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# Rural livelihoods and environmental resource dependence in Cambodia

Trung Thanh Nguyen[a,*], Truong Lam Do[a,b], Dorothee Bühler[a], Rebecca Hartje[a], Ulrike Grote[a]

[a] Institute for Environmental Economics and World Trade, Leibniz University Hannover, Königsworther Platz 1, 30167 Hannover, Germany

[b] Department of Planning and Investment, Faculty of Economics and Rural Development, Vietnam National University of Agriculture, Hanoi, Vietnam

[*] Corresponding author, Tel: +49 51 1762 4827, Fax: +49 511 762 2667, Email: thanh.nguyen@iuw.uni-hannover.de.

**Abstract**

Understanding rural livelihood strategies and environmental resource dependence can help to reduce and prevent livelihood stresses induced by environmental resource degradation. This study identifies livelihood strategies of farm households in rural Cambodia and explores their determinants with a focus on environmental resource dependence. The data are derived from a survey of 580 households in 30 villages of Stung Treng province in Cambodia undertaken in 2013. An activity-based two-step cluster analysis is conducted to identify different livelihood clusters and regression models are performed to determine the major factors affecting the choice of livelihood strategies and the dependence on environmental resources. The results demonstrate how different levels of environmental and household capital influence livelihood strategies. Environmental resources contribute a significant portion of household income (27%) and act as a means to reduce income inequality (7%) among households. The absolute environmental income is positively correlated with the total income but the relative environmental income decreases with an increase in total income. Thus, it appears that low income households are not to be blamed for environmental degradation, because they are unable to undertake activities with high return. The findings of this study suggest that promoting off-farm employment, education and social networking reduces the extraction of environmental resources.

***Key words:*** Livelihood, environmental income, cluster, regression models, Cambodia.

*JEL classification*: Q57, Q20, Q12

## 1. Introduction

A detailed understanding of different livelihood activities undertaken by rural households in developing countries is crucial in order to provide useful information for rural development initiatives (Ameha et al., 2014). These initiatives need to be adapted to the livelihoods of the targeted communities and individuals (Nielsen et al., 2013). Even though rural households in developing countries pursue a wide range of livelihood activities (Babulo et al., 2008), there is a common notion that there exist, to some degree, distinct livelihood strategies across rural households (van de Berg, 2010). The identification of livelihood strategies offers an imperative insight into the policy interventions that may improve rural livelihoods (Soltani et al., 2012). Moreover, by providing a glimpse of the rural livelihood-related constraints and opportunities, the analysis of livelihood strategies is expected to increase the efficiency of the interventions targeted at the improvement of rural livelihoods (Ellis and Manda, 2012; Zenteno et al., 2013).

Environmental resources provide a variety of life-supporting ecosystem services to rural households in developing countries such as timber, non-timber forest products and fish (Babulo et al., 2009; Thondhlana et al., 2012; Nguyen et al., 2013; Bühler et al., 2015). The extraction of environmental resources in rural areas is often considered an important source of income and a means of livelihoods for low income rural households (Jansen et al., 2006; Kamanga et al., 2009; Naidu, 2011; Schaafsma et al., 2014). However, in many parts of the world, environmental resources have been constantly degraded (WCED, 1987; Beck and Nesmith, 2001; Freeman et al., 2014). Therefore, understanding rural livelihood strategies and environmental resource dependence can help to reduce and prevent livelihood stresses induced by the degradation of environmental resources during the development process, especially for low income households (de Sherbinin et al., 2008; Babigumira et al., 2014).

Even though efforts to quantify the contribution of non-cultivated environments to rural income have been undertaken for decades (Beck, 1994; Beck and Nesmith, 2001; Mamo et al., 2007; Jodha, 2008; Rayamajhi et al., 2012; Thondhlana and Muchapondwa, 2014), some issues still need to be further examined in order to enrich our understanding. These are: (i) the underestimation or ignorance of environmental income. Environmental resources providing income are often communally owned or open access and thus are omitted in rural household surveys, which cover only conventional activities such as crop production and livestock rearing (Babulo et al., 2009; Morsello et al., 2014); and (ii) the factors determining the dependence of rural households on environmental sources are often site-specific (Adhikari et al., 2004; Pouliot and Treue, 2013), which makes the generalization of the research findings difficult (Angelsen et al., 2014). In fact, the generalization of research findings is only possible if the findings from different site-specific studies are pooled in order to identify common observable patterns. These issues lead to the need for more empirical evidence based on sound theoretical frameworks and carefully implemented rural household surveys.

Cambodia is one of the least developed countries in the world and is characterized by a relatively low Gross Domestic Product (GDP), a high poverty incidence, and a high dependence on environmental resources (World Bank, 2014). The agricultural sector accounts for about 35% of the GDP and over 80% of the population live in rural areas. With a national forest cover of about 59% (FAO, 2010; Travers et al., 2015) and considerable water resources, Cambodia is rich in environmental resources. The principal water bodies are the Mekong River, the Tonle Sap (Great Lake) and the Tonle-Bassac River, which form together a network of river channels, levees and basins and offer fishing opportunities for the rural population. However, fish and forest resources have significantly decreased over time. This decrease is not only due to the growing rural population, but also to the illegal and unsustainable fishing and timber harvesting activities by commercial enterprises, military and local authorities (McKenney and Tola, 2002; Travers et al., 2011). As a result, rural livelihood activities have been increasingly impaired (Bühler et al., 2015). The contribution of environmental resources to household income has been documented for many parts of the world, particularly for forest and water resources (Babulo et al., 2008; Narain et al., 2008; Kamanga et al., 2009; Völker and Waibel, 2010; Rayamajhi et al., 2012). However, for Cambodia, this contribution is still not more than an estimate (Ra et al., 2011). Information is scarce about the value of environmental resources in terms of overall rural household welfare, and about how their use and value might vary across household types (Cavendish, 2000). Understanding the dependence of the rural Cambodian population on environmental resources is an urgent need. Similar to other developing countries, one of the main environmental and development concerns in Cambodia is to avoid environmental degradation induced livelihood stresses for the rural population due to the overexploitation of environmental resources (Dasgupta et al., 2005; Clements et al., 2010).

This study reports on the livelihood strategies pursued by rural households in Cambodia with a focus on environmental resource extraction. We addressed the following three questions: (i) what are the livelihood strategies of rural households and how are they determined? (ii) how much is the environmental income and how is it distributed? and (iii) what are the determinants of environmental resource extraction? The answers to these questions provide useful information for policy makers and practitioners to design effective programs for rural development and environmental conservation in Cambodia.

## 2. Conceptual framework

### *2.1 Livelihood strategy of a rural household*

The livelihood approach (Ashley and Carney, 1999; de Sherbinin et al., 2008; Soltani et al., 2012) is used in this paper as a conceptual framework describing the livelihood activity choices (Lambini and Nguyen, 2014) and the factors determining these choices (Nguyen et al., 2010; Wunder et al., 2014). A livelihood is defined as the capabilities, assets, and activities of a means of living (Ashley and Carney, 1999). When applied to developing countries, a rural household in this framework is considered the basic decision making unit regarding production and consumption (Ellis, 2000). In most developing countries, the livelihood of a rural household is linked to environmental resources since the income from agriculture and other sources might not suffice. The livelihood framework includes three closely connected components: livelihood platforms, livelihood strategies and livelihood outcomes (Figure 1).

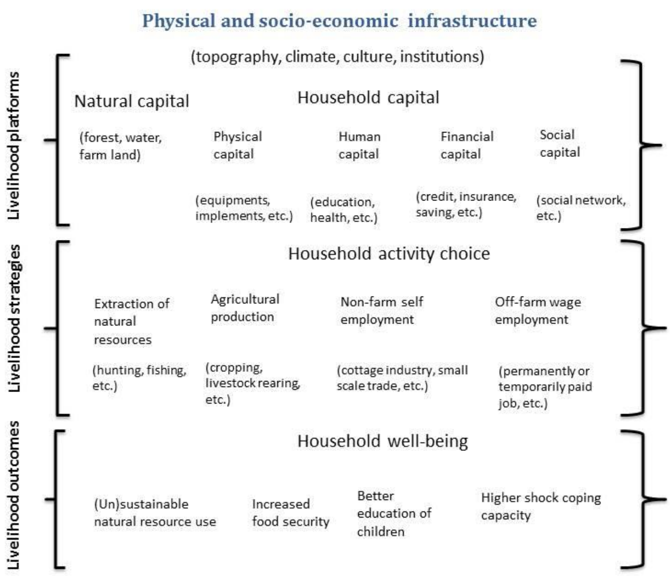


**Figure 1: Conceptual framework for the analysis of livelihoods** (Source: modified from Ashley and Carney, 1999; de Sherbinin et al., 2008; Babulo et al., 2009; Soltani et al., 2012)

The livelihood platforms consist of environmental resources as part of the natural capital (van den Berg, 2010) and household capital (Ellis, 2000). The natural capital is defined as the natural ecosystems available to the household and provides a flow of valuable ecosystem goods and services (Turner and Daily, 2008). However, the household might not legally own the respective land, even though it can extract certain types of goods from this capital. In many developing regions, forest and water resources are open access or communally owned (Angelsen et al., 2014). Therefore, the household does not have full control over this capital, but only the limited right to use it (Nguyen, 2008). The household capital is classified into physical capital (e.g. tractors), human capital (e.g. education), financial capital (e.g. remittances), and social capital (e.g. social network integration).

