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Environmental Reliance Traps and Pathways – Theory and Analysis of Empirical Data From Rural Nepal

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Existing theoretical and empirical work on poverty traps does not in detail investigate interactions between environmental reliance and socioeconomic factors over time. A string of studies has documented that environmental products provide rural households with both subsistence and cash income and that high environmental reliance is often associated with poverty. These studies are snapshots and do not allow an understanding of environmental reliance dynamics – are households trapped at high levels of environmental reliance, what factors enable movement from high to low reliance, and how are such movements associated with total household income? Here we develop and present a theory of environmental reliance traps that allows analysis and explanation of changes in household-level environmental reliance over time. We propose operational parametric and non-parametric models for empirical investigation of the theory and employ these using an environmentally augmented three-wave panel household income and asset dataset (n = 427, pooled n = 1212) from Nepal. We found no evidence of an environmental reliance trap in the study population, meaning that all households converged on a single long-term environmental reliance equilibrium point. Households with high environmental reliance moving down toward the equilibrium (n = 358) have low income and asset endowments; while households with low environmental reliance moving up toward the equilibrium (n = 854) are better off, in terms of both income and assets. The approach identified the poorer households that make a living from harvesting substantial amounts of environmental products The probability of being a high-downward moving household is negatively associated with the size of landholding, market access, and female headship, and positively associated with the household head being born in the village and belonging to the most common caste. We argue that the identification of environmental reliance pathways can simultaneously inform interventions aimed at environmental conservation and poverty reduction.

Keywords: environmental dependence, environmental dynamics, environment and development, poverty traps, rural livelihoods, Himalayas

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INTRODUCTION

Environmental products – fuel, food, medicine, construction materials and other products from natural, non-cultivated environments (Angelsen et al., 2011a) – provide an average of 28% of total income for households with moderate-to-good forest access in tropical and sub-tropical countries (Angelsen et al., 2014). Here, building on Sjaastad et al. (2005), environmental income is defined as the added value from raw and processed environmental products, including timber, non-timber forest products (NTFPs), and incomes generated from environmental activities (e.g., environmental wages) and services (e.g., payments for ecosystem services or from forest user groups). Understanding the dynamics of environmental income reliance is important to improve our knowledge of the relationships between persistent poverty and environmental sustainability and how environmental products can contribute to the Sustainable Development Goal to end poverty in all forms (Swamy et al., 2018).

Our knowledge on the economic importance of environmental products and services to rural livelihoods in the Global South has advanced substantially, in particular in the past decade. A string of studies has investigated the contribution to households' current consumption (e.g., Cavendish, 2000; Shackleton et al., 2007; Rayamajhi et al., 2012; Uberhuaga et al., 2012; Córdova et al., 2013; Hogarth et al., 2013; Hickey et al., 2016) and in providing seasonal gap filling and safety nets (e.g., Pouliot and Treue, 2013; Wunder et al., 2014). Concerning the role of environmental products in providing a pathway out of poverty, it has been argued that households with high reliance on environmental resource extraction are more likely to remain in poverty as such activities are low return and undertaken by households that have no other options, e.g., due to limited skills, assets, and capital (Angelsen and Wunder, 2003). While there is a dearth of environmentally augmented household-level panel datasets, recent advances have shown that: environmentally augmented income data improves estimates of poverty incidence and dynamics (Walelign et al., 2016), livelihood strategy analysis and movements between strategies are best analyzed using a combination of income and asset data (Walelign et al., 2017), rural livelihood strategies may often change (Jiao et al., 2017), and environmental reliance is highest in low remunerative livelihood strategies (Walelign and Jiao, 2017). However, existing studies at the nexus of household-level environmental reliance, livelihoods, and poverty (e.g., Heubach et al., 2011; Giesbert and Schindler, 2012; Nielsen et al., 2012; Kabubo-Mariara, 2013; Naschold, 2013; Angelsen et al., 2014; Chilongo, 2014; Nguyen et al., 2015; Porro et al., 2015; Walelign, 2016a) are limited by data constraints. They do not analyze changes in environmental reliance over time or identify the covariates determining these changes. There is a lack of theorizing as well as empirical investigation (Barrett et al., 2011).

In a review of traps and sustainable development in rural areas, Haider et al. (2018) argue that work on poverty traps has been heavily influenced by research in the field of development economics which, however, tends to ignore interactions between social and environmental factors. For instance, high environmental reliance may trigger the depletion of natural resources through overharvesting which in turn may further impoverish environmental resource reliant poor households, as labor productivity and standards of living fall (Barbier, 2010; Barrett et al., 2011). Here we contribute to the traps and sustainable development literature by proposing a theory of environmental reliance traps and analyzing household-level temporal shifts in relation to socio-economic variables. This work cuts across the development economics, social-ecological, and sociology research fields (as categorized by Haider et al., 2018) by integrating trajectories (path dependency) into environmental trap analysis, which can be considered a poverty trap sub-type. We define an 'environmental reliance trap' as a self-reinforcing mechanism that keeps people highly reliant on environmental income. Using household-level panel datasets from Nepal, the paper answers the following research questions: (RQ1) is there an environmental reliance trap; (RQ2) what environmental reliance pathways do households follow; (RQ3) what characterizes different environmental reliance pathways in terms of income and asset endowment; and (RQ4) what factors influence households' environmental reliance dynamics (change) and movement between environmental reliance pathways in the medium or long term. To test for the presence of an environmental reliance trap and to identify pathways, we employed non-parametric regression (RQ1 and RQ2). Income composition and asset holdings were analyzed in means and SD with *t*-tests (RQ3). We employed fourth-degree polynomial regression and dynamic probit models to identify the factors influencing environmental reliance dynamics (change) and environmental pathways, respectively (RQ4).

THEORY AND MODELS

A Theory of Environmental Reliance Traps

Rural households are heterogeneous (Ellis, 2000; Ansoms and McKay, 2010; Walelign et al., 2017), their degree of environmental income reliance varies (Angelsen et al., 2014), and livelihood outcomes and environmental factors interact dynamically (Cinner, 2011; Enfors, 2013; Laborde et al., 2016; Haider et al., 2018). Therefore, some households may accumulate assets or experience positive shocks (e.g., huge remittance inflow) and increasingly engage in more remunerative livelihood activities (e.g., through business ownership or skilled wage employment) (Walelign, 2017). While such households reduce their reliance on environmental resources (Charlery and Walelign, 2015), they most commonly continue to use them as they provide inputs into agricultural production processes or asset building, e.g., construction of higher quality houses (Walelign and Jiao, 2017). There is evidence indicating a general pattern of more well-off rural households in the tropics and sub-tropics harvesting larger amounts of environmental products than poorer households (Angelsen et al., 2014). Poorer households tend to be more reliant on environmental income and natural capital as productive assets (Angelsen et al., 2014; Barrett et al., 2016). **Figure 1** shows the self-reinforcing vicious

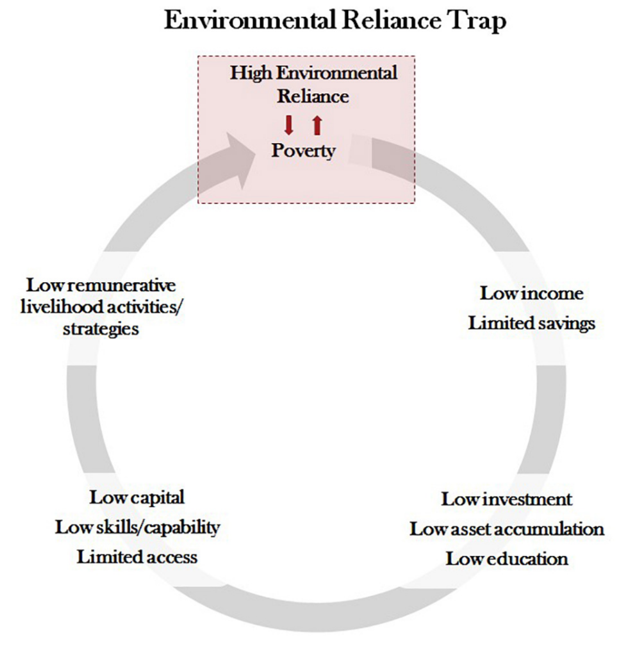

FIGURE 1 | The household-level self-reinforcing vicious cycle of an environmental reliance trap.

circle of the environmental reliance trap: households with a high degree of environmental reliance cannot accumulate assets and improve skills, preventing them from accessing more remunerative livelihood strategies, thus locking them in low-entry requirement and low-return environmental product harvesting activities (Angelsen and Wunder, 2003; Walelign, 2017). In this paper, we empirically test for the existence of such environmental reliance traps.

