Environmental Challenges 5 (2021) 100295

Contents lists available at ScienceDirect

Environmental Challenges

journal homepage: www.elsevier.com/locate/envc

Wood for thought? Untold consequences of the Himalayan gold collection in the Central Himalaya

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ARTICLE INFO

Keywords:
Caterpillar fungus
Fuelwood
Hindu Kush Himalaya
Kailash Sacred Landscape
Natural resources

ABSTRACT

Every year, in the Central Himalaya, the caterpillar fungus collectors collect fuelwood from the alpine shrublands to meet their energy needs for cooking and heating. The fuelwood collection continues unabated, and its long-term impact on the alpine ecology is still less understood. We conducted a questionnaire survey and fuelwood measurements in the summer of 2019 at the 'open-access' and 'closed-access' collection sites of caterpillar fungus in the Kailash Sacred Landscape of Nepal in the Central Himalaya. The 'open access collection site' referred to the site being accessible to any Nepali citizen from anywhere upon the payment of the collection fee. The 'closed collection site' referred to the site being accessible only to members of a particular community. The study objectives were to estimate fuelwood consumption by fungus harvesters and ascertain if fungus collection time and the number of people in a tent have an influence over fuelwood consumption in two sites. We randomly selected thirty harvesters in each fungus collection site for the study. The study results were supplemented by the satellite images to understand decadal changes in shrub cover at closed and open access collection sites. The open-access site had a more significant number of people in a tent, a longer length of stay, and a greater fuelwood consumption. The duration of stay at the open-access site far exceeded the recommended period of one month for harvesting the caterpillar fungus. On the contrary, the length of stay at the closed collection site was one month. The open-access site had a daily consumption of six kilogram fuelwood, and the closed site consumed four and a half kilograms of fuelwood daily. The decadal decline in shrub cover was higher in the open-access site. The study suggests that the current practices of fuelwood removal may be unsustainable and likely to deplete the alpine shrublands, and ultimately harm the caterpillar fungus, especially at the open-access collection sites. There is an urgency to replace the current fuelwood resource use practiced by collectors with more sustainable energy systems. Moreover, it is imperative to address this issue holistically through stringent policies that regulate the number of people and days spent at collection sites.

1. Introduction

The Caterpillar Fungus (*Ophiocordyceps sinensis*) is a highly valued resource in the Hindu Kush Himalayan countries of Bhutan, China, India, and Nepal. The fungus is found at altitudes between 3200 to 5200 masl and collected from May to June annually. The collection sites are in the most challenging environment with difficult accessibility and rough terrain. However, these hurdles have not deterred the influx of a large number of people annually at the collection sites during the season. The sites lack basic amenities to support the collection, therefore, collectors arrange their supplies to see them through the harvest period. Caterpillar fungus is harvested in an extremely cold environment with high fuel requirements (Khuman et al., 2011; Kumar and Sharma, 2009; Rawat et al., 2009; Sati, 2005). Hence, it has long been the biggest challenge for collectors to meet their energy needs for cooking and heating over the entire season. Collectors have overcome the challenge by relying on fuelwood at the collection sites. Although fuelwood is used at the sites for several years, less attention is given to understanding the levels of fuelwood consumption and its impact on alpine shrublands. There is a lack of studies assessing the impacts of caterpillar fungus collection on the surrounding resources despite the fungus being studied comprehensively for its production and sustainability (Cannon et al., 2009; Chettri et al., 2019; He, 2018; Hopping et al., 2018; Shrestha and Bawa, 2014; Winkler, 2020, 2008, 2011). Hence, limited empirical evidence on the subject warrants a scientific investigation into the implications of fungus collection activities in the alpine environment.