These different types of capital are the platforms for a household to choose its livelihood strategy as a combination of assets and activities (Brown et al., 2006). A household can allocate its assets to different activity choices, for example, extraction of environmental resources (e.g., collecting forest products and fishing), agricultural production (e.g., crop production and livestock rearing), non-farm self-employment (e.g., cottage industry or small-scale trade), and permanent or temporary off-farm wage employment. Each livelihood strategy selected by the household leads to a set of livelihood outcomes such as the sustainable or unsustainable use of environmental resources.

### *2.2 Environmental income as a part of rural livelihoods*

Environmental income is generally defined as the income earned from wild or uncultivated environmental resources (Angelsen et al., 2014). Thus, it does not include the income from forest plantations, agricultural fields or aquacultural farms. In contrast, naturally generated forests or surrounding water systems providing readily harvestable goods or services are sources of environmental income (Sjaastad et al., 2005).

Environmental income can be very important for rural low-income households who have little household capital for other livelihood alternatives (Cavendish, 2000; Vedeld et al., 2007). A clear understanding of how low-income households depend on their environment is fundamental in shaping policies aiming to safeguard and develop environmental assets for these households. In particular, environmental income may sustain the livelihood of households during periods of income shortages and act as a safety net against shocks (Wunder et al., 2014). The dependence of rural households on environmental income is mediated by the availability and mobility of household capital under various specific physical and socio-economic factors (Babigumira et al., 2014). A better understanding of the factors determining the environmental dependence of rural households may help to formulate rural development strategies aimed at economic development and nature conservation (Clements et al., 2014; Thondhlana and Muchapondwa, 2014). In this regard, the linkage between rural household livelihood strategies and environmental resource dependence deserves further attention.

## 3. Study design

### *3.1 Study site*

This study was conducted in the province of Stung Treng located in the northeastern part of Cambodia, 500 km from the nation's capital, Phnom Penh (Figure 2). This province was selected because of its relatively high incidence of poverty (41% in 2009) and high dependence on environmental resources (NCDD, 2009; NIS, 2013). The Stung Treng province is remote and sparsely populated, comprising 129 villages in five districts. It is unique with extensive forests (Virachey National Park) and intersecting rivers (Mekong, Sekong, Sesan, and Sreapok).

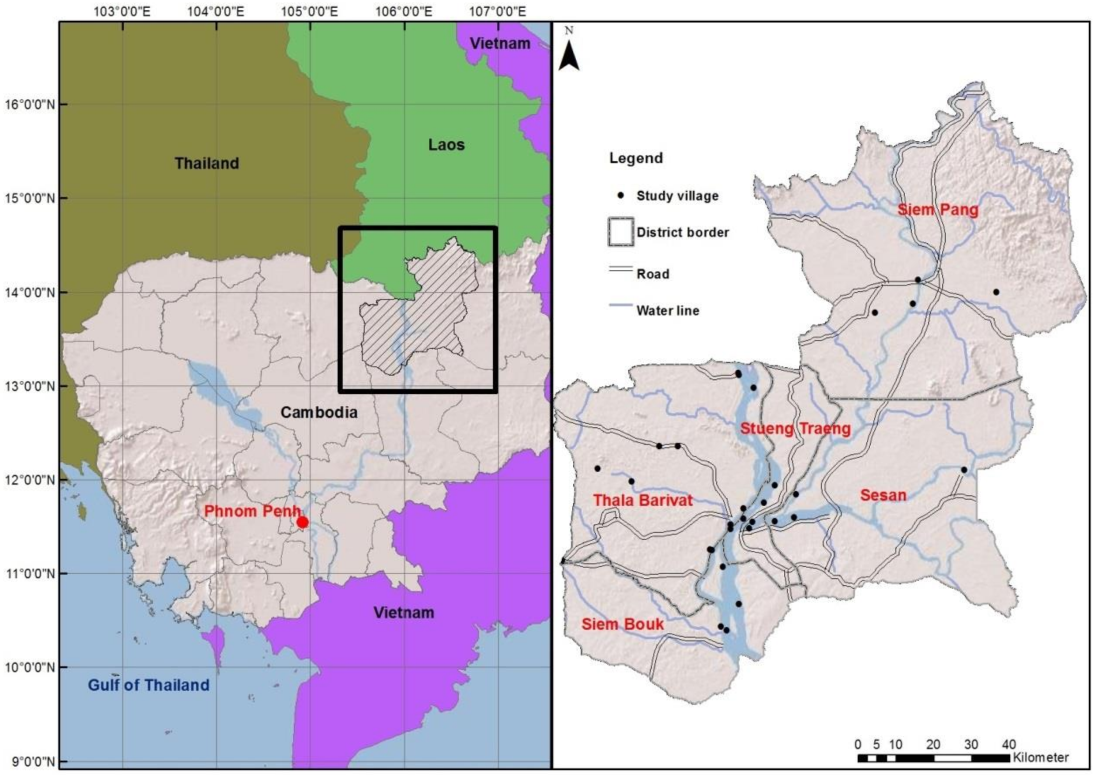


**Figure 2: Map of Cambodia (left) and of the Stung Treng province (right)**

Stung Treng's economy is largely based on agriculture and extraction of environmental resources from forests and rivers (McKenney and Tola, 2002; NCDD, 2009; NIS, 2013). The majority of households (85%) are engaged in small-scale farming (NCDD, 2010). However, households' farm land titles are generally not available (Bühler et al., 2015). Regarding forest and water resources, the property rights regime in the study site can be described as "unregulated", even though forest and river resources are *de jury* state property and are managed by governmental authorities. In reality, existing regulations are not enforced. Therefore, it is common to claim land just by cutting forests. This leads to a situation in which people mainly perceive environmental resources as being open access even though legally this is not the case. For example, Navy and Bhattarai (2009) reported this *de facto* open access regime for fishing in the rivers. This also leads to a decline of these diverse natural resources which negatively impacts on local livelihoods as well as the national economy (Magnan and Thomas, 2011). This raises the need to correctly identify which livelihood strategies are pursued by rural farmers and to which extent these livelihood strategies depend on forest and water resources.

### *3.2 Data collection*

The two-step procedure for data collection follows the method described by Hardeweg et al. (2013) based on the guidelines of the United Nations Department of Economic and Social Affairs (UN, 2005). The village is identified as the primary sampling unit. In the first step, 30 of the 129 villages of the province were selected by sampling proportional to a village's size (measured as the number of households in the village). This means that the probability of each village to be part of the sample is as high as its share of the total number of households in the province. Therefore, each household is equally likely to be included in the sample. The information about the size of each village was obtained from the Cambodian National Census 2008 (NIS, 2008). The amount of villages to be surveyed, which is nearly one quarter of all the villages in the province, was set to cover as much as possible the variation within the province, while at the same time confining costs and time to a reasonable limit. In the second step, twenty households of each village were randomly drawn from the village list of households. The final sample consists of 600 rural households from 30 villages.

Two survey questionnaires with structured interviews[1], one for the households and one for the village heads, were used to collect data. The household questionnaire is 90 pages long and contains sections on education, health and employment status of household members, agricultural production, household expenditure and income, remittances and financial transfers, with a separate subsection on environmental income-generating activities (e.g. fishing, hunting, collecting, and logging). These income-generating activities were recorded along with information on types of extracted products, places of extraction, distance to home and markets, intensity of extraction, payments in cash or in kind for permission to extract, cost of extraction (e.g. fuels and materials), and the quantity and value of total outputs. Interviewees were also asked to assess the changes in environmental resources over the last 20 years. As for all income relevant variables, the reference period in the questionnaire was one year, i.e. that data on all environmental income items for the past 12 months was collected, including various types of seasonal activities. The household questionnaire was administered to the household head. In the cases in which the household head was not available, his/her spouse was interviewed. The village questionnaire captures village-scale data on population, infrastructure, economics, social structure, natural disasters, public transport to the village, and the relationship to the neighboring villages. It was administered to the village head or the vice head.

The data collection was conducted in April and May 2013 by a team of 15 Cambodian enumerators, two Cambodian team leaders, two German team leaders and three data typists. All Cambodian enumerators had previous experience in conducting household surveys in

[1] Both village and household questionnaires are available and can be provided upon request.

