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Commercial Medicinal Plant Collection Is Transforming High-altitude Livelihoods in the Himalayas

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*Environmental products can contribute to livelihoods through support of current consumption and provision of an economic safety net. But what is their role in lifting households out of poverty? Here we investigate the absolute and relative economic importance of commercial medicinal plants, including the high-value Chinese caterpillar fungus (*Ophiocordyceps sinensis*), to rural livelihoods in the high mountains of Nepal. We assess their role in providing a household-level pathway out of poverty. Data are derived from a structured household survey (*$n = 72$*) conducted in Jumla District and covering a 9-year period (2006–2015), supplemented with key informant interviews. We found that income from selling wild-collected medicinal plant products constituted an average of 58% of the total annual household income and 78% of cash income. Medicinal plant income increased in the observation period—even though medicinal plant income per collection day decreased, income at the community level doubled. We argue that medicinal plant commercialization is a rare opportunity to increase locally derived and controlled incomes with a range of positive outcomes, such as supporting livelihood strategies and mitigating the negative effects of outmigration.*

Keywords: *Environmental income; environmental products;* Ophiocordyceps sinensis*; poverty alleviation; livelihoods; Nepal.*

Peer-reviewed: *February 2019* ***Accepted:*** *June 2019*

Introduction

Environmental products are economically important for rural livelihoods throughout the global South: their average annual contribution has been estimated at 28% of total household income (Angelsen et al 2014). While there is general agreement that such products are important in preventing poverty, supporting current consumption (eg Hickey et al 2016; Nielsen et al 2017) and acting to some degree as safety nets and gap fillers (Wunder, Börner, et al 2014), their role in reducing poverty is less well understood. Some authors argue that environmental products do not play a substantial role in asset accumulation and lifting households out of poverty (Wunder, Angelsen, et al 2014; Walelign et al 2017), while others note that this may be important in certain locations. For example, Shackleton et al (2007) found that the informal non-timber forest product sector provided an escape from poverty for a limited number of households in South Africa.

In this paper, we empirically investigate the role of commercial medicinal plants in Nepal in lifting rural households out of poverty. We limit our focus to income poverty (see Angelsen and Wunder 2003 for a broader discussion of environmental products and concepts of poverty). This is a particularly interesting case as (1) there is a huge nationwide collection and trade in medicinal plants with annual volumes of tens of thousands of tons, distributed across more than 50 products, worth tens of millions of US dollars (Edwards 1996; Olsen 2005; Olsen and Helles 2009); (2) there are recent indications that volumes and unit prices are increasing for many products in response to increased demand from India and China (Pyakurel et al 2018); and (3) there is a dearth of local-level studies documenting the economic importance of these commercial medicinal plant products to rural households.

These products are commercialized by local harvesters without reliance on external government or civil society actors (Olsen and Helles 2009; Pyakurel et al 2018). They therefore constitute a resource that is not captured by the government or corporations (Winkler 2005, 2008), but is reliant on local resource access and control, harvesting knowledge, and low capital requirements (Olsen and Helles 1997; Winkler 2005). Olsen and Larsen (2003) found that medicinal plant collection was an integral part of high mountain livelihoods, contributing 3–44% of annual income, with an average of 12%. These findings are echoed in Rasul et al (2012), who reported a household income contribution of 21% from medicinal plants in 2 districts in far-western Nepal. Recent studies have estimated that Chinese caterpillar fungus (*Ophiocordyceps sinensis*) contributes 21% of total annual household and 53% of cash income in Dolpo District (Shrestha and Bawa 2014), 38–85% of cash in Jumla District, and almost all cash income for collectors in upper Gorkha (Childs and Choedup 2014) and Darchula (Pouliot et al 2018) Districts.

Thus, while Chinese caterpillar fungus trade has received recent attention, there are no studies in the past decade on the economic importance of the range of commercial medicinal plants to rural livelihoods in Nepal, and there is limited information on the importance to total household income. This study (1) estimates the economic importance of the entire portfolio of commercial medicinal plants to total household income, using a case study in Jumla District, from 2006 (the end of the civil war) to 2015 (data collection year), and (2) discusses the role of these products in providing a pathway out of poverty.

Methodology

Study area

The study was carried out in Paterasi Village Development Committee (VDC; the lowest administrative unit; called Paterasi rural municipality since 2017) in the Chaudabise valley of Jumla District (29.34°N, 82.50°E) in the mountains of midwestern Nepal (Figure 1). Altitudes range from 2700 to 6500 m and the area of 44,010 ha consists mainly of forest and rangelands (Larsen 2002; Jumla Local Development Office 2010). All villages are located in the valley bottom at around 2700 m. The area is relatively isolated, with a dry-season dirt road, constructed in 2012, and livelihoods are made up of the 3 traditional pillars of limited crop production, raising livestock, and engaging in limited trade. Maize, millet, wheat, barley, potatoes, and beans are the most common crops. In 2010, the total population of the VDC was 3791, distributed among 625 households, with 74% being high-caste Chhetri, 19% lower-caste Dalits (such as Kami and Sarki), and 7% others (Jumla Local Development Office 2010). All villages have similar access to commercial medicinal plants that are harvested in communal areas regulated through forest user groups or in government-owned and controlled habitats outside the VDC. Collection in the latter areas formally requires a permit, but this is not enforced.

Data collection

Data were collected in March and April 2015 using a structured household questionnaire supplemented with interviews with key informants (5 local district officers, eg from the District Forest Office, to inform the content and structure of the household questionnaire) and a mix of participatory rural appraisal methods: a seasonal calendar to temporally map agriculture, livestock, and medicinal plant collection activities; a preference ranking to understand main livelihood activities (eg showing that medicinal plant collection is done for cash and considered risky, on par with agricultural crop growing); and a historical timeline, showing, for example, that *O. sinensis* harvesting began on a large scale in 1998 and that the first tractor drove to the area in 2012.

