_i)}{\{1-F(\theta Z_i)\}} \tag{5d}$$

where $\sigma_{1\varphi}$ is the covariance coefficient between ϵ_{1i} and φ_i, $\sigma_{2\varphi}$ is the covariance coefficient between ϵ_{2i} and φ_i, *F(.)* is a cumulative normal distribution function, and *f(.)* is a normal density distribution function. Cases (5a) and (5b) represent the actual expectations observed in the sample. Cases (5c) and (5d) represent the counterfactual expected outcomes. We calculate the average effect of regime "to extract" on the treated (ATT) as the difference between (5a) and (5c):

$$ATT = \mathrm{E}(y_{1i}|\mathrm{I}_i = 1) - \mathrm{E}(y_{2i}|\mathrm{I}_i = 1) = (\gamma_1 - \gamma_2)X_{1i} + (\sigma_{1\varphi} - \sigma_{2\varphi}) \frac{f(\theta Z_i)}{F(\theta Z_i)} \tag{6a}$$

which represents the effect of extraction on household welfare of the households that actually extract. Similarly, we calculate the average effect of regime "to extract" on the untreated (ATU) for the households that do not extract as the difference between (5d) and (5b) as follows:

$$ATU = \mathrm{E}(y_{1i}|\mathrm{I}_i = 0) - \mathrm{E}(y_{2i}|\mathrm{I}_i = 0) = (\gamma_1 - \gamma_2)X_{0i} + (\sigma_{1\varphi} - \sigma_{2\varphi}) \frac{f(\theta Z_i)}{\{1-F(\theta Z_i)\}} \tag{6b}$$

RESULT

Household livelihoods and resource extraction

Tables S5 to S13 presents the main characteristics of the sampled households and villages. At the household level, the farmland size, age of household heads, household dependency ratio, the number of TLU, and the share of the households with off-farm income are not statistically different between these two groups. The extracting group, however, has a shorter distance to the extracting ground, a higher share of male-headed households, a lower education level of household heads, a lower asset value, a lower share of mobile phone use, and a higher number of shocks (Tables S5, S6). The extracting group also has a lower level of income and consumption. Overall the extraction of forest and water resources contributes about 8% to the annual household income of the extracting group (Table S7). With the threshold of 2 PPP$ per capita per day, poverty seems still popular in the study area. The extracting group has higher levels of poverty (Table S8) and food insecurity (Table S9).

Various types of forest and water resources are extracted. Fish, vegetables and fruits are extracted throughout the year by the majority of the households; and their extracting grounds are rather close to the households. Meanwhile, logging is far from home but the extracted value is higher (Table S10). The extracted products are used both for sales and for home consumption. Whereas wood has a higher value for sales, the other extracted products are used more for home consumption. Regarding income inequality, our results show that environmental income contributes to reducing income inequality among rural households (Figure 3). Excluding the environmental income the household income inequality, calculated with the Gini coefficients, would increase by 2.5% (Table S11). This suggests that the resources play an important role in equalizing household income differences.

(Insert Figure 3 here)

Figure 3. Lorenz curves of household income with and without environmental income: (a) for the whole sample and (b) for the extracting group

Environmental income is more important to the poor (Table S12). In absolute terms, the annual environmental income is smallest in the poorest quartile and highest in the richest quartile. However, in relative terms, it is highest in the poorest quartile and lowest in the richest quartile. Thus, it appears that the rich extract the resources much more than the poor because the poor are unable to undertake the activities with high returns (e.g., logging). In addition, the richest quartile has the value of wood extraction six times higher than that of the poorest one. The former also depends less on non-wood forest products than the latter (Table S13). This finding further indicates that (i) the poor mainly extract non-wood forest products while the rich mainly extract wood, and as a consequence (ii) the rich are likely to contribute more to the degradation of the resources.

Factors affecting resource extraction and dependence

The determinants of the extraction and dependence are presented in Table 1. The participation in the extraction is significantly affected by the distance to the extracting ground, gender and education level of household heads, number of TLU, off-farm employment opportunities, number of shocks, and physical accessibility to the villages. The absolute environmental income is significantly affected by the distance to the extracting grounds, farm land size, education level of household heads, household dependency ratio, asset value, number of shocks, and physical accessibility to the villages; meanwhile the relative environmental income is significantly affected by education level and age of household heads, household dependency ratio, off-farm employment opportunities, number of shocks, and physical accessibility to the villages. The higher the distance to the extracting ground, the less likely it is that the households participate in the extraction. This is plausible because of an increased opportunity cost of extraction. However, a higher distance to the extracting ground can lead to a higher absolute environmental income. This is because if one would like to hunt a game or to log (high monetary values), he must go far inside forests. If he just collects non-timber forest products (low economic values), then he does not have to go far away. Thus, the longer the distance is, the higher the absolute environmental income is. This indicates that high value resources are becoming scarcer.

