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Earning a Livelihood From Himalayan Caterpillar Fungus in Kumaon Himalaya: Opportunities, Uncertainties, and Implications

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The trade of Himalayan caterpillar fungus, or Ophiocordyceps sinensis, *is believed to have transformed the rural economy of certain Himalayan villages. Most scholarly work on the caterpillar fungus focuses on its ecology, physiology, and pharmacological attributes, followed by conservation and sustainability issues. Few studies have tried to understand it from a socioeconomic and political perspective. Of the few studies examining its economic contribution to households, most are concentrated in Nepal and Tibet, and a handful focus on India. In the present study, we estimated the mean annual cash income per household in Gori valley, Kumaon Himalaya, and the relative economic contribution of caterpillar fungus. We compared the incomes of caterpillar fungus collectors with those of noncollectors, identified harvest trends from 2009 to 2017, and took stock of people's perceptions regarding this short seasonal occupation. Results show that earnings from caterpillar fungus contribute 60–78% to the annual household income of collectors, with noncollectors earning 15–55% less than collectors. The study suggests that an increase in the number of harvesters may explain an observed decline in individual harvests. Though caterpillar fungus provides opportunities for economic emancipation to half the valley's population, inconsistent harvest, unreliable prices, and illegality of the trade are decreasing its viability for many. Furthermore, discordant and complex governance meted out through various state directives is increasingly jeopardizing this local natural resource-based livelihood enhancement strategy—a strategy that has incidentally outperformed concerted state efforts for poverty alleviation in the region.*

Keywords: Ophiocordyceps sinensis*; livelihood; conservation; development; natural resource dependency; Gori valley; India.*

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Introduction

Natural resource dependency and the socioeconomic status of dependent communities are critical to the urgent global debate on synchronizing efforts toward biodiversity conservation and poverty alleviation (Barrett et al 2011; Miller et al 2011; Billé et al 2012). Since most biodiversity hotspots are also home to some of the poorest indigenous communities (Fisher and Christopher 2007), site-specific estimation of economic contribution from natural resources is essential to gauge dependency trends and assess the ecological thresholds of such dependencies. It can improve research and policy measures for conservation interventions, sustainable harvest mechanisms, and alternative sustainable and (resilient) livelihood-enhancing strategies to prevent adverse impacts of dependence on natural resources.

In the present article, we explore the opportunities and uncertainties governing the lives of people in a remote area of the state of Uttarakhand, northern India, who have become dependent on a highly rewarding natural resource—Himalayan caterpillar fungus *Ophiocordyceps sinensis* (henceforth CF)—for economic development.

Background

Also known as *yarsa gumba, kida jadi,* or Chinese caterpillar mushroom, CF is an entomophilous fungus found in the Tibetan Plateau and adjoining high-altitude areas of Central and Eastern Himalaya in Bhutan, Nepal, and the Indian states of Uttarakhand, Sikkim, and Arunachal Pradesh (Cannon et al 2009). It mostly occurs in the altitudinal range of 3000–5000 m in moist alpine meadows. As the snow melts and alpine plants begin sprouting in summer, its fruiting body emerges from the head of the larvae in a clublike shape from beneath the soil (Negi et al 2014). Believed to have antiaging, antitumor, and anticancer effects and to cure digestive, renal, respiratory, and cardiac ailments (Ng and Wang

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2005), CF is especially popular as a cure for hyposexuality (Zhu et al 1998; Holliday and Cleaver 2008; Zhou et al 2009). The supposed extraordinary curative properties of this rare fungus have made it one of the most expensive natural resources in the world. Historically, it was used in Tibetan, Chinese, and Bhutanese traditional medicine, but today China is the biggest consumer by far (Winkler 2009). Considered more valuable than gold, China's capitalist economy has transformed this traditionally valued medicine into a highly prized *Guanxi* (networks or connections that open new business avenues or facilitate deals) gift or social gift, in particular for government officials, leaders, or someone generally viewed as superior, to facilitate business or other dealings (Yeh and Lama 2013). Tan (2018) reports that CF as a *Guanxi* gift is seldom consumed by its recipients but instead is passed upward in the social hierarchy. Commodification of CF has triggered high demand and increased its market price from US$ 13,000 to 20,000 per kilogram from 1995 to 2015 (Negi et al 2015). This price rise has led thousands of people from remote Himalayan and Tibetan communities to rake the alpine meadows between May and June in search of CF for harvest (Garbyal et al 2004; Negi et al 2006; Winkler 2009; Singh et al 2010; Shrestha and Bawa 2013). CF trade has emerged as a promising means of income for unemployment-ridden mountain villages.