The questionnaire followed the Poverty Environment Network format and guidelines (PEN 2007; Angelsen et al 2011), and was developed to allow structured quantification of total household income, including environmental income. The questionnaire also recorded household characteristics, such as caste, household size, and education of the household head. The questionnaire was tested in a neighboring village outside the sampling frame.

Households were randomly sampled ($n = 72$) from the 3 main villages in Paterasi VDC, using forest user group membership lists as sampling frame (all households must be members in order to gain access to daily products such as firewood), with a proportional distribution reflecting the number of households in each village.

Interviews lasted 20–40 minutes and all were undertaken in Nepalese with the head of the household. They were conducted inside the house to minimize disturbances. Confidentiality was stressed and informed consent obtained. The structured survey included 3 reference years: 2006–2007, 2009–2010, and 2014–2015 (Nepalese years 2063, 2066, and 2071), selected to aid recall: 2006–2007 marked the end of the civil war, 2009–2010 was prominent as a suspension bridge was built in Paterasi VDC, while 2014–2015 was the ongoing year (where medicinal plant collection had been completed in the previous fall).

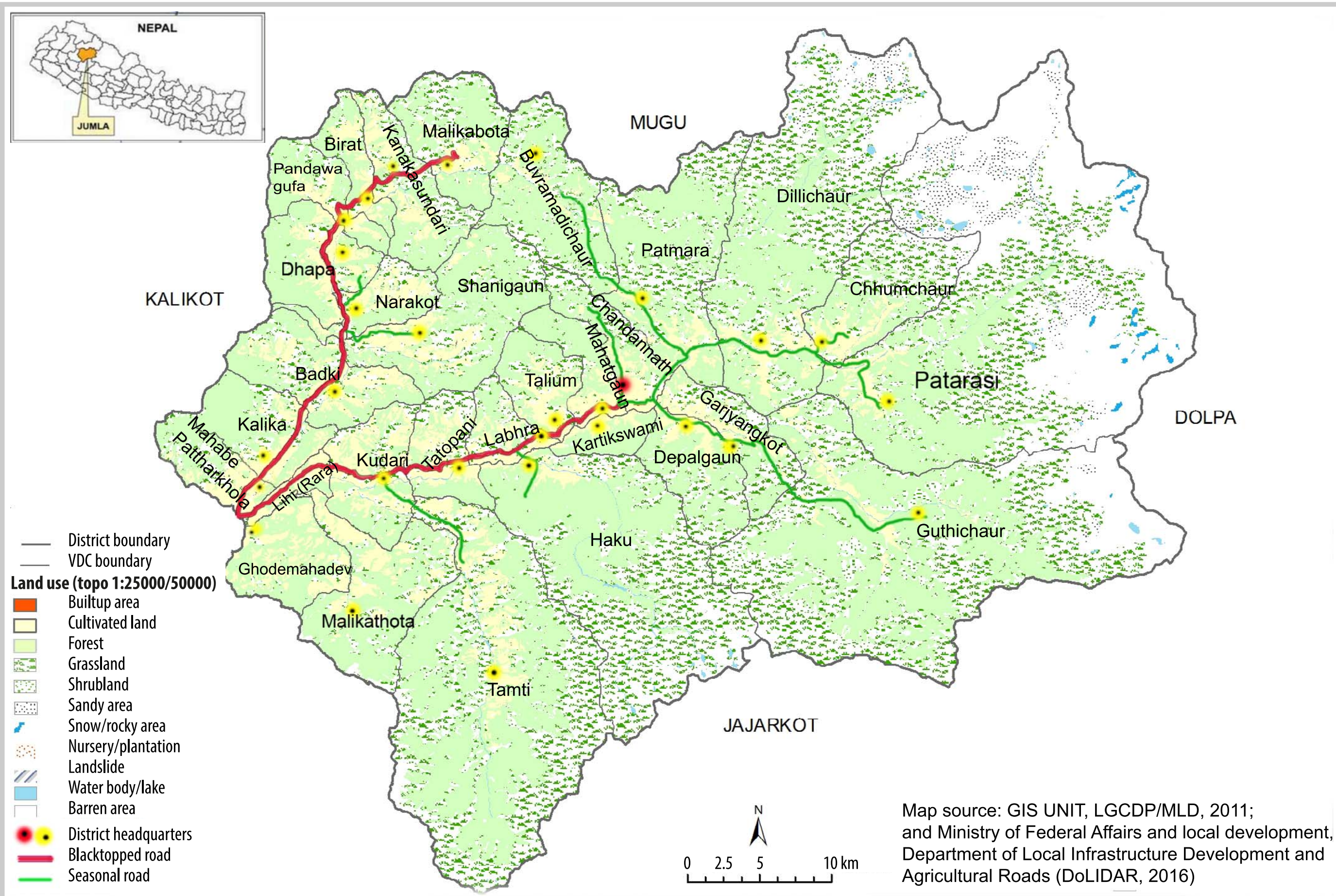
Household income and asset estimation

Annual total household income is the sum of all outcomes of household economic activities, thus including both subsistence and cash income (not subtracting the value of household's own labor). It is measured per adult equivalent unit (AEU) using the equivalence adjustments proposed by Cavendish (2002; adult [15–60 years] male given a value of 1.00, adult female 0.88, children [0–14 years] 0.67), enabling comparison of empirical results across households differing in composition and size (using the common scale of the number of adult male equivalents).

Total income is divided into 3 major components: farm, environmental, and nonfarm incomes. "Farm income" refers to subsistence and cash income from households' own farming activities, including crop production and livestock products. External inputs were not used in agricultural production, as households used their own seeds and livestock manure as fertilizer, and net and gross incomes are assumed to be similar. Likewise, environmental income relies on household labor and involves negligible capital costs. Environmental income is subdivided into forest and medicinal plant incomes. The former includes incomes from collection of firewood and forest litter used for forage. Other forest income sources were marginal and are not included. Medicinal plant income includes cash income from wild-harvested products, excluding the value of medicinal plants for own-subsistence use. Nonfarm income includes household businesses (including shopkeeping and income from buying and selling medicinal plants), gifts, and loans. All registered values are farm-gate prices as recommended by Wunder et al (2011), except for firewood and forest litter, which were estimated using contingent valuation (willingness to pay) because of lack of markets.

