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Dynamics of rural livelihoods and environmental reliance: Empirical evidence from Nepal☆

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ABSTRACT

Using environmentally augmented panel dataset of 2009 and 2012 from four districts in Nepal, we assess environmental reliance of households in different livelihood strategies and dynamic transition groups. We employ a latent class cluster analysis to determine the optimal number of livelihood clusters and assign individual households to particular cluster; and regression models were used to examine the covariates of change in environmental income and reliance. The analysis identifies six distinct livelihood clusters in terms of asset investment in different livelihood activities. Results show that majority of households persist in the relatively lower remunerative livelihood strategies between 2009 and 2012. Environmental income is important to all livelihood strategies. However, households in the least remunerative strategy and downward transition group have higher environmental reliance. It is also found that households with upward transition are likely to have reduced environmental dependency. Hence, enhancement of poverty reduction strategies in supporting poorer household in asset accumulation and undertake alternative higher remunerative livelihood strategies will eventually reduce the pressure and dependency on environment. Furthermore, conservation policies and natural resource management are critical in the study areas to sustain the increased demands on environmental products and services.

1. Introduction

People living in rural areas in developing countries are highly dependent on environmental resources and services provided by their natural ecosystems, such as water, cultivable land and non-timber forest products. Environmental resources and related income generation activities are an integral part of rural livelihoods (Mamo et al., 2007; Mcelwee, 2008; Shackleton and Shackleton, 2004; Walelign, 2013). These resources and activities often provide one or more of the following four essential functions in maintaining or improving rural livelihoods, including: (i) subsistence, supporting current year round households consumption needs; (ii) seasonal gap-filling, covering income or consumption shortfalls due to seasonality of certain income generation activities; (iii) safety net, providing support to overcome unexpected income losses or subsidize consumption shortfall due to unexpected shocks (e.g. crop failure) or high expenditures (e.g. wedding, funeral); and (iv) pathway out of poverty, providing households with a regular cash income that can be saved and used to buy assets (Angelsen and Wunder, 2003; Cavendish, 2002). Contribution of environmental resources and services to rural livelihoods can be measured in monetary units and constituent environmental income in households' total income accounting (Angelsen et al., 2014; Babulo et al., 2009). The share of environmental income to household's total income reflects households' environmental dependency. Overall, rural households often exhibit a higher level of dependency on environmental resources (Angelsen et al., 2014; Babulo et al., 2009; Vedeld et al., 2007; Walelign and Nielsen, 2013).

Due to a high degree of heterogeneity observed in rural livelihoods (Ansoms and McKay, 2010; Ellis, 2000; Yaro, 2002), households are more likely to have distinct level of environmental dependency. Hence, environmental dependency assessments should be undertaken at subgroups of a population – by grouping households that exhibit some level of similarity. In the previous studies on household level environmental dependency, distinct wealth groups are often identified based on income, assets or both. For instance, Córdova et al. (2013), Hogarth et al. (2013)), Yemiru et al. (2010), Vedeld et al. (2007) and Mamo et al. (2007) used income quintiles, Rayamajhi et al. (2012) and Babulo et al. (2009) used income quartiles, Adhikari et al. (2004a), Heubach et al. (2011) and Kabubo-Mariara (2013) used income terciles, Walelign (2013) used two income poverty groups, Charlery and Walelign (2015)

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and Nielsen et al. (2012) used four poverty groups based on a combined income and asset measure. These studies provide better understanding on household environmental dependency of different categories. Often, the richer households extract more resources from the environment, while the poor are more dependent on environmental resources.[1]

Unlike other studies, we identify livelihood strategy categories instead of wealth categories in this paper. Wealth based categories fail to capture the diversity that may present with each wealth group. For instance, rural households that are identified as poor are not homogeneous, rather they are often heterogeneous in the way that they make a living, engaging in different mix of livelihood activities to maintain or improve their livelihoods (Ansoms and McKay, 2010; Yaro, 2002). Hence, we assert that environmental dependency is better understood if the household categories are identified on the basis of what they do (e.g. income they get from different livelihood activities, assets investments into the activities or both) rather than what they currently own (e.g. total income, assets or both). And, understanding environmental dependency in the context of rural livelihood strategies improves the efficiency of policy interventions.

Nguyen et al. (2015), Porro et al. (2015), Walelign (2016), Chilongo (2014), Tesfaye et al. (2011), Zenteno et al. (2013) and Babulo et al. (2008) identify livelihood strategy groups to assess environmental dependency of rural households. They employee hierarchical and/or k-means cluster analysis to identify livelihood strategies using absolute income or share of income (to total income) generated from different livelihood activities as a choice variable.[2] Three major limitations underpin these studies. First, income per se is stochastic and does not reflect the amount of assets households invested in different activities[3] (Nielsen et al., 2012). Hence, the use of income is not well suited to identify and categorize household into livelihood strategies (Jansen et al., 2006; Nielsen et al., 2013). Second, the use of agglomerative and k-means cluster algorithms is relatively arbitrary and subjective in livelihood strategy clustering (Haughton et al., 2012; Magidson and Vermunt, 2002). Third, the studies overlooked the dynamics in livelihood strategies amid the presence of ample evidence that rural households' switch or modify livelihood strategies (Berhanu et al., 2007; Jones and Thornton, 2009; Van den Berg, 2010). Thus, lacking this dynamic aspect is a major flaw for livelihood studies (De Haan and Zoomers, 2005; Scoones, 2009).

This paper is aimed at empirically investigating the dynamics of livelihood strategy transitions and changes in environmental reliance, and their interrelationship. We focus on three questions: i) what are the household livelihood strategies and their transitions? ii) How much do households dependent on environmental income over the years (2009–2012) and across livelihood strategies? and iii) how does changes in environmental reliance associate with transitions of livelihood strategies over the years (2009–2012)? Using an environmentally augmented panel dataset from Nepal, a latent model clustering approach was employed to identify livelihood strategies and households' environmental dependency were analyzed across the various livelihood strategy and dynamic transition groups.

2. Conceptual framework

This study is theoretically grounded in the conceptual frameworks on sustainable rural livelihoods (Scoones, 1998, 2015; Ellis, 2000), and household livelihood strategy framework (Winters et al., 2001; Nielsen et al., 2013). The sustainable livelihood approach lays out a basis for livelihood analysis and draws on key factors (i.e. livelihood resources, contexts and institutional processes, livelihood strategies and outcomes) that affect rural livelihoods. Household livelihood strategy framework elaborates further and enables a closer examination of the relationships between livelihood assets, activities, outcomes and contextual factors. In addition, this paper makes use of the recent methodological advances to quantify environmental augmented rural household income data (Angelsen et al., 2011; Cavendish, 2002).

Fig. 1 presents the analytical framework of this paper which is based on the household strategy framework (Nielsen et al., 2013) originally adapted from Winters et al. (2001). The household is considered a social unit for the analysis under the framework. The main concepts used for analyses are assets, activities, outcomes and context. Assets (natural, social, physical, human and financial capital) play critical roles in the livelihood dynamics; they are influencing directly the choices of livelihood activities and outcomes as well as decisions to adapt. Livelihood strategy is the portfolio of livelihood activities that a household is undertaken; similarly, it is dynamic and adaptable to availability resources (e.g., labour, physical assets, and financial capital) and changing context. Environmental reliance is conceptualized here as the relative income share of the total household income; it varies across livelihood strategies and changes over time. Moreover, transitions of livelihood strategies are interacted with changes in environmental reliance.