Trade of CF

Historically, CF was traded in equivalence to its weight in gold or silver in China (Gupta and Negi 2010). In the 17th century, Tibetans bartered it for tea and silk with China (Winkler 2008). In Nepal, its trade began around 1987 and was legalized in 2001 (Shrestha and Bawa 2013). In Bhutan, CF harvesting was considered illegal until 2004; thereafter, restricted harvesting was introduced in an effort to deter poaching and encourage stewardship by villagers (Cannon et al 2009). In India, CF harvesting began in the early 1990s, and CF continues to be traded clandestinely via middlemen (Sharma 2004).

Impact on rural economy

The price of CF typically multiplies several times before reaching the final customer. Nevertheless, it fetches unprecedented, large sums for harvesters when first sold to middlemen. The rural economy of certain Himalayan and Tibetan villages has been practically transformed by the trade of CF. Studies from Nepal (Shrestha et al 2014) and various parts of Tibet Autonomous Region (TAR; Winkler 2008; Woodhouse et al 2013) show that soaring prices of CF have led to remarkable increases in annual cash income for certain households. In some locations, CF accounts for 50–80% of aggregate rural income, making it one of the most profitable local sources of income.

In India, the earliest documentation of CF's contribution to the rural economy was from Dharchula block, Kumaon Himalaya, when 0.5 kg of CF was found to fetch ~US$ 667 in early 2000 (Garbyal et al 2004). Negi et al (2006) reported a 1256% increase in the price of CF locally in Kumaon between 1999 and 2004. Furthermore, between 2004 and 2009, the estimated annual income contribution of CF in Munsyari block, Kumaon, was reported to be US$ 972–1485 per collector (Pant and Tewari 2014). There have been no estimations of CF's economic contribution to household incomes since then. However, the ongoing income contribution of CF to the households of Kumaon Highlanders is important to understand because this natural resource-dependent livelihood strategy—which currently provides unprecedented economic security—has overshadowed the concerted state efforts towards poverty alleviation. As a result, the present study sought to (1) estimate the contribution of CF to household incomes; (2) compare the incomes of collectors and noncollectors; (3) as well as identify harvest trends (2009–2017); and (4) take stock of people's perceptions.

Study area

Gori valley (Figure 1), in the Pithoragarh district of Uttarakhand, India, and Kumaon Himalaya, extends from 79°59′9.0348″E to 80°29′38.5008″E and 30°35′58.9194″N to 29°44′52.1664″N. It stretches from the TAR of China in the north to Nepal in east. Spread across a mosaic of land uses—comprising settlements, terraced farms, *Van Panchayat* (VP; forests governed by village forest councils), reserve forests, and the Askot Musk Deer Sanctuary (643 km^2)—the Gori valley features an elevation gradient range of 600–7065 m. Nearly 26% of the valley is snow covered, and approximately 16% is inhabited by people. According to the Census of India (2011), Gori valley's 52 VPs have a total population of 18,722. Of that total, 19% are the Scheduled Tribes of *Shaukas* or *Bhotias,* who move seasonally to their summer villages in the interior of the valley Johar—located between 3200 and 3432 m and 29 km from a motorable road. Rainfed subsistence agriculture and livestock rearing are dominant local occupations.

Methodology

Considering socioeconomic heterogeneity, we undertook a preliminary classification of VPs through principal component analysis using relevant indicators (elevation, distance from town, population density, sex ratio, total working population, total income, literacy rate, economic amenities, and Scheduled Castes and Scheduled Tribes population) from the Census of India (2001). A two-step cluster analysis was performed using the principal components, and 3 mutually exclusive clusters of VPs were derived (Table 1). The principal components characterizing the clustered VPs are large settlements with a large working population and more households that are economically