Table 1. Determinants of forest and water resource extraction and dependence

(Insert Table 1 here)

The positive association between the absolute environmental income and farm land size shows that large landholders extract more. This supports our earlier finding that the poor extract less than the non-poor. This is also confirmed by the positive association between the absolute environmental income and the household asset value. Therefore, the poor should not be blamed for over-extraction of the resources. The negative association between the education level of the household heads and the absolute and relative environmental income illustrates the importance of education as a driver that reduces the extraction of and dependence on the resources. Higher education is usually associated with the possibility to engage in higher skilled jobs. This is in line with the positive effects of off-farm employment opportunities. Households with a higher dependency ratio extract and depend more on the resources. Furthermore, households who are more frequently exposed to shocks are more likely to participate in the extraction. However, the exposal to shock reduces both absolute and relative environmental income. This is probably due to the effect of shocks that the household is incapable of participating much in high-return extraction activities due to health or financial reasons. Regarding the villages characteristics, the physical accessibility to the village has negative effects as it might provide local residents with better opportunities for off-farm employment outside the villages. These findings indicate that promoting education and off-farm employment opportunities, developing livestock rearing, and investing in road systems could reduce the probability that a rural household would participate in the extraction and the level of extraction and dependence. The impact of shocks is also important because shocks force non-extracting households to switch on the extraction. Therefore, specific safety net programs should be designed to support rural households, both extracting and non-extracting ones, to recover from shocks.

Impacts of extraction on household welfare

Table 2 reports the estimates of the endogenous switching regression model on the determinants of the household welfare indicators. The results of the selection models are similar to those of the Heckman model presented above, which confirms the robustness of our estimates. Regarding the welfare indicators, the farm land size is negatively correlated with the daily consumption and income per capita of the non-extracting group. This group has higher self-employment income and thus farming becomes less important. The age of household heads is negatively correlated with the daily consumption per capita of the extracting group, but positively correlated with the daily consumption and income per capita of the non-extracting group. The education level of the head is positively associated with a higher FCS of the non-extracting group. The dependency ratio is negatively correlated with the daily consumption of both groups. It is also negatively correlated with the daily income per capita of the extracting group. The number of TLU is positively correlated with the FCS and daily income per capita of the extracting group because for this group livestock is mainly used for home consumption. The asset value has positive effects on all three welfare indicators of both groups. Off-farm employment opportunities have positive effects on daily income per capita in both groups. Meanwhile the number of shocks has negative effects on FCS in both groups and on daily consumption per capita in the extracting group. A river in the village could increase FCS of both groups and the daily income of the extracting group. The road conditions have positive effects on the extracting group in terms of FCS and daily income per capita.

Table 2. Determinants of household food security, income and consumption

(Insert Table 2 here)

Table 3 presents the results of the counterfactual analysis and its last column shows the treatment effects of the extraction on the welfare indicators. For the extracting group, FCS would drop sharply by 63% if it would not extract. For the non-extracting group, FCS would increase marginally by 5.5% if it would extract. Regarding the daily consumption per capita, for the extracting group, its daily consumption per capita would drop by 78% if it would not extract. For the non-extracting group, its daily consumption per capita would also reduce by 66.1% if it would extract. Similarly, for the extracting group, its daily income per capita would decrease by 75% if it would not extract. For the non-extracting group, its daily income per capita would decrease by 47.4% if it would extract. This finding is important as it indicates the need to prevent non-extracting households from the factors forcing them to extract the resources.

Table 3. Effect of forest and water resource extraction on household food security, income and consumption

(Insert Table 3 here)

CONCLUSION

In this study, we examined the determinants and the welfare impacts of forest and water resource extraction. Our findings show that the extracting group has a lower level of livelihood platforms than the non-extracting group. The former is constrained by a low level of human capital (education), financial capital (household assets), and a higher number of shocks. The extraction contributes to household consumption and income, and acts as an income equalizer. Poor extracting households depend more on the resources (mainly non-wood forest products) than the wealthier, although the latter derives more absolute environmental income (mainly wood). This suggests that it is not the poor who are to be blamed for over-extraction of the resources as they are less likely to engage in extraction activities with higher returns (e.g., logging).

Furthermore, forest and water resource extraction increases food security of rural households. Non-extracting households are more food secure than extracting households as the former has a higher education level and a higher capacity for self-employment. Thus, the impact of the extraction on food security is relatively smaller for non-extracting households than for extracting households. In terms of household income and consumption, the extraction has positive effects for extracting households, but negative effects for non-extracting households.

These results are important to design policies for effective resource conservation and rural development. First, given the importance of the resources to rural households, access to the resources should be effectively regulated in order to prevent over-extraction. More specifically, as the poor depend more on non-wood forest products and less on wood, stricter regulations of logging should be done. This would reduce the vulnerability of the rural poor due to their high level of dependence on non-wood products. Second, however, the resources should not be considered as the “insurer” of the rural poor. Instead, providing the rural population in general and the rural poor in particular with more income generating alternatives is recommended. In this regard, promotion of rural education and off-farm employment opportunities as well as developing rural infrastructure would reduce the extraction of and dependence on the resources. Programs to support farming activities for a higher return should also be taken into account. Third, rural households should also be supported in helping them to recover from shocks. This is particularly important not only to the extractors as they do not have many other income-generating alternatives, but also to the non-extractors to prevent them from being forced to participate in the extraction.