3. Methods

3.1. Study area and data collection

The data was collected from six village development committees (VDCs, an administrative unit) under the Community-based Forest and Tree management in the Himalayas (ComForM) project following the Poverty Environment Network (PEN) study approach (PEN, 2007). The VDCs are located in four districts (Kaski, Chitwan, Mustang and Gorkha) in the Western and Central Development regions and span across the three major agro-ecological zones of Nepal (Mountains, Mid-hills and Terai). The study villages were selected purposefully considering the following criteria: (i) the altitudinal and vegetation variation in Nepal, (ii) households' environmental reliance, (iii) community's attitude towards long-term research, and (iv) village accessibility and safety for researchers (due to the ongoing civil war in Nepal during site selection in 2005) (Larsen et al., 2014).

Data collection involved a series of structured household surveys, including biannual and quarterly survey instruments. The biannual surveys were conducted at the start and end of each survey year. The start survey collected basic household information such as demographics, assets, access to forest and markets for forest products. The end survey focused on household livelihood changes in the survey period of one year (e.g. regarding gain or loss of assets, whether households experienced crises or unexpected expenditure). The quarterly surveys were designed to collect high quality income data with relatively short recall periods of maximum three months being applied to minimize errors arising from long recall periods as well as the seasonality of income sources. Income is defined as the value added of labour and capital; the total value of cash or goods obtained from the trade of goods and/or services by members of the households minus the cost of input except households labour. Similarly, environmental income is defined as the value added of labour and income from collection of products from forest and non-forest environments (e.g., grassland, bushlands, wetlands, fallows). Labour was not considered in the income calculation due to estimation difficulties and the poor labour market in the study sites. The resulting data is a panel data from 2008 and 2012 in Gorkha and in 2009 and 2012 in the remaining districts. We put all variables measured in monetary units in 2009 prices using the national Consumer Price Index (CPI).

[1] A notable exception to this finding is Heubach et al. (2011) who report that the richer households generates more income from and also are more dependent on environmental resources in Northern Benin.

[2] Porro et al. (2015) and Babulo et al. (2008) are an exception. Both do not employ cluster analysis to identify livelihood strategies. Porro et al. (2015) generates livelihood strategy groups based on assessment of households dependency on income from livelihood activities, forest income, agricultural income and wage and business income while Babulo et al. (2008) generates environmental dependency quartiles and label these groups as livelihood strategy groups.

[3] This limitation does not apply for Nguyen et al., 2015 which employ asset as activity based choice variables.

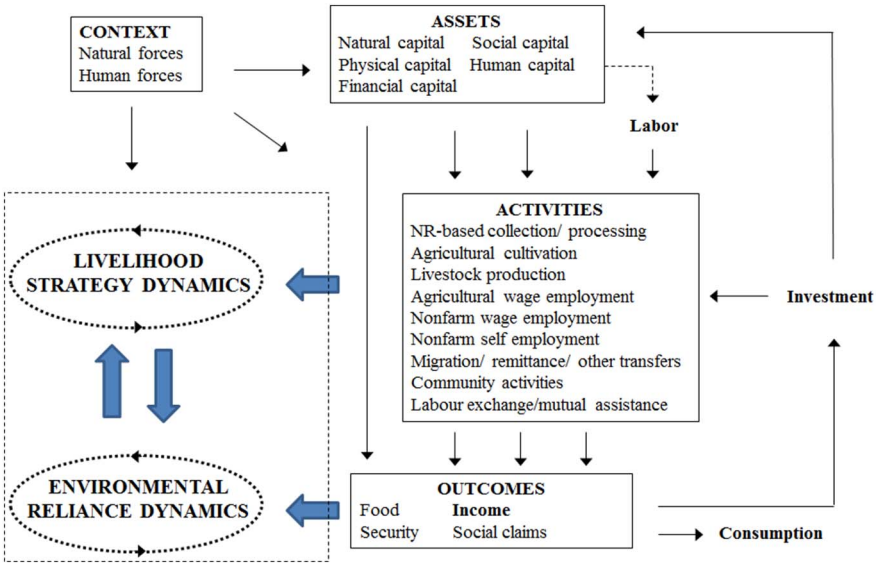

Fig. 1. Dynamic household livelihood strategy framework (adapted from Nielsen et al., 2013 and Winters et al., 2001).

A total of 863 households from the four districts (120 in Kaski, 239 in Chitwan, 199 in Mustang and 305 in Gorkha) were surveyed in 2009, and 805 of them were resurveyed in 2012. In total, 59 households dropped out in the 2012 survey resulting in an attrition rate of about 6%. A probit analysis was applied to test the presence of attrition bias suggesting that attrition is not a pervasive problem for the current analysis (not presented here, can be provided on request). One household was excluded from further analysis due to an implausibly large total income in 2012. Hence, we use a balanced data of 804 households in the analysis. The sample households were selected through simple random sampling, implemented at village level. The sampling frame used in Lete and Kunjo was the latest census list of households provided by the respective VDCs while the sampling frame in Hemja and Chainpur was the respective forest user groups (FUGs) members list from the respective VDCs. The sampling frames were updated with the help of key informants as they were several years old (Larsen et al., 2014).

3.2. Data analysis

The overall empirical strategy was developed in accordance with the conceptual framework and research questions. We first combined income and asset variables statistically by regressing income from each livelihood activity against assets that overcomes the limitation of using income and asset choice variables (separately) for livelihood clustering (Walelign et al., 2015, 2016b). Latent cluster models were then employed to determine the optimal number of clusters and assign individual households to particular livelihood strategy. These models are less subjective alternatives compared to the conventional hierarchical cluster analysis and K-means algorithms (Haughton et al., 2012; Magidson and Vermunt, 2002). Household income composition and environmental dependency were further analyzed across the identified livelihood clusters. Finally, we examined the dynamic transitions between livelihood strategy groups and environmental dependency in relation to the transitions (e.g., upward or downward transition associated with income generation).

3.2.1. Generation of activity choice variables

The activity choice variables – used for identifying livelihood clusters – for this study are generated through an approach proposed by Walelign et al. (2015, 2016b): combining income and asset variables using a two-part regression model of incomes from each livelihood activities against assets. In our income dataset, some households earn a negative/zero income from livelihood activities. To minimize negative predictions due to the use of Ordinary Least Squares (OLS), we employee a two-part regression model where one part is a probit model that predicts the probability of getting a positive income from a particular livelihood activity and another part is an OLS that predict the positive incomes. We run the two-part model for incomes from five livelihood activities: environmental resource extraction, crop production, livestock rearing, wage employment and business ownership. Assets included in the models as explanatory variables are implements, livestock, land owned, head education, maximum household education, age of household head, whether the head belong to the biggest caste, number of adult household members, households trust on the community, households help from the community, household Forest User Group (FUG) activities participation, jewelry, saving and debt. District and year dummies are also included as controls. The fitted values of the two-part model (the income predictions) represent the composite asset index invested in environmental resource extraction, crop production, livestock rearing, wage employment and business ownership, respectively. The two-part model is not run for transfer income as households do not allocate their current asset to earn income from transfers, but it is directly included as a choice variable (Walelign et al., 2015, 2016b). Hence, we use six activity choice variables: environmental asset index, crop asset index, livestock asset index, wage asset index, business asset index and transfer income.

3.2.2. Identification of livelihood strategies

In order to reduce the correlation among the choice variables and the consequent distortion in household clustering, we use Principal Component Analysis (PCA). PCA generates a new set of uncorrelated choice variables, called principal component scores, on the basis of the overall variance in the original choice variables (Hair et al., 1998). The Kaiser-Mayer-Olkin measure of sample adequacy and Barlett's test of sphericity reveal the presence of enough correlation among the choice variables and hence, support the suitability of our data to undertake PCA. Kaiser criterion of determining optimal number of principal component scores suggests two principal components scores are optimal for further analysis, e.g. cluster analysis. These two component scores explained about 64% of the overall variation in the original choice variables.