Fuel in the form of wood is an essential source of energy (Ruiz-Mercado and Masera, 2015), and fuelwood is the primary energy source

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https://doi.org/10.1016/j.envc.2021.100295
Received 16 July 2021; Received in revised form 3 September 2021; Accepted 20 September 2021

for cooking in the Himalaya (Pokharel et. al. 2019; Rawat et al., 2009), especially in areas above the tree line where alternate sources of energy are limited. The collection patterns of fuelwood in the Himalayas are explored (Chitale et al., 2020; Gautam et al., 2020; Khuman et al., 2011; Kumar and Sharma, 2009; Pokharel and Rijal, 2019; Rawat et al., 2009), and few studies attribute the increased level of fuelwood collection to greater household size and cold season (Lam et al., 2017; Woodhouse et al., 2014). However, these studies originate from mid-hill settlements with access to diverse sources of fuel. Examining the effects of caterpillar fungus harvest activities on the alpine ecosystem, Byers et al. (2017) noted the illegal removal of juniper shrubs at the fungus collection sites within the national park. Xu et al. (2015) also reported the negative impacts of caterpillar fungus harvest on alpine grassland and soil. Depending upon several factors, the extent of fuelwood removal could vary among collection sites. Hence, it is imperative to ascertain the level of fuelwood consumption at collection sites and their causes.

To understand differences between caterpillar fungus collection sites in fuelwood consumption and causes of differences in the consumption amount, we compared the open-access and closed-access fungus collection sites within the Kailash Sacred Landscape in the Central Himalaya. As there is growing interest in the impact of resource exploitation, this research seeks to investigate whether the current fuelwood consumption is sustainable in the high-altitude environment. The answer to this question could prompt policy responses and may lead to better outcomes. Hence, the study objectives were to assess the level of fuelwood consumption and time spent by collectors at the open access and closed access sites and ascertain if fungus collection time and the number of people in a tent have an influence over fuelwood consumption in two sites.

2. Materials and methods

2.1. Description of the study area

The Kailash Sacred Landscape in the Central Himalaya was identified for the study as it is known to have large areas under caterpillar fungus. Two districts within the landscape i.e. Bajhang and Darchula were selected (Fig. 1). The human population in Bajhang is 195,159 and Darchula 133,274 (Government of Nepal, 2011). Both districts are least developed. They are located in the far western province of Nepal. The majority of people in these districts depend on agriculture and are very poor due to lack of basic infrastructure, difficult geophysical conditions, traditional agricultural practice, low literacy rate, and low population growth. They are highly dependent on caterpillar fungus which is collected from the alpine region in summer. The climate of the area is generally characterized by high rainfall and humidity. The climatic condition varies along with the elevation gradient from subtropical to alpine. In the north, most parts have an alpine climate and remain under snow. In the southern part, the climate is subtropical. Mid-hills have a temperate climate. Most precipitation falls between May and September. Juniper trees and rhododendron shrubs dominate the vegetation at the collection site of caterpillar fungus. The collection sites experience an alpine climate with cool summer and freezing winter.

2.2. Study site selection and approach

The first site selected for the study was at Kuntison in Byans Rural Municipality of Darchula district. Kuntison represented the 'closed-access' collection site as it allows access only to members of the Byasi community. The site falls inside the Api Nampa Conservation Area, therefore, the collection of caterpillar fungus on this site is governed by the Yarsagumba Management (Collection and Transport) Directive of the Ministry of Forests and Soil Conservation, Nepal (MFSC, 2017).

The second site of the study was Raidhungi in Saipal Rural Municipality of Bajhang district. Raidhungi represented the 'open-access' collection site of the caterpillar fungus and does not fall within a protected area. The site is open-access because it provides access to any Nepali citizen upon the payment of the collection fee. Hence, the residents of adjoining rural municipalities of Datola, Musta, Talkot, and Dailekh collect the caterpillar fungus from Raidhungi.

2.3. Data collection

Data was collected in the summer of 2019 during the caterpillar fungus collection season. The collectors included both men and women. Thirty respondents were selected randomly from each site. Specific information was collected through key informant interviews and common information was gathered through two focused group discussions. A questionnaire was used to interview respondents at the collection sites. Towards finding the differences between the two sites, we gathered information on the origin of collecters, the total number of people in each tent, the ratio of men and women in each tent, average time spent at the collection sites during the season, and the amount of fuelwood consumed daily. For the precise estimation of the quantity of fuelwood consumed daily by each tent, the fuelwood load was weighed physically with a weighing scale at the campsites. Fuelwood was not collected daily but collected in a single stack lasting for several days. From the fuelwood stack, the collectors extracted an amount of fuelwood for the day which was weighed. Depending upon the availability of key informants, interviews were conducted in the morning, daytime, and evening. At each site, the data collection was completed in three days. Finally, the respondents were asked about trees and shrubs which were used as fuelwood.