Total asset value was estimated as the sum of savings, debt, and standardized livestock and land values. These were estimated using the average of the own-reported unit values (eg per cow, horse, chicken) obtained during the household survey. There was no trading of houses in Paterasi and these are not included in asset estimation. Furthermore, human and social capital is not included because human relations cannot be monetized (Cavendish 2002). All prices were converted to 2014–2015 prices using the Nepal Rastra Bank consumer price index.

FIGURE 1 Map of Jumla District and Paterasi VDC. (Map by Dipesh Pyakurel)



Wealth groups

Households were divided into 3 wealth groups: poorest, poor, and better off. To include the dynamic aspects of poverty and to better predict a household's ability to adapt to income changes, the wealth groups were ranked based on total annual income/AEU and total asset value/AEU (Nielsen et al 2012). The "poorest" wealth group comprises households from the lowest tercile in income and assets (1 + 1) or medium tercile in either income or assets (2 + 1 or 1 + 2). The "poor" group includes households with terciles 1 + 3, 2 + 2, and 3 + 1, and the "better-off group" are households with scores 2 + 3, 3 + 2, and 3 + 3.

Data analysis

All local units were converted to the International System of Units and analyzed using the SPSS statistics package. Frequency and percentage histograms were used to understand how data were clustered or grouped. Differences between wealth groups were tested using *t*-tests, and analysis of variance (ANOVA) was used to compare the means of the 3 observation points for key variables such as the number of medicinal plant collection days per household (post hoc corrections were not applied).

We applied descriptive statistics and multiple ordinary least squares (OLS) linear regression models to determine which variables influenced total annual income and medicinal plant income. Predictive variables were household characteristics (age, sex, and education of household head; size; caste; location), assets (cropland, pastureland, livestock units), and medicinal plant collection (number of days, years of collection experience). The variance inflation factor for each of the explanatory variables was low (ranging from 0.2 to 1.7), indicating that multicollinearity is not problematic.

Foster–Greer–Thorbecke decomposable poverty measures (Foster et al 1984) were calculated to estimate the prevalence (the proportion of households with per AEU income below the poverty line), depth (the average income shortfall as a proportion of the poverty line), and severity (the variation in income distribution among households below the poverty line) of poverty.

The national poverty line was defined in 2010–2011 as NPR 19,261/person/y (NPR 102 = US$1; DFID 2013). Adjusted for inflation, the 2014–2015 national poverty line was estimated as NPR 25,039/person/y, equivalent to US$ Purchasing Power Parity 1.63/person/d.

Data checking

At the end of each working day in the field, data were checked for errors and inconsistencies. This allowed revisits to households the following day to clarify issues. Mean, mode, and median values of households' own-reported value estimates, as well as the mean standard deviation, were compared (Wunder et al 2011) and showed the pattern reported by Rayamajhi and Olsen (2008)—similar mean,

TABLE 1 Characteristics of households across 3 wealth groups, Jumla District, 2014–2015.[a)]

Characteristics	Poorest, $n = 25$ (SD)	Poor $n = 25$ (SD)	Better off $n = 22$ (SD)	Mean, $n = 72$ (SD)	Minimum–maximum range
Membership of dominant caste, %	90	60B	95A	82 (39)	0–100
Household size, AEU	8.0 (4.1)A	7.1 (2.2)A	5.6 (1.2)B	7.0 (2.9)	3.5–21.0
No. of children, 0–14 y	2.4 (1.3)A	2.0 (1.3)A,B	1.8 (0.7)B	2.1 (1.2)	0–6.03
No. of adults, 15–60 y	4.7 (3.3)A	4.3 (1.8)A	3.0 (1.1)B	4.0 (2.4)	1.9–10.4
Household head education, y	1.8 (3.3)A	1.9 (3.2)A	3.3 (3.2)A	2.3 (3.3)	0.0–8.0
Age of household head, y	36.9 (11.3)A	36.7 (12.9)A	34.4 (9.2)A	36.1 (11.2)	19.0–65.0
Livestock units	5.7 (7.4)A	3.9 (4.1)A	3.9 (3.0)A	4.5 (5.2)	0–29.3
Land size, ha[b)]	0.9 (0.5)A	1.3 (0.9)A,B	1.5 (3.6)B	1.3 (0.5)	0.3–4.5
Food-insufficient households, %	48A	32A,B	14B	30 (17)	30–50
Food-insufficient mo, mean	2.0 (3)A	2.0 (3)A	0.8 (2.1)A	1.7 (2.7)	0–9
Households having wage income, %	32A	52A	32A	40 (11)	32–52
Household having own business, %	8A	16A	18A	14 (5)	8–18
Households having savings, %	60A	80A	77A	72 (45)	60–80

[a)]Small capital letters (A, B, C) indicate *t*-test in rows. A different letter indicates a significant mean difference ($\alpha = 5\%$).
[b)]Converted from *hal* to hectares. 1 *hal* equals 0.128 ha and 2.5 *ropanis* (Bishop 1990).

mode, and median values showing little skewness, standard deviations lower than the means—thus indicating that households provided valid and reliable estimations of product values. Medicinal plant values for 2014–2015 were also checked against the central wholesaler purchasing prices published online by the Asia Network for Sustainable Agriculture and Bioresources and consistently found to be lower, as expected; prices obtained by collectors were lower than those offered by central wholesalers further up the value chain (eg Olsen and Helles 1997, 2009).