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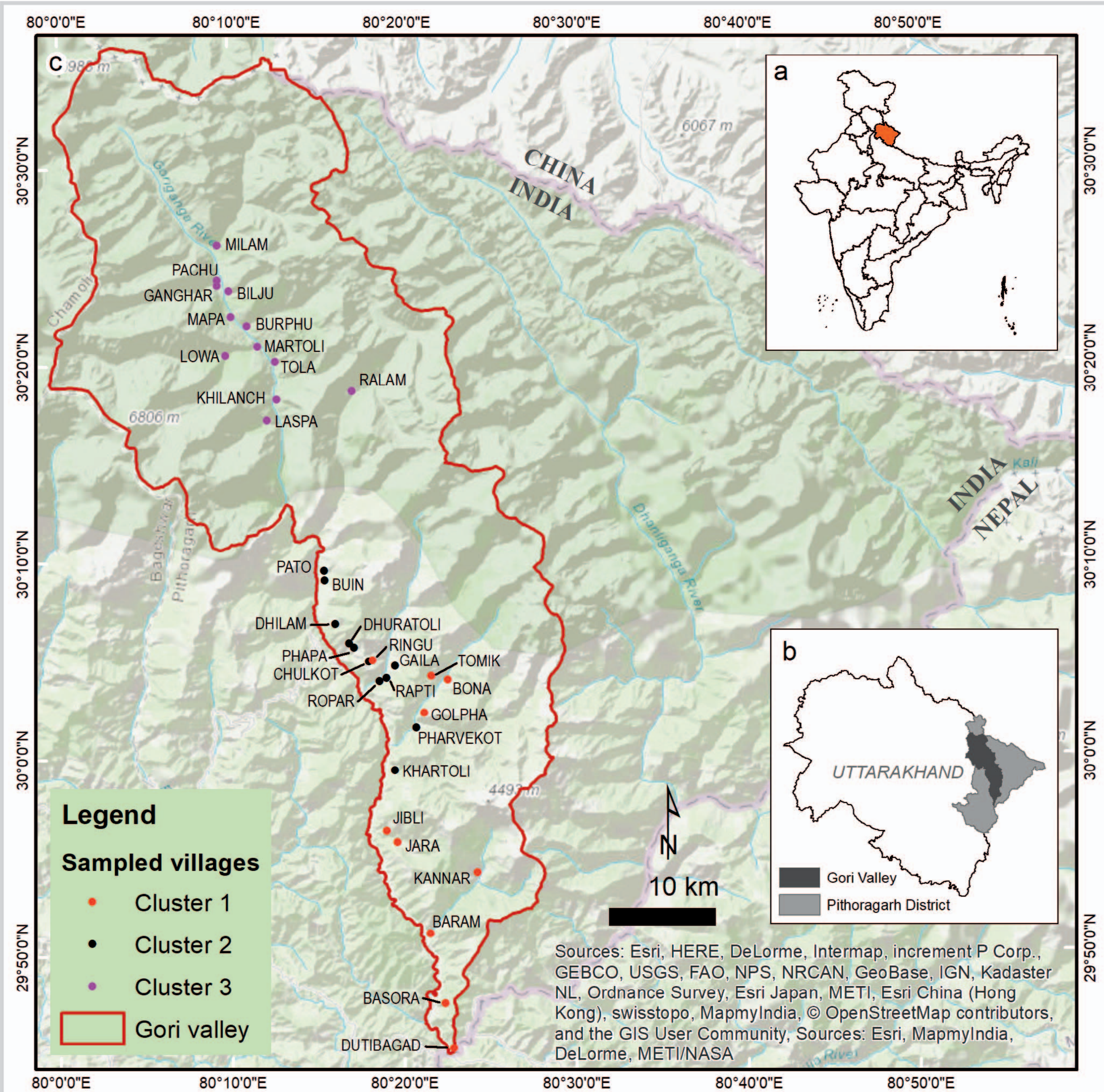
FIGURE 1 (A) Inset map of India; (B) Gori valley in the Pithoragarh district of the State of Uttarakhand; (C) clusterwise depiction of sampled villages in Gori valley. (Map by the Wildlife Institute of India)



well off (Cluster 1); female-biased population, relatively far from the road in comparison with Cluster 1 (Cluster 2); and highly literate population (Cluster 3). At the same time, a mixed questionnaire schedule was prepared following a pilot survey of 70 households in 8 VPs. To obtain a nuanced understanding of the socioeconomic dynamics in the valley, 432 interviews were conducted in an intensive survey. VPs were sampled across the elevation gradient in the valley. All hamlets in a sampled VP were further sampled via representative quota sampling of kin groups, wherein randomized sampling of households was carried out. We interviewed 226 households in Cluster 1, 89 households in Cluster 2, and 117 households in Cluster 3, comprising 17% of all households in Gori valley. The questionnaire focused on demographic and socioeconomic information concerning occupations and associated incomes, expenditures, and respondent perceptions regarding income from CF.

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TABLE 1 Sociodemographic characteristics of the 3 clusters of Gori valley.

Cluster characteristics		Cluster 1	Cluster 2	Cluster 3
Average household size		7 (± 0.021)	6 (± 0.029)	5 (± 0.020)
Sex ratio (male to female)		226	89	117
Social composition[a] (%)	Other backward classes	75.22	71.58	0.0
	Scheduled Castes	4.87	14.74	15.32
	Scheduled Tribes	19.91	13.78	84.68
Literacy rate (%)		66	67	79
Education 12th grade and above (%)		39.9	51.1	27.9
Elevation (m)	Min	628	1419	3238
	Max	2413	2367	3634
Distance from the road (km)		1–17	7–20	25–40

[a] The terminology is from the Census of India (2001, 2011).