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Figures

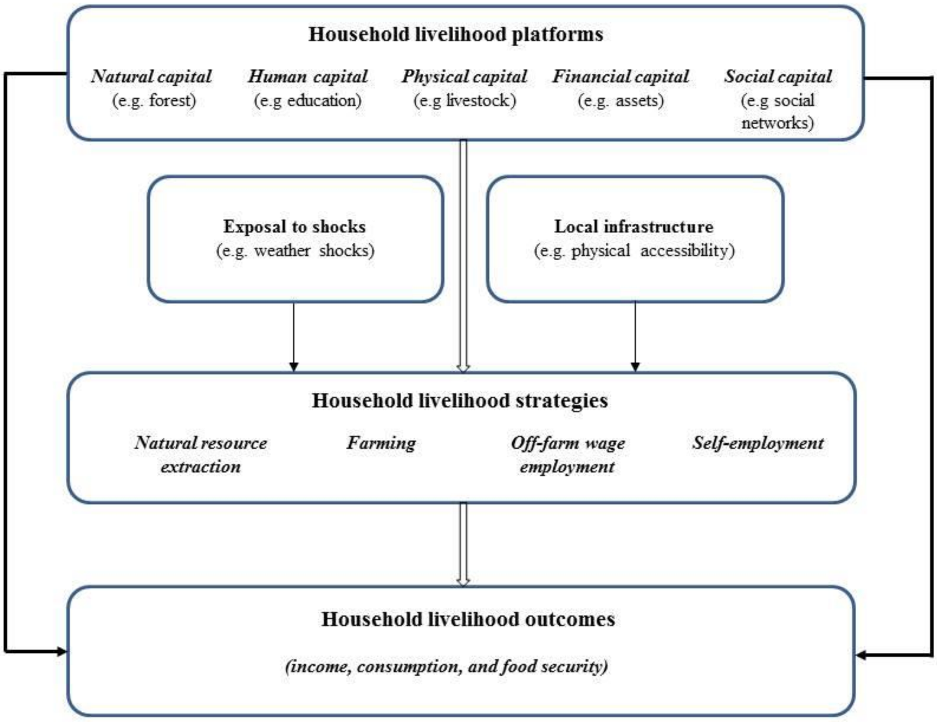

Figure 1. Conceptual framework for the study

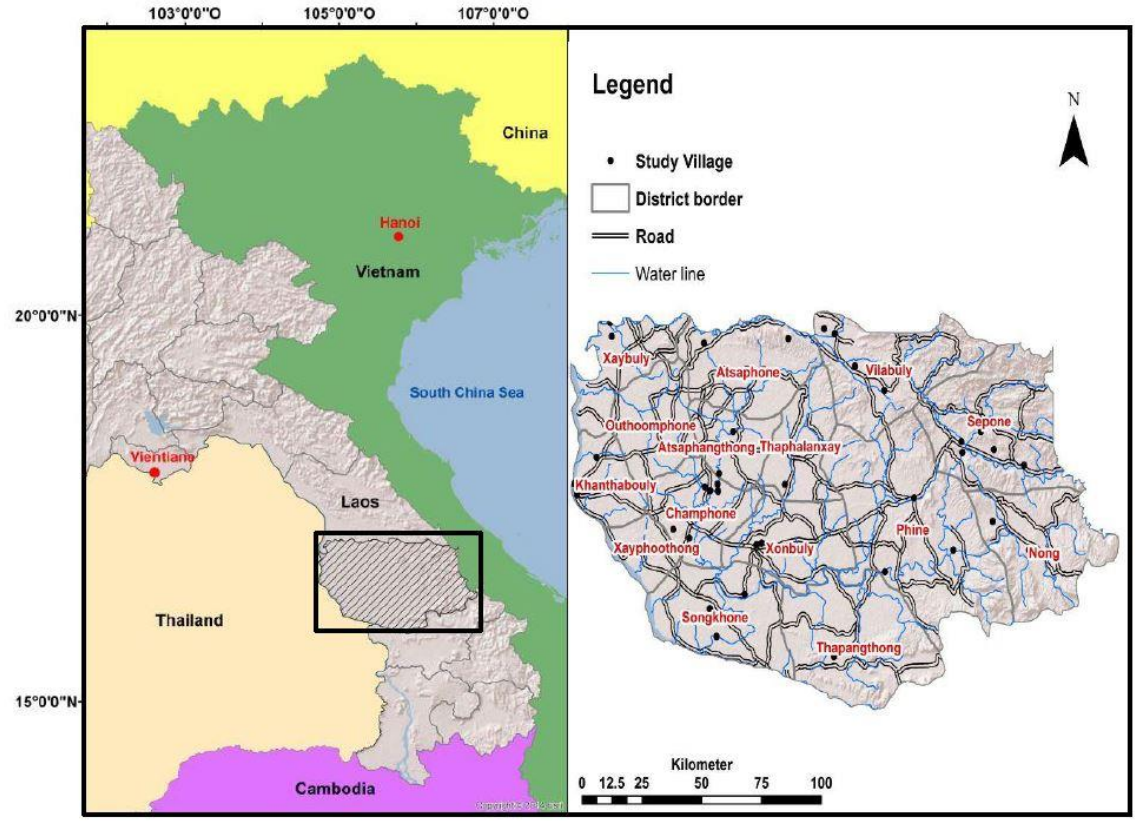

Figure 2. Laos (left) and of Savannakhet province (right), where the study villages are indicated