We then input the two component scores into cluster analysis. We prefer the latent cluster model analysis compared to the conventional hierarchical cluster analysis and K-means algorithms for two major reasons. First, latent cluster models are less arbitrary as they minimize

Table 1
Mean values of asset indexes for each livelihood activity and total transfers by livelihood clusters (values in parenthesis are the asset investments relative to an average household).

Asset indexes	Cluster 1: diversified small scale farmers (n = 474)	Cluster 2: diversified medium scale farmers (n = 422)	Cluster 3: small scale farmers with wage employment (n = 367)	Cluster 4: business owners with remittances (n = 203)	Cluster 5: wage labors with remittances (n = 135)	Cluster 6: business operators and large scale farmers (n = 7)	ANOVA
Environmental asset index	9390 (0.6)	17,463 (1.1)	10,154 (0.6)	28,270 (1.8)	18,584 (1.2)	226,786 (14.4)	131.0***
Crop asset index	6818 (0.4)	20,574 (1.4)	5336 (0.4)	23,740 (1.6)	7735 (0.5)	665,599 (43.9)	238.56***
Livestock asset index	11,301 (0.1)	21,199 (0.3)	7933 (0.1)	53,864 (0.7)	13,723 (0.2)	14,700,000 (178.1)	106.96***
Business asset index	13,279 (0.5)	16,917 (0.6)	5619 (0.2)	111,609 (4.0)	2216 (0.8)	526,245 (18.9)	90.86***
Wage asset index	1410 (0.5)	2769 (1.0)	3121 (1.1)	3430 (1.2)	7260 (2.5)	406 (0.1)	94.80***
Transfer income	14,072 (0.8)	13,837 (0.8)	7367 (0.4)	34,852 (2.1)	29,736 (1.8)	128,116 (7.6)	39.45***

Exchange rate: 1 USD = 77.48 NRs (in 2009), 1 USD = 83.43 NRs (in 2012) (source: Nepal Rastra Bank).
* Significant at 10%, the very high for households in cluster 6 is due to engagement of some households in largescale production and sell of livestock (e.g. chicken, goats, buffalo).
** Significant at 5%.
*** Significant at 1%.

within cluster variation by assigning each household membership probabilities for each cluster solution. Second, latent cluster models are model based clustering approaches that provide information and significance tests for the selection of a model with optimal livelihood clusters (Haughton et al., 2012; Magidson and Vermunt, 2002). Selection of optimal cluster solution is based on Bayesian Information Criteria (BIC) for logarithm of the likelihood function (*LL*) and the lower the BIC, the better the fit of the model. The analysis is carried out using Latent Gold 5.0 (Vermunt and Magidson, 2013). We considered two latent cluster methods – the standard latent class cluster model (LCM) and the latent Markov model (LMM) – for our livelihood clustering.

3.2.3. Modelling covariates of environmental income and reliance change

To identify the covariates of changes in households' environmental income and reliance (focusing on livelihood strategy transitions), we employes Ordinary Least Square (OLS) regressions for dynamic absolute and relative environmental income models Eqs. (1) and (2) respectively). The models are specified as:

$$\Delta A_{it} = \beta_0 + \beta_1{}^{A} A_{it-1} + \beta_2 T_{it,it-1} + \beta_3 E_{it-1} + \beta_4 S_{it-1} + \beta_5 L_{it-1} + \varepsilon_{it} \quad (1)$$

$$\Delta S_{it} = \beta_0 + \beta_1{}^{s} S_{it-1} + \beta_1 T_{it-1} + \beta_1 E_{it-1} + \beta_1 S_{it-1} + \beta_1 L_{it-1} + \varepsilon_{it} \quad (2)$$

where A_{it-1} is log transformed absolute environmental income of household i in 2009 and $\beta_1{}^{A}$is its coefficient; S_{it-1} is logit transformed environmental reliance of household i in 2009 and $\beta_1{}^{S}$is its coefficient; $T_{it,it-1}$ is vector transitions dummies and β_2 is its vector of coefficients; E_{it-1} is vector of asset endowments and is β_3 its vector of coefficients; S_{it-1} is household shock experience and β_4 is its coefficient; L_{it-1} is vector of location dummies and β_5 is its vector of coefficients and ε_{it} is the random error term.

The inclusion of lagged environmental income and reliance enables us to assess the pattern of changes in environmental income and reliance with respect to households' previous status. Livelihood transition dummies were also included as covariates, supporting the analysis of how household's environmental income varies with households' distinct livelihood transition. The choice of the other covariates followed the literature on environmental dependency and rural livelihoods and this variables has been found instrumental to dictate households environmental income and reliance (see e.g., Córdova et al., 2013; Hogarth et al., 2013; Yemiru et al., 2010; Vedeld et al., 2007; Mamo et al., 2007; Rayamajhi et al., 2012; Babulo et al., 2009; Adhikari et al., 2004a; Heubach et al., 2011; Walelign et al., 2016a; Nielsen et al., 2012; Angelsen et al., 2014). The inclusion of lagged environmental income and reliance and shock variables in the models allows mitigating the potential problem of regression towards the mean that may arise from random unobserved shocks and measurement errors resulting in extreme values of particularly income and asset in one time period.

4. Result

4.1. Identification of livelihood strategies

Six livelihood strategies were identified using latent cluster models. In the LMM, the heterogeneity of household activity choice variables were best explained by the 6 states - 1 class LMM as the BIC (4991.73) was the lowest with a large number of parameters (Npar) of 62 compared to other LMMs. Similarly, within the LCM models, the 7 cluster LCM described best households' variation in the activity choice variables with lowest BIC (5307.727) and high Npar (49). Comparing the two optimal models, 6 states-1 class LMM had lower BIC and larger Npar than the 7 cluster LCM meaning that the former model explained our data best than all the other models considered (see Appendix A). Hence, the subsequent analyses are based on the results of the 6 states - 1 class LMM.

Table 1 presents the six identified livelihood states (hereafter clusters) that were labelled based on the dominant asset composition and investment in different livelihood activities compared within the cluster as well as the overall sampled household. Households in the first and third clusters made relatively low investment in most activities, but the first cluster invested evenly across the livelihood activities while the third cluster invested more on wage employment. Hence, the former and the later were named diversified small scale farmers and small scale farmers with wage labors, respectively. Households in the second cluster invested their assets in a diversified manner similar to households in cluster 1, but in larger volume and hence cluster 2 was labelled diversified medium scale farmers. Households in the sixth cluster made relatively the largest investments in all activities, except wage employment, and this cluster was named business operators and large scale farmers. Households in the fourth cluster invested mostly in business and earned relatively higher income from transfers and this cluster was labelled business owners with remittances; while households in cluster 5 invested relatively large amount of assets on wage employment and received moderate amount of transfer income and this cluster was named wage labors with remittances. Differences in asset investments composition between livelihood strategies were mostly significant (see Appendix B).

4.2. Income composition and environmental dependency

Table 2 shows average household annual income by sources for each livelihood cluster and overall sampled households both in absolute value and relative share. Income composition of the clusters largely

Table 2
Household annual income (in 2009 prices in NRs, aeu adjusted) (total and by source) for livelihood strategy clusters.