Conversely, households able to accumulate assets and acquire skills can transit to higher return activities and thus more remunerative livelihood strategies, reducing their reliance on environmental resource extraction.

These household-level environmental reliance pathways are illustrated in **Figure 2**. The x-axis represents initial household-level environmental reliance, and the y-axis represents current environmental reliance. The 45-degree line thus represents the situations where initial and current environmental reliance are equal (equilibrium over time). We assume that environmental product extraction is associated with less utility and constitutes a less attractive livelihood activity: many environmental products have low return to labor, are strenuous to collect, and seasonal and perishable (Angelsen and Wunder, 2003). Movements over time to more remunerative livelihood strategies are thus often associated with a reduction in environmental reliance (Jiao et al., 2017; Walelign et al., 2017). Rural households, however, maintain a level of environmental reliance across strategies (Nielsen et al., 2013; Jiao et al., 2017; Walelign and Jiao, 2017) and there are situations where household engagement in higher return activities may increase environmental reliance, e.g., directly through engagement in timber harvesting (Uberhuaga et al., 2012) or indirectly as more livestock requires higher amounts of fodder (Rayamajhi et al., 2012). Hence, environmental reliance can remain the same, decrease, or increase over time.

On this basis, we identify two environmental reliance trajectories in **Figure 2**. An environmental reliance trap may exist if the trajectory has multiple equilibriums. Two approaches can be used to determine the presence of environmental reliance traps: (i) the presence of multiple equilibria with a specific group of households trapped at the highest environmental reliance equilibrium point, or (ii) presence of equilibrium points above an environmental reliance threshold irrespective of the number of equilibrium points (Giesbert and Schindler, 2012; Naschold, 2013). Since it is difficult to decide on an environmental reliance trap threshold level, the current paper adopted the former approach. In the first trajectory (convergence) in **Figure 2** (the blue curve), in which the entire environmental reliance distribution is concave downward as shown with $f_1(EP_{\mathrm{t}-1})$, households reduce or increase their environmental reliance over time to converge to a single stable environmental reliance equilibrium point (EP_c^*, as the curve cuts the 45-degree line from above), which does not constitute an environmental reliance trap. In the second S-shaped trajectory (divergence) (the red curve), the environmental reliance distribution is concave downward in one part and concave upward in another part, as shown with $f_2(EP_{\mathrm{t}-1})$, and thus cuts the 45-degree line three times, resulting in two stable (EP_p^* and EP_c^*, as the curve cuts the 45-degree line from above) and one unstable (EP_{m}, as the curve cuts the equilibrium point from below) equilibrium point. The upper environmental reliance equilibrium point (EP_c^*) is associated with an environmental reliance trap. The economic mechanism behind the nature of environmental reliance triggers the S-shape trajectory: it is mainly made up of subsistence income (e.g., Angelsen et al., 2014) that does not allow households to save up and accumulate capital to engage in more remunerative livelihood strategies (Banerjee and Duflo, 2011). Hence, the high environmental reliant households become more and more environmental reliant, while the low environmental reliance households become less and less so. At the unstable equilibrium, environmental reliance bifurcates: a household above this threshold increases or reduces environmental reliance to settle on the upper stable equilibrium EP_c^*, where the household is trapped in high environmental reliance (i.e., in an environmental reliance trap). A household below the threshold reduces or increases its environmental reliance to settle on the lower equilibrium EP_p^*. Thus, there are two basic paths: one toward a higher level of equilibrium, and one toward a lower level. Given the predominance of studies showing that environmental reliance decreases with rising incomes, we hypothesize that households move toward a stable lower level of equilibrium. It should be noted that changes such as land reforms or infrastructural developments, that influence households' portfolio of livelihood activities, cause a change in trajectories and a consequent shift in the equilibrium points. Trajectories and equilibrium points are thus likely to change over time.

Once we determine the presence or absence of environmental reliance traps (RQ1), we identify the environmental reliance pathways (RQ2), characterize these pathways in terms of

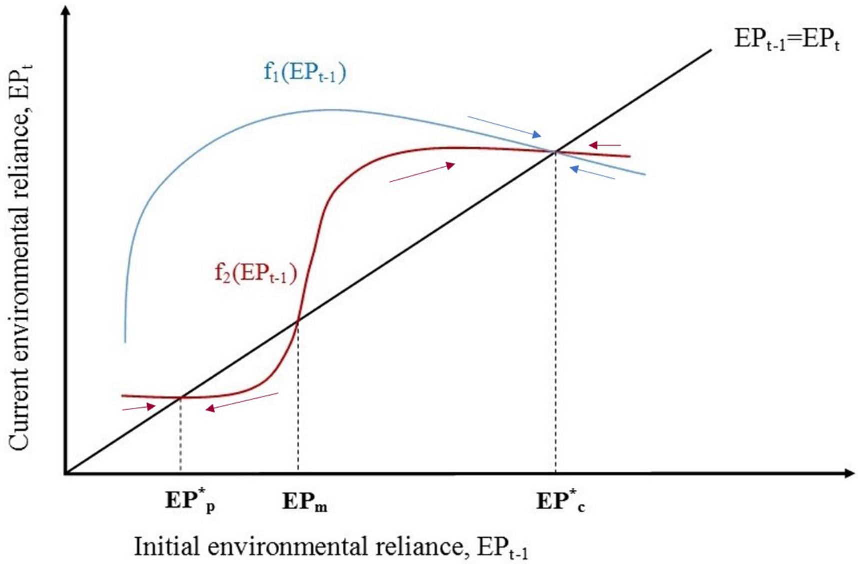

FIGURE 2 | Hypothetical household environmental reliance paths.

income and assets (RQ3), and identify the covariates of the pathways (RQ4).

Modeling Environmental Reliance Traps

We employed a non-parametric model to determine the presence of an environmental reliance trap; a fourth-degree polynomial parametric model to identify the covariates of environmental reliance dynamics (changes in reliance); and a dynamic probit model to examine what factors characterize households moving along the high-downward pathway (higher environmental reliance). The models are detailed below.