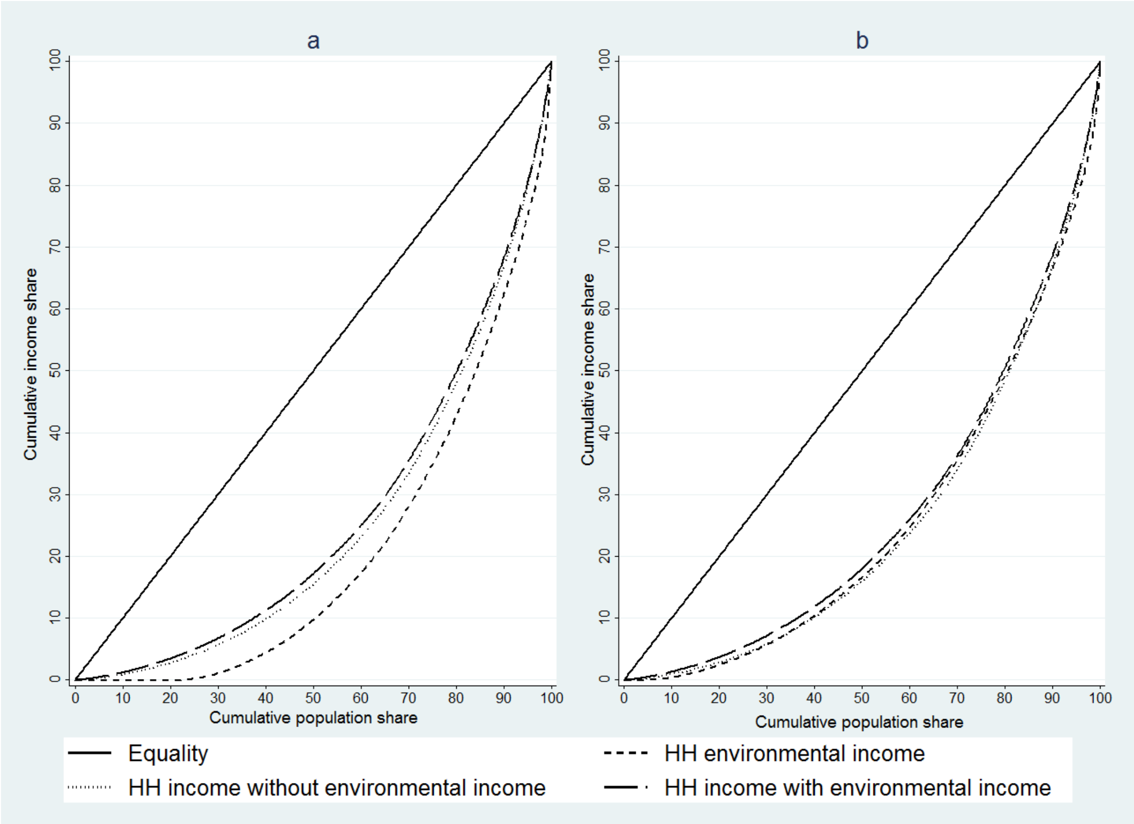

Figure 3. Lorenz curves of household income with and without environmental income: (a) for the whole sample and (b) for the extracting group

Tables

Table 1. Determinants of forest and water resource extraction and dependence

variable	Absolute environmental income (PPP$) (ln)		Relative environmental income (%) (ln)	
	Selection model	*Outcome model*	*Selection model*	*Outcome model*
Household level				
Natural capital				
envidist (ln)	-0.323***	0.107*	-0.316***	0.090
	(0.099)	(0.058)	(0.099)	(0.057)
landsize (ln)	0.054	0.067*	0.053	0.028
	(0.043)	(0.035)	(0.043)	(0.046)
Human capital				
hhage	0.000	-0.005	0.000	-0.015***
	(0.007)	(0.004)	(0.007)	(0.004)
hhgender	0.561**	-0.066	0.581***	-0.305
	(0.226)	(0.212)	(0.220)	(0.286)
hheduc	-0.050**	-0.032**	-0.050**	-0.044**
	(0.020)	(0.016)	(0.020)	(0.020)
hhdepend	0.020	0.266***	0.019	0.365***
	(0.115)	(0.081)	(0.117)	(0.079)
Physical capital				
trolivu (ln)	0.046*	0.040	0.047*	-0.028
	(0.027)	(0.026)	(0.027)	(0.029)
Financial capital				
asset (ln)	-0.031	0.128***	-0.034	0.044
	(0.070)	(0.042)	(0.070)	(0.053)
off-farm	-0.231*	-0.106	-0.221*	-0.743***
	(0.134)	(0.136)	(0.130)	(0.157)
Social capital				
mobile	-0.057	-0.086	-0.059	-0.095
	(0.211)	(0.146)	(0.211)	(0.143)
Shocks				
shock	0.246***	-0.144**	0.248***	-0.160**
	(0.059)	(0.061)	(0.059)	(0.079)
Village level				
water	-0.420**	-0.142	-0.419**	-0.599*
	(0.209)	(0.229)	(0.200)	(0.328)
road	-0.483**	-0.371*	-0.492**	-0.812***
	(0.229)	(0.198)	(0.234)	(0.246)
Regional level				
region_1	-0.786***	-0.231	-0.786***	-0.068
	(0.256)	(0.144)	(0.255)	(0.237)
region_2	-0.070	0.129	-0.078	-0.012
	(0.236)	(0.141)	(0.236)	(0.158)
constant	1.275*	5.304***	1.285*	3.511***
	(0.664)	(0.479)	(0.671)	(0.530)
Model statistics				
No. of observations		430		430
Wald chi^2 (15)		121.549		209.080
Prob. > chi^2		0.000		0.000