Results

Household characteristics

The households were in many ways similar (Table 1), with a few notable exceptions: (1) The better-off households were significantly smaller (as measured in AEU), with fewer children and fewer adults (the latter significant only in relationship to the poorest households). (2) The poorest households had significantly lower landholdings and were more food insecure compared to the better-off poor households. The wealthier households also tended to own more businesses, have higher savings, and be less food insufficient. Education levels were low across the board, with high illiteracy: 65% of respondents never went to school. Wage work, recorded in 28 households (40%), was mainly as masons, while 10 households (14%) had their own business, a small shop or trade in medicinal plants.

Household incomes

Again, the households were similar in many ways (Table 2). In relative terms, the distribution of income was similar across the 3 terciles, with environmental income being the dominant source (average of 65% of annual total household income, ranging from 62–67%) of income, followed by nonfarm income (19%, 18–21%) and farm income (16%, 15–17%). The largest variation was in wage income, which was relatively less important for the better-off households (8% versus 15% for the other groups), who instead generated income from their own businesses (13% versus 2% and 4%). In absolute terms, the total annual household income per AEU of the better-off households was significantly higher, and more than double the income of the poorest, including significantly higher incomes from environmental resources, agricultural products, and own businesses. There was also a remarkably similar distribution of productive assets, with the largest difference being significantly higher total asset value in the better-off group. Around 40% of the households in the sample fell below the national poverty line, with a poverty depth of 13% and 6% of households living in severe poverty.

The single most important and dominant source of income was from wild harvest and sale of medicinal plants. There were no significant differences between the wealth groups, with an average share in annual total household income of 58% (ie of the sum of household cash and subsistence income), ranging from 55–60% across the groups. In absolute terms, however, medicinal plant income for the poorest households was significantly lower than for the other households, with the better-off households earning an average of almost 3 times more. Medicinal plant income made up an average of 78% of all cash income, with 46% of households having medicinal plant sales as their sole source of cash.

Products harvested and traded were bulbs of *Fritillaria cirrhosa* D. Don, morels *Morchella* spp, rhizomes of *Nardostachys jatamansi* (D. Don) DC. and *Neopicrorhiza scrophulariiflora* (Pennell) D.Y. Hong, roots of *Rheum australe* D. Don, tubers of *Dactylorhiza hatagirea* (D. Don) Soó, rhizomes of *Paris polyphylla* Sm., pseudobulbs of *Eulophia* spp., and *O. sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones &

TABLE 2 Nested total absolute (Abs) (NPR/AEU) and relative (Rel) (%) annual household income and productive assets by wealth groups, Jumla District, 2014–2015.[a)]

	Poorest[b)] ($n = 25$)		Poor[b), c)] ($n = 24$)		Better off[b)] ($n = 22$)		Sample mean (SD) ($n = 71$)	
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel
Annual income								
Environmental income	13,614 (6309)A	65.4	24,155 (19,435)B	66.9	34,470 (14,691)B	62.2	24,080 (13,478)	64.5
Medicinal plant income[d)]	11,437 (6744)A	55.0	21,827 (19,414)B	59.8	31,514 (14,172)B	56.8	21,593 (10,041)	57.8
Forest income excluding medicinal plants	2177 (1184)A	10.5	2328 (1599)A,B	6.5	2956 (1232)B	5.3	2487 (413)	6.6
Firewood and timber	1647 (894)A	7.9	1848 (1485)A	5.1	2193 (1006)A	4.0	1896 (276)	5.1
Forest litter	530 (318)A	2.5	487 (269)A	1.4	763 (710)A	1.4	593 (148)	1.6
Farm income	3533 (2243)A	17.0	5282 (3327)B	14.6	9338 (4833)C	16.8	6051 (2978)	16.2
Agricultural products	2716 (1410)A	13.0	4191 (2192)B	11.6	7609 (4107)C	13.7	4839 (2510)	13
Livestock products	817 (1656)A	4.0	1.091 (1906)A	3.0	1728 (2343)A	3.1	1212 (467)	3.2
Nonfarm income	3664 (5539)A	17.6	7035 (10,801)A,B	18.4	11,642 (15,568)B	21.0	7220 (7332)	19.3
Wage work	3255 (5407)A	15.6	5251 (9667)A	14.6	4277 (7390)A	7.7	4261 (1109)	11.4
Own business	408 (1760)A	2.0	1342 (3825)A	3.9	7027 (16,044)B	12.7	2775 (6222)	7.4
Gifts and government support	0 (0)A	0.0	223 (758)A	0.5	337 (1142)A	0.6	184 (171)	0.5
Total annual income	20,810 (8380)A	100	36,082 (62,357)A,B	100	55,450 (19,233)B	100	37,353 (17,360)	100
Productive assets								
Land value	216,037 (133,440)A	83.7	217,965 (85,966)A	86.6	286,745 (155,518)A	82.7	240,249 (40,278)	84.1
Livestock value	35,083 (44,290)A	13.6	28,245 (25,073)A	11.2	39,959 (27,439)A	11.5	34,429 (5884)	12.1
Savings	1145 (1643)A	0.4	3390 (4763)B	1.3	18,074 (51,861)A,B	5.2	7536 (9195)	2.6
Debt	5943 (12,608)A	2.3	2245 (4525)A	0.9	1990 (4533)A	0.6	3393 (2212)	1.2
Total value	246,332 (126,615)A	100	247,354 (85,685)A	100	342,783 (163,491)B	100	278,819 (125,261)	100

[a)] Standard deviations in parentheses. Exchange rate: NPR 102 = US$ 1.
[b)] Small capital letters (A, B, C) indicate *t*-test in rows. A different letter indicates a significant mean difference ($\alpha = 5\%$).
[c)] One household excluded because of extreme value (NPR 1,900,000 from medicinal plant trade).
[d)] Income sources are nested, eg "Firewood and timber" and "Forest litter" add up to "Forest income excluding medicinal plants".