Following the literature on poverty traps, we model households' environmental reliance dynamics to test for the presence of environmental reliance traps using non-parametric regressions. The non-parametric model can be specified as:

$$EP_{i,t} = f(EP_{i,t-1}) + \varepsilon_{i,t} \quad (1)$$

Where $EP_{\mathrm{i,t}}$ is the environmental reliance at time t, $EP_{\mathrm{i,t-1}}$ is initial reliance, and $\varepsilon_{\mathrm{i,t}}$ is an error term with normal distribution, zero mean, and constant variance. *i* and t stand for household and time (discrete), respectively. Eq. 1 can be estimated with a number of alternative non-parametric estimation techniques, e.g., locally weighted scatterplot smoother, kernel weighted local linear smoother, kernel weighted local polynomial smoothers, piecewise spline, natural spline, and penalized spline. However, all tend to lead to similar results (Naschold, 2013). In this paper, Eq. 1 is estimated with local polynomial smoothing regression with Epanechnikov kernel weights. The non-parametric models are flexible as they do not assume any functional form of *f*. The analysis was done in STATA with the *lpoly* command that generates a smoothed curve relating current environmental reliance with lagged environmental reliance. If the curve cuts the 45-degree line that represents long-term equilibrium points only once from above as presented in **Figure 2** (the blue curve), there is no indication of an environmental reliance trap. If the curve cuts the 45-degree line multiple times as presented in **Figure 2** (the red curve), this indicates the presence of an environmental reliance trap.

The major disadvantage of non-parametric regression is that it does not allow the inclusion of covariates other than the initial environmental reliance and hence does not allow identification of the determinants of environmental reliance dynamics and pathways. To identify these determinants, following previous empirical studies on asset growth (Giesbert and Schindler, 2012; Quisumbing and Baulch, 2013), we employed the fourth-degree polynomial parametric regression model that is specified as:

$$EP_{i,t} - EP_{i,t-1} = \beta_0 + \sum_{j=1}^{4} \beta_j EP^{j}_{i,t-1} + \delta X_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

Where $EP_{\mathrm{i,t}}$ is the environmental reliance at time t, $EP_{\mathrm{i,t-1}}$ is initial environmental reliance, *i* and t stand for household and time (discrete), respectively, $X_{\mathrm{i,t-1}}$ is a vector of initial explanatory variables (e.g., household and household head characteristics, location dummies, income from environmental products, and income from non-environmental sources), δ is the associated vector of coefficients, $\sum_{j=1}^{4} \beta_j EP^{j}_{i,t-1}$ is the fourth degree polynomial of initial environmental reliance, and $\sum_{j=1}^{4} \beta_j$ (i.e., β_1, β_2, β_3, and β_4) is the associated coefficients, β_0 is the regression intercept, and $\varepsilon_{\mathrm{i,t}}$ is an error term which has a normal distribution with zero mean and constant variance (see **Supplementary Appendix A** for explanation and descriptive statistics of the explanatory variables included in the model). To investigate the presence (or not) of an environmental reliance trap with the point of departure in the parametric regression model, the model estimates were interpreted in relation to the environmental reliance dynamics curves in **Figure 2** (Naschold, 2013): we predicted environmental reliance change from the model, added the initial (lagged) environmental reliance to recover the (current) environmental reliance from the predictions and plotted the result against lagged environmental reliance (**Supplementary Appendix C**). The rule for the presence of environmental reliance is the same as in the non-parametric regression (see above).

Equation 2 was estimated with a fixed-effects panel data estimator for the whole sample for two reasons. First, we suspect the presence of endogeneity arising from household time-invariant unobserved heterogeneity (e.g., household members attitude to work) that could potentially correlate with some of the explanatory variables included in the model (particularly, environmental reliance) and the fixed-effects estimator is a powerful tool to wipe out the resulting bias. The fixed-effects cannot, however, overcome the endogeneity of environmental income arising from time-varying observables. To address this, we applied heteroskedasticity-based instrument variables for environmental reliance (see **Supplementary Appendix B**). Following Lewbel (2012), heteroscedastic-based instruments are generated through the interaction between the demeaned (centered) regressors and the error term of the environmental reliance regression model. The results of the standard and the instrumental variable fixed-effects were similar, suggesting the bias arising from the endogeneity of environmental reliance due to time-varying unobservables is minimal. Hence, we discuss the results of the standard fixed-effects model. Second, the Hausman specification test ($A = X^2(16) = 536.73$; $P\text{-}value < 0.01$) rejected the null hypothesis that the random-effects is preferred over the fixed-effects estimator. Thus the fixed-effects model was applied.

To identify the covariates of environmental reliance pathways, we modeled the probability of being above the environmental reliance equilibrium point (high environmental reliance) using a dynamic probit model. The equation for the latent dependent variable can be specified as (Stewart, 2006):

$$EP^*_{i,t} = \delta EP_{i,t-1} + \beta X_{i,t} + \alpha_i + \mu_{i,t} \quad (3)$$

Where $EP^*_{i,t}$ is the latent dependent variable, $EP_{i,t-1}$ is the observed initial binary environmental reliance outcome variable and δ is the associated coefficient, i and t stand for household and time (discrete), respectively, X_{it} is a vector of explanatory variables (see **Supplementary Appendix A**), and β is the associated vector of coefficients. α_i is an individual specific time-invariant error term and $\mu_{i,t}$ is the time and individual variant error term which has a normal distribution with zero mean and constant variance.

The conditional probability of being in the higher environmental reliance group for each period t can be defined as:

$$P(EP_{i,t}|X_{i,t}, \alpha_i, EP_{i,t-1}) = \begin{cases} 1 \; if \; EP^*_{i,t} \geq \eta \\ 0 \; otherwise \end{cases} \quad (4)$$

η stands for the estimated equilibrium point. One estimation challenge with the dynamic probit model for being in the higher environmental reliance group is that the initial environmental reliance, $EP_{i,t-1}$, cannot be exogenous due to correlation with the unobserved determinants of households' environmental reliance (α_i). The simplest solution would be to treat $EP_{i,t-1}$ as exogenously given by assuming $EP_{i,t-1}$ is independent of α_i. This strong assumption results in inconsistent estimates and hence an approach that acknowledges the endogeneity of $EP_{i,t-1}$ is employed. Two alternative solutions are applied in the literature: the Heckman (1981) approach jointly models individual heterogeneity and the endogenous initial condition, while the Wooldridge (2005) approach models the unobserved heterogeneity as a function of the initial state, the average of the explanatory variables, and a new random error term that is uncorrelated with the initial state. Comparison studies indicate that the performance of the two approaches is similar, but the Wooldridge approach has estimation convenience (Arulampalam and Stewart, 2009; Akay, 2012) and is hence employed here to handle the initial condition problem.

MATERIALS AND METHODS

Study Area

Data was collected in Lete and Kunjo Village Development Committees (VDCs, the lowest administrative unit) in Mustang District, Hemja VDC in Kaski District, and Chainpur VDC in Chitwan District in Nepal, **Figure 3**. The study locations span the main physiographic regions of Nepal, i.e., the lowlands, mid-hills, and mountains. The study VDCs were selected considering the following criteria: (i) the altitudinal and vegetation variations in Nepal, (ii) households' environmental reliance, (iii) communities' attitudes toward long-term research, and (iv) village accessibility and researcher safety (due to the civil war in Nepal during site selection in 2005) (Meilby et al., 2006; Larsen et al., 2014). Data collection was conducted by the Community-based Forest and Tree Management in the Himalaya (ComForM) project, adopting the Poverty Environment Network (PEN) approach to collecting income and asset data (Angelsen et al., 2011a; Larsen et al., 2014).