* Significant at 10%, ** significant at 5%, *** significant at 1%, robust standard error clustered at the village level in parentheses

Table 2. Determinants of household food security, income and consumption

Variable	Food consumption score (ln)			Daily consumption per capita (ln)			Daily income per capita (ln)		
	Selection model	*Extracting group*	*Non-extracting group*	*Selection model*	*Extracting group*	*Non-extracting group*	*Selection model*	*Extracting group*	*Non-extracting group*
Household level									
Natural capital									
envidist (ln)	-0.277**			-0.356***			-0.332***		
	(0.121)			(0.124)			(0.098)		
landsize (ln)	0.065*	-0.009	0.001	0.051	-0.017	-0.084**	0.054	-0.002	-0.110**
	(0.038)	(0.008)	(0.017)	(0.039)	(0.018)	(0.036)	(0.042)	(0.029)	(0.052)
Human capital									
hhage	0.001	0.001	0.005	0.001	-0.006**	0.012*	0.000	0.003	0.026***
	(0.007)	(0.001)	(0.003)	(0.007)	(0.002)	(0.007)	(0.007)	(0.004)	(0.010)
hhgender	0.575**	0.052	-0.146	0.567**	0.051	-0.178	0.550***	0.122	-0.424
	(0.228)	(0.048)	(0.110)	(0.234)	(0.108)	(0.203)	(0.211)	(0.159)	(0.363)
hheduc	-0.044**	0.006	0.025**	-0.049**	0.011	0.033	-0.050**	0.015	-0.001
	(0.022)	(0.004)	(0.012)	(0.022)	(0.009)	(0.024)	(0.020)	(0.011)	(0.033)
hhdepend	0.030	0.001	-0.001	0.094	-0.394***	-0.298**	0.025	-0.376***	-0.300
	(0.144)	(0.023)	(0.066)	(0.162)	(0.050)	(0.145)	(0.117)	(0.070)	(0.225)
Physical capital									
trolivu (ln)	0.046*	0.010*	0.010	0.050*	0.007	-0.010	0.049*	0.038*	-0.020
	(0.026)	(0.006)	(0.011)	(0.026)	(0.012)	(0.024)	(0.027)	(0.019)	(0.030)
Financial capital									
asset (ln)	-0.032	0.022**	0.075***	-0.017	0.160***	0.190***	-0.024	0.074**	0.231**
	(0.061)	(0.011)	(0.028)	(0.065)	(0.023)	(0.060)	(0.074)	(0.036)	(0.099)
off-farm	-0.218	0.022	0.019	-0.211	-0.020	-0.169	-0.234*	0.535***	0.472**
	(0.176)	(0.032)	(0.080)	(0.176)	(0.068)	(0.169)	(0.131)	(0.084)	(0.231)
Social capital									
mobile	-0.058	0.007	0.039	-0.085	-0.065	0.116	-0.082	-0.094	0.122
	(0.211)	(0.035)	(0.100)	(0.217)	(0.074)	(0.215)	(0.210)	(0.112)	(0.360)
Shocks									
shock	0.265***	-0.029*	-0.103**	0.267***	-0.077**	-0.155	0.250***	-0.034	-0.127
	(0.093)	(0.015)	(0.049)	(0.095)	(0.034)	(0.118)	(0.060)	(0.047)	(0.153)
Village level									

water	-0.394*	0.138***	0.176*	-0.408*	0.121	0.177	-0.435**	0.339*	0.365
	(0.230)	(0.050)	(0.108)	(0.230)	(0.109)	(0.212)	(0.202)	(0.204)	(0.272)
road	-0.465*	0.092*	0.093	-0.508**	0.165	0.449	-0.496**	0.470***	0.797**
	(0.245)	(0.052)	(0.132)	(0.251)	(0.112)	(0.304)	(0.241)	(0.149)	(0.319)
Regional level									
region_1	-0.766***	0.040	0.089	-0.787***	-0.008	0.278	-0.785***	-0.058	0.294
	(0.220)	(0.045)	(0.131)	(0.222)	(0.102)	(0.286)	(0.254)	(0.178)	(0.403)
region_2	-0.058	-0.089***	-0.170	-0.088	-0.082	-0.144	-0.087	0.157**	0.331
	(0.235)	(0.034)	(0.118)	(0.242)	(0.074)	(0.252)	(0.235)	(0.069)	(0.367)
constant	1.115*	3.936***	3.034***	1.025	0.433*	-1.348	1.249*	-0.137	-2.894**
	(0.657)	(0.113)	(0.391)	(0.680)	(0.242)	(0.906)	(0.656)	(0.334)	(1.257)
σ_i		-1.364***	-0.964***		-0.590***	-0.312		-0.221***	0.036
		(0.038)	(0.235)		(0.055)	(0.265)		(0.043)	(0.116)
ρ_j		-0.079	-1.400**		0.459	-1.040*		0.251	-0.360
		(0.250)	(0.637)		(0.365)	(0.632)		(0.287)	(0.466)

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard error in parentheses

Table 3. Effect of forest and water resource extraction on household food security, income and consumption