Households were the unit of analysis in the clusters of sampled VPs. Mean annual cash income per household was estimated by summing up incomes from on-farm, off-farm, and other income sources—in addition to income from CF among collectors. On-farm incomes included agriculture, livestock keeping, herb cultivation, and rearing of load-bearing animals. Off-farm incomes included wage labor, woolen cottage industry, general small-scale business, sales of homebrewed alcohol, and government or private jobs. Not every income source was prevalent in each cluster—for example, rearing of load-bearing animals and woolen cottage industry predominated solely in Cluster 3.

Because of variations in the quantity and quality of harvests and fluctuating market prices, CF could not be considered a consistent and reliable income source among collectors. In addition, because our survey and documentation of CF collectors' incomes spanned more than 4 years, calculating household CF-related incomes for individual years would be misleading. Thus, we estimated the expected CF-based income of individual collectors by sampling random values of their respective harvests from a uniform distribution specified by minimum and maximum harvests (pieces) of an individual's harvesting career and random values of the CF market price (price per piece) in recent years. We computed the income more than 1000 iterations and estimated the mean and 2.5–97.5 percentile income as an interval measure within which an individual's annual income is likely to fall. Estimation was carried out using R data analysis software. The earnings of CF collectors were compared with those of noncollectors to identify differences in income.

To assess CF harvest trends, we enquired regarding the minimum and maximum harvests and corresponding years in a sampled collector's harvesting career (total number of years an individual had been harvesting). While minimum or maximum harvest is a relative measure among collectors, it was used as a proxy to indicate low and high harvest years, as well as to assess the volatility of this income source. The cumulative number of harvesters reporting maximum and minimum harvests in a particular year from 2009 to 2017 was compared with the cumulative number of sampled harvesters in those years, to show year-wise trends of good and less good CF harvest years. This methodology was devised to avoid computational errors based on respondents' inability to recall specific long-term quantitative information from memory, as well as lack of reliable documentation on CF-related trade volumes and revenues in the valley. Our methodology also aimed to reveal patterns of competition governing high-value natural resource extraction.

The perception of respondents was assessed with questions regarding investment in CF harvesting, the reliability of the occupation, possible alternate sources of income (in case of resource exhaustion), probable reasons for declining harvests, and lifestyle changes based on earnings from CF.

Results

Incomes of CF collectors and noncollectors

Households in the valley are characterized by diverse livelihood portfolios (Figure 2): 21% of the sampled population has 1 income source, 30% has 2 sources, and 49% has more than 2 income sources (Figure 3). The mean annual cash income per household is INR 72,617 (± 6674) in Cluster 1 (US$ 1029), INR 59,010 (± 6711) in Cluster 2 (US$ 836), and INR 126,282 (± 14,347) in Cluster 3 (US$ 1790).

A comparison (Figure 4) of the mean annual household incomes of CF collectors (49%) versus noncollectors