Chainpur and Hemja VDCs are similar in terms of accessibility and infrastructural development: they have year-round motorable road access to market centers, and villagers have access to engage in skilled and unskilled employment opportunities in the connected town centers. As a result, the contribution of environmental income in Hemja and Chainpur VDCs is relatively low (Larsen et al., 2014). Lete and Kunjo VDCs are more remote, with less infrastructural development. The completion of a tertiary (dry-weather) road in 2008, connecting the town centers of Beni and Jomsom (transecting Lete VDC), has significantly increased access to these areas during the dry season (Charlery et al., 2015). The contribution of environmental income to households in Lete and Kunjo VDCs, particularly in Kunjo, is relatively high due to limited alternative livelihood opportunities (Rayamajhi et al., 2012; Larsen et al., 2014). Livelihood activities in the study areas are diverse and dynamic, reflecting considerable variation in natural asset endowments (such as forest areas) and contextual differences (such as infrastructure). In Hemja and Chainpur

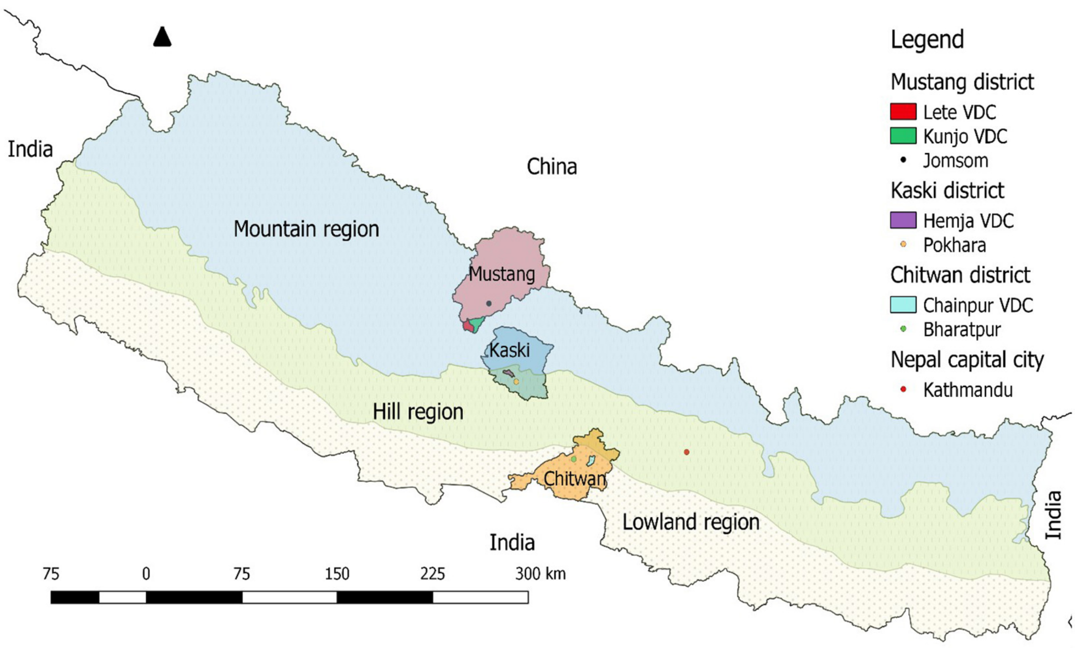

FIGURE 3 | Location of study sites in Nepal.

VDCs, the primary livelihood activities are crop and vegetable farming, livestock rearing, and remittances. In Lete VDC, the primary livelihood activities are tourism, trade, and remittances; and in Kunjo VDC, they are agricultural production, trade, and livestock rearing (Larsen et al., 2014). Integrated into livelihood strategies in all villages are substantial uses of environmental products, ranging from common uses such as firewood for fuel and leaf litter for composted manure, to specialized extraction including medicinal plants for sale and wild foods for own consumption [e.g., see Rayamajhi et al. (2012) for an example of forest products used in Lete and Kunjo VDCs]. In addition to these overall differences across study villages (Meilby et al., 2014), significant variation exists between households within villages, in terms of environmental income and reliance (e.g., Rayamajhi et al., 2012). The dominant castes are Brahmin and Chhetri in Hemja and Chainpur VDCs, Kami and Thakali in Lete VDC, and Thakali in Kunjo VDC.

Data Collection

Data were collected in 2006, 2009, and 2012. The PEN prototype questionnaire (PEN, 2008) and guidelines (PEN, 2007) – implemented since 2005 (Angelsen et al., 2011b) – were adopted, tested, and finalized for use at the village and household levels. All data collection instruments are included in Larsen et al. (2014). In each study year, household income data were collected quarterly (using recall periods of 3 or 1 months, depending on the product) while asset data was collected twice (at the beginning and end of each year). Income is defined as the value-added of household labor and capital. This is net income – the total annual value of cash and subsistence income less the cost of all inputs except labor provided by household members which are difficult to estimate (Angelsen et al., 2014). Income data were collected at product or service level, i.e., all goods produced or collected by the household, including goods used for home consumption (subsistence), were valued and counted as part of household income. Product or service level annual net income was aggregated into annual net income groups (e.g., crop, livestock, environment) and annual net total income (PEN, 2007, 2008; Wunder et al., 2011). Farm-gate prices were used to value products whenever possible; subsistence products were valued using substitute product prices or opportunity cost of time (i.e., local wage labor rate). For a site-level example of methods applied and the basic distributional statistics indicating that estimated values have acceptable properties allowing their use as prices, see Rayamajhi and Olsen (2008). Incomes related to environment product extraction, crop production, and livestock rearing activities have cash and subsistence components. As noted above, environmental income is defined as income generated through the extraction of products from non-cultivated sources, e.g., forests, grasslands, bushlands, wetlands, fallows, as well as wild plants and animals harvested from croplands. Environmental income also includes incomes from non-harvesting environmental activities (e.g., environmental wages) and services (e.g., payments from forest user groups) (Angelsen et al., 2014). Environmental reliance is measured as the ratio between environmental income and total income (Angelsen et al., 2014). All nominal values are reported in 2006 prices, adjusted using the national consumer price index (CPI). All quantitative values were adjusted for household size using adult equivalent units (aeu) based on Cavendish (2002). These adjustments enable comparisons across study years and households.

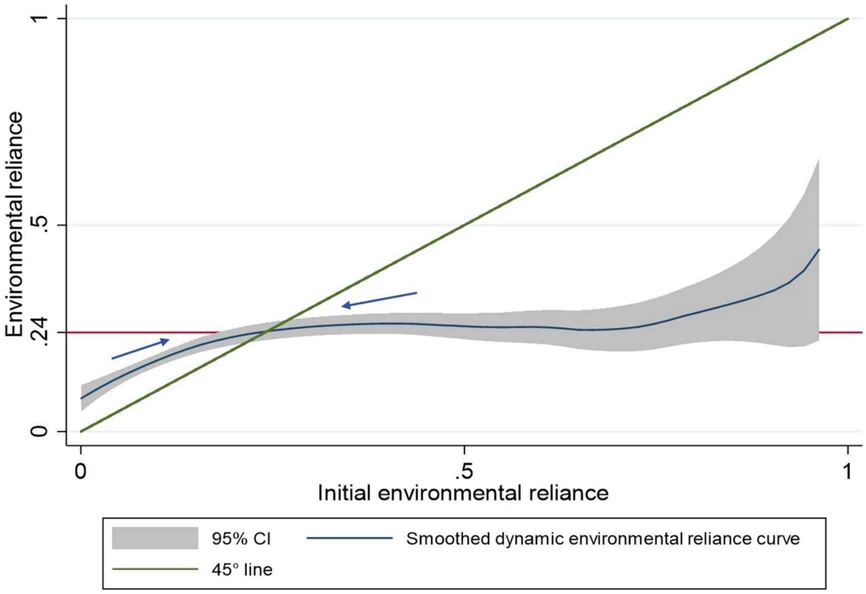

FIGURE 4 | The dynamics of rural household (pooled n = 1212) environmental reliance, based on non-parametric regression, in three districts of Nepal, 2006–2012 (the horizontal red line represents the equilibrium point).