Cambodia. Ten of the enumerators were from Phnom Penh and had much experience, while the other five were natives of the Stung Treng Province and had good knowledge of the local mentality and dialects[2]. They were all trained intensively before the survey took place and then organized into two survey teams. Each enumerator conducted face to face interviews. Each interview took, on average, three hours. The questionnaires were checked by the team leaders at the end of the day for consistency and plausibility, and if the required data were missing or not plausible, another visit to the interviewed household was conducted.

### *3.3 Data analysis*

#### *3.3.1 Clustering households with different livelihood strategies*

Given the relatively diverse nature of activities that rural households realize to sustain their livelihoods, it has not always been defined as to what comprises a distinct livelihood strategy rather than just a slight mix of diverse activities within one broad livelihood strategy (Brown et al., 2006). The most important issue to consider when differentiating households into distinct livelihood strategies is the group of factors (variables) that could be used to separate or discriminate between households. One of the most popular approaches in the literature is the application of a cluster analysis (Barrett et al., 2001) using either the income shares from different sources or the household's assets and activities pursued to make a living (Nielsen et al., 2013). The income share method has been long advocated given that income is an important factor which is directly comparable, making the method straightforward in its interpretation and use in quantitative analysis (Soltani et al., 2012). However, aggregate household income data may vary across years. Thus, unless the household income share data is available over time, an income share of a particular year reflects a household's short-term livelihood strategy rather than a long-term one (Jansen et al., 2006).

[2] The Cambodian enumerators were selected by the Cambodia Development Resource Institute (CDRI).

Another method is to use the assets and activities of the households as proxies for livelihood strategies. This method requires gathering data on household asset endowment and income-generating activities using household surveys (Brown et al., 2006). A household can allocate its assets to different activities in order to generate outcome portfolios such as consumption, food security, and investment spending (Nielsen et al., 2013). Since households use different assets to sustain their livelihoods, the variables used to measure the allocation of household capital (e.g. land, labor, input costs) to different income-generating activities have to be included to encompass all important aspects of livelihood strategy choices (Barrett et al., 2001). In this sense, the asset and activity based livelihood method is applied in this study.

The method is undertaken in two steps. In the first step, a Principal Component Analysis (PCA) is used to reduce the dimensionality of the input variables and identify major factors. In the second step, a cluster analysis of the major factors related to livelihood strategies is conducted. Conducting a PCA is advantageous when datasets contain a large number of variables that must be accounted for. Since many variables account for a household's participation in different livelihood activities, this approach is useful to create groups which are homogeneous within themselves and heterogeneous between each other (Backhaus et al., 2011), although one of the disadvantages of this two-step approach is a reduction in the variability within the clusters. According to Jansen et al. (2006) and Soltani et al. (2012), a cluster analysis based on a factor analysis usually results in a clearer delineation of clusters than only a cluster analysis.

In the first step of the method, a total of 21 observed variables[3] representing households' participation in livelihood activities were included in the PCA. The Kaiser criterion (K1; Ford et al., 1986) which retains all factors with eigenvalues greater than one, was used to determine

[3] For more information, see Tables S1 to S5 in the supplementary section; the list of these variables are in Table S1.

the number of factors to be retained, resulting in six factors which explain a total of 58 % of the variance. Following Hair et al. (2009), only the factors with loadings greater than 0.30, i.e. meeting the minimum practical significance level, are interpreted.

In the second step of the method, the factors determined by the PCA were used as the input to an agglomerative hierarchical cluster analysis. We applied the Ward-linkage method based on the squared Euclidean distance. The Calinski-Harabasz criterium and the Duda/Hart index (Garson, 2012) were used to determine the most appropriate number of livelihood clusters. From the 600 sampled households, 580 could be classified. Eighteen of the remaining 20 households were excluded due to missing values in important variables and the other two households were excluded due to outliers in the household income and education level of the household head. The nonparametric k-sample test (Kruskal-Wallis test), $\chi 2$ test, and Wilcoxon rank sum test were realized in order to test the significance of differences between clusters in terms of the variables representing the livelihood platforms and livelihood outcomes. This two-step approach led us to define three livelihood clusters. For further analyses, cluster two was used as the reference cluster and consisted of households which all extract environmental resources.

### *3.3.2 Identifying the determinants of livelihood strategy choices and environmental resource dependence*

Two different regression models were used to assess the factors determining (i) the livelihood strategy choices, and (ii) the environmental resource extraction. A multinomial logit model was applied in the first regression to assess the likelihood of a household belonging to a specific livelihood cluster. Thus, the dependent variable can take on a number of different discrete outcomes, the respective cluster number. The coefficients of the independent variable may therefore be interpreted as factors increasing or decreasing the probability to be part of a respective cluster other than cluster two. Probabilities are not well estimated by the linear ordinary least square (OLS) methods; therefore a logit model using the maximum likelihood (ML) method was applied. We estimated that:

$$(1) \qquad C_{xh} = \beta_0 + \beta_1 N_{xh} + \beta_2 H_{xh} + \beta_3 P_{xh} + \beta_4 F_{xh} + \beta_5 S_{xh} + \beta_6 Sk_{xh} + \beta_7 V_i + e_{xh}$$

where $C_{xh}$ denotes household h's chance to be part of cluster $x \in \{1,3\}$ instead of cluster two. $N_h$, $H_h$, $F_h$, $P_h$, and $S_h$ are the vectors of variables representing natural, human, physical, financial, and social capital, respectively. $Sk_h$ is the number of shocks household $h$ faced in the past five years. $V_i$ is a vector capturing village variables in village *i,* and $e_h$ is an error term.

The independent variables of this multinomial regression model were identified based on the conceptual livelihood framework and represent various types of capital that a household possesses. This allows for an investigation of how different livelihood platforms motivate different livelihood choices and levels of environmental resource extraction. Natural capital is represented by the average distance to the main extracting grounds of environmental resources and agricultural landholding of the household as farm land size might be suggestive of wealth, status and political power in rural areas of developing countries. Human capital is represented by household size, household labor, education level, gender, age, and ethnicity[4] of the household head. Physical capital includes the number of Tropical Livestock Units[5] (TLU), tractors, fishing boats, and motorbikes (the main mode of transport in the province). The distance to the district's central town and the annual remittances and financial transfers represent financial capital. The distance to the district's central town represents the accessibility to markets and financial institutions for the inputs and outputs of farm

[4] Khmer is the dominant ethnic group in Cambodia, accounting for 90% of the population (CIA, 2015)

[5] Tropical Livestock Unit (TLU) is a measure to convert different types of livestock into one standardized unit based on cattle equivalent with a body weight of 250kg (FAO) http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Mixed1/TLU.htm (accessed September 16, 2015).

production. Social capital is represented by the number of mobile phones currently used by household members and by a dummy variable based on the adhesion of a household adult to a social or political group. The number of currently used mobile phones of household members is an indicator of social capital reflecting the contacts and the network a household has, as they allow the members staying in contact with friends, relatives or business partners (Hartje and Hübler, 2015). In addition, the number of shocks experienced by the household during the last five years is also included. It consists of different types of idiosyncratic (e.g., a health, theft) and covariate (weather, food price) shocks which have consequences for the households.

At the village level, the four following variables are included: a dummy variable of whether a river is inside the village, a dummy variable of whether the village is physically accessible during the whole year, the number of enterprises with more than five employees which represents the off-farm wage opportunities in the village, and a dummy variable of whether the village has a good relationship with its neighboring villages. These independent variables and the corresponding references are summarized in Table 1. As the number of independent variables is high, the variance inflation factor (VIF) test is used to detect potential multicollinearity. The result of the test rejects the null hypothesis of the problem[6]. Taking into account the potential problem of spatial correlation, the standard errors are clustered at the village level both in this regression model and the following one, and they are bootstrapped with 10 000 replications.

The second regression model aims to identify the determinants of environmental resource extraction represented by the absolute environmental income. Several points need to be taken into account when using the environmental income as a proxy for environmental resource

[6] See Table S6 in the supplementary section for the VIF test

extraction: (i) incomplete local markets can lead to underestimating the resource extraction, which might be greater than the direct income from environmental resources. This study quantifies the contribution of environmental resources to a household's living, both for home consumption and for sale, and thus can provide a reasonable estimate; (ii) non-pecuniary benefits from environmental resources such as health benefits of standing forests (Garg, 2015), other ecosystem services such as water purification, flood mitigation, or carbon sequestration (Jack et al, 2008), and sedimentation prevention (Nguyen et al., 2013) are not accounted for in our calculation. Obviously, if these ecosystem services were accounted for, the environmental income would be higher. Thus, the estimated environmental income is likely to be a lower bound estimate of the environmental resource extraction; and (iii) classic common situations can lead to over-exploitation of resources, resulting in overestimating the resource extraction. In this study, as income-generating activities other than farming and environmental resource extraction are limited, we did not consider the effect of such an overestimation to be significant.