TABLE 3 Household ($n = 71$) socioeconomic determinants of total annual household and medicinal plant incomes, Jumla District, 2014–2015.[a)]

Explanatory variables	Total annual household income/AEU				Total annual medicinal plant income/AEU			
	Coefficient	SE	*t* value	*P* > z	Coefficient	SE	*t* value	*P* > z
Age of household head (y)	0.000	0.008	0.001	0.684	0.012	0.018	0.047	0.347
Sex of household head (1 = female)	0.115	0.343	0.033	0.438	0.679	0.500	0.067	0.125
Education of household head (y)	0.000	0.025	0.001	0.685	0.022	0.032	0.047	0.351
Household members (AEU)	−0.048*	0.022	−2.19	0.033	0.027	0.063	0.030	0.466
Caste (1 = dominant caste)	−0.515*	0.229	−2.24	0.029	−0.052	0.615	−0.08	0.648
Cropland (ha/AEU)	0.283*	0.117	0.113	0.018	0.365	0.226	0.084	0.078
Pasture land (ha/AEU)	−0.137	0.239	−0.58	0.394	0.158	0.569	0.019	0.544
Livestock units	−0.080	0.096	−0.83	0.283	−0.120	0.154	−0.780	0.306
Medicinal plant collection days	0.009*	0.004	0.103	0.026	0.029*	0.014	0.087	0.044
No. of medicinal plant collection years	0.026*	0.011	0.113	0.019	−0.015	0.031	−0.480	0.439
Member of village 2	0.215	0.156	0.110	0.051	−0.488	0.522	−0.930	0.246
Member of village 3	0.162	0.214	0.053	0.313	−0.109	0.943	−1.160	0.174
Constant	9.717	0.517	0.804	0.000	7.262	1.543	0.216	0.000
$F_{12,59}$	5.22				1.71			
P	0.000				0.087			
R^2	0.34				0.29			
RMSE	0.60				1.34			

[a)]SE, standard error; *t* value, the calculated difference represented in units of standard error; *P*, the probability of obtaining test results at least as extreme as the observed results; RMSE, root mean square error (the standard deviation of the residuals).
*$P < 0.05$.

Spatafora (the high unit price for the latter meant that 29% of households collected only this product).

All species were harvested, air-dried, and then sold to local traders who feed production networks leading to India and China, with local and domestic consumption being minimal. There was no local knowledge of end uses besides the anecdotal, for example that *O. sinensis* is used as an aphrodisiac in China.

Determinants of medicinal plant income

Because of the low variation in the sampled households, as noted above, the OLS regressions (Table 3) did not produce many significant results. Only the number of medicinal plant collection days significantly and positively influenced the total annual medicinal plant income. There was no significant difference in the number of medicinal plant collection days between any wealth groups. This variable was also significant and positive for "total annual household income," as was "collection experience" (expressed as number of medicinal plant collection years). The number of household members had a negative effect, probably because of more unproductive members: while our data do not allow for a fine-grained analysis, the poorest households had significantly more children, which could prevent the allocation of adult labor to medicinal plant collection through the need to provide childcare. Likewise, dominant caste membership had a negative and significant influence on total annual household income (see Discussion).

Changes in medicinal plant collection and income from 2006–2007 to 2014–2015

The number of medicinal plant-collecting households increased from 78% in 2006–2007 to 100% in 2014–2015. Men were the main collectors, but women's participation increased by 27% in the period. Plants were usually collected during 2 to 3 dedicated trips per year.

In the observation period, the average number of collection days per household increased significantly, from 25 days in 2006–2007 to 62 in 2014–2015 (Table 4), as did income, from NPR 11,000/AEU to NPR 21,000/AEU. The income per collection day, however, decreased significantly, from NPR 577/d to NPR 375/d. The total income in the studied population increased from NPR 800,000 in 2006–2007 to NPR 1.5 million in 2014–2015.

Some households had specialized in medicinal plant collection to the extent that they had abandoned other livelihood activities. In particular, *O. sinensis* collectors had left crop production; as the collection season overlaps with the agricultural season, cultivation of rice had completely stopped, and the cultivation of barley and wheat had decreased. Respondents reported that everybody had enough money to purchase food, limiting the need to cultivate it. In the words of a respondent: "Nowadays we

TABLE 4 Medicinal plant collection: collection days and income in 3 reference years, Jumla District.

	2014–2015 ($n = 71$)	2009–2010 ($n = 67$)	2006–2007 ($n = 55$)	$P > z$[a]
No. of collection d/household (SD)	61.6 (23.4)	40 (21.4)	24.5 (19.9)	0.000**
Income (NPR)/AEU (SD)	21,215 (16,370)	19,035 (26,356)	11,037 (16,236)	0.007**
Income (NPR)/collection day (SD)	375 (312)	407 (457)	577 (730)	0.088*
Sum of community medicinal plant income (NPR)	1,520,752	1,218,654	801,412	—

[a]ANOVA.
*$P < 0.1$.
**$P < 0.01$.

don't wait for food, we just buy it." Decreasing crop production had reduced agricultural labor demand, allowing more children to go to school. Two new private schools opened in 2014–2015, indicating that parents could afford school fees and wanted to invest in their children's future.

Use of medicinal plant income

Most households (54%) indicated that they were spending medicinal plant income on domestic consumption, including food and other household necessities. Around 19% spent money on new house construction, while 15% invested in livestock, 14% bought new land, 13% invested in shops, and 6% invested in their children's education.

Medicinal plant income and poverty measures

In 2014–2015, 40% of households fell below the national poverty line, with a poverty depth of 13% and 6% living in severe poverty. If medicinal plant income is excluded, these figures increase to 83%, 29%, and 16%. In the same year, the Gini coefficient decreased from 0.51 to 0.39 when medicinal plant income was included, indicating that medicinal plant income had a strong positive effect on income equality. The lack of total household income data for earlier years does not allow a comparison of Gini coefficients across time.