	Decision		Treatment effect
	To extract	*Not to extract*	
FCS (ln)			
Extracting group	4.177	3.549	ATT = 0.628***
	(0.005)	(0.012)	(0.008)
Non-extracting group	4.286	4.231	ATU = 0.055***
	(0.013)	(0.022)	(0.015)
Daily consumption per capita (ln)			
Extracting group	0.696	-0.087	ATT = 0.783***
	(0.022)	(0.028)	(0.016)
Non-extracting group	0.583	1.244	ATU = -0.661***
	(0.053)	(0.053)	(0.033)
Daily income per capita (ln)			
Extracting group	0.327	-0.422	ATT = 0.750***
	(0.025)	(0.042)	(0.027)
Non-extracting group	0.214	0.688	ATU = -0.474***
	(0.061)	(0.081)	(0.054)

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard error in parentheses

Supporting Information (SI) Section

Table S1. Name and definition of the independent variables in the regression models

Variable	Definition	Scale
Household level		
Natural capital		
envidist	Average distance to the extracting grounds	Metric, in km
landsize	Household (HH) farm land area	Metric, in ha
Human capital		
hhage	Age of HH head	Metric, in years
hhgender	Gender of HH head	Binomial, male =1
hheduc	Education of HH head	Metric, in years
hhdepend	HH dependency ratio	Metric
Physical capital		
trolivu	No. of Tropical Livestock Units (TLU) of HH	Metric, in TLU
Financial capital		
asset	Monetary value of assets	Metric, in PPP $
off-farm	If HH has off-farm income	Binomial, yes =1
Social capital		
mobile	If HH has a mobile phone	Binomial, yes =1
Shocks		
shock	No. of shocks during the last three years	Metric
Village level		
water	A river run throughout residential area of the village	Binomial, yes =1
road	All time accessible to the village	Binomial, yes =1
Regional level		
region_1	If HH in Mekong region	Binomial, yes =1
region_2	If HH in Lowland region	Binomial, yes =1

Table S2. Multicollinearity test

Variable	VIF (Variance Inflation Factor)	1/VIF
envidist (ln)	1.11	0.90
landsize (ln)	1.18	0.85
hhage	1.17	0.85
hhgender	1.14	0.88
hheduc	1.24	0.81
hhdepend	1.21	0.83
trolivu (ln)	1.24	0.81
asset (ln)	1.51	0.66
off-farm	1.07	0.93
mobile	1.43	0.70
shock	1.04	0.96
water	1.13	0.88
road	1.30	0.77
region_1	1.57	0.64
region_2	1.68	0.60
Mean	**1.27**	

Table S3. Normality and homoscedasticity tests for Heckman and Switching models

Model	Dependent variable	Normality (skewness and kurtosis test)	Homoscedasticity (hettest)
Switching	Food Consumption Score (FCS) (ln)	1.60 (2) [0.4501]	0.53 (1) [0.4657]
Switching	Daily consumption per capita (ln)	1.73 (2) [0.4212]	0.44 (1) [0.5076]
Switching	Daily income per capita (ln)	2.78 (2) [0.2494]	1.57 (1) [0.2106]
Heckman	Absolute environmental income (ln)	3.90 (2) [0.1419]	1.69 (1) [0.1935]
Heckman	Relative environmental income (ln)	1.48 (2) [0.4764]	1.52 (1) [0.2183]

Degrees of freedom of each χ^2 statistic in round brackets while the p-value of each test in squared brackets

Table S4. Test on validity of the selection instrument

Variable	Probit model	OLS		
		Food consumption score (ln)	*Daily consumption per capita (ln)*	*Daily income per capita (ln)*
Household level				
Natural capital				
landsize (ln)	0.054	-0.004	-0.037**	-0.035
	(0.039)	(0.007)	(0.015)	(0.023)
Human capital				
hhage	0.000	0.002	-0.004	0.005
	(0.007)	(0.001)	(0.002)	(0.003)
hhgender	0.568**	0.047	-0.063	-0.069
	(0.229)	(0.040)	(0.087)	(0.133)
hheduc	-0.050**	0.007*	0.017**	0.014
	(0.022)	(0.004)	(0.008)	(0.012)
hhdepend	0.022	0.002	-0.371***	-0.374***
	(0.146)	(0.022)	(0.048)	(0.073)
Physical capital				
trolivu (ln)	0.046*	0.014***	0.001	0.023
	(0.026)	(0.005)	(0.010)	(0.015)
Financial capital				
asset (ln)	-0.033	0.025**	0.169***	0.103***
	(0.063)	(0.010)	(0.021)	(0.032)
off-farm	-0.228	0.010	-0.052	0.509***
	(0.177)	(0.029)	(0.063)	(0.096)
Social capital				
mobile	-0.054	0.013	-0.013	-0.066
	(0.213)	(0.033)	(0.071)	(0.109)
Shocks				
shock	0.246***	-0.028*	-0.091***	-0.039
	(0.094)	(0.014)	(0.031)	(0.047)
Village level				
water	-0.415*	0.132***	0.144	0.326**
	(0.231)	(0.042)	(0.091)	(0.139)
road	-0.486*	0.051	0.256***	0.604***
	(0.248)	(0.043)	(0.093)	(0.142)
Regional level				
region_1	-0.787***	0.018	0.103	0.041
	(0.222)	(0.037)	(0.079)	(0.121)
region_2	-0.072	-0.106***	-0.082	0.192*
	(0.239)	(0.033)	(0.072)	(0.110)
Selection instruments				
envidist (ln)	-0.321***	-0.011	0.009	0.010
	(0.123)	(0.015)	(0.031)	(0.048)
constant	1.270*	3.903***	0.353	-0.308
	(0.660)	(0.106)	(0.228)	(0.347)
Wald test (Chi^2/ F-tat)	6.81	0.57	0.08	0.04
P-value (Chi^2/ F-stat -test)	0.009	0.453	0.784	0.837
No. of observations	430	430	430	430
Chi^2/ F-stat	90.51	4.87	17.57	9.83
Prob. > chi^2	0.000	0.000	0.000	0.000
Pseudo R^2	0.222			
Adjusted R^2		0.119	0.367	0.236