Environmental income was calculated from the collected products, their prices at local markets and the incurred costs (e.g. fuel, fees, or transportation costs) in the past year, as reported by households. All values were converted to 2013 PPP$[7]. The environmental income was identified both in absolute and relative terms, i.e. in PPP$ and in percentage of the annual household income. Household income inequality was analyzed using the Gini coefficients and Lorenz curve, which also allowed us to determine whether and to what extent the environmental income contributes to reduce income inequality among households.

[7] PPP: Purchasing Power Parity

**Table 1: Name and definition of the independent variables in the regression models**

| Variable | Definition | Scale | Literature |
|---|---|---|---|
| ***Natural capital*** | | | |
| envidist | Average distance to the extracting ground | Metric, in km | Adhikari et al., 2004; Babulo et al., 2008 |
| landsize | HH farm land area | Metric, in ha | Nguyen et al., 2014 |
| ***Human capital*** | | | |
| hhsize | HH size | Metric, in persons | Ellis, 2000; Kamanga et al., 2009 |
| hhlabor | HH labor | Metric, in laborers | Ellis, 2000; Narain et al., 2008 |
| hheduc | Education of HH head | Metric, in years | Ellis, 2000; Jansen et al., 2006 |
| hhgender | Gender of HH head | Binomial, male =1 | Rayamajhi et al., 2012 |
| hhage | Age of HH head | Metric, in years | Soltani et al., 2012 |
| ethnic | Ethnicity of HH head | Binomial, Khmer =1 | Nguyen et al., 2010 |
| ***Physical capital*** | | | |
| trolivu | No. of TLU of HH | Metric, in TLU | Angelsen et al., 2014 |
| tracto | No. of tractors of HH | Metric | Ellis, 2000 |
| fishboat | No. of fishing boats of HH | Metric | Ellis, 2000; Jansen et al., 2006 |
| motorbike | No. of motorbikes of HH | Metric | Brown et al., 2006 |
| ***Financial capital*** | | | |
| remtrans | Total remittances and transfers | Metric, in PPP $ | Nguyen et al., 2015 |
| towndist | Distance to district's town | Metric, in km | Cavendish, 2000 |
| ***Social capital*** | | | |
| mobile | No. of mobile phones of HH | Metric | Hartje and Huebler, 2015 |
| SPO | Member of a social/political group | Binomial, membership = 1 | |
| **Shocks** | | | |
| shock | No. of shocks during the last 5 years | Metric | Völker and Waibel, 2010 |
| **Village variable** | | | |
| watersys | Rivers inside the village | Binomial, yes =1 | |
| roadtype | Accessible to the village | Binomial, all time accessible =1 | Soltani et al., 2012; Nielsen et al., 2013 |
| relationship | Relationship with neighboring villages | Binomial, good =1 | Nguyen et al., 2015 |
| enterprise | No. of enterprises with more than 5 employees in the village | Metric | Angelsen et al., 2014 |

The factors influencing environmental resource extraction are analyzed for the whole sample and for each livelihood cluster. The logarithm of the absolute environmental income of the households is used as the dependent variable. The absolute environmental income is continuous and higher than or equal to zero. In the overall sample and in clusters one and three, the absolute environmental income is censored with participants having a positive environmental income and all others having zero environmental income. This specific characteristic of the data leads the OLS estimators to be biased and inconsistent, but is appropriate for the Tobit type II model (identical to the model introduced by Heckman, 1979). In this model, the decision to participate in environmental resource extraction is modeled separately from the amount of environmental income. In the first step, the decision to participate is explained in a Probit model which has the following form:

$$(2) \qquad Y_h^* = \beta_0 + \beta_1 N_h + \beta_2 H_h + \beta_3 Pd_h + \beta_4 F_h + \beta_5 S_h + \beta_6 Sk_h + \beta_7 V_i + \beta_8 D_d + e_{h1,}$$

with

$$(3) \qquad Y_h^* = \begin{cases} 1 & if \quad Y_h > 0 \\ 0 & if \quad Y_h = 0 \end{cases}$$

where $Y_h$ is the logarithm of environmental income. All other variables and vectors are defined as in (1).

In the second step, the impact of the independent variables on the logarithm of absolute environmental income is estimated for the households for which $Y_h > 0$, i.e. which are identified to take part in environmental extraction activities in the first equation. The regression equation is:

$$(4) \qquad Y_h = \beta_0 + \beta_1 N_h + \beta_2 H_h + \beta_3 P_h + \beta_4 F_h + \beta_5 S_h + \beta_6 Sk_h + \beta_7 V_i + e_{h2}$$

Equations (2) and (4) are estimated simultaneously using the ML estimation and accounted for a correlation of $e_{h1}$ and $e_{h2}$ which are assumed to be jointly normally distributed (Cameron and Trivedi, 2010). Again, the standard errors are clustered at the village level and bootstrapped with 10 000 replications. A test for heteroscedasticity does not reject the homoscedasticity hypothesis. A likelihood ratio test was done for the independence of (2) and (4). It clearly rejects the null hypothesis, indicating dependence between the two equations as assumed in the Tobit type II model. A test for normality does not reject the normality hypotheses for the whole sample and for clusters number one and three[8]. Due to the lack of an exclusion restriction, identification in the Tobit II model comes solely from the nonlinear functional form.

Cluster two exclusively consists of environmental resource extractors and hence environmental income is not censored. Consequently, we omit the first step explaining the participation in environmental resource extraction and estimate an equation similar to equation (4) in an OLS model to explain environmental income in this cluster.

As a test of robustness, we estimate an ordinary Tobit model (Tobin, 1958). It assumes that all variables which have an impact on the decision to participate in environmental income earning activities have the same impact on the amount of environmental income, which may not always be the case. Besides, the assumption of normality of the censored data, an underlying assumption of the Tobit model, is not satisfied. This can potentially lead to inconsistent estimators. Despite these problems, the results lead to estimates similar to the Tobit type II model[9] estimates. The robust results make us confident that we can still infer on the effect of the independent variables on environmental income from these models.

[8] Tests for homoscedasticity and normality in Table S7 in the supplementary section

[9] Standard Tobit estimates in Table S8 in the supplementary section

## 4. Results and discussion

### 4.1 Description of household livelihood strategies

The identified livelihood clusters are: (i) low-skilled/non-permanent wage employment and farming, (ii) environmental resource extraction and farming, and (iii) high-skilled/permanent wage employment and/or self-employment and farming (Table 2). The first cluster (38% of all households) includes the households participating in low-skilled employment, either in the agricultural (ploughing, taking care of livestock, or weeding) or non-agricultural sector (e.g. casual employment in construction activities). The second cluster (32% of all households) includes the households who are extractors of environmental resources (fishing, logging, or collecting non-timber forest products). The third cluster (30% of all households) includes households who are self-employed (e.g. retail shop owners, petty traders, or middlemen of environmental products) or have at least one member working as a high-skilled or permanently paid worker (e.g. teacher, police officer). All sampled households have in common (i) their engagement in their own agricultural production activities (crop production or livestock rearing), and (ii) their dependence on environmental resources. The results of the cluster analysis show that there are multiple income sources of rural households. This supports the findings on rural livelihood strategies (Brown et al., 2006; van den Berg, 2010; Nielsen et al., 2013; Angelsen et al., 2014). For example, Babulo et al. (2009) reported four different livelihood strategies of rural households in the highlands of Tigray, Ethiopia. Soltani et al. (2012) reported seven different livelihood strategies of rural households in Zagros, Iran, and Nielsen et al. (2013) reported five different livelihood strategies of rural households in Bolivia, Nepal, and Mozambique.

**Table 2: Rural livelihood clusters**

| Cluster | No. of households | Main livelihood activities |
|---|---|---|
| Cluster 1 | 221 (38 %) | Low-skilled non-permanent wage employment and farming |
| Cluster 2 | 185 (32 %) | Environmental resource extraction and farming |
| Cluster 3 | 174 (30 %) | High-skilled or permanent wage employment/ self-employment and farming |
| **Total** | **580 (100 %)** | |

The differences among the livelihood clusters in the characteristics and assets of the households are summarized in Table 3. The results of the Kruskal-Wallis and $\chi^2$ tests reveal that, except for household size, share of male-headed households, and financial transfers and remittances that are not statistically different among the clusters, for other variables, there are at least two clusters that are significantly different from each other. In addition, the results of the Wilcoxon rank sum test also reveal that, for example, the education level of household heads of cluster one and cluster two is not significantly different, but that of cluster three is statistically higher than the other two clusters. The number of days that household members engage in the extraction of environmental resources is statistically different among the clusters and highest in cluster two. Households in cluster one have the lowest numbers of TLU, tractors, fishing boats, motorbikes, and mobile phones, while the number of fishing boats is highest in cluster two. The number of shocks is highest in cluster one. Weather (floods, storms, and droughts) and health shocks are most common, accounting for 73% of the households who reported shocks. The education level of household heads is highest in cluster three, indicating the capacity of taking part in higher-skilled wage employment or engaging in self-employment. The numbers of TLU, tractors, and motorbikes indicate that cluster three appears to be richer in terms of these assets.