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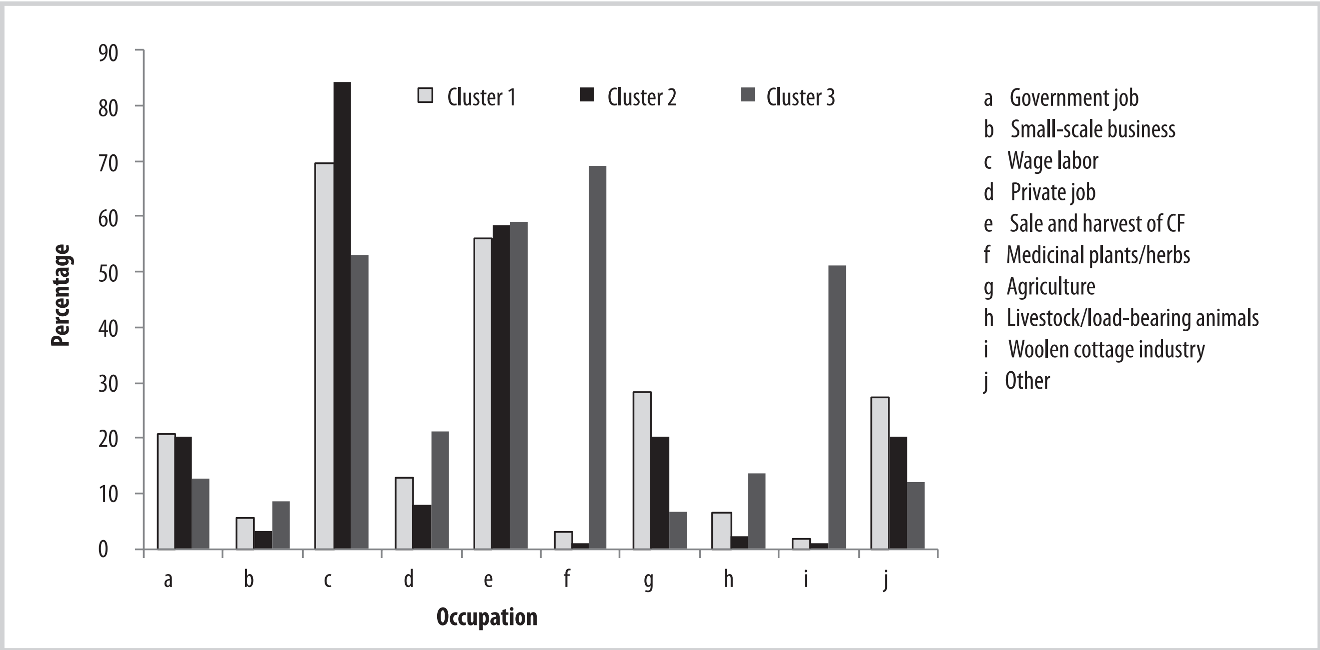
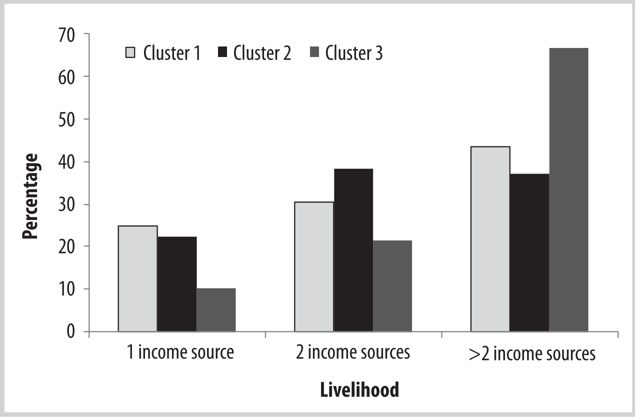
FIGURE 2 Percentage of households engaged in different income sources in the 3 clusters of Gori valley.



(51%) reveals that the income of noncollectors is 19% less in Cluster 1, 53% less in Cluster 2, and 55% less in Cluster 3 compared with that of collectors (Table 2). There were no statistically significant differences in mean annual household incomes among noncollectors in the clusters ($F = 1.726$, $P = 0.180$).

However, statistically significant differences were found in the mean annual household income of CF collectors in the clusters ($F = 10.630$, $P = 0.000$). The Tukey post hoc test revealed that the household incomes of collectors in Cluster 3 were significantly higher than those of collectors in Cluster 1 ($P = 0.000$) and Cluster 2 ($P = 0.009$). No significant difference was found between the incomes of households in Cluster 1 and Cluster 2 ($P = 0.686$). CF contributed 78% of household income in Cluster 1, 68% in Cluster 2, and 60% in Cluster 3 to the total annual household income in the respective clusters. There was no statistically significant difference among incomes from CF in the 3 clusters as determined by one-way analysis of variance (ANOVA; $F = 1.836$, $P = 0.161$).

FIGURE 3 Percentage of households with 1, 2, or >2 income sources in the 3 clusters in Gori valley.