The 2006 data was collected from 507 randomly selected households (drawn from village level population lists) in the four VDCs (n = 207 from Chainpur, n = 114 from Hemja, n = 88 from Kinjo, and n = 98 from Lete) of which 446 were resurveyed in 2009 (attrition rate of 12%) and 428 in 2012 (attrition rate of 4% between 2009 and 2012). The attrition rate totaled 16% over the 6 years. An assessment of the effect of attrition, based on static and dynamic attrition tests, indicated no bias on the estimates of the current analysis (Walelign, 2016b). One household was dropped due to implausibly high total income; thus, we made use of the balanced dataset covering 427 households. About five percent of households had a negative total/forest/non-forest environmental income in one observation year and were excluded from the analyses including that year as negative income produced an environmental reliance estimate out of the acceptable 0–1 range. Hence, we obtained a final pooled sample of 1212 households for analysis over the 3-year periods.

RESULTS

Environmental Reliance Traps and Pathways

Figure 4 displays the environmental reliance dynamics of the sampled households. The blue line represents households' dynamic environmental reliance curve and the shaded area the 95% confidence interval. The households' environmental reliance curve cuts the 45-degree line only once meaning that all households move toward a single environmental reliance long-term equilibrium point, at 24% environmental reliance. There is hence no evidence of an environmental reliance trap. Two pathways of households are identified: households with low environmental reliance (n = 854) moving up toward the equilibrium (low-upward) and households with high environmental reliance (n = 358) moving down toward the equilibrium (high-downward). The environmental reliance curve is closer to the 45-degree line before the long-term equilibrium point with the gap between the two lines widening afterward. This indicates that households below the equilibrium move toward the long-term equilibrium more slowly than households above the equilibrium.

We found evidence for the presence of group-specific environmental reliance equilibria (**Table 1**) although we were unable to test for statistically significant differences due to lack of formal tests. Female-headed households move toward a slightly higher equilibrium (25%) than male-headed households (24%). Similar minor differences were found between households whose head (i) was born in the village and those who were not, and (ii) belonged to the most common caste in the village vs. those who did not. Households experiencing moderate and severe negative shocks moved toward a higher equilibrium (29%) than other households (21%). Households in Kunjo VDC converged on the highest equilibrium (about 34%). Households in Hemja VDC converged on the lowest equilibrium (about 14%), and households in Chainpur and Lete VDCs on intermediate points of 19 and 23% environmental reliance level. This indicates that the overall environmental equilibrium level is highly influenced by the high level of environmental reliance in relatively remote Kunjo.

Environmental Reliance Pathways and Household Livelihoods

Table 2 presents the mean absolute and relative income by source for households below and above the equilibrium point

TABLE 1 | Group-specific environmental reliance equilibria identified using local polynomial non-parametric regression, Nepal, 2006–2012.

	Approximate location of the equilibrium	95% confidence interval	
		Lower bound	Upper bound
Sex of household head			
Male	0.24	0.19	0.31
Female	0.25	0.20	0.28
Head born in the village			
Yes	0.25	0.20	0.30
No	0.23	0.18	0.27
Head belong to the most common caste in the village			
Yes	0.24	0.19	0.28
No	0.25	0.20	0.30
Location			
Chainpur	0.19	0.14	0.26
Hemja	0.14	0.10	0.18
Kunjo	0.34	0.29	0.38
Lete	0.23	0.16	0.28
Shock			
Yes	0.29	0.22	0.34
No	0.21	0.17	0.25

in each study site. The two pathways of households are identified based on households' environmental reliance over time as opposed to the conventional approach of using total income. Households with high environmental reliance moving downward had significantly higher environmental income in both absolute (more than three-fold) and relative (more than six-fold) terms. In comparison, households with low environmental reliance moving upward had significantly higher absolute income in all other income sources. Environmental income constituted 49 and 7% of total household income for the high-downward and low-upward environmental reliance pathway groups, respectively. The two most important income sources for low-upward households were business income (28%) and remittances (18%), while environmental income was the second least important income (only surpassing wage income). The most important income sources for high-downward households were environmental (49%) and livestock income (14%), with business income being of least importance. Two points stand out regarding variations within each pathway group across study sites. First, environmental reliance in both pathways was highest in Kunjo (57 and 15% for the high and low environmental reliance groups) and lowest in Hemja (25 and 4%). Second, in all villages, the high-downward environmental reliance pathway group depends significantly on environmental income while business income is of major importance in the low-upward environmental reliance pathway group.

An overview of household asset endowments across the two environmental reliance groups in each study site is presented in **Table 3**. Households in the high-downward environmental reliance pathway group, on average, had significantly lower asset endowments for all asset types (lower but not significant for the number of male adult members and landholdings). In particular, households in the low-upward environmental reliance pathway group had much higher values of implements and bank savings as well as education. There is not a single case, across all sites and all types of assets, where a high-downward environmental reliance pathway group has significantly more assets.

Covariates of Environmental Reliance Changes and Pathways

Table 4 presents the determinants of changes in households' environmental reliance and the probability of being on the high-downward environmental reliance pathway using the fixed-effects and dynamic probit models. In the fixed-effects model, the included explanatory variables explained about 81% of the variation and are jointly significant at 1% suggesting the included independent variables have good explanatory power to predict households' environmental reliance change. The explanatory variables in the probit model are also jointly significant at 5%.

Changes in households' environmental reliance are negatively associated with initial environmental reliance implying that households with a higher environmental reliance are more likely to reduce their current environmental reliance and hence that households converge on a single environmental reliance point in the long-term. This is supported by the plot of the predicted (current) environmental reliance from the model against lagged environmental reliance (**Supplementary Appendix C**) and consistent with the results of the non-parametric regression. The square term was marginally significant individually, and all the four terms (including the cubic and quadratic terms of initial environmental reliance) were jointly significant, albeit the cubic and quadratic terms were insignificant individually. This justifies the quadratic specification of our model. The age of the household head in level and squared terms is positively and negatively associated, respectively, with changes in households' environmental reliance and both terms are jointly significant, suggesting the presence of a life cycle effect: households' environmental reliance increases with increasing household head age until a certain age when reliance starts to decrease. Households with the household head born in the study site and belonging to the most common caste in the village are more likely to experience an increase in environmental reliance. In contrast, female-headed households are more likely to experience a decrease in their environmental reliance level. Households who live far away from forests are more likely to experience a decline in their reliance on environmental products.

The dynamic probit model provides similar results regarding initial environmental reliance, household age, and distance from forest. The negative coefficient of initial environmental reliance confirms that households in the high-downward environmental reliance pathway are less likely to remain highly reliant, implying a decreasing trend in environmental reliance until the equilibrium point, again reflecting convergence in environmental reliance. Landholding is also negatively associated with the probability of being in the high-downward environmental reliance group. Households living in Hemja, Chainpur, and Lete VDCs, relative to living in Kunjo VDC, are less likely to be in

TABLE 2 | Household absolute (Nr/aeu in 2006 prices) and relative (%) mean income by source, site, and environmental reliance group, Nepal, 2006–2012; values in parenthesis are SD of the mean.