**Table 3: Basic characteristics and assets of livelihood clusters**

| Variable | Whole sample | Cluster | | | $\chi^2$ |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| hhsize | 5.22 | $5.39^{2*c}$ | $5.04^{1*c}$ | $5.21^{c}$ | $2.74^{a}$ |
| | (1.90) | (1.91) | (1.80) | (1.97) | |
| hhlabor | 3.33 | $3.30^{c}$ | $3.17^{3**c}$ | $3.52^{2**c}$ | $5.05^{*a}$ |
| | (1.44) | (1.40) | (1.36) | (1.56) | |
| hheduc (year) | 3.46 | $2.76^{3***c}$ | $2.88^{3***c}$ | $4.95^{1***2***c}$ | $42.06^{***a}$ |
| | (3.27) | (2.89) | (2.86) | (3.65) | |
| share of HH with gender = 1 (%) | 87.93 | $86.43^{b}$ | $89.73^{b}$ | $87.93^{b}$ | $1.04^{b}$ |
| | (32.60) | (34.33) | (30.44) | (32.67) | |
| hhage (year) | 44.54 | $43.46^{3***c}$ | $43.38^{3***c}$ | $47.13^{1***2***c}$ | $8.90^{**a}$ |
| | (14.02) | (13.65) | (14.49) | (13.72) | |
| share of HH with ethnic = 1 (%) | 82.59 | $86.43^{2***b}$ | $71.35^{1***3***b}$ | $89.66^{2***b}$ | $24.55^{***b}$ |
| | (37.96) | (34.33) | (45.33) | (30.54) | |
| landsize (ha) | 1.78 | $1.65^{2*c}$ | $1.79^{1*3**c}$ | $1.93^{2**c}$ | $7.48^{**a}$ |
| | (3.77) | (2.56) | (1.98) | (5.92) | |
| environmental resource extraction (day) | 146 | $135^{2***3***c}$ | $232^{1***3***c}$ | $68^{1***2***c}$ | $136.02^{***a}$ |
| | (157) | (134) | (170) | (122) | |
| trolivu | 2.65 | $1.84^{2***3**c}$ | $2.56^{1***c}$ | $3.77^{1**c}$ | $8.01^{**a}$ |
| | (4.46) | (3.09) | (3.28) | (6.40) | |
| tracto | 0.22 | $0.14^{2***3**c}$ | $0.23^{1***c}$ | $0.31^{1**c}$ | $7.61^{**a}$ |
| | (0.43) | (0.36) | (0.42) | (0.50) | |
| fishboat | 0.39 | $0.33^{2***c}$ | $0.50^{1***3***c}$ | $0.34^{2***c}$ | $8.74^{**a}$ |
| | (0.53) | (0.47) | (0.56) | (0.54) | |
| motorbike | 0.75 | $0.60^{3***c}$ | $0.62^{3***c}$ | $1.07^{1***2***c}$ | $36.72^{***a}$ |
| | (0.70) | (0.60) | (0.60) | (0.81) | |
| mobile | 1.21 | $0.90^{3***c}$ | $0.96^{3***c}$ | $1.86^{1***2***c}$ | $62.92^{***a}$ |
| | (1.18) | (0.91) | (1.00) | (1.40) | |
| shock | 2.99 | $3.16^{3**c}$ | $2.96^{c}$ | $2.81^{1**c}$ | $5.54^{*a}$ |
| | (1.59) | (1.52) | (1.58) | (1.68) | |
| remtrans (PPP $) | 126.58 | $100.08^{c}$ | $82.09^{c}$ | $207.55^{c}$ | $0.34^{a}$ |
| | (419.76) | (253.22) | (235.81) | (662.88) | |
| share of HH with SPO = 1 (%) | 56.03 | $62.90^{2***b}$ | $47.03^{1***3*b}$ | $56.90^{2*b}$ | $10.37^{***b}$ |
| | (49.68) | (48.42) | (50.05) | (49.68) | |

$^{*}$ Significant at 10%, $^{**}$ significant at 5%, $^{***}$ significant at 1%, standard deviations in parentheses, $^{a}$ Nonparametric k-sample test (Kruskal-Wallis test), $^{b}$ $\chi^2$ test, $^{c}$ Wilcoxon rank sum test; the superscripts in columns 3, 4, 5 indicate the difference of each respective cluster to the other clusters, e.g. the household size in cluster one is significantly different to that in cluster two at 10% significance level according to the Wilcoxon rank sum test; column 6 includes the tests for the difference of all clusters and shows if at least two clusters are significantly different from each other.

These differences lead to variations in livelihood outcomes, which are represented by the levels of income and consumption (Table 4). Households in cluster three are better-off with the highest levels of both income and consumption, meanwhile households in cluster one have a lower level of income and consumption. Rural households with environmental resource extraction and farming as their livelihood strategy are in the middle in terms of the livelihood outcomes (income and consumption) (Table 4).

**Table 4: Consumption and income of livelihood clusters**

| | Whole sample | Cluster | | | $\chi^2$ |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| **Consumption (PPP $)** | | | | | |
| Annual household consumption | 3244 | $2764^{2**3***c}$ | $3061^{1**3***c}$ | $4048^{1***2***c}$ | $55.84^{***a}$ |
| | (1690) | (1384 | (1449) | (1976) | |
| Daily per capita consumption | 1.89 | $1.54^{2***3***c}$ | $1.83^{1***3***c}$ | $2.42^{1***2***c}$ | $64.37^{***a}$ |
| | (1.05) | (0.73) | (0.92) | (1.30) | |
| **Income (PPP $)** | | | | | |
| Annual household income | 4104 | $3188^{2**3***c}$ | $4402^{1**3*c}$ | $4951^{1***2*c}$ | $14.81^{***a}$ |
| | (4649) | (2830) | (5895) | (4829) | |
| Daily per capita income | 2.48 | $1.85^{2***3***c}$ | $2.66^{1***3*c}$ | $3.09^{1***2*c}$ | $22.05^{***a}$ |
| | (3.17) | (2.07) | (3.66) | (3.62) | |
| **Income share (%)** | | | | | |
| Crop production | 25 | $33^{2*3***c}$ | $26^{1*3***c}$ | $19^{1***2***c}$ | $29.85^{***a}$ |
| | (25) | (29) | (21) | (22) | |
| Livestock rearing | 7 | $4^{2,3c}$ | $8^{1,3c}$ | $7^{1,2c}$ | $0.23^{a}$ |
| | (41) | (31) | (51) | (39) | |
| Self-employment | 23 | $5^{2**3***c}$ | $10^{1**3***c}$ | $50^{1***2***c}$ | $101.71^{***a}$ |
| | (67) | (39) | (62) | (89) | |
| Off-farm employment | 13 | $32^{2***3***c}$ | $3^{1***3***c}$ | $8^{1***2***c}$ | $154.03^{***a}$ |
| | (37) | (53) | (12) | (17) | |
| Environmental resource extraction | 27 | $22^{2***3***c}$ | $50^{1***3***c}$ | $8^{1***2***c}$ | $165.60^{***a}$ |
| | (60) | (49) | (85) | (17) | |
| Remittances and transfers | 3 | $3^{2,3c}$ | $2^{1,3c}$ | $4^{1,2c}$ | $0.82^{a}$ |
| | (9) | (8) | (5) | (13) | |
| Capital income | 2 | $1^{2,3*c}$ | $1^{1,3***c}$ | $4^{1*2***c}$ | $7.72^{**a}$ |
| | (9) | (6) | (4) | (14) | |

$^{*}$ Significant at 10%, $^{**}$ significant at 5%, $^{***}$ significant at 1%, standard deviations in parentheses, $^{a}$ nonparametric k-sample test (Kruskal-Wallis test), $^{c}$ Wilcoxon rank sum test; the superscripts in columns 3, 4, 5 indicate the difference of each respective cluster with the other clusters, e.g. the annual household consumption in cluster one is significantly different to that in cluster two at the 5% significance level and to that in cluster three at the 1% significance level according to the

Wilcoxon rank sum test; column 6 includes the tests for the difference of all clusters and shows if at least two clusters that are significantly different.

Farming (both crop production and livestock rearing) plays an important role in the income share of all clusters, accounting for more than 25% in each cluster. However, there are differences among the clusters. While 37% of annual household income of cluster one are from farming, it accounts for only 26% in cluster three. Moreover, households in cluster one derive 32% of their income from off-farm employment, which is much higher than the 13% derived by the average household in the whole sample. Households in cluster three derive 50% of their income from self-employment. The extraction of environmental resources contributes the highest income share for households in cluster two (50%). It is quite important for households in cluster one (22%), and lowest for households in cluster three (8%).