Income sources	Cluster 1: diversified small scale farmers (n = 474)		Cluster 2: diversified medium scale farmers (n = 422)		Cluster 3: small scale farmers with wage employment (n = 367)		Cluster 4: business owners with remittances (n = 203)		Cluster 5: wage labors with remittances (n = 135)		Cluster 6: business operators and large scale farmers (n = 7)		ANOVA	Overall (n = 1608)		2009		2012	
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel		Abs	Rel	Abs	Rel	Abs	Rel
Environmental income	6921	14	7203	11	8134	27	9428	9	13,942	19	19,496	6	2.15*	8233	14	7107	13	9358	15
Crop income	5352	11	7701	12	3844	13	8376	8	3459	5	1810	1	6.23***	5832	10	9242	17	2421	4
Livestock income	8286	17	8994	14	3856	13	11,392	11	3257	4	37,800	12	9.64***	7559	13	8141	15	6977	11
Remittances	10,006	20	6846	11	5167	17	22,488	22	24,084	33	119,310	38	29.90***	11,306	19	11,730	21	10,881	17
Support income[a]	4066	8	6991	11	2200	7	12,363	12	5652	8	8806	3	20.86***	5609	10	7105	13	4113	7
Other income	6237	13	6705	10	2669	9	17,291	17	5208	7	19,929	6	2.84**	6914	12	3922	7	9906	16
Business income	7946	16	19,410	30	1543	5	19,326	19	15,340	21	106,988	34	1.42	11,982	20	6094	11	17,869	28
Wage income	936	2	832	1	2669	9	351	0	2812	4	236	0	26.10***	1385	2	1412	3	1357	2
Total income	49,749	100	64,682	100	30,081	100	101,015	100	73,754	100	314,375	100	9.29***	58,818	100	54,753	100	62,884	100

Abs = absolute income; Rel = relative income.
Exchange rate: 1 USD = 77.48 NRs (in 2009), 1 USD = 83.43 NRs (in 2012) (source: Nepal Rastra Bank).
[a] Support income includes income from government and non-governmental support, gifts and pensions.
*** Significant at 1%.
** Significant at 5%.
* Significant at 10%.

follows a similar pattern of investments in livelihood activities. For livelihood cluster 3, environmental income contributes significantly (27%) to total household income, followed by remittance (17%), crop and livestock income (13%). For livelihood cluster 6 and 5, major income sources are remittance and business income; noticeably, environmental income contributes 19% to the total income of cluster 5. Income composition of livelihood cluster 1, 2 and 4 are more diversified; while remittance and business income remain important income sources for these clusters. Most cluster level mean differences were statistically significant (see Appendix C).

Environmental income is an important income source for most of the livelihood clusters, ranging from 6 to 27% of total income. In general, it shows a moderate environmental dependency in the study area; on average, environmental income accounts for 14% of total household annual income. Households in the high remunerative livelihood strategy (Cluster 6) earns the most from environmental income in absolute value, while environmental income is most important to the poorest group (Cluster 3) in its relative share. Comparing environmental income between 2009 and 2012, an increasing trend is observed in both absolute and relative income (environmental dependency and dynamics are further investigated at product level in the following section). Other dynamic changes include significant drop in crop, livestock, remittance and support income; and increase in business and other income.

Product level disaggregation of environmental income indicates that households in the different livelihood strategies engage in extraction of different combination of one or more of environmental products (Table 3). Overall, fodder grass contributes most (33%) to the total environmental income, followed by firewood (21%), sand and stone (11%) for all sampled households on average. Similar composition of environmental income can be observed in Cluster 1, 2, and 4, with significantly high income share from fodder grass (34% -53%) and firewood (19%–26%), while contribution from other sources is relatively minor. It is more diversified in Cluster 3, income from firewood accounts for 24% of total environmental income, followed by fodder grass (19%), processed products (15%) and environmental wage (14%). Income from sand and stone contribute significantly to the total environmental income of Cluster 5 (52%) and Cluster 6 (35%). Remarkable income increases are observed in firewood income (17% to 25%) and fodder grass income (26% to 39%) in 2012 compared with 2009, while sharp drop in sand and stone income (22% to 3%). It is also found that majority of environmental income are subsistence income to the households (83% on average).

4.3. Transitions of livelihood strategies and environmental dependence

On the basis of total income generation of each livelihood cluster, three broader livelihood strategies are identified. Livelihood cluster 1 and 3 generate relatively lower total income and categorized as low remunerative livelihood strategies (LRLS); while total income of livelihood cluster 2 and 5 are moderate and categorized as medium remunerative livelihood strategies (MRLS); livelihood clusters 4 and 6 are categorized as high remunerative livelihood strategies (HRLS). The three livelihood strategies exhibit significant differences in total income ($F(2, 1607) = 15.47$; p-value < 0.01), suggesting that our categorization is valid and resulted in livelihood strategies with distinct remuneration.

Table 4 presents the livelihood transition matrix between LRLS, MRLS and HRLS. The results indicate that about half of the sampled households adopted LRLS in both 2009 and 2012, followed by MRLS (38% and 31% in 2009 and 2012 respectively). Very few households (approx. 7%) were able to adopt HRLS in 2009, however, an increasing trend is observed and the figure reached almost 20% that adopted HRLS in 2012. The distribution of households across three livelihood strategies were significantly different between 2009 and 2012 ($X^2(4) = 441.70$; p-value < 0.01). It is found that the majority of the house-

Table 3
Product level mean environmental income (in 2009 prices in NRs, aeu adjusted) by livelihood strategies.

Environmental income	Cluster 1: diversified small scale farmers (n = 474)		Cluster 2: diversified medium scale farmers (n = 422)		Cluster 3: small scale farmers with wage employment (n = 367)		Cluster 4: business owners with remittances (n = 203)		Cluster 5: wage labors with remittances (n = 135)		Cluster 6: business operators and large scale farmers (n = 7)		Overall (n = 1608)		2009		2012	
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel
Firewood	1765	26	1416	20	1950	24	1797	19	2067	15	1926	10	1746	21	1178	17	2314	25
Timber and pole	213	3	229	3	538	7	160	2	130	1	59	0	277	3	334	5	220	2
Wild food	338	5	262	4	446	6	406	4	382	3	301	2	355	4	286	4	424	5
Fodder grass	2324	34	3253	45	1555	19	5029	53	2050	15	6847	35	2730	33	1852	26	3609	39
Forest liter	410	6	328	5	620	8	292	3	447	3	1035	5	427	5	290	4	565	6
Sand and stone	349	5	230	3	372	5	201	2	7300	52	6836	35	916	11	1583	22	249	3
Environmental product processing	479	7	452	6	1199	15	390	4	− 434	− 3	858	4	550	7	468	7	631	7
Environmental services and FUG payments	457	7	478	7	140	2	318	3	189	1	1326	7	354	4	547	8	161	2
Environmental wages	359	5	326	5	1098	14	250	3	1657	12	0	0	613	7	396	6	829	9
Other	227	3	229	3	218	3	585	6	155	1	310	2	265	3	173	2	357	4
Cash	1084	16	1236	17	2128	26	805	9	1894	14	1409	7	1397	17	1251	18	1542	16
Subsistence	5837	84	5967	83	6006	74	8622	92	12,048	86	18,087	93	6836	83	5856	82	7816	84

Abs = absolute income; Rel = relative income.
Exchange rate: 1 USD = 77.48 NRs (in 2009), 1 USD = 83.43 NRs (in 2012) (source: Nepal Rastra Bank).

Table 4
Livelihood transition matrix (values in parenthesis are the number of households).