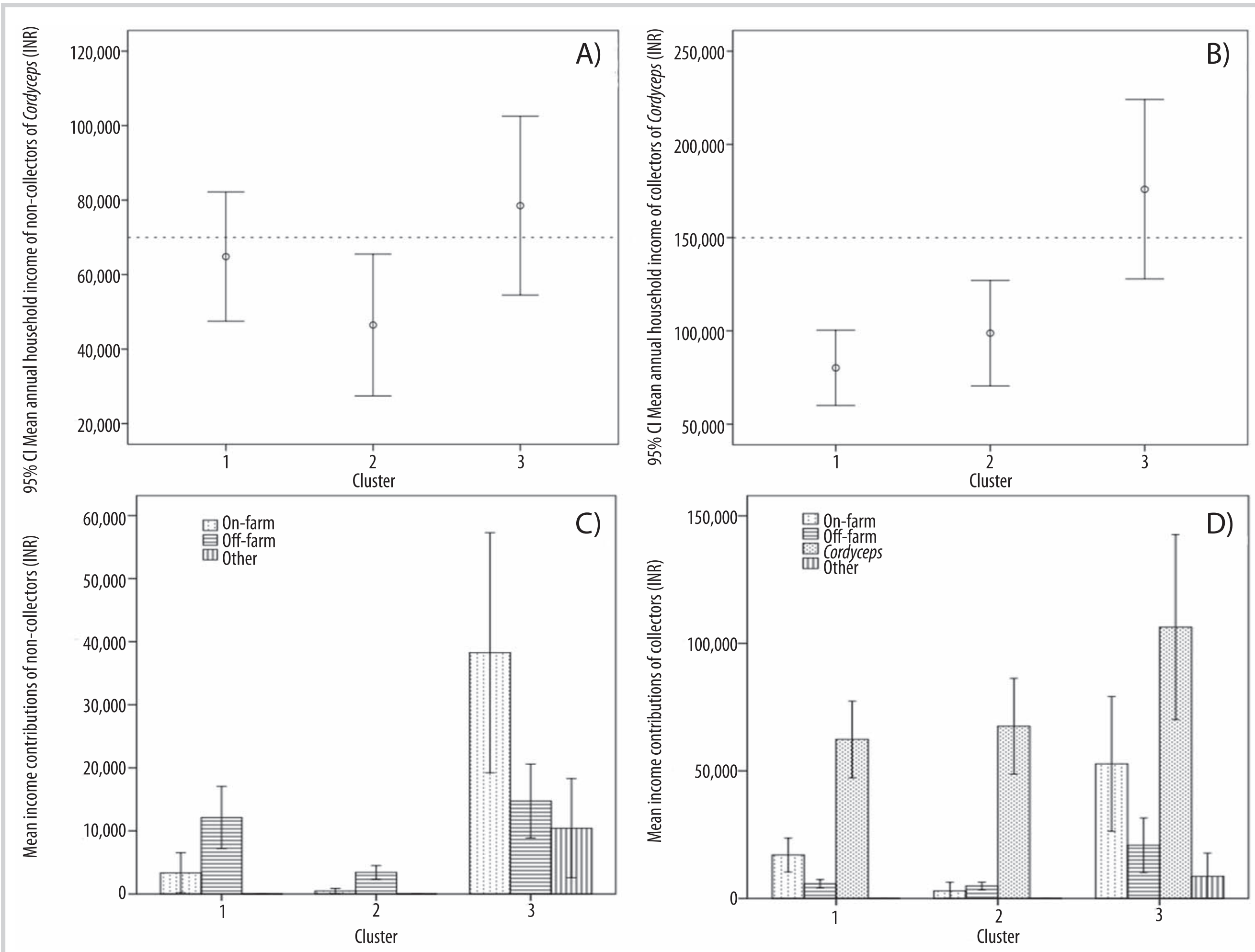
Trends of maximum and minimum CF harvest years

People have been harvesting CF in the valley since the early 1990s. Findings suggest that between 2009 and 2013, the number of CF harvesters increased steadily and reached a saturation point (Figure 5). An analogous trend of maximum and minimum harvest years may be identified, implying good harvest years for most and unprofitable years for some. Year 2014 was not a good harvest year, because few reported it to be their maximum harvest year. Year 2015 onward have been minimum harvest years for most, with few reporting their maximum harvest years in this period, implying relatively unprofitable harvests for the majority.

People's perceptions of CF

Most CF collectors (85%) no longer consider this activity as a reliable source of income, owing to declining or below average annual harvests—as opposed to consistent harvests when minimum amounts are collected. Almost half (48%) of the collectors claim that per capita harvests have declined because of growing numbers of harvesters. According to 36% of the harvesters, reduced productivity is due to lack of timely rain. About 32% of the harvesters assert that they do not fully depend on CF and would

FIGURE 4 Clusterwise comparison of mean annual household incomes of (A) noncollectors and (B) CF collectors; and economic contribution of (C) on-farm, off-farm, and other income sources for noncollectors, and (D) on-farm, off-farm, other, and CF for collectors to mean annual household income in Gori valley.



prefer engaging in less taxing and more secure work. While most view wage labor as their only option in case of CF depletion, 19.8% have an optimistic view of CF and believe it will improve their situation. Furthermore, 39.6% of CF collectors state that agriculture that suffered because of neglect should be pursued with renewed efforts. In terms of investment, CF collectors in Cluster 1, far from the harvest areas (unlike Clusters 2 and 3), pay US$ 100–275 to camp in the alpines during harvesting season. Their expenses are covered with credit that is paid back after the harvest is sold. Respondents who harvest smaller quantities of CF state that a substantial portion of their earnings must be used to pay off debts.