### 4.2 Determinants of household livelihood strategies

The results of the multinomial logit regression are presented in Table 5[10]. The probability to be in cluster one rather than in cluster two is significantly affected by the distance to the extracting ground of the environmental resources, household size, ethnicity of the household head, number of fishing boats, membership of a social or political group, and road type. *Ceteris paribus*, households which are situated closer to extracting grounds are more likely to belong to cluster two than to cluster one. Similarly, the probability for larger households to belong to cluster one is higher. A higher number of fishing boats increase the probability that the household opts for environmental resource extraction as a livelihood strategy. However, the membership of a social or political group would reduce the chance to be in cluster two. Finally, in terms of the village characteristics, if a village is physically accessible during the

[10] The marginal effects of the multinomial regression are presented in Table S9 in the supplementary section.

whole year, it would increase the probability that a household in that village belongs to cluster one. One reason for this is that it would increase the opportunities for off-farm employment.

**Table 5: Determinants of livelihood clusters (cluster two as the reference)**

| **Variable** | ***Coefficient*** | |
|---|---|---|
| | 1 | 3 |
| **Natural capital** | | |
| envidist | -0.108*** (0.031) | -0.080*** (0.026) |
| landsize | -0.015 (0.023) | 0.013 (0.027) |
| **Human capital** | | |
| hhsize | 0.256** (0.114) | 0.059 (0.123) |
| hhlabor | 0.006 (0.165) | -0.292 (0.209) |
| hheduc | -0.023 (0.034) | 0.170*** (0.038) |
| hhgender | -0.206 (0.224) | -0.223 (0.365) |
| hhage | -0.002 (0.009) | 0.022* (0.013) |
| ethnic | 1.226*** (0.329) | 0.779** (0.320) |
| **Physical capital** | | |
| trolivu | -0.049 (0.051) | 0.080** (0.036) |
| tracto | -0.551 (0.379) | 0.489 (0.499) |
| fishboat | -0.694*** (0.259) | -1.417*** (0.380) |
| motorbike | 0.113 (0.204) | 0.581*** (0.187) |
| ***Financial capital*** | | |
| remtrans | -0.000 (0.000) | 0.001** (0.000) |
| towndist | -0.003 (0.007) | -0.007 (0.008) |
| ***Social capital*** | | |
| mobile | -0.128 (0.201) | 0.515*** (0.184) |
| SPO | 0.493** (0.224) | 0.054 (0.298) |
| ***Shocks*** | | |
| shock | 0.019 (0.073) | -0.024 (0.082) |
| ***Village variable*** | | |
| watersys | -0.423 (0.559) | -0.843 (0.692) |
| relationship | 0.144 (0.524) | 0.605** (0.295) |
| roadtype | 0.736* (0.421) | 0.275 (0.485) |
| enterprise | -0.926 (0.583) | 0.622 (0.689) |
| constant | -1.382* (0.768) | -2.626*** (0.839) |
| *N* | *580* | |
| *Log pseudo-likelihood* | *-492.30* | |
| *Pseudo R2* | *0.224* | |

* Significant at 10%, ** significant at 5%, *** significant at 1%, robust standard error bootstrapped with 10000 replications and clustered at the village level in parenthesis

The probability to be in cluster three instead of cluster two is significantly affected by a lower distance to the extracting ground, a higher education level, higher age, and Khmer ethnicity of household head, a higher number of TLU, motorbikes and mobile phones, a lower number of fishing boats, and a higher level of financial transfers and remittances. The findings in this section are thus consistent with the cluster analysis presented in the previous section that the households in the study site pursue different livelihood strategies in accordance with different types of capital that they possess. Further, the differences in livelihood platforms lead to different livelihood strategy choices. Our findings correspond with those of Barrett et al. (2001), Mano et al. (2007), Babulo et al. (2008), Soltani et al. (2012), and Angelsen et al. (2014) that a mixed livelihood structure of farming and high-skilled off-farm employment or self-employment results in the highest welfare level. Households with a higher education level (human capital), higher numbers of motorbikes (physical capital) and mobile phones and membership of a social group (social capital) are less likely to choose environmental resource extraction.

**4.3 Environmental income**

Various types of water and forest products are collected by rural households. These include fish (tilapia, snakehead fish), honey, red ants' eggs, lizards, frogs, toads, mollusks, snakes, birds, deer, wild pigs, mushrooms, herbs, bamboo shoots, lotus, other vegetables and fruits, and wood. These products can be grouped into (i) fish, (ii) small animal, (iii) game, (iv) vegetables and fruits, and (v) wood. The most popular products are fish, bamboo shoots, vegetables, and firewood, which are extracted throughout the year. On average, fishing grounds are rather close to the households (2.8 km) whereas households travel a longer distance to hunt game (6.9 km). The output value of fishing is highest (Table 6), indicating the importance of water resources in the study site. The sales value is higher than the home consumption value and demonstrates the importance of environmental resources as a source of cash income for rural households. In addition, the higher the distance, the higher the total output value. This indicates that households must go far to look for high monetary value environmental resources. This is consistent with the findings of Davis et al. (2010) and Angelsen et al. (2014) that environmental resources are becoming scarce, and thus extraction is subject to increasing opportunity costs (e.g. in terms of traveling time and labor).

**Table 6: Extraction of environmental resources**

| Product | No. of HH | Mean distance (km) | Output value (PPP $) | For sales (PPP $) | For consumption (PPP $) |
|---|---|---|---|---|---|
| Fish | 369 | 2.8 | 1401 | 861 | 540 |
| Small animals | 48 | 4.3 | 330 | 183 | 147 |
| Game | 18 | 6.9 | 852 | 611 | 241 |
| Vegetables and fruits | 256 | 3.5 | 491 | 415 | 76 |
| Wood | 242 | 4.0 | 406 | 286 | 120 |

The finding above is not surprising since there has been a decreasing trend regarding the availability of environmental resources over the last 20 years as reported by 83% of the respondents who have been living in the villages for at least 20 years. Only less than 1% of the respondents declare that there has been no change in forest resources. This trend is also reported by De Lopez (2003), Strange et al. (2008), Poffenberger (2009), and Ra et al. (2011). Similarly, in terms of water resources, 86% of the respondents state that there is less fish of all kinds.

The extraction of environmental resources is mainly undertaken in open access grounds without any restrictions (Table 7). This does not mean that there are no regulations (Kanchanaroek et al., 2013) but rather that the enforcement of regulations is ineffective or absent. This is confirmed by Travers et al. (2011) and Clements et al. (2010) who find that the institutions dealing with environmental resources in Cambodia are weak.

**Table 7: Property right status of the extracting grounds**

| Product | No. of HH | Open-access (%) | Community (%) | Others (%) |
|---|---|---|---|---|
| Fish | 369 | 88 | 7 | 5 |
| Small animals | 48 | 98 | 2 | 0 |
| Game | 18 | 94 | 6 | 0 |
| Vegetables and fruits | 256 | 95 | 2 | 3 |
| Wood | 242 | 94 | 2 | 4 |

(Others include either private property or state property)

Overall the extraction of environmental resources contributes 27% of the annual household income (Table 8). This is not much different to the recent finding from a study of 8000 rural households in 24 developing countries by Angelsen et al. (2014) that environmental income accounts for 28% of household income. In our study, this 27% includes 19% from water resources and 8% from forest resources. Given the importance of environmental resources to household income and the fact that the extraction is mainly undertaken in open access areas, it is necessary to effectively formulate and enforce certain regulations to prevent the degradation of environmental resources; otherwise it leads to income vulnerability in the future (Dercon, 1996; Klasen and Waibel, 2015).

**Table 8: Contribution of environmental income to annual household income**

| Cluster | Average household income (PPP $) | Contribution of environmental income (%) | | |
|---|---|---|---|---|
| | | Total | Water resources | Forest resources |
| 1 | 3188 | 22 | 16 | 6 |
| 2 | 4402 | 50 | 35 | 16 |
| 3 | 4951 | 8 | 6 | 2 |
| **Total** | **4104** | **27** | **19** | **8** |

Environmental income also contributes to reduce income inequality among rural households (Table 9 and Figure 3). Excluding the environmental income the household income inequality, calculated with the Gini coefficients, would increase by 7% for the whole sample.

This figure exceeds the global average of 4.7% reported by Angelsen et al. (2014). For households in cluster two (environmental resource extractors), it is even higher (9%). This suggests that environmental resources play an important role in equalizing household income differences in our study site. This finding is consistent with Kamanga et al. (2009) who reported that forest income reduces income inequality in rural Malawi by 4%. The finding is not surprising as it is widely noted in the literature that poorer households rely more heavily on environmental resource extraction (Vedeld et al., 2007; Soltani et al., 2012). At the same time this may be a coping strategy, i.e. they have a relatively high level of environmental resource dependence because they recently faced a shock, leading them to extract environmental resources as a shock-coping strategy (Völker and Waibel, 2010).