		2012				
		LRLS	MRLS	HRLS	Total	
2009	LRLS	42.79 (344)	12.06 (97)	0.25 (2)	55.10 (443)	χ^2 (4) = 441.70***
	MRLS	5.35 (43)	18.91 (152)	13.93 (112)	38.18 (307)	
	HRLS	1.37 (11)	0.12 (1)	5.22 (42)	6.72 (54)	
	Total	49.50 (398)	31.09 (250)	19.40 (156)	100.00 (804)	

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

holds (67%) persisted in their original livelihood strategies (i.e. LRLS, MRLS, or HRLS). Of the total sample households, the persistence was the highest and the lowest for the LRLS (43%) and HRLS (7%), respectively. The remaining 33% of the households transited between livelihood strategies, mainly characterized by an upward movement from MRLS to HRLS or from LRLS to MRLS. Based on the transitions of livelihood strategies, we further identified three major dynamic livelihood groups: i) households that made an upward livelihood transition (from LRLS to MRLS, LRLS to HRLS or MRLS to HRLS); ii) households that made a downward livelihood transition (from MRLS to LRLS, HRLS to MRLS or HRLS to LRLS); and iii) households that stayed at the original livelihood strategies (at LRLS, MRLS, or HRLS). The subsequent analysis focused on these three dynamic livelihood transition groups.

Table 5 presents income composition of three transition groups between 2009 and 2012, indicating that households across different dynamic livelihood groups experienced distinct pattern of income change. In general, sampled households experienced increases in environmental income, business income and other income between 2009 and 2012, and significant decreases in some other income sources (i.e. crop, livestock and support income). Remittance increased by 162% for the upward transition group while declined for other two groups. An increasing trend of environmental income was observed with all three dynamic livelihood transition groups. However, households that made downward transitions experienced the greatest increase in environmental income, hinting the potential safety net role of environmental income.

We further disaggregated environmental income at product level as well as cash and subsistence components to examine the patterns of environmental resources use across livelihood transition groups (Table 6). All three transition groups experienced positive changes in incomes from firewood collection, wild food, fodder, forest liter and environmental wage. However, the magnitude of the positive change was the greatest for households who made downward transition for most of the products (and services); except that upward transition group experienced the greatest positive change in wild food; and households that stayed in any of the livelihood strategies had the highest positive change in environmental wage. It is also found that all three transition groups experienced negative changes in sand and stone, environmental services and FUG payments. However, downward transition group experienced the least negative change in environmental services and FUG payments. While upward transition group experienced the least negative changes in sand and stone. Households who made an upward transition had a slight positive change in Timber and pole, while the other two dynamic livelihood groups experienced negative changes. Oppositely, upwards transition group experienced a significant decrease in processed forest product, while other two transition groups enjoyed positive changes in this source (especially for the downwards transition group). Household who made downward transition also showed greatest increase in dependence on environ-

Table 5
mean change of household income (NRs, aeu adjusted) (total and each source) of dynamic livelihood transition groups (mean value of changes between years).

Income sources	Downward		Stay		Upward		Overall	
	Change	%	Change	%	Change	%	Change	%
Environmental income	5958	100	1800	23	2434	41	2251	32
Crop income	− 8339	− 80	− 7429	− 81	− 4872	− 53	− 6820	− 74
Livestock income	− 5842	− 49	− 1076	− 13	− 166	− 2	− 1163	− 14
Remittances	− 22,415	− 70	− 3457	− 30	11,424	162	− 848	− 7
Support income	− 3453	− 51	− 3617	− 51	− 1277	− 18	− 2992	− 42
Other income	3602	132	6055	221	6421	89	5983	153
Business income	28,274	541	11631[a]	− 12572[a]	7840	35	11,775	193
Wage income	96	19	− 87	− 5	− 12	− 1	− 55	− 4
Total income	− 2120	− 3	3820	8	21,792	32	8130	15

Change = change between 2009 and 2012, % = percentage change between 2009 and 2012.
Exchange rate: 1 USD = 77.48 NRs (in 2009), 1 USD = 83.43 NRs (in 2012) (source: Nepal Rastra Bank).
[a] The change was positive, but the relative share was negative. This was due to the negative average business income in 2009.

mental resource both for subsistence use and income generation.

Table 7 presents the results of multiple regressions of changes between 2009 and 2012 in absolute and relative environmental income against livelihood strategy transitions and household characteristics. The included explanatory variables were jointly significant at 1% level suggesting the variables have a predictive power over the dependent variables. It is found that households with upward livelihood strategy transition has a negative association with changes in relative environmental income share, indicating that households with upward livelihood transitions are more likely to have lower environmental dependency. Higher environmental income in 2009 is also negatively associated with changes in environmental income both in absolute and relative terms. Changes in absolute environmental income is also positively influenced by land holdings and distance to village center, and negatively influenced by asset value and number of shocks experienced. It is also found that asset value and number of adults in the family are negatively associated with change in environmental dependency. In addition, significant and positive coefficients of the district dummy variables suggesting that changes in environmental income and dependency vary for households living in different geographical settings.

5. Discussion

The latent cluster analysis identifies six distinct livelihood strategies undertaken by local households in the study areas in rural Nepal. It shows that the LMM performs better than the LCM method as expected, and LMM is theoretically preferred over LCM for longitudinal data (Vermunt and Magidson, 2013). Results show that diversification in asset investments is common across livelihood strategy clusters, and each livelihood strategy often generates income from multiple sources. This confirms previous evidence that diversification is a norm in rural livelihoods to minimize the adverse livelihood effects of prevailing risks in a rural economy (e.g., shocks in the form of drought, flood, policy changes) (Davis, 2006; Kandulu et al., 2012; Nielsen et al., 2013). Households also benefit from synchronism of livelihood activities. For example, engagement in crop production lead to engagement in livestock production or vice versa; similarly, engagement in business activities lead to engagement in large scale investment in crop production and livestock production or vice versa (Walelign, 2016). These enable them to be self-reliant in fulfilling household needs, especially in remote areas where markets access is underdeveloped.

Low remunerative livelihood strategies remain the dominant livelihood strategies in the study area. The findings from livelihood strategy transitions indicate that limited capacity and resource is available for poorer households to uptake more remunerative livelihood strategies, though a general improving trend of rural livelihoods is observed in the study areas. Between 2009 and 2012, the majority of the households stay in the same level of livelihood strategies implying certain level of persistence in livelihood strategy; while the remaining households either move up to a relatively better-off or move down to the relatively worse-off livelihood strategies. Such dynamics in rural livelihood strategies has been also documented in previous studies (Van den Berg, 2010; Walelign et al., 2015).

Total income and income sources from each livelihood activities are found significantly different between most pairs of livelihood strategies, reflecting the differences in households' asset endowment and the consequent asset investment across livelihood strategies. This is largely

Table 6
mean of change in product level environmental income (NRs, aeu adjusted) of households in different livelihood transition groups (mean value of changes between years).

Income source	Downward		Stay		Upward		Overall	
	Change	%	Change	%	Change	%	Change	%
Firewood	1856	166	1163	97	881	78	1136	96
Timber and pole	− 138	− 36	− 161	− 42	14	8	− 113	− 34
Wild food	161	58	105	35	215	88	138	48
Fodder grass	2953	181	1460	82	2204	105	1758	95
Forest liter	384	98	305	92	171	111	275	95
Sand and stone	− 678	− 76	− 1874	− 88	− 130	− 37	− 1335	− 84
Forest product processing	960	718	562	118	− 1063	− 200	163	35
Environmental services and FUG payments	− 211	− 27	− 364	− 74	− 492	− 79	− 387	− 71
Environmental wage	293	186	523	132	238	52	432	109
Other	378	229	80	39	397	427	184	106
Cash	605	55	591	52	− 558	− 35	290	23
Subsistence	5353	111	1209	18	2992	70	1961	33

Exchange rate: 1 USD = 77.48 NRs (in 2009), 1 USD = 83.43 NRs (in 2012) (source: Nepal Rastra Bank).

Table 7
Regression of changes in absolute and relative environmental income against livelihood strategy transitions and household characteristics.