Discussion

The economic importance of medicinal plants to total household income

The average share of income from commercial medicinal plants in total annual household income in 2014–2015 was 58%, ranging in a narrow band from 55–60% across the terciles. This is outside the previously reported range of 3–53% for all environmental products in studies that report total household incomes (Rayamajhi et al 2012; Meilby et al 2014; Chhetri et al 2015; Charlery et al 2016; Oli et al 2016). This is likely to reflect our in-depth focus on the medicinal plant portfolio, the rising prices for many products, and the tendency for households to allocate more labor to medicinal plant collection over time. The average share of commercial medicinal plants in total annual household cash income in 2014–2015 was 78%; this is within the 53–92% contribution of *O. sinensis* to total household cash income reported in recent studies from Nepal (Childs and Choedup 2014; Shrestha and Bawa 2014; Laha et al 2018; Pouliot et al 2018).

In absolute terms, medicinal plant income was significantly lower in the poorest tercile than in the more well-off terciles. This also translated into a marginally lower relative share for the poorest households. This differs from the previously recorded and consistent pattern of higher relative economic importance in the poorest households (Olsen and Larsen 2003; Rijal et al 2011; Shrestha and Bawa 2014; Shrestha et al 2019). This new pattern could reflect local responses to market dynamics as households are pulled into medicinal plant collection through rising prices (Winkler 2008). This could be a new general pattern in the high mountains throughout Nepal, where medicinal plants are widely collected (Olsen 2005; Olsen and Helles 2009; Pyakurel et al 2018).

In our low-income study area, all households invested in medicinal plant collection, and the success of more well-off households, in terms of higher absolute income, may reflect a lower dependency ratio and hence more available labor: we know they had significantly fewer children. Larger families may not have more collectors, because of an increase in demand for childcare, but the size of the family lowers the values per AEU. To further understand this, we need data on adult labor availability (eg the number of elderly across wealth groups). Another possible explanation could be improved medicinal plant access for more well-off households, though this was not mentioned in interviews.

The studied population had a very low level of education. This could explain the absence of remittances: only 5.6% of households had long-term outmigrating members who were otherwise important in similar areas (Rayamajhi et al 2012; Chhetri et al 2015). Mobility was instead characterized by movement out of the area before the snow arrived, to trade in the lowlands, before returning in spring (Shrestha-Shipper 2010). Lack of human capital could push households toward higher environmental-product reliance, while the high medicinal plant income could also serve to limit the outmigration that has been documented in other high-altitude areas (Childs et al 2014). Respondents mentioned that migrants had started to return during the medicinal plant collection season to get a share of the valuable harvest. Local expenditure patterns for in-migrants are not known, including how much medicinal plant income is exported out of the area.

Other studies have found that medicinal plant collection is mainly undertaken by low-caste groups (Larsen 2002; Kunwar et al 2008) and, more generally, that caste membership influences livelihood strategies (Nielsen et al 2013). This pattern was not found in our study, reflecting the limited caste variation and dominance of the Chhetri caste (high caste), which made up 82% of the sample, including more than 90% of the poorest tercile. Paudel (2007) also did not find a correlation between caste and medicinal plant income in Jumla District. This indicates that lower castes are not prevented from accessing medicinal plant resources, whether in communal areas in the VDC or in government-owned habitats outside the VDC that are de facto considered open access. We did find, however, a significant negative relationship between dominant caste membership and total annual household income, indicating that there is not a simple relationship between castes and wealth groups. Asset levels were constant across the wealth groups (eg in terms of livestock ownership and education) with the only significant difference being that better-off households have significantly more land than the poorest households. Hence, it may be that this 2014–2015 finding reflects households in transitory poverty (rather than chronic poverty; Nielsen et al 2012), pushed there temporarily by unrecorded income shocks (Møller et al 2019) but with assets that could facilitate upward income mobility.

Incomes increased from 2006–2007 to 2014–2015, and 97% of respondents gave increasing medicinal plant income—almost doubling per household in the period—as the main explanation. According to 95% of respondents, the driver was higher unit prices, especially for *O. sinensis*, which increased by 2300% from 2001–2011 (Shrestha and Bawa 2014). The fungal commodification of the rural economy in Tibet (Winkler 2008) is also occurring in the Himalayan range: *O. sinensis* trade accounted for 60% of medicinal plant income in 2014–2015. An increase in price for other high-altitude species has also been noted elsewhere (Pyakurel et al 2018). The average income per collection day significantly decreased in the observation period, while the number of collection days and total medicinal plant income per collector significantly increased.

Interviews showed a widespread belief that medicinal plants were becoming scarcer, reflecting the lower income per day. This could, however, be due to the increasing number of collectors and collection days rather than a supply decrease. We did not find evidence to support the assumption by Hopping et al (2018) that collectors can distinguish between shortages deriving from total shortage versus a higher number of collectors. In addition, while collection income per day decreased, community-level income almost doubled in the observation period.

While many authors have argued that commercial harvesting is negatively impacting *O. sinensis* productivity (eg Winkler 2009; Shrestha and Bawa 2013; Shrestha et al 2014; Negi et al 2015; Hopping et al 2018; Laha et al 2018), for example through premature harvesting and overharvesting, no studies have documented that harvesting is unsustainable. Such studies are complicated by the complex life cycle of the caterpillar fungus: are critical production limits related to the dispersal of fungal spores or larvae production rates, for example? The determinants of harvesting sustainability are not known (Pouliot et al 2018).

The role of medicinal plants in providing a pathway out of poverty

The results suggest that medicinal plant income reduces income measures of poverty while also contributing to increased income equality. This is in line with existing findings for both medicinal plants (Shrestha et al 2019) and environmental income (Rayamajhi et al 2012; Chhetri et al 2015; Walelign et al 2016). The increased medicinal plant income has reinforced the trade component of high-altitude Himalayan livelihood strategies, providing households with hitherto unseen amounts of cash and thus new opportunities to diversify or specialize livelihood strategies.