**Table 9: Gini coefficients of annual household income**

| ***Income sources*** | ***Whole sample*** | **Cluster** | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Household income with environmental income | 0.46 | 0.40 | 0.47 | 0.47 |
| Household income without environmental income | 0.53 | 0.45 | 0.56 | 0.49 |
| ***Difference*** | ***0.07*** | ***0.05*** | ***0.09*** | ***0.02*** |

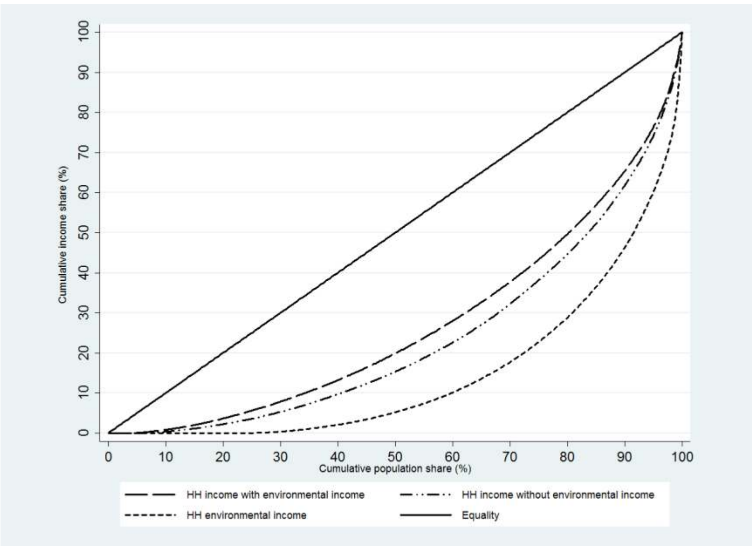


**Figure 3: Lorenz curves of household income with and without environmental income**

The importance of environmental income to the rural poor can also be observed in Table 10. When the whole sample is divided into income quantiles, in absolute terms, annual environmental income is smallest in the poorest quintile (319 PPP$) and highest in the richest quintile (2550 PPP$). However, in relative terms, it is highest in the poorest quintile (50%) and lowest in the richest quintile (25%). In other words, the absolute environmental income is positively correlated with the total income but the relative environmental income decreases with increased total income. Thus, it appears that it is not the poor who are to be blamed for environmental degradation because they are unable to undertake the activities with high return. This finding is consistent with Cavendish (2000), Kamanga et al. (2009), Heubach et al. (2011), and Faße and Grote (2013), who reported that poorer households are relatively more dependent on environmental resources in order to fulfill basic needs rather than wealthier households; but the rich are in fact the main extractors of environmental resources.

**Table 10: Absolute and relative environmental income**

| **Quintile** | **Observations** | | **Environmental income** | | **Total income (PPP $)** |
|---|---|---|---|---|---|
| | No. | Share (%) | Absolute (PPP $) | Relative (%) | |
| 1st | 116 | 20 | 319 | 50 | 639 |
| 2nd | 116 | 20 | 513 | 26 | 1970 |
| 3rd | 116 | 20 | 913 | 30 | 3050 |
| 4th | 116 | 20 | 1172 | 26 | 4466 |
| 5th | 116 | 20 | 2550 | 25 | 10396 |
| **Total** | **580** | **100** | **1093** | **27** | **4104** |

## 4.4 Determinants of environmental income

The results of the Heckman (Tobit type II) and OLS regression models are presented in Table 11[11]. Columns 1, 3 and 5 show the coefficients and standard errors of the Probit estimation with the probability to extract natural resources as the dependent variable ($Y_h^*$). Columns 2, 4

[11] The marginal effects of the Heckman model are in Table S10 in the supplementary information section.

and 6 display the results of the conditional effects model on the log of (non-zero) environmental income ($Y_h$). Column 7 shows the OLS results for cluster two with the dependent variable of log of environmental income ($Y_h$).

**Table 11: Determinants of environmental resource extraction**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | Heckman model | | Heckman model | | Heckman model | | OLS |
| | Whole sample | | Cluster 1 | | Cluster 3 | | Cluster 2 |
| | $Y_h$* | $Y_h$ | $Y_h$* | $Y_h$ | $Y_h$* | $Y_h$ | $Y_h$ |
| ***Natural capital*** | | | | | | | |
| envidist | 0.002 | 0.060*** | -0.093*** | 0.020 | 0.020 | 0.046* | 0.035** |
| | (0.016) | (0.010) | (0.030) | (0.029) | (0.031) | (0.027) | (0.013) |
| landsize | -0.013 | 0.001 | 0.004 | -0.025 | -0.024 | 0.016 | -0.008 |
| | (0.016) | (0.023) | (0.058) | (0.031) | (0.039) | (0.057) | (0.029) |
| ***Human capital*** | | | | | | | |
| hhsize | -0.046 | 0.057 | 0.099 | 0.085 | -0.213* | 0.089 | 0.064 |
| | (0.059) | (0.045) | (0.100) | (0.064) | (0.115) | (0.094) | (0.063) |
| hhlabor | 0.209** | -0.069 | 0.059 | 0.107 | 0.278* | -0.203 | -0.095 |
| | (0.092) | (0.069) | (0.188) | (0.101) | (0.167) | (0.155) | (0.091) |
| hheduc | -0.065*** | -0.036* | -0.007 | -0.011 | -0.037 | -0.125*** | -0.032 |
| | (0.022) | (0.019) | (0.045) | (0.028) | (0.038) | (0.037) | (0.035) |
| hhgender | 0.147 | 0.257 | -0.098 | 0.189 | 0.269 | 0.719* | 0.056 |
| | (0.215) | (0.178) | (0.380) | (0.249) | (0.404) | (0.379) | (0.233) |
| hhage | -0.014** | -0.008* | -0.012 | -0.017** | -0.015 | -0.009 | -0.009* |
| | (0.006) | (0.005) | (0.011) | (0.007) | (0.011) | (0.010) | (0.005) |
| ethnic | -0.461** | -0.136 | -0.367 | 0.063 | -0.132 | -0.678** | -0.139 |
| | (0.202) | (0.150) | (0.423) | (0.245) | (0.441) | (0.341) | (0.160) |
| ***Physical capital*** | | | | | | | |
| trolivu | 0.005 | 0.010 | 0.032 | -0.006 | 0.032 | 0.032* | 0.027 |
| | (0.020) | (0.013) | (0.046) | (0.029) | (0.030) | (0.017) | (0.029) |
| tracto | 0.199 | -0.146 | 0.573 | 0.332 | 0.566* | -0.577** | -0.073 |
| | (0.189) | (0.129) | (0.476) | (0.226) | (0.310) | (0.243) | (0.168) |
| fishboat | 1.465*** | 0.321** | 1.193*** | 0.648*** | 1.616*** | 0.205 | 0.503*** |
| | (0.184) | (0.138) | (0.363) | (0.191) | (0.347) | (0.272) | (0.166) |
| motorbike | -0.135 | -0.020 | 0.091 | 0.013 | -0.041 | -0.072 | 0.111 |
| | (0.123) | (0.092) | (0.251) | (0.146) | (0.194) | (0.151) | (0.120) |
| ***Financial capital*** | | | | | | | |
| remtrans (log) | 0.011 | 0.005 | 0.008 | -0.013 | 0.016 | 0.043* | 0.027 |
| | (0.015) | (0.012) | (0.029) | (0.018) | (0.028) | (0.026) | (0.021) |
| towndist | 0.004 | 0.002 | 0.007 | 0.007* | -0.003 | -0.001 | 0.000 |
| | (0.004) | (0.002) | (0.008) | (0.004) | (0.007) | (0.005) | (0.002) |
| ***Social capital*** | | | | | | | |
| mobile | -0.222*** | 0.088 | -0.274* | -0.029 | -0.069 | 0.140 | 0.051 |
| | (0.078) | (0.062) | (0.164) | (0.108) | (0.130) | (0.115) | (0.116) |
| SPO | -0.089 | -0.322*** | -0.851*** | -0.216 | 0.261 | -0.755*** | -0.370** |
| | (0.142) | (0.110) | (0.313) | (0.170) | (0.277) | (0.234) | (0.176) |
| ***Shocks*** | | | | | | | |
| shock | 0.138*** | 0.010 | 0.108 | 0.068 | 0.195** | 0.074 | -0.015 |
| | (0.046) | (0.037) | (0.080) | (0.058) | (0.083) | (0.069) | (0.026) |
| ***Village variable*** | | | | | | | |
| watersys | 0.306* | 0.233 | -0.077 | 0.412* | 0.293 | -0.582** | 0.308 |
| | (0.185) | (0.146) | (0.334) | (0.225) | (0.319) | (0.260) | (0.231) |
| relationship | -0.256 | 0.458*** | -0.272 | 0.164 | -0.701 | 0.574 | 0.533* |
| | (0.239) | (0.177) | (0.455) | (0.250) | (0.507) | (0.420) | (0.289) |
| roadtype | 0.123 | -0.355*** | -0.221 | -0.599*** | 0.419 | -0.422 | -0.115 |
| | (0.173) | (0.133) | (0.264) | (0.183) | (0.306) | (0.263) | (0.239) |
| enterprise | -0.536*** | -0.127 | 6.855 | 0.080 | -0.472* | 0.307 | -0.076 |
| | (0.181) | (0.212) | (2.32e+08) | (0.415) | (0.264) | (0.273) | (0.161) |
| constant | 1.128** | 6.341*** | 1.787* | 5.184*** | 0.051 | 7.208*** | 6.786*** |