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard error in parenthesis

Table S5. Basic household and village characteristics and assets

Variable	Whole sample (n=430)	Non-extracting group (n=78)	Extracting group (n=352)	Test
Household level				
Natural capital				
envidist	1.75	2.04	1.68	3.51***b
	(1.43)	(1.72)	(1.36)	
landsize	1.75	1.52	1.80	-1.03b
	(1.47)	(1.47)	(1.46)	
Human capital				
hhage	49.60	49.26	49.67	0.39b
	(13.04)	(11.52)	(13.36)	
hhgender	0.87	0.77	0.89	8.50**c
	(0.34)	(0.42)	(0.31)	
hheduc	3.34	4.62	3.06	2.47**b
	(3.78)	(4.23)	(3.61)	
hhdepend	1.53	1.43	1.55	-0.72b
	(0.63)	(0.58)	(0.64)	
Physical capital				
trolivu	3.52	3.20	3.59	-0.67b
	(4.75)	(4.50)	(4.81)	
Financial capital				
asset	4032	5820	3635	2.36**b
	(6760)	(9820)	(5816)	
off-farm	0.28	0.36	0.27	2.66c
	(0.45)	(0.48)	(0.44)	
Social capital				
mobile	0.69	0.78	0.67	3.55*c
	(0.46)	(0.42)	(0.47)	
Shocks				
shock	1.18	0.88	1.25	-4.15***a
	(0.92)	(0.77)	(0.94)	
Village level				
water	0.12	0.21	0.10	7.32**c
	(0.32)	(0.41)	(0.30)	
road	0.13	0.28	0.10	19.39***c
	(0.34)	(0.45)	(0.30)	

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard deviations in parentheses, a T test, b Wilcoxon rank sum test, c χ^2 test.

Table S6. Average number of shocks by shock category

	Whole sample (n=430)	Non-extracting group (n=78)	Extracting group (n=352)	χ^2
weather shock	0.41	0.17	0.46	-5.37***a
	(0.56)	(0.38)	(0.58)	
• flood	0.22	0.10	0.25	-2.84**a
	(0.42)	(0.31)	(0.44)	
• drought	0.12	0.04	0.13	-4.11***a
	(0.32)	(0.19)	(0.34)	
• rainfall	0.02	0.01	0.03	-1.17a
	(0.15)	(0.11)	(0.16)	
• storm	0.05	0.01	0.06	-1.80*a
	(0.22)	(0.11)	(0.23)	
health shock	0.38	0.44	0.36	0.58a
	(0.54)	(0.52)	(0.54)	
market shock	0.03	0.03	0.03	0.43b
	(0.18)	(0.16)	(0.18)	
other shock	0.37	0.26	0.39	-2.46**b
	(0.55)	(0.47)	(0.56)	

[*] Significant at 10%, [**] significant at 5%, [***] significant at 1%, standard deviations in parentheses, [a] T test, [b] Wilcoxon rank sum test; other shocks include theft and job loss.

Table S7. Household consumption and income

	Whole sample (n=430)	Non-extracting group (n=78)	Extracting group (n=352)	χ^2
Consumption (PPP $)				
Annual HH consumption	5188	7087	4768	4.84***
	(3227)	(4588)	(2670)	
Daily per capita consumption	2.89	4.45	2.54	5.28***
	(2.47)	(3.27)	(2.11)	
Income (PPP $)				
Annual HH income	4461	5586	4212	2.18**
	(4235)	(5247)	(3942)	
Daily per capita income	2.32	3.62	2.04	2.82**
	(2.33)	(3.64)	(1.81)	
Income share (%)				
Crop production	27.4	15.0	31.0	-3.23**
	(27.6)	(24.9)	(27.3)	
Livestock rearing	13.1	10.1	13.9	-1.61
	(24.2)	(23.0)	(24.5)	
Forest and water resource extraction	6.0	0.0	7.7	-14.46***
	(10.1)	(0.0)	(10.9)	
Off-farm employment	16.7	21.4	15.3	0.91
	(27.3)	(29.7)	(26.4)	
Self-employment	18.3	28.2	15.4	2.41**
	(32.3)	(36.5)	(30.4)	
Financial transfers	17.2	23.3	15.4	1.71*
	(26.4)	(35.3)	(22.9)	
Capital income	1.4	1.9	1.3	2.47**
	(3.3)	(2.9)	(3.4)	

* Significant at 10%, ** significant at 5%, *** significant at 1%, standard deviations in parentheses, Wilcoxon rank sum test.