Variable	Change in environmental income (log, (Abs))	Change in environmental dependency (logit (Rel))
Environmental income (2009) (log, logit)	− 0.750*** (0.048)	− 0.656*** (0.047)
Livestock value (Rs)	0.005 (0.005)	− 0.006 (0.005)
Land size (m^2)	0.305*** (0.116)	0.180 (0.218)
Assets value (Rs)	− 0.009* (0.005)	− 0.036*** (0.011)
Number of adult	0.008 (0.018)	− 0.045* (0.025)
Number of dependents	0.003 (0.022)	0.049 (0.031)
Distance from village center (minutes)	0.002* (0.001)	0.000 (0.001)
Head education (years of education)	− 0.014 (0.010)	− 0.027 (0.014)
Head female (1 = yes)	− 0.027 (0.089)	− 0.192 (0.154)
Age head	0.003 (0.003)	0.002 (0.004)
Age head squared (centered)	0.000 (0.000)	0.000 (0.000)
Head belong to the biggest cast (1 = yes)	0.098 (0.078)	0.165 (0.117)
FUG participation (1 = yes)	0.029 (0.087)	− 0.183 (0.129)
Number of shocks	− 0.163** (0.063)	− 0.078 (0.103)
Livelihood movement: upward	0.033 (0.072)	− 0.407*** (0.123)
Livelihood movement: downward	− 0.009 (0.159)	− 0.108 (0.231)
District: Gorkha	0.957*** (0.099)	1.246*** (0.147)
District: Kaski	0.777*** (0.132)	0.339* (0.199)
District: Mustang	1.447*** (0.114)	1.381*** (0.165)
Constant	5.623*** (0.435)	− 1.192*** (0.300)
F(19,730)	21.61***	18.92***
R^2	0.42	0.43

*** Significant at 1%.
** Significant at 5%.
* Significant at 10%.

in line with previous empirical studies (Tesfaye et al., 2011; Walelign, 2016). Environmental income is an important source for all livelihood strategy groups contributing 6–27% to the total household annual income. Households in the least remunerative livelihood strategy group are featured with highest environmental dependency and limited assets and capital to invest in other more remunerative livelihood activities (e.g., business, remittance). Households in the highest remunerative livelihood strategy group earn the largest environmental income in the absolute value but with least environmental dependency. These results are largely consistent with previous findings that report rich households extract more resources from the environment while environmental income remains more important to the livelihood of poorer households in Nepal (Adhikari et al., 2004b; Charlery and Walelign, 2015; Chhetri et al., 2015; Panta et al., 2009; Rayamajhi et al., 2012) and elsewhere (Córdova et al., 2013; Hogarth et al., 2013; Kabubo-Mariara, 2013; Mamo et al., 2007; Yemiru et al., 2010); however, it contrasts with Heubach et al. (2011) and Walelign (2016) who point out that poorer households generate more environmental income in both absolute term and dependency.

Fodder and firewood remain the two most important environmental resources in the study areas (Chhetri et al., 2015; Panta et al., 2009; Rayamajhi et al., 2012), and majority of environmental income are used for household subsistence consumption (Rayamajhi et al., 2012). However, households in the lowest remunerative livelihood strategy (cluster 3) generate the largest cash environmental income than any other livelihood strategies, revealing the importance of environmental resources in cash income generation to cover expenses of household necessities (e.g., oil, sugar, salt) for the poor households. It is also found that households in the lowest remunerative livelihood strategy are more diversified in benefiting from environmental products and wage. On the other hand, households in the highest remunerative strategy extract natural resources mostly from fodder grass and sand stone. It is also documented in other studies that richer households generate higher income from these resources (Pouliot and Treue, 2013; Rayamajhi et al., 2012), possibly as subsistence income for maintaining the increasing livestock wealth and building quality housing.

A positive change in environmental income (both in terms of absolute and relative terms) is observed for all the sampled households between 2009 and 2012. It is also found that income from firewood and fodder grass showed considerable increase in 2012 compared with the status in 2009. In addition, households with downward transition in livelihood strategies experienced the highest increase in total environmental income as well as most of the environmental income sources. These findings indicate the safety net role and increased importance of natural resources and environmental dependency in the study areas, especially for the worse-off households, which is consistent with the finding by Nepal et al. (2011) for firewood use in Nepal. However, this does not mean that households that escape from low remunerative livelihood strategies do not depend on environmental products. It shows an increasing importance of some environmental products (i.e. sand and stone, timber and pole) to the households that made upward transition to higher remunerative livelihood strategies, possibly to fulfill the emerging demands for better quality housing construction.

Households with downward transition experienced the largest increased in environmental income (both in cash and subsistence); while households with upward transition experienced a declined cash income and increased subsistence income derived from environmental resources. These findings suggest that the former group rely more on environmental resources for both cash generation and subsistence; while the latter group tends to substitute cash environmental income with subsistence as they could benefit more from high remunerative cash income sources (e.g. remittances, business income). The regression model further confirms that households with upward transitions have less environmental dependency. Despite the key role played by environmental resources to the livelihood of household in the downward transition, the findings from the regression models also question the role of forest and non-forest environmental resources in coping with documented shocks to the study community. This is consistent with Wunder et al. (2014) and contradicts with Debela et al. (2012) and Völker and Waibel (2010). Even though we witness significant decline in the number of adult household members ($F(1, 1607) = 8.28$, p-value < 0.01) which is mainly due to out-migration from the villages to bigger cities (e.g., Pokhara, Kathmandu) and abroad (e.g., Dubai, Qatar) (Maskay and Adhikari, 2013; Thagunna and Acharya, 2013), we found evidence that number of adult household members did not associate with change in absolute and relative environmental income.

6. Conclusion

This paper provides quantitative empirical study in assessing dynamic contribution of environmental income to rural household livelihoods in different strategies and transition groups, using environmentally augmented two-year panel dataset. Six household livelihood strategies are identified in the study areas through latent cluster analysis and results show that they are different in relation to income generation and composition. The majority of households tend to stay within the similar income level livelihood strategy groups; however, it is also dynamic that households shift between strategies (i.e. upwards or downwards) in response to changing circumstances. It is observed that environmental income increased in 2012 both in absolute value and relative share for all sampled households, implying increased importance and dependency of environmental resources to rural livelihoods in the study areas. Even though households in the lowest remunerative livelihood strategy and in the downward transition group

are found most dependent on environmental income while households with upwards transition are likely to have reduced environmental dependency, households in all livelihood strategies and livelihood transition appear to drive part of their income from environmental resources. This confirms the inherence of environmental resources use to the livelihoods of rural Nepalese, particularly the poor, to support current consumption. These findings strongly suggest that conservation policies and natural resource management are critical in the study areas to sustain the increased demands and reliance of local livelihoods on environmental products and services. Enhancement of poverty reduction strategies in supporting poorer household in asset accumulation and undertake alternatives higher remunerative livelihood strategies will eventually reduce the pressure and dependency on environment.

Like many other studies that base on the rural livelihood framework, this study did not address the endogeneity issue that could arise from reverse causality of household income, asset and livelihood strategies. This is mainly because the variables are often affected by the same process and lack of valid instruments that affects one of the variables without affecting the others. Hence, the results should be interpreted with care that they suggest the association between income and livelihood strategy transitions rather than causality.