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | (0.475) | (0.378) | (1.032) | (0.572) | (0.891) | (0.867) | (0.647) |
| No. of observations | 580 | | 221 | | 174 | | 185 |
| Log likelihood | -867.224 | | -321.435 | | -173.538 | | |
| Wald $chi^2(24)$ | 102.891 | | 60.605 | | 77.636 | | |
| Prob. > $chi^2$ | 0.000 | | 0.000 | | 0.000 | | |
| F (21, 163) | | | | | | | 11.81 |
| Prob. > F | | | | | | | 0.000 |
| $R^2$ | | | | | | | 0.260 |

[*] Significant at 10%, [**] significant at 5%, [***] significant at 1%, robust standard errors in parentheses; in columns 1, 3, 5 the dependent variable is a binary variable (= 1 if the environmental income is positive, and = 0 otherwise); in columns 2, 4, 6, and 7 the dependent variable is the log of environmental income. For the whole sample and for clusters one and three the Heckman models are estimated, for cluster two an OLS model is estimated.

For the whole sample, the decision to participate in environmental resource extraction is significantly and positively affected by the number of household laborers, fishing boats, and shocks, and the proximity to a river. It is, however, significantly and negatively affected by education, age, and ethnicity of the household head, and the numbers of mobile phones and enterprises. Regarding the number of shocks, Table 3 shows that cluster one has more shocks than cluster three. This indicates that the poor are more likely to be subject to shocks and thus participate more in the extraction. These findings confirm the notion that vulnerable households, such as ethnic minority households or households that experience shocks, are more likely to opt for environmental resource extraction. In Cambodia, minority ethnic groups are normally located in remote areas. Thus, they have less access to other income opportunities.

The level of environmental income is significantly and positively correlated with the distance to the extracting grounds, the number of fishing boats, and a good relationship with the neighboring villages. Household head education and age, membership of a social or political group, and the physical accessibility to the village have a negative effect on the level of environmental income. The positive effect of the distance to the extracting ground for the whole sample and for cluster two confirms our earlier finding (Table 6) and is consistent with Angelsen et al. (2014) who find that environmental resources are becoming scarce and extractors must go further to find them. Higher education is usually associated with the possibility to engage in higher skilled jobs. This in turn makes households less vulnerable and enables them to generate income from more secure sources. Thus, environmental income loses its importance. Households with younger household heads seem to have a higher level of environmental income. One reason for this finding could be that younger household heads are less experienced and thus their households are more vulnerable. However, it might also reflect their ability to engage in harder manual labor. Therefore, they seem to rely relatively more on environmental income. Interestingly, the participation in a social or political group reduces the dependence on environmental income.

The effect of farm land size on environmental income is not statistically significant because in the study area farm land is not scarce. Farmers can claim land just by cutting forest trees and farming is mainly for subsistence. In addition, the extraction of environmental resources is undertaken not in the farm land of the household but in the *de facto* open resources. This is in line with Kamanga et al. (2009) who reported that farm size has no significant effect on forest income of rural households in Malawi.

Turning to the separate regressions per cluster the results displayed in column three reveal that the probability to extract environmental resources of cluster one decreases with a higher distance to the extracting ground. This appears reasonable as this cluster represents the poorer households which might not have the means to access remote areas. The human capital variables seem to be of lower importance for the participation decision of cluster one as they are all insignificant. Similar to the result for the whole sample, the number of fishing boats is positively and statistically significantly associated with the decision to extract, while the number of mobile phones and the membership in a social or political group is negatively correlated with it. This is probably because poor households rely on each other to look for low-skilled wage employment opportunities rather than environmental resource extraction, which, for them, is mainly for home consumption such as fish or fuelwood.

The amount of environmental income of cluster one (column 4) is positively correlated with the number of fishing boats, the distance to the district's town, and the proximity of a river inside the village. It is negatively correlated with the head's age and the road type. Thus, accessibility to environmental resources and markets appears to be decisive for households in cluster one. A lower distance to the district's town increases environmental income. It indicates that an increased accessibility to financial and environmental product markets might motivate the poor to extract more. Social group membership is associated with a lower chance to participate in the extraction. Therefore, it is advisable to encourage membership in social organizations so that their social capital is promoted. This could create better opportunities for other income-generating alternatives rather than extraction of environmental resources.

The results of the Heckman model for cluster three and the OLS model for cluster two show that the amount of environmental income is positively correlated with the distance to the extracting grounds and the number of fishing boats. This is consistent with the earlier finding for the whole sample that households must go longer distances to access high value products, even though it is less important for cluster three. This is also confirmed by the negative effect of the river dummy variable on the amount of environmental income of cluster three. For cluster three, a smaller household size is associated with a lower probability that the household would participate in the extraction. The opposite is true for the number of household laborers. The negative correlation of the education level and the amount of environmental income confirms the importance of education in looking for other livelihood alternatives. Male-headed and minority households in cluster three seem to extract higher amounts of environmental income. Similarly, households with a higher number of TLU are likely to generate higher amounts of environmental income. One reason for this could be that these households use buffalos and cows for timber extraction (mainly transportation). Timber products generate higher environmental income compared to other products collected by poorer households (e.g. firewood). The number of tractors is positively correlated with the decision to participate, but negatively with the amount of environmental income. Households with a higher level of financial transfers and remittances in this cluster seem to have a higher level of environmental income. It might be that these households are able to invest more in extracting high value environmental products. Similar to the whole sample, the membership of a social or political group is associated with lower environmental income. Households who are more frequently exposed to shocks are more likely to participate in the extraction. This is consistent with the finding from Völker and Waibel (2010) which suggests that extracting environmental resources is a coping strategy for Vietnamese households. Meanwhile, the number of enterprises with more than five employees in the village is negatively associated with the probability to extract environmental resources. One reason for this might be that better off-farm employment opportunities reduce the probability of natural resource extraction. These findings are in line with those from various authors, for example, Ellis (2000), Brown et al. (2006), Völker and Waibel (2010), and Angelsen et al. (2014), who show that promoting off-farm wage employment reduces the dependence on environmental resources.

## 5. Conclusions and policy implications

This study has investigated the livelihood strategies and the extraction of environmental resources of rural households of the Stung Treng province of Cambodia. Our findings reveal that households pursue different livelihood strategies due to the differences in various types of capital. These strategies are classified into three distinct livelihood clusters. Higher levels of human capital (e.g. education), physical capital (e.g. number of fishing boats and motorbikes), and social capital (e.g. the number of mobile phones) make better-off households to benefit more from environmental resource extraction.

Environmental income is a significant contribution to household income and acts as an income equalizer. The share of income from environmental resources is higher for low income households than for wealthier households, although the latter derive more absolute income from environmental resources. The level of environmental resource extraction is influenced by the human, physical, social, and financial capital, and by the shocks and village characteristics. Our findings confirm the notion that rural households are highly dependent on environmental resources for their livelihoods, even though the level of dependence differs. This difference suggests that households are not homogenous and that the heterogeneity in terms of household livelihood platforms, strategies, and outcomes needs to be taken into account. In this sense, rural development and nature conservation programs should be designed to fit the needs of different groups of rural residents. In addition, the fact that wealthier households have a higher level of absolute environmental income suggests that it is not the low income households who are to be blamed for environmental degradation in Cambodia. Our analysis reveals that they are less likely to engage in extraction activities with higher returns than wealthier households.

Given the importance of environmental resources to household income and the fact that the extraction is mainly undertaken in open access areas, we recommend that the access to environmental resources should be effectively regulated in order to prevent their over-extraction. This would reduce the vulnerability of environmental income of the rural poor due to the degradation of environmental resources. However, environmental 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 must be promoted. More specifically, for households in cluster one, specific safety net programs should be designed to support them to recover from a shock, and social networking programs should be designed to assist them in finding off-farm wage employment opportunities. For households in clusters two and three, policies should concentrate on enforcing extraction regulations to reduce over-extraction of environmental resources, and at the same time enable them to participate in off-farm labor market. Other programs to support farming activities for a higher return should also be taken into account. In general, capacitating the rural population would be a way to reduce their extraction of environmental resources. This can be done by providing more off-farm employment opportunities, facilitating the establishment of rural social networks, and promoting education. Development efforts should facilitate investments in off-farm jobs by entrepreneurs. Public investment programs should facilitate the improvement and development of human and social assets of rural households.

Our research can be extended in several ways. Extending the study to other provinces and over several time periods would contribute to the generalization of the research findings for Cambodia. Furthermore, including non-pecuniary benefits from environmental sources would provide better estimates of the dependence on environmental resources.

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