Table S8. Poverty status at the threshold of two PPP$ per capita

	Whole sample (n=430)	Non-extracting group (n=78)	Extracting group (n=352)
Consumption poverty			
Headcount index (P0)	0.447	0.256	0.489
Poverty gap (P1)	0.161	0.072	0.180
Poverty severity (P2)	0.079	0.031	0.090
Income poverty			
Headcount index (P0)	0.588	0.474	0.614
Poverty gap (P1)	0.314	0.283	0.321
Poverty severity (P2)	0.209	0.192	0.213

Table S9. Household food consumption score (FCS) by food source

FCS source	Whole sample (n=430)		Non-extracting group (n=78)		Extracting group (n=352)		Test	
	(1)	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*
From staple	15.5	22.6	15.2	21.0	15.6	23.0	-1.88*b	-3.44***b
	(2.9)	(6.4)	(2.9)	(6.5)	(2.8)	(6.3)		
From pulses	6.8	10.0	7.5	10.4	6.7	9.9	0.85b	0.38b
	(5.3)	(6.4)	(6.0)	(7.0)	(5.2)	(6.3)		
From fruits	3.2	4.7	3.6	4.9	3.1	4.6	2.07**b	1.64b
	(1.9)	(2.5)	(2.1)	(2.8)	(1.8)	(2.4)		
From vegetables	5.6	8.2	5.6	7.7	5.6	8.3	-0.37b	-1.79*b
	(1.5)	(2.8)	(1.6)	(2.8)	(1.4)	(2.8)		
From fish	13.8	20.2	13.2	18.2	14.0	20.6	0.36b	-0.38b
	(7.1)	(8.4)	(7.7)	(9.1)	(7.0)	(8.2)		
From meat	10.5	15.3	10.7	14.8	10.4	15.4	0.12b	-1.03b
	(6.1)	(7.3)	(7.2)	(8.8)	(5.9)	(6.9)		
From eggs	9.9	14.5	12.2	16.9	9.4	13.9	1.63b	1.29a
	(7.8)	(9.2)	(8.6)	(9.5)	(7.5)	(9.0)		
From milk	0.9	1.3	1.4	1.9	0.8	1.1	2.09**b	2.06**b
	(3.4)	(4.3)	(4.6)	(5.0)	(3.1)	(4.1)		
From oil	0.9	1.4	1.3	1.8	0.9	1.3	3.49***b	3.28**b
	(1.0)	(1.2)	(1.1)	(1.4)	(0.9)	(1.2)		
From sugar	1.4	2.0	1.7	2.3	1.3	1.9	2.41**a	1.48b
	(1.1)	(1.6)	(1.3)	(1.6)	(1.1)	(1.6)		
Total FCS	68.5	100	72.2	100	67.7	100	2.11**b	
	(19.9)		(21.5)		(19.5)			

Columns (1) and (2) present absolute and relative value (%) of the FCS, respectively; *significant at 10%, ** significant at 5%, *** significant at 1%, standard deviations in parentheses, a T test, b Wilcoxon rank sum test.

Table S10. Extraction of forest and water resources

Product	No. of extracting HH	Distance (km)	Environmental income (PPP $)	Environmental income from sales (PPP $)	Environmental income from consumption (PPP $)
Fish	254	1.7	188	51	137
Small animals	125	1.5	95	18	77
Vegetables and fruits	284	1.7	155	46	109
Wood	16	4.5	751	473	278

Table S11. Gini coefficients of per capita household income with and without environmental income by income quartile

Gini coefficient	Whole sample	1st quartile (poorest)	2nd quartile	3rd quartile	4th quartile (richest)
Without environmental income	0.5013	0.3601	0.3077	0.2455	0.2764
With environmental income	0.4768	0.2981	0.2748	0.2340	0.2656
Mean difference	-0.0245	-0.0620	-0.0329	-0.0115	-0.0108

Table S12. Household absolute and relative environmental income by income quartile

Quartile	Observations		Environmental income		Total HH income (PPP $)
	No. of HH.	Share (%)	Absolute (PPP $)	Relative (%)	
1st	108	25	163	18	881
2nd	107	25	259	12	2178
3rd	108	25	308	7	4456
4th	107	25	314	3	10363
Total	**430**	**100**	**261**	**6**	**4461**

Table S13. Household forest and water extraction of the whole sample and of the extracting group by income quartile

Whole sample (430 HH)							Extracting group (352 HH)							
							Fish		***Small animals***		***Vegetables and fruits***		***Wood***	
Quartile	***No. of HH***	***Fish (PPP$/HH)***	***Small animals (PPP$/HH)***	***Vegetables and fruits (PPP$/HH)***	***Wood (PPP$/HH)***	***Environmental income (PPP$/HH)***	No. of HH	Value (PPP$/HH)	No. of HH	Value (PPP$/HH)	No. of HH	Value (PPP$/HH)	No. of HH	Value (PPP$/HH)
1st	108	60	17	75	11	163	56	116	25	74	77	112	4	298
2nd	107	109	27	103	20	259	67	175	36	80	72	153	3	717
3rd	108	139	31	124	14	308	69	223	34	98	72	202	3	499
4th	107	123	35	90	66	314	62	219	30	126	63	156	6	1197
Total	**430**	**108**	**27**	**98**	**28**	**261**	**254**	**188**	**125**	**95**	**284**	**155**	**16**	**751**