Discussion

Relatively poor economic returns from various on- and off-farm income sources have apparently led many people in this remote valley in Uttarakhand to seek other income sources reliant on natural resources. CF is one such natural resource whose economic promise has attracted many in the valley, including some who have evidently

TABLE 2 Mean annual household income of noncollectors and collectors of CF in Gori valley.

Cluster	Noncollectors	CF collectors
1	INR 64,825 (± 8769) (US$ 918)	INR 80,169 (± 10,179) (US$ 1112)
2	INR 46,449 (± 9451) (US$ 658)	INR 98,783 (± 14,040) (US$ 1370)
3	INR 78,515 (± 12,019) (US$ 1062)	INR 175,937 (± 23,988) (US$ 2441)

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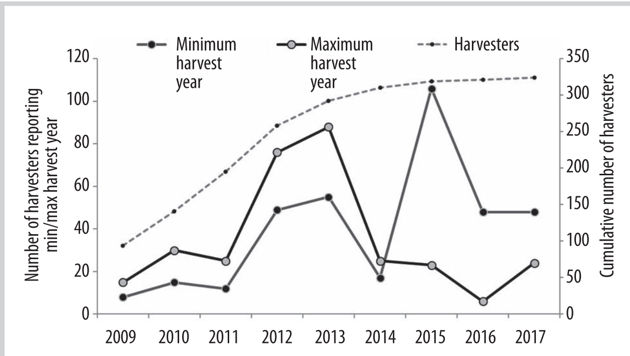
FIGURE 5 Trend of maximum and minimum harvest years in relation to the cumulative number of harvesters from 2009 to 2017 in Gori valley.



become highly dependent on this short, seasonal enterprise. Similar to findings in Nepal and TAR (Shrestha and Bawa 2014; Winkler 2008), our results show that the harvest and sale of CF in Kumaon has become an important means of cash income for half of the population.

The mean annual household income of noncollectors in Cluster 2 was found to be lower than that of Clusters 1 and 3. Our findings indicate that noncollectors in Cluster 1 derive income mainly from on- and off-farm work, such as agriculture and wage labor, whereas those in Cluster 3 do so from profitable on-farm sources (rearing load-bearing animals or selling medicinal and aromatic plants) and relatively more off-farm work and other sources. In Cluster 2, wage labor appears to be the only prominent source of income. This makes Cluster 2 particularly economically vulnerable due to the lack of dependable alternate sources of income.

However, highlighting differences of income between CF collectors and noncollectors without examining other determinants of individual income-generating capacities does not provide a complete picture. Differences in economic status among households in the 3 clusters can be correlated to income opportunities available because of the elevational location of villages and their proximity to motorable roads, markets, and alpine spaces. The relatively strong economic status of households in Cluster 1 is partly due to the large-scale cultivation of potato and kidney beans for commercial purposes. The proximity and links of villages to motorable roads and markets provides more opportunities for income through wage labor (especially road construction). The proximity of households in Cluster 3 to resource-rich alpine pastures enables income opportunities based on natural resources, including cultivation and harvest of medicinal and aromatic plants, rearing of load-bearing animals like mules and horses (used to ferry goods to Indo-Tibetan Border Police camps), and rearing of sheep and goats for wool and sale. Moreover, in winters when these households return to their homes in the valley they are closer to motorable roads and markets. By contrast, households in Cluster 2 are located farther from motorable roads, markets, and alpine spaces and must depend on relatively scarce wage labor available for shorter periods.

Furthermore, a crucial determinant of income from CF is access to the fertile pastures where CF grows: this is essentially a (contentious) matter of land rights. Uttarakhand is one of the earliest examples of collective natural resource management of common resources through its system of VPs. In the system, designated *Panchayat* forests (12% of forest area) are used by villagers to derive important subsistent benefits. Traditionally, these include obtaining fodder for livestock and leaves for bedding, using grazing spaces, and gathering fuelwood and timber for house construction and agricultural tools. VPs were entrusted with the protection and development of forests, equitable distribution of forest products to rightful users, and utilization of surplus earnings for the community. Over the years, however, through multiple amendments to the Van Panchayat Act, VPs have been reduced to a more nominal role, with authority and financial control residing primarily with the Forest and Revenue Department. The growing CF economy is not covered by the rights of resource utilization granted to VPs, because the alpine meadows where CF is found are pasture meadows dedicated, by village, to transhumant pastoralists with predefined user rights. This makes the harvest and trade of CF essentially illegal. The sparse distribution of CF, coupled with restrictive pasture rights, makes CF hard to come by for all but those whose recognized grazing areas overlap with it. Recently, certain VPs have permitted outsiders to harvest CF if they purchase special passes. Only those members who have sufficient resources to invest and rightful access to VPs where CF is found can take advantage of this opportunity.