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Appendix A. Optimal livelihood cluster determination statistics based on LCM and LMM

LCM					LMM				
	LL	BIC(LL)	Npar	Class.Err		LL	BIC(LL)	Npar	Class.Err.
1-Cluster	− 5412.6	10,854.8	4	0.0000	1-State 1-Class	− 5412.6	10,852.0	4	0.0000
2-Cluster	− 3184.9	6451.0	11	0.0233	2-State 1-Class	− 3175.9	6432.1	12	0.0283
3-Cluster	− 2700.9	5534.8	18	0.0825	3-State 1-Class	− 2636.0	5419.1	22	0.0861
4-Cluster	− 2571.9	5350.5	28	0.1700	4-State 1-Class	− 2434.1	5095.7	34	0.1301
5-Cluster	− 2527.9	5314.2	35	0.2180	5-State 1-Class	− 2343.8	5002.0	47	0.1660
6-Cluster	− 2502.4	5315.0	42	0.2597	6-State 1-Class	− 2288.5	4991.7	62	0.1728
7-Cluster	− 2473.0	5307.7	49	0.3159	7-State 1-Class	− 2237.5	5003.6	79	0.2240
8-Cluster	− 2461.1	5335.7	56	0.3244	8-State 1-Class	− 2189.8	5035.2	98	0.2193
9-Cluster	− 2445.8	5356.8	63	0.3354	9-State 1-Class	− 2148.5	5093.1	119	0.2169
10-Cluster	− 2429.1	5375.0	70	0.3350	10-State 1-Class	− 2107.1	5164.2	142	0.2166

Appendix B. Pairwise comparison of asset investments indexes using Bonferroni method

	Environmental asset index	Crop asset index	Livestock asset index	Business asset index	Wage asset index	Transfer income
Cluster 1 vs 2	***	***	NS	NS	***	NS
Cluster 1 vs 3	NS	NS	NS	NS	***	*
Cluster 1 vs 4	***	***	NS	***	***	***
Cluster 1 vs 5	***	NS	NS	NS	***	***
Cluster 1 vs 6	***	***	***	***	NS	***
Cluster 2 vs 3	***	***	NS	NS	NS	*
Cluster 2 vs 4	***	NS	NS	***	*	***
Cluster 2 vs 5	NS	NS	NS	NS	***	***
Cluster 2 vs 6	***	***	***	***	NS	***
Cluster 3 vs 4	***	***	NS	***	NS	***
Cluster 3 vs 5	***	NS	NS	NS	***	***
Cluster 3 vs 6	***	***	***	***	NS	***
Cluster 4 vs 5	***	*	NS	***	***	NS
Cluster 4 vs 6	***	***	NS	***	*	***
Cluster 5 vs 6	***	***	***	***	***	***

NS = not significant. ** Significant at 5%.
*** Significant at 1%.
* Significant at 10%.

Appendix C. Pairwise comparison of income sources using Bonferroni method

	Environmental income	Crop income	Livestock income	Remittances	Support income	Other income	Business income	Wage income	Total income
1 vs 2	NS	NS	NS	NS	***	NS	NS	NS	NS
1 vs 3	NS	NS	**	NS	NS	NS	NS	***	NS
1 vs 4	NS	*	NS	***	***	*	NS	NS	***

1 vs 5	*	NS	NS	***	NS	NS	NS	***	NS
1 vs 6	NS	NS	***	***	NS	NS	NS	NS	***
2vs 3	NS	***	**	NS	***	NS	NS	***	**
2 vs 4	NS	NS	NS	***	***	NS	NS	NS	NS
2 vs 5	NS	**	***	***	NS	NS	NS	NS	NS
2 vs 6	NS	NS	***	***	NS	NS	NS	***	***
3 vs 4	NS	***	***	***	***	***	NS	NS	***
3 vs 5	NS	NS	NS	***	*	NS	NS	***	NS
3 vs 6	NS	NS	***	***	NS	NS	NS	NS	***
4 vs 5	NS	**	***	NS	***	NS	NS	***	NS
4 vs 6	NS	NS	***	***	NS	NS	NS	NS	***
5 vs 6	NS	NS	***	***	NS	NS	NS	NS	***

NS = not significant.
*** Significant at 1%.
** Significant at 5%.
* Significant at 10%.

References

Adhikari, B., Di Falco, S., Lovett, J.C., 2004a. Household characteristics and forest dependency: evidence from common property forest management in Nepal. Ecol. Econ. 48, 245–257.

Adhikari, M., Nagata, S., Adhikari, M., 2004b. Rural household and forest: an evaluation of household's dependency on community forest in Nepal. J. For. Res. 9, 33–44.

Angelsen, A., Wunder, S., 2003. Exploring the Forest–Poverty Link: Key Concepts, Issues and Research Implications. CIFOR, Bogor, Indonesia.

Angelsen, A., Larsen, H.O., Lund, J.F., Smith-Hall, C., Wunder, S., 2011. Measuring Livelihoods and Environmental Dependence: Methods for Research and Fieldwork. Earthscan, London.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, C., Wunder, S., 2014. Environmental income and rural livelihoods: a global-comparative analysis. World Dev. 64, S12–S28.

Ansoms, A., McKay, A., 2010. A quantitative analysis of poverty and livelihood profiles: the case of rural Rwanda. Food Policy 35, 584–598.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., Mathijs, E., 2008. Household livelihood strategies and forest dependence in the highlands of Tigray, Northern Ethiopia. Agric. Syst. 98, 147–155.

Babulo, B., Muys, B., Nega, F., Tollens, E., Nyssen, J., Deckers, J., Mathijs, E., 2009. The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. Forest Policy Econ. 11, 109–117.

Berhanu, W., Colman, D., Fayissa, B., 2007. Diversification and livelihood sustainability in a semi-arid environment: a case study from southern Ethiopia. J. Dev. Stud. 43, 871–889.

Cavendish, W., 2002. Quantitative Methods for Estimating the Economic Value of Resource use to Rural Households. In: Campbell, B.M., Luckert, M.K. (Eds.), Uncovering the Hidden Harvest: Valuation Methods for Woodland and Forest Resources. Earthscan, London.

Charlery, L., Walelign, S.Z., 2015. Assessing environmental dependence using asset and income measures: evidence from Nepal. Ecol. Econ. 118, 40–48.

Chhetri, B.B.K., Larsen, H.O., Smith-Hall, C., 2015. Environmental resources reduce income inequality and the prevalence, depth and severity of poverty in rural Nepal. Environ. Dev. Sustain. 17, 513–530.

Chilongo, T., 2014. Livelihood strategies and forest reliance in Malawi. For. Trees Livelihoods 23, 188–210.

Córdova, J.P.P., Wunder, S., Smith-Hall, C., Börner, J., 2013. Rural income and forest reliance in highland Guatemala. Environ. Manag. 51, 1034–1043.

Davis, J., 2006. Rural non-farm livelihoods in transition economies: emerging issues and policies. J. Agric. Dev. Econ. 3, 180–224.

De Haan, L., Zoomers, A., 2005. Exploring the frontier of livelihoods research. Dev. Chang. 36, 27–47.

Debela, B., Shively, G., Angelsen, A., Wik, M., 2012. Economic shocks, diversification, and forest use in Uganda. Land Econ. 88, 139–154.

Ellis, F., 2000. Rural Livelihoods and Diversity in Developing Countries. Oxford university press.

Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C., 1998. Multivariate Data Analysis. Printice Hall, New Jersey.

Haughton, D., Legrand, P., Woolford, S., 2012. Review of three latent class cluster analysis packages: latent Gold, poLCA, and MCLUST. Am. Stat. 63, 81–91.

Heubach, K., Wittig, R., Nuppenau, E.-A., Hahn, K., 2011. The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural west African communities: a case study from northern Benin. Ecol. Econ. 70, 1991–2001.

Hogarth, N.J., Belcher, B., Campbell, B., Stacey, N., 2013. The role of forest-related income in household economies and rural livelihoods in the border-region of Southern China. World Dev. 43, 111–123.