			Environmental income	Crop income	Livestock income	Remittance	Support income[1]	Other income	Business income	Wage income	Total income
Hemja	Reliance below the equilibrium point (*n* = 163)	Abs.	4325[a] (2947)	9701 (24709)	7844 (9932)	15807[a] (36543)	11825[a] (17759)	18251 (99937)	36328[a] (144168)	284 (1503)	104364[a] (187426)
		Rel.	4.1[a]	9.3[b]	7.5[a]	15.1[b]	11.3	17.5[b]	34.8[a]	0.3	100
	Reliance above the equilibrium point (*n* = 116)	Abs.	7712[a] (5760)	6031 (7540)	6304 (10131)	2302[a] (6250)	4679[a] (7361)	2927 (7297)	681[a] (6861)	469 (951)	31105[a] (25469)
		Rel.	24.8[a]	19.4[b]	20.3[a]	7.4[b]	15	9.4[b]	2.2[a]	1.5	100
	Overall	Abs.	5733 (4645)	8175 (19560)	7204 (10026)	10192 (28962)	8854 (14787)	11879 (76806)	21507 (111539)	361 (1303)	73905 (148483)
		Rel.	7.8	11.1	9.7	13.8	12	16.1	29.1	0.5	100
Chainpur	Reliance below the equilibrium point (*n* = 374)	Abs.	1829[b] (1571)	3771[a] (5547)	6795[a] (10104)	11636[a] (27729)	2534[a] (4573)	3346[c] (15479)	8054[a] (27300)	936 (2642)	38901[a] (43735)
		Rel.	4.7[a]	9.7	17.5	29.9[a]	6.5[b]	8.6	20.7[a]	2.4[b]	100.0
	Reliance above the equilibrium point (*n* = 138)	Abs.	9771[b] (59673)	1580[a] (2976)	2960[a] (6377)	3101[a] (13741)	974[a] (2651)	872[c] (2117)	−426[a] (7702)	1295 (2088)	20127[a] (75762)
		Rel.	48.5[a]	7.9	14.7	15.4[a]	4.8[b]	4.3	−2.1[a]	6.4[b]	100.0
	Overall	Abs.	3970 (31127)	3180 (5077)	5761 (9398)	9336 (25025)	2113 (4199)	2679 (13315)	5768 (23961)	1033 (2508)	33841 (54814)
		Rel.	11.7	9.4	17.0	27.6	6.2	7.9	17.0	3.1	100.0
Lete	Reliance below the equilibrium point (*n* = 130)	Abs.	7812[a] (6564)	5607[b] (9326)	9203[b] (16744)	8691[a] (20694)	5148[a] (10419)	13888[a] (29221)	35646[a] (63471)	788[a] (2479)	86783[a] (72075)
		Rel.	9.0[a]	6.5	10.6	10.0[b]	5.9[b]	16.0[a]	41.1[a]	0.9[a]	100.0
	Reliance above the equilibrium point (*n* = 85)	Abs.	17200[a] (15732)	2958[b] (4994)	4811[b] (6832)	1868[a] (4522)	805[a] (2513)	1938[a] (4372)	3678[a] (9193)	2584[a] (3954)	35842[a] (24145)
		Rel.	48.0[a]	8.3	13.4	5.2[b]	2.2[b]	5.4[a]	10.3[a]	7.2[a]	100.0
	Overall	Abs.	11524 (12012)	4560 (7994)	7467 (13855)	5993 (16654)	3431 (8512)	9164 (23591)	23007 (52029)	1498 (3258)	66644 (63115)
		Rel.	17.3	6.8	11.2	9.0	5.1	13.8	34.5	2.2	100.0
Kunjo	Reliance below the equilibrium point (*n* = 120)	Abs.	10148[a] (9402)	8716[a] (10198)	15093[b] (39941)	11046[a] (22905)	3718[a] (7028)	7084[a] (16481)	10050[a] (29997)	939[a] (2456)	66794[a] (72980)
		Rel.	15.2[a]	13.0	22.6	16.5[c]	5.6[c]	10.6[b]	15.0[a]	1.4	100.0
	Reliance above the equilibrium point (*n* = 86)	Abs.	21964[a] (22111)	4120[a] (4597)	6028[b] (5300)	3242[a] (6687)	880[a] (3079)	1457[a] (4064)	−295[a] (7214)	1028[a] (1596)	38424[a] (29646)
		Rel.	57.2[a]	10.7	15.7	8.4[c]	2.3[c]	3.8[b]	−0.8[a]	2.7	100.0
	Overall	Abs.	15081 (16975)	6798 (8620)	11309 (30948)	7788 (18384)	2533 (5880)	4735 (13125)	5731 (23876)	976 (2135)	54950 (60439)
		Rel.	27.4	12.4	20.6	14.2	4.6	8.6	10.4	1.8	100.0
All sample	Reliance below the equilibrium point (*n* = 854)	Abs.	4525[a] (5615)	6017[a] (12980)	8616[a] (18609)	11059[a] (27197)	5061[a] (10436)	8318[a] (47022)	17259[a] (72107)	792[a] (2357)	61647[a] (99368)
		Rel.	7.3[a]	9.8	14.0	17.9[a]	8.2[b]	13.5[a]	28.0[a]	1.3[a]	100
	Reliance above the equilibrium point (*n* = 358)	Abs.	14950[a] (39582)	3215[a] (4708)	4292[a] (6464)	2993[a] (10186)	1367[a] (3724)	1476[a] (3654)	956[a] (8359)	1330[a] (2509)	30579[a] (51590)
		Rel.	48.9[a]	10.5	14.0	9.8[a]	4.5[b]	4.8[a]	3.1[a]	4.3[a]	100
	Overall	Abs.	7604 (22510)	5190 (11263)	7339 (16129)	8677 (23773)	3970 (9146)	6297 (39638)	12443 (61142)	951 (2414)	52470 (89110)
		Rel.	14.5	9.9	14.0	16.5	7.6	12.0	23.7	1.8	100

[a]Significant at 1%, [b]significant at 5%, and [c]significant at 10%; [1]Support income includes income from governmental and non-governmental support, pensions, and gifts.

TABLE 3 | Household asset endowment (Nr/aeu in 2006 values) by asset type, site, and environmental reliance group, Nepal, 2006–2012; values in parenthesis are SD of the mean.