Investments made possible by medicinal plant income have led to the emergence of a new cash-dependent economy, including gap-filling nonfarm jobs in the winter season, reducing the need for circulation to the lowlands. Medicinal plant collection in the high Himalayas in Nepal, rather than being an employment of last resort or a poverty trap (Angelsen et al 2014), appears to be an environmental-income-led pathway out of poverty. This is evidenced by the reliance on commercial medicinal plant collection in total household income and for cash, as well as the increasing importance of this income source over time, as seen in the increased labor allocated into collection (eg in number of collection days or in decisions to stop rice cultivation). However, as commercial medicinal harvesting may be unsustainable for many species, even if this is not yet documented, collecting households are vulnerable to decreasing supplies, indicating an urgent need to invest in determining sustainable harvest rates and the development of sustainable management practices.

Conclusion

In the study period from 2006–2007 to 2014–2015, rural household incomes from commercial medicinal plants increased significantly. Even though the income per collection day decreased, collectors were able to increase the number of collection days and almost double this income in the period. This development is brought about by increasing unit prices for high-altitude medicinal plant products and constitutes a rare opportunity for highland communities and households to increase their incomes using locally available resources. Commercial medicinal plants, with the current high prices, thus arguably provide a pathway out of poverty for rural households in remote areas. The findings indicate that commercial medicinal plant resources, assuming that sustainable harvest rates are estimated and that sustainable resource management practices are implemented, should be a development priority for the new provincial governments being established in the high mountains of Nepal.

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REFERENCES

Angelsen A, Jagger P, Babigumira R, Belcher B, Hogarth NJ, Bauch S, Börner J, Smith-Hall C, Wunder S. 2014. Environmental income and rural livelihoods: A global-comparative analysis. *World Development* 64:S12–S28.
Angelsen A, Larsen HO, Lund JF, Smith-Hall C, Wunder S, editors. 2011. *Measuring Livelihoods and Environmental Dependence – Methods for Research and Fieldwork*. London, United Kingdom: Earthscan.
Angelsen A, Wunder S. 2003. *Exploring the Forest–Poverty Link: Key Concepts, Issues and Research Implications*. CIFOR Occasional Paper No. 40. Bogor, Indonesia: Center for International Forestry Research.
Bishop BC. 1990. *Karnali Under Stress*. Geography Research Paper Nos. 228–229. Chicago, IL: University of Chicago Press.