Adding to these uncertainties and questions of legality are the realities of declining household-level CF harvests and fluctuating market prices. Based on a rapid vulnerability assessment of CF conducted in Pithoragarh, Negi et al (2015) found that CF yields dropped by ~25% between 2008 and 2012. Similarly, studies in Nepal point to a 37% reduction in CF harvests in Dhorpatan Hunting Reserve between 2008 and 2010 (Thapa et al 2014) and a 28% reduction in Dolpa District between 2006 and 2010 (Shrestha et al 2014), as well as a 70–97% reduction in Yunnan province of China (Stone 2008). Most of these studies suggest that declining productivity is the result of overharvesting, habitat degradation, and/or unsustainable harvesting practices. Winkler (2009), however, stresses that without temporal data, the impact of intensive CF harvesting or habitat degradation cannot be indicated. Furthermore, Stewart et al (2013) contend that the decline in CF productivity cannot be attributed to overharvesting on the basis of short-term studies.

According to our results, there was a steady increase in the number of CF harvesters in our study area between 2009 and 2012. This was likely because of the rapid rise in

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international market prices for CF (Paul et al 2009; Shrestha and Bawa 2013). Our findings indicate growing competition among harvesters, as seen in the higher numbers of good harvest years reported before 2013 and the relatively unprofitable harvest years reported by most harvesters thereafter. It is likely that only the best adapted, skilled, and/or knowledgeable CF collectors succeed in harvesting profitably year after year. Collectors whose CF harvests continue to decline may eventually abandon the practice as economically unviable. In the absence of extensive evidence or research indicating productivity loss because of habitat degradation or overharvesting/exploitation, one can speculate that the observed decline in individual harvests is at least partly due to a growing competition among seasoned harvesters.

Furthermore, the fluctuating market price of CF requires greater attention, because this is already an uncertain vocation. In 2013 and 2014, the price of 1 kg of CF in India was around INR 1,200,000 (US$ 18,604); by 2016, it had plummeted to INR 700,000 (US$ 10,852). Though the purchase price of CF locally depends on harvest quality and grading standards that differ from valley to valley, CF's loss of value on the international market has an impact and may be traced back to the Chinese CF industry and related sociopolitical and economic dynamics. The drop in CF prices may be the result of recent anticorruption measures forbidding certain forms of gift giving, introduced by the president of China, Xi Jinping, since 2013 (Szto 2016). If this is the case, international CF prices are more likely to continue to fall than rebound.

Finally, the challenges faced by CF collectors are complicated by governance issues. For example, in response to public interest litigation concerning conservation of certain alpine meadows of the Chamoli district of Uttarakhand, the High Court of Uttarakhand announced a ban on "overnight stay in all alpine/subalpine meadows/*bugyals* of Uttarakhand" on 21 August 2018, among many other directives aimed at conserving the alpine ecosystem. Since harvest of CF is predominantly carried out by people staying in tents near where it grows, this judgment will greatly affect those whose livelihoods largely depend on income from CF. Meanwhile, in a bid to stop illegal CF trafficking, the Uttarakhand Cabinet announced a new policy on 12 September 2018, according to which harvesters of wild CF must register with the government, while the Uttarakhand Forest Development Corporation (UAFDC) has been entrusted with the responsibility to market CF, needless to say at a much lower rate than the present market price. In addition, harvesters must pay INR 1000 (US$ 14) for every 100 g of harvest, with revenues ostensibly going to the VP. The question is whether CF collectors will be willing to sell their harvests legally when illegal channels promise greater profits.

Conclusion

The present study shows that income from CF harvesting benefits half the population of Gori valley and that the income of noncollectors is 19–55% lower than that of CF collectors. Harvest trends suggest that struggling CF collectors may abandon the vocation as economically unviable, limiting CF-related natural resource dependence. Given the uncertainty of CF harvesting and other livelihood forms, only subsistence agriculture provides some form of security and economic resilience for many in our study area. The case provides yet another vivid example of the challenges involved in balancing protection of natural resources and poverty alleviation.

The opportunities of the CF economy have been somewhat diminished by complex governance issues. Poverty alleviation and biodiversity conservation efforts can be mutually reinforcing or placed in opposition to each other, depending on higher-level policies and decisions. With or without CF, solutions are needed for sustainable economic development of biodiversity-rich regions such as our study area, where unemployment is rife and the temptation to exploit natural resources is high.

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