To supplement the study results, we acquired satellite images of shrub cover of open and closed access sites. We confined our shrub cover analyses within 6 km from the campsite, which excluded settlements and road networks that are known to affect land cover. We used the Landsat imagery of 30 m resolution for the vegetation analysis due to its long data archive and relatively high spatial resolution. From the United States Geological Survey (USGS) via Google Earth Engine (GEE), Landsat 5 and Landsat 8 images were acquired for 2010 and 2020, respectively. The image collections were filtered and the images with cloud cover exceeding 20 percent were excluded. Over time, the shrub cover was analyzed using the Normalized Difference Vegetation Index (NDVI), a widely used vegetation index for global environmental and climatic change analysis (Bhandari et al., 2012). The range of NDVI values for the alpine shrubland was computed as an average of the NDVI values of Hashim et al. (2019) and Akbar et al. (2019). The NDVI values (0.20- 0.40) were extracted from the satellite images of 2010 and 2020. We compared the images of 2010 and 2020 to determine the decadal change in shrub cover at open and closed collection sites.

2.4. Data analysis

The study generated quantitative data. The dataset was processed in Microsoft Excel and exported to SPSS version 25 (IBM, 2004) for analysis. Data were summarized with descriptive statistics. Three separate independent sample t-tests were run to detect significant differences between the two sites. Sites were the explanatory variables, while the dependent variables were the total number of people in a tent, duration of stay at the collection sites, and amount of fuelwood used. Since there were more than two types of tents (type defined by the number of people in a tent), three separate one-way ANOVA tests were run to detect differences among tent categories in the duration of stay, fuelwood consumed, and the number of people in different tent categories. Here, the tent categories were the explanatory variables. Since the individual site was not replicated, we could not generate the interaction effects of the collection site by tent category. Differences between means were considered significant when the statistical p-value was smaller than five percent. Tukey's pairwise comparison was made in the ANOVA tests to check the specific differences between tent types.