		Total livestock	Total implements	Total land	Bank saving	Jewelry	# of male adults	# of female adults	Head educ.	Max. hh educ.
Hemja	Reliance below the equilibrium point (*n* = 163)	24406 (21636)	27097[a] (35602)	1599[b] (2328)	12267 (32328)	17562[c] (19955)	1.8 (1.1)	1.9 (1.0)	6.7 (5.4)	12.0[a] (3.7)
	Reliance above the equilibrium point (*n* = 116)	25571 (27469)	15081[a] (28710)	1061[b] (929)	10744 (29405)	13083[c] (24005)	1.6 (1.0)	1.8 (1.0)	5.9 (4.6)	10.4[a] (3.7)
	Overall	24890 (24192)	22101 (33388)	1375 (1893)	11634 (31101)	15700 (21801)	1.7 (1.0)	1.8 (1.0)	6.4 (5.1)	11.3 (3.7)
Chainpur	Reliance below the equilibrium point (*n* = 374)	25699[a] (23155)	9336[a] (18763)	1479 (4480)	3674[b] (13253)	5830[b] (10347)	1.8 (1.1)	1.9 (1.0)	3.3[b] (4.3)	10.0[a] (3.9)
	Reliance above the equilibrium point (*n* = 138)	18830[a] (17824)	3864[a] (11678)	942 (1509)	1185[b] (3765)	3715[b] (8659)	1.9 (1.2)	1.8 (1.0)	2.3[b] (3.7)	7.9[a] (3.4)
	Overall	23848 (22041)	7861 (17305)	1334 (3914)	3003 (11543)	5260 (9956)	1.8 (1.1)	1.9 (1.0)	3.0 (4.2)	9.4 (3.9)
Lete	Reliance below the equilibrium point (*n* = 130)	80436[a] (208182)	18461[a] (25181)	2314 (2651)	47245[a] (94264)	45250[b] (76618)	1.7 (1.2)	1.6 (1.0)	4.1[a] (4.7)	8.9[a] (3.8)
	Reliance above the equilibrium point (*n* = 85)	17569[a] (37806)	5074[a] (7890)	2209 (2904)	12441[a] (29178)	23536[b] (51138)	1.7 (1.2)	1.5 (1.0)	1.4[a] (3.0)	7.1[a] (3.8)
	Overall	55581 (166239)	13169 (21206)	2273 (2747)	33485 (77340)	36666 (68399)	1.7 (1.2)	1.6 (1.0)	3.0 (4.3)	8.1 (3.9)
Kunjo	Reliance below the equilibrium point (*n* = 120)	51078 (187214)	10756[a] (17400)	2366 (2355)	21326[c] (46005)	22690 (57228)	1.7 (1.0)	1.6 (1.0)	3.2[b] (3.7)	8.1[a] (3.5)
	Reliance above the equilibrium point (*n* = 86)	27710 (42820)	5690[a] (6248)	2514 (4027)	11541[c] (27202)	14321 (25957)	1.7 (1.1)	1.5 (0.9)	2.0[b] (2.7)	6.7[a] (3.0)
	Overall	41322 (145737)	8641 (14079)	2428 (3154)	17241 (39481)	19196 (46879)	1.7 (1.0)	1.6 (0.9)	2.7 (3.3)	7.5 (3.4)
All sample	Reliance below the equilibrium point (*n* = 854)	37310[a] (110611)	14926[a] (26221)	1708 (3443)	14737[b] (46638)	16837[c] (41284)	1.8 (1.1)	1.9[a] (1.0)	4.2[a] (4.8)	10.0[a] (3.9)
	Reliance above the equilibrium point (*n* = 358)	21660[a] (32020)	5742[a] (9448)	1668 (2721)	8238[b] (24604)	12659[c] (30358)	1.7 (1.1)	1.6[a] (0.9)	2.6[a] (3.8)	7.5[a] (3.6)
	Overall	32687 (94716)	12213 (22982)	1696 (3246)	12817 (41465)	15603 (38417)	1.7 (1.1)	1.8 (1.0)	3.7 (4.5)	9.3 (4.0)

[a]*Significant at 1%,* [b]*significant at 5%, and* [c]*significant at 10%.*

the high-downward reliance pathway. The number of shock types that households experienced is negatively associated with being in the high-downward environmental reliance group.

DISCUSSION

Is There an Environmental Reliance Trap?

We found no empirical evidence for the presence of environmental reliance traps in rural Nepal – households are not caught in self-reinforcing mechanisms that keep them dependent on environmental resources in the medium or long term. This is in line with studies finding that rural incomes in Nepal are increasing (e.g., Meilby et al., 2014; Charlery et al., 2015). Instead, the results indicate the presence of a single long-term environmental reliance level (equilibrium point) toward which households converge: the average across all sites and households is about 24% of total household income (**Figure 4**) with different equilibrium points for different socio-economic groups and locations (**Table 1**). The average finding of 24% is a counterintuitive result: available studies indicate lower levels of environmental income reliance in many locations (Meilby et al., 2014; Chhetri et al., 2015; Charlery and Walelign, 2015), that households decrease their environmental reliance over time, e.g., in response to improved infrastructure (Charlery et al., 2016) or opportunities to generate remittances (Thieme and Wyss, 2005; Maskay and Adhikari, 2013; Thagunna and Acharya,

TABLE 4 | Fixed-effects and dynamic probit models results for households' environmental reliance change and pathway, Nepal, 2006–2012; values in parenthesis are SEM.

	Fixed-effects model (Dependent variable: change in environmental reliance)	Dynamic probit model (Dependent variable: belonging to high-downward environmental reliance group)
Environmental reliance initial	−1.53108*** (0.11501)	–
Environmental reliance initial (squared)	−0.62398* (0.35719)	–
Environmental reliance initial (cubic)	−0.59285 (2.43675)	–
Environmental reliance initial (quadratic)	3.24555 (3.46672)	–
Environmental reliance category initial	–	−1.02413*** (0.36298)
Head age	0.00242* (0.00141)	0.03107 (0.01940)
Head age (squared)	−0.00012** (0.00005)	−0.00194** (0.00091)
Head female[1]	−0.07461** (0.03778)	−1.00815 (0.63091)
Head belongs to the most common caste in the village[1]	0.03069* (0.01660)	0.29412 (0.22129)
Head born in the village[1]	0.05216* (0.02723)	0.01311 (0.31906)
Distance from village center[2]	−0.00001 (0.00040)	−0.00115 (0.00552)
Number of shock types experienced	−0.01241 (0.01097)	−0.26822* (0.13706)
Non-land assets (value) (log)	−0.00515 (0.00993)	0.04722 (0.13095)
Land assets (in square meters) (log)	−0.00576 (0.00853)	−0.28194** (0.10970)
Head education[3]	−0.00157 (0.00398)	−0.06416 (0.05352)
Maximum household education[3]	0.00329 (0.00280)	−0.02342 (0.04045)
Distance from forest[2]	−0.00070** (0.00031)	−0.00950** (0.00415)
Village: Chainpur	–	−0.75479** (0.35252)
Village: Hemja	–	−0.99233** (0.40372)
Village: Lete	–	−0.84336** (0.35289)
Constant	0.26228** (0.12452)	2.84815** (1.33068)
Joint test of model	84.16***	48.73**
Joint significance test of the environmental reliance lagged quadratic term; F (4, 402)	256.52***	–
Joint significance test of age squared term; F(2,402) and X^2(2), respectively	3.15**	5.86*
R-squared	0.8089	–
# of observations (changes between two consecutive years: 2006–2009 and 2009–2012)	772	

**Significant at 10%, **significant at 5%, and ***significant at 1%; [1]could change when the household head changes; [2]could change when the household changes location or the forest or the village structure changes; [3]could change when the household head or the household member with the highest education changes, or the household head or the household member with the highest education attends more years of education.*

2013), and a wish to move out of arduous environmental product collection (Larsen and Smith, 2004). There are several possible explanations for this counterintuitive finding. First, there is substantial variation in the equilibrium point across space, from 14% in Hemja to 34% in Kunjo (**Table 1**). These differences are as expected, with higher levels of environmental income reliance at high altitude with lower population density, more environmental resources, and fewer livelihood diversification opportunities. Second, the equilibrium point(s) is a long-term state that households converge toward, all other things being equal. This ceteris paribus assumption is unlikely, however, to hold. There are many examples of recent and rapid developments that influence the total income portfolio of rural households and that are likely to reduce the future weight of environmental income, e.g., the widespread access to remittances (Thieme and Wyss, 2005; Maskay and Adhikari, 2013; Thagunna and Acharya, 2013) or the impact of infrastructural development (Charlery et al., 2015, 2016). Consequently, the current equilibrium point could be lower than our estimate for the 2006–2012 period. There are also examples of the opposite, however, with environmental products becoming the main source of income for rural households in the high mountains (Pouliot et al., 2018). In connection to discussions of the future economic importance of environmental income to rural households, it should also be noted that Meilby et al. (2014), using a combination of forest productivity and household income studies in Nepal, found considerable scope for increasing rural household forest incomes while keeping within sustainable harvesting levels. This indicates that environmental income levels, at least in some locations, can be increased and be sustainable at the same time. Other important indications of possible increased environmental incomes come from increasing prices for many non-timber forest products in the past decade, in response to increasing demand from China and India (Pyakurel et al., 2018), as well as the recent rapid emergence of environmental product processing industries in Nepal (Caporale et al., 2020).