Jansen, H.G., Pender, J., Damon, A., Wielemaker, W., Schipper, R., 2006. Policies for sustainable development in the hillside areas of Honduras: a quantitative livelihoods approach. Agric. Econ. 34, 141–153.

Jones, P.G., Thornton, P.K., 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. Environ. Sci. Pol. 12, 427–437.

Kabubo-Mariara, J., 2013. Forest-poverty nexus: Exploring the contribution of forests to rural livelihoods in Kenya. Nat. Res. Forum 37, 177–188.

Kandulu, J.M., Bryan, B.A., King, D., Connor, J.D., 2012. Mitigating economic risk from climate variability in rain-fed agriculture through enterprise mix diversification. Ecol. Econ. 79, 105–112.

Larsen, H.O., Rayamajhi, S., Chhetri, B.B.K., Charlery, L.C., Gautam, N., Khadka, N., Puri, L., Rutt, R.L., Shivakoti, T., Thorsen, R.S., 2014. The Role of Environmental Incomes in Rural Nepalese Livelihoods 2005–2012: Contextual Information. Department of Food and Resource Economics, University of Copenhagen.

Magidson, J., Vermunt, J., 2002. Latent class models for clustering: a comparison with K-means. Can. J. Mark. Res. 20, 36–43.

Mamo, G., Sjaastad, E., Vedeld, P., 2007. Economic dependence on forest resources: a case from Dendi District, Ethiopia. Forest Policy Econ. 9, 916–927.

Maskay, N.M., Adhikari, S.R., 2013. Remittances, Migration and Inclusive Growth: The Case of Nepal. ARTNeT Policy Brief #35. http://www.unescap.org/sites/default/files/polbrief35.pdf (accessed July 7, 2016).

Mcelwee, P.D., 2008. Forest environmental income in Vietnam: household socioeconomic factors influencing forest use. Environ. Conserv. 35, 147–159.

Nepal, M., Nepal, A., Grimsrud, K., 2011. Unbelievable but improved cookstoves are not helpful in reducing firewood demand in Nepal. Environ. Dev. Econ. 16, 1–23.

Nguyen, T.T., Do, T.L., Bühler, D., Hartje, R., Grote, U., 2015. Rural livelihoods and environmental resource dependence in Cambodia. Ecol. Econ. 120, 282–295.

Nielsen, M.R., Pouliot, M., Bakkegaard, R.K., 2012. Combining income and assets measures to include the transitory nature of poverty in assessments of forest dependence: evidence from the Democratic Republic of Congo. Ecol. Econ. 78, 37–46.

Nielsen, Ø.J., Rayamajhi, S., Uberhuaga, P., Meilby, H., Smith-Hall, C., 2013. Quantifying rural livelihood strategies in developing countries using an activity choice approach. Agric. Econ. 44, 57–71.

Panta, M., Kim, K., Lee, C., 2009. Households' characteristics, forest resources dependency and forest availability in central Terai of Nepal. J. Korean For. Soc. 98, 548–557.

PEN, 2007. PEN Technical Guidelines Version 4. Poverty Environment Network. Retrieved from. http://www.cifor.org/pen/research-tools/the-pen-technical-guidelines.html.

Porro, R., Lopez-Feldman, A., Vela-Alvarado, J.W., 2015. Forest use and agriculture in Ucayali, Peru: livelihood strategies, poverty and wealth in an Amazon frontier. Forest Policy Econ. 51, 47–56.

Pouliot, M., Treue, T., 2013. Rural people's reliance on forests and the non-forest environment in West Africa: evidence from Ghana and Burkina Faso. World Dev. 43, 180–193.

Rayamajhi, S., Smith-Hall, C., Helles, F., 2012. Empirical evidence of the economic importance of central Himalayan forests to rural households. Forest Policy Econ. 20, 25–35.

Scoones, I., 1998. Sustainable Rural Livelihoods: A Framework for Analysis. 72 Institute for Development Studies, Brighton, UK (Working Paper).

Scoones, I., 2009. Livelihoods perspectives and rural development. J. Peasant Stud. 36, 171–196.

Scoones, I., 2015. Sustainable Livelihoods and Rural Development (Agrarian Change and Peasant Studies 4). Practical Action Publishing, Bourton on Dunnesmore, Rugby.

Shackleton, C., Shackleton, S., 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. S. Afr. J. Sci. 100, 658–664.

Tesfaye, Y., Roos, A., Campbell, B.M., Bohlin, F., 2011. Livelihood strategies and the role of forest income in participatory-managed forests of Dodola area in the bale highlands, southern Ethiopia. Forest Policy Econ. 13, 258–265.

Thagunna, K.S., Acharya, S., 2013. Empirical analysis of remittance inflow: the case of Nepal. Int. J. Econ. Finan. Issues 3, 337–344.

Van den Berg, M., 2010. Household income strategies and natural disasters: dynamic livelihoods in rural Nicaragua. Ecol. Econ. 69, 592–602.

Vedeld, P., Angelsen, A., Bojö, J., Sjaastad, E., Berg, G.K., 2007. Forest environmental incomes and the rural poor. Forest Policy Econ. 9, 869–879.

Vermunt, J.K., Magidson, J., 2013. Latent GOLD 5.0 Upgrade Manual. Statistical Innovations Inc., Belmont.
Völker, M., Waibel, H., 2010. Do rural households extract more forest products in times of crisis? Evidence from the mountainous uplands of Vietnam. Forest Policy Econ. 12, 407–414.
Walelign, S., 2013. Forests beyond income: the contribution of forest and environmental resources to poverty incidence, depth and severity. Int. J. AgriSci. 3, 533–542.
Walelign, S.Z., 2016. Livelihood strategies, environmental dependency and rural poverty: the case of two villages in rural Mozambique. In: Environment, Development and Sustainability, pp. 593–613.
Walelign, S.Z., Nielsen Ø, J., 2013. Seasonal household income dependency on forest and environmental resources in rural Mozambique. Int. J. AgriSci. 3, 91–99.
Walelign, S.Z., Pouliot, M., Larsen, H.O., Smith-Hall, C., 2015. A Novel Approach to Dynamic Livelihood Clustering: Empirical Evidence From Nepal. University of Copenhagen, Department of Food and Resource Economics.
Walelign, S.Z., Charlery, L., Smith-Hall, C., Chhetri, B.B.K., Larsen, H.O., 2016a. Environmental income improves household-level poverty assessments and dynamics. Forest Policy Econ. 71, 23–35.
Walelign, S.Z., Pouliot, M., Larsen, H.O., Smith-Hall, C., 2016b. Combining household income and asset data to identify livelihood strategies and their dynamics. J. Dev. Stud. 53, 769–787.
Winters, P., Corral, L., Gordillo, G., 2001. Rural livelihood strategies and social capital in Latin America: Implications for rural development projects. In: Working Paper Series in Agricultural and Resource Economics. University of New England, Armidale, Australia.
Wunder, S., Angelsen, A., Belcher, B., 2014. Forests, livelihoods, and conservation: broadening the empirical base. World Dev. 64, S1–S11.
Yaro, J.A., 2002. The poor peasant: one label, different lives. The dynamics of rural livelihood strategies in the Gia-Kajelo community, Northern Ghana. Nor. Geogr. Tidsskr. 56, 10–20.
Yemiru, T., Roos, A., Campbell, B., Bohlin, F., 2010. Forest incomes and poverty alleviation under participatory forest management in the Bale Highlands, Southern Ethiopia. Int. For. Rev. 12, 66–77.
Zenteno, M., Zuidema, P.A., de Jong, W., Boot, R.G., 2013. Livelihood strategies and forest dependence: new insights from Bolivian forest communities. Forest Policy Econ. 26, 12–21.