Cavendish W. 2002. Quantitative methods for estimating the economic value of resource use to rural households. *In:* Campbell BM, Luckert ML, editors. *Uncovering the Hidden Harvest*. London, United Kingdom: Earthscan, pp 17–65.
Charlery L, Nielsen MR, Meilby H, Smith-Hall C. 2016. Effects of new roads on environmental resource use in the Central Himalaya. *Sustainability* 8(4):363. doi.org/10.3390/su8040363.
Chhetri BBK, Larsen HO, Smith-Hall C. 2015. Environmental resources reduce income inequality and the prevalence, depth and severity of poverty in rural Nepal. *Environment, Development and Sustainability* 17(3):513–530.
Childs G, Choedup N. 2014. Indigenous management strategies and socioeconomic impacts of Yartsa Gunbu (*Ophiocordyceps sinensis*) harvesting in Nubri and Tsum, Nepal. *Himalaya* 34(1):8–22.
Childs G, Craig S, Beall CM, Basnyat B. 2014. Depopulating the Himalayan highlands: Education and outmigration from ethnically Tibetan communities of Nepal. *Mountain Research and Development* 34(2):85–94.
DFID [Department for International Development]. 2013. *Regional Dimensions of Poverty and Vulnerability in Nepal: Background Reports*. London, United Kingdom: Department for International Development. www.gov.uk/government/uploads/system/uploads/attachment_data/file/209483/Regional-dimension-poverty-nepal-background.pdf; accessed on 5 December 2018.
Edwards DM. 1996. The trade in non-timber forest products from Nepal. *Mountain Research and Development* 16(4):383–394.
Foster J, Greer J, Thorbecke E. 1984. A class of decomposable poverty measures. *Econometrica* 52:761–766.
Hickey GM, Pouliot M, Smith-Hall C, Wunder S, Nielsen MR. 2016. Quantifying the economic contribution of wild food harvests to rural livelihoods: A global-comparative analysis. *Food Policy* 62:122–132.
Hopping KA, Chignell SM, Lambin EF. 2018. The demise of caterpillar fungus in the Himalayan region due to climate change and overharvesting. *Proceedings of the National Academy of Sciences of the United States of America* 115(45): 11489–11494.
Jumla Local Development Office. 2010. *Paterasi Village Profile 2066*. Jumla, Nepal: Jumla Local Development Office.
Kunwar RM, Chowdhary CL, Bussmann RW. 2008. Diversity, utilization and management of medicinal plants in Baitadi and Darchula districts, Far West Nepal. *The Initiation* 2(1):157–164.
Laha A, Badola R, Hussain SA. 2018. Earning a livelihood from Himalayan caterpillar fungus in Kumaon Himalaya: Opportunities, uncertainties, and implications. *Mountain Research and Development* 38(4):323–331.
Larsen HO. 2002. Commercial medicinal plant extraction in the hills of Nepal: Local management system and ecological sustainability. *Environmental Management* 29(1):88–101.
Meilby H, Smith-Hall C, Byg A, Larsen HO, Nielsen ØJ, Puri L, Rayamajhi S. 2014. Are forest incomes sustainable? Firewood and timber extraction and forest productivity in community managed forests in Nepal. *World Development* 64:S113–S124.
Møller LR, Smith-Hall C, Meilby H, Rayamajhi S, Herslund LB, Larsen HO, Nielsen ØJ, Byg A. 2019. Empirically based analysis of households coping with unexpected shocks in the central Himalayas. *Climate and Development* 11(7):597–606.
Negi CS, Joshi P, Bohra S. 2015. Rapid vulnerability assessment of *yartsa gunbu* (*Ophiocordyceps sinensis* [Berk.] G.H. Sung et al.) in Pithoragarh District, Uttarakhand State, India. *Mountain Research and Development* 35(4):382–391.
Nielsen MR, Pouliot M, Bakkegaard KR. 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. *Ecological Economics* 78:37–46.
Nielsen MR, Pouliot M, Meilby H, Smith-Hall C, Angelsen A. 2017. Global patterns and determinants of the economic importance of bushmeat. *Biological Conservation* 215:277–287.
Nielsen ØJ, Rayamajhi S, Uberhuaga P, Meilby H, Smith-Hall C. 2013. Quantifying rural livelihood strategies in developing countries using an activity choice approach. *Agricultural Economics* 44(1):57–71.
Oli B, Treue T, Smith-Hall C. 2016. The relative importance of community forests, government forests, and private forests for household-level incomes in the Middle Hills of Nepal. *Forest Policy and Economics* 70:155–163.
Olsen CS. 2005. Valuation of commercial central Himalayan medicinal plants. *Ambio* 34(8):607–610.
Olsen CS, Helles F. 1997. Medicinal plants, markets and margins in Nepal Himalaya: Trouble in paradise. *Mountain Research and Development* 17(4):363–374.
Olsen CS, Helles F. 2009. Market efficiency and benefit distribution in medicinal plant markets: Empirical evidence from South Asia. *International Journal of Biodiversity Science & Management* 5(2):53–62.
Olsen CS, Larsen HO. 2003. Alpine medicinal plant trade and Himalayan mountain livelihood strategies. *Geographical Journal* 169:243–254.
Paudel M. 2007. Non-timber forest products from community forestry practices, problems and prospects for livelihood strategy in Jumla. *Banko Janakari* 17(2):45–54.
PEN [Poverty Environment Network]. 2007. *The PEN Technical Guidelines*. Version 4. Bogor, Indonesia: Centre for International Forestry Research.
Pouliot M, Pyakurel D, Smith-Hall C. 2018. High altitude organic gold: The production network for *Ophiocordyceps sinensis* from far-western Nepal. *Journal of Ethnopharmacology* 218:59–68.
Pyakurel D, Sharma IB, Smith-Hall C. 2018. Patterns of change: The dynamics of medicinal plant trade in far-western Nepal. *Journal of Ethnopharmacology* 224:323–334.
Rasul G, Choudhary D, Pandit BH, Kollmair M. 2012. Poverty and livelihood impacts of a medicinal and aromatic plants project in India and Nepal: An assessment. *Mountain Research and Development* 32(2):137–148.
Rayamajhi S, Olsen CS. 2008. Estimating forest products value in Central Himalaya, methodological experiences. *Scandinavian Forest Economics* 42:468–488.
Rayamajhi S, Smith-Hall C, Helles F. 2012. Empirical evidence of the economic importance of Central Himalayan forests to rural households. *Forest Policy and Economics* 20:25–35.
Rijal A, Smith-Hall C, Helles F. 2011. Non-timber forest product dependency in the Central Himalayan foot hills. *Environment, Development and Sustainability* 13(1):121–140.
Shackleton CM, Shackleton SE, Buiten E, Bird N. 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy and Economics* 9(5):558–577.
Shrestha UB, Bawa KS. 2013. Trade, harvest, and conservation of caterpillar fungus (*Ophiocordyceps sinensis*) in the Himalayas. *Biological Conservation* 159:514–520.
Shrestha UB, Bawa KS. 2014. Economic contribution of Chinese caterpillar fungus to the livelihoods of mountain communities in Nepal. *Biological Conservation* 177:194–202.
Shrestha UB, Dhital KR, Gautam AP. 2019. Economic dependence of mountain communities on Chinese caterpillar fungus *Ophiocordyceps sinensis* (*yarsagumba*): A case from western Nepal. *Oryx* 53(2):256–264.
Shrestha UB, Shrestha S, Ghimire S, Nepali K, Shrestha BB. 2014. Chasing Chinese caterpillar fungus (*Ophiocordyceps sinensis*) harvesters in the Himalayas: Harvesting practice and its conservation implications in Western Nepal. *Society & Natural Resources* 27(12):1242–1256.
Shrestha-Shipper S. 2010. Migration from Jumla to the southern plain. *European Bulletin of Himalayan Research* (35–36):62–79.
Waleligh SZ, Charlery L, Smith-Hall C, Chhetri BBK, Larsen HO. 2016. Environmental income improves household-level poverty assessments and dynamics. *Forest Policy and Economics* 71:23–35.
Walelign SZ, Pouliot M, Larsen HO, Smith-Hall C. 2017. Combining household income and asset data to identify livelihood strategies and their dynamics. *Journal of Development Studies* 53(6):769–787.
Winkler D. 2005. Yartsa gunbu – *Cordyceps sinensis*: Economy, ecology & ethno-mycology of a fungus endemic to the Tibetan plateau. *In:* Boesi A, Cardi F, editors. *Wildlife and Plants in Traditional and Modern Tibet: Conceptions, Exploitation and Conservation*. Milano, Italy: Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano, pp 69–85.
Winkler D. 2008. Yartsa Gunbu (*Cordyceps sinensis*) and the fungal commodification of Tibet's rural economy. *Economic Botany* 62(3):291–305.
Winkler D. 2009. Caterpillar fungus (*Ophiocordyceps sinensis*) production and sustainability on the Tibetan Plateau and in the Himalayas. *Asian Medicine* 5:291–316.
Wunder S, Angelsen A, Belcher B. 2014. Forests, livelihoods, and conservation: Broadening the empirical base. *World Development* 64:S1–S11.
Wunder S, Börner J, Shively G, Wyman M. 2014. Safety nets, gap filling and forests: A global-comparative perspective. *World Development* 64:S29–S42.
Wunder S, Luckert M, Smith-Hall C. 2011. Valuing the priceless: What are non-marketed products worth? *In:* Angelsen A, Larsen HO, Lund JF, Smith-Hall C, Wunder S, editors. *Measuring Livelihoods and Environmental Dependence*. London, United Kingdom: Earthscan, pp 127–145.