What Environmental Reliance Pathways Do Households Follow and What Characterizes the Associated Livelihood Outcomes?

The study empirically found two pathways based on households' movements toward the single environmental reliance equilibrium: low-upward and high-downward environmental reliance pathways. These pathways were identified based on households' environmental reliance over time, not income which is the conventional grouping metric in the environmental reliance literature. As noted above, there is no simple unidirectional scenario of decreasing environmental incomes throughout the country and the environmental reliance paths (**Figure 2**) can shift both right and left with a change in the pattern of the curvature.

Households on the two identified pathways perform differently in terms of income and asset endowment. The high-downward environmental reliance pathway group was less wealthy (both in terms of income and assets) and made about half of their income from environmental resources. Households in the low-upward environmental reliance pathway group were wealthier (both in terms of income and asset) and with low reliance on environmental resources (less than 10%). The high-downward environmental reliance pathway group was mainly composed of households from the two lowest income quartiles (constituting about 70% of the households, **Supplementary Appendix D**). Many other studies have reported higher environmental income reliance among poorer households (e.g., Adhikari et al., 2004; Heubach et al., 2011; Nielsen et al., 2012; Kabubo-Mariara, 2013; Nguyen et al., 2015; Porro et al., 2015; Walelign, 2016a). Households in the low-upward environmental reliance pathway group derived a large proportion of their total household income (45%) from non-agrarian and more remunerative livelihood activities, particularly business and remittances, which has also been reported elsewhere (Iiyama et al., 2008; Tesfaye et al., 2011; Nielsen et al., 2013; Walelign, 2016a) as well as for Nepal (Maskay and Adhikari, 2013; Thagunna and Acharya, 2013).

The lack of evidence for an environmental reliance trap does not exclude the existence of a poverty-environment trap; in the latter type of trap, the high reliance of the poor on environmental resource extraction leads to resource depletion and environmental degradation that compromise future livelihoods (Barrett et al., 2011, 2016). However, this is unlikely given infrastructural developments (Charlery et al., 2015), livelihood shifts to non-environment based activities (Thieme and Wyss, 2005; Maskay and Adhikari, 2013; Thagunna and Acharya, 2013), and the unrealized potential of Nepalese forest environments (Meilby et al., 2014). It is also important to note that the group of high-downward households have higher absolute and relative environmental incomes: targeting and supporting this group of households with policy interventions for alternative livelihoods would lower harvests of environmental products.

This result, that absolute environmental income in the high-downward pathway group (poorer households) is about three times larger – mainly from firewood and fodder (Walelign and Jiao, 2017) – than in the low-upward pathway group (wealthier), is important. It suggests that our approach is successful in identifying households that have high environmental income both in relative and absolute terms. Most other studies, differentiating households based on total income, find that more well-off households have higher absolute environmental income than the poor; this has been found in both Nepal (Rayamajhi et al., 2012; Meilby et al., 2014; Chhetri et al., 2015) and elsewhere throughout the tropics and subtropics (e.g., Angelsen et al., 2014). Documented exceptions include Adhikari (2005) in Nepal and Uberhuaga et al. (2012) in Bolivia; both studies found that asset endowed households were better positioned to access forest incomes. The Adhikari (2005) finding has not been found elsewhere in Nepal and could be due to more widespread local elite capture of benefits two decades ago in his case year of 2000; it has recently been argued that a process of recentralization has taken place since 1999, leading to increasing lack of local forest control and erosion of community forestry income (Basnyat et al., 2020). Whatever the reason, our finding differs as high environmental incomes in our study areas are accessed, in both absolute and relative terms, by households with fewer assets and lower incomes. In other words: if we organize our households according to the standard approach using income brackets, such as the quintiles in Chhetri et al. (2015) or the quartiles in Rayamajhi et al. (2012), both using a subset of the present data, we find the usual pattern of high environmental reliance and low absolute environmental income for the poorer households. But the choice of welfare indicator matters (Charlery and Walelign, 2015; Jiao et al., 2019; Walelign et al., 2019). When we isolate the households with the highest reliance on environmental income, as we do in the present approach to identify environmental reliance pathways, we find the subset of households that are poorer (both in terms of total household income and household asset endowments) also have significantly higher absolute environmental income. This group is thus the poorer households that make a living from harvesting substantial amounts of environmental products. This has policy implications: the approach allows identification and hence interventions aimed at the poorer households harvesting more environmental products than other households, hence facilitating simultaneous targeting of poverty reduction and environmental conservation outcomes.

What Factors Influence Households' Movement Between Environmental Reliance Pathways?

The life cycle effect suggests that households' environmental reliance increases until a certain age after which it decreases, as was also found by Bwalya (2013) in rural Zambia. This is in line with environmental product extraction being physically demanding. Other environmentally reliant households are those with the household head born in the village or belonging to the most common caste in the village, both of which arguably would have environmental product access facilitated by their social capital. This implies that households having one or more of these characteristics should be targeted in interventions aimed at promoting shifts to non-environmental based livelihood strategies. Targeting high-downward moving households would also, as noted above, simultaneously have pro-poor effects as these households are less well off in both income and asset terms. On the other hand, households headed by women, or having larger landholdings or better market access, are less likely to be highly reliant on environmental resources. Rayamajhi et al. (2012), for data collected in 2006, found a non-significant positive relationship between female-headed households and environmental reliance, the change in sign could be due to the increasing importance in such households of remittances up till 2012 (CBS, 2011). The findings on landholdings and market access are in line with expectations, e.g., Charlery et al. (2016) found decreasing environmental income reliance with improved road infrastructure.

The findings suggest that poverty reduction and environmental conservation objectives can be achieved simultaneously through interventions that (i) target and support households on the high-downward (high reliance) pathway in order to decrease environmental reliance without compromising their livelihoods, and/or (ii) shift the environmental reliance equilibrium point toward a lower level. Such interventions could focus on: (i) promoting non-environmental based livelihood alternatives aimed at male-headed households with head born in the village or belonging to the most common caste in the village; (ii) improving the access of poor households to land, e.g., through better markets for land rental or tenancy arrangements; (iii) enhancing communities and households' preparedness and adaptive capacity in response to risks and shocks; and (iv) improving poor households' access to markets and credit, e.g., through continued development of road infrastructure (Charlery et al., 2015).

CONCLUSION

This paper explored the dynamics of rural households' environmental reliance using an environmental augmented panel dataset over a 6-year period from Nepal. We proposed an environmental reliance trap theory explaining trajectories of household-level environmental reliance over time. No empirical evidence was found for the existence of environmental reliance traps in our study area and period. From 2006–2012, households in rural Nepal converged toward a single long-term environmental reliance equilibrium point (approximately 24% of total household income) with substantial variation across physical locations. Households moved toward the equilibrium in two groups: low environmental reliant households moving up toward the point, and high environmental reliant households moving down toward the point. Acknowledging that environmental reliance pathways shift with structural factors, such as changes in the inflow of remittances or improved physical infrastructure, identification of such pathways and characterization of the groups of households following them can arguably contribute to improved interventions, from small independent projects to changes in public policies aimed at environmental conservation and/or poverty reduction, through the identification of poorer households that are highly reliant on environmental income. Given the limited empirical work on environmental reliance pathways and their likely variation across space and time, it is not yet possible to conclude whether environmental reliance traps exist somewhere and, if they do, under what conditions. The adverse consequences of their existence, they would likely lock already marginalized people in poverty, warrant further case studies.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Department of Food and Resource Economics. The patients/participants provided their informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors were involved in designing the study as well as writing the manuscript. SW conducted data management and analysis.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/ffgc.2020.571414/full#supplementary-material

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