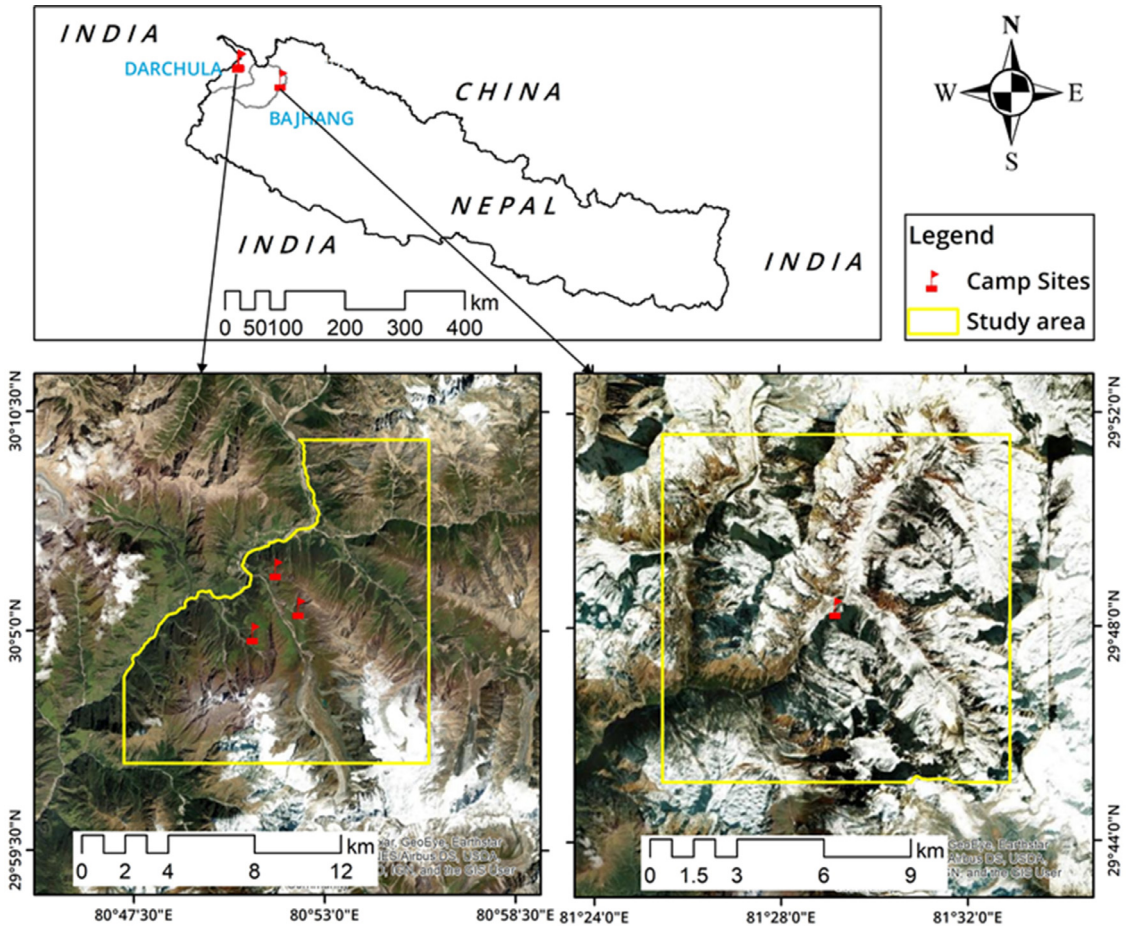

Fig. 1. Study sites (Closed and Open access sites of caterpillar fungus collection) at Kuntison (Darchula District) and Raidhungi (Bajhang District) within Kailash landscape in the Central Himalaya.

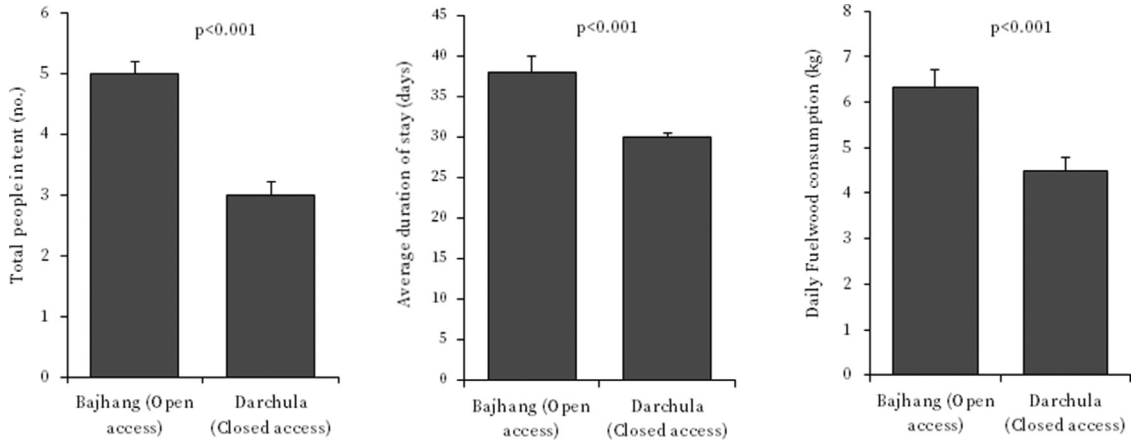

Fig. 2. Total people in tent, duration of stay, and daily fuelwood consumption between open and closed access sites of caterpillar fungus collection.

3. Results and discussion

3.1. Tent size, duration of stay, and amount of fuelwood consumed at open and closed access collection sites

Fig. 2 presents the tent categories, duration of stay, and amount of fuelwood consumed at the collection sites in Bajhang and Darchula districts. The open-access site in Bajhang had a significantly greater number of people in a tent and a longer duration of their stay at collection sites than the closed-access site in the Darchula district. These are most likely the results of easy accessibility to the collection sites at Raidhungi along with the lack of stringent rules that regulate the duration of stay. Since many people are often associated with resource depletion (Dasgupta et al., 2019; Repetto and Holmes, 1983), more collectors at the open site meant more pressure on resources. A greater number of collectors at this site also highlight the unregulated collection triggered by increasing market demand and a higher price for caterpillar fungus. Adding to more harvesters is the longer duration of their stay at the open site. The duration of stay exceeded the permissible period of 30 days for fungus collection (MFSC, 2017), which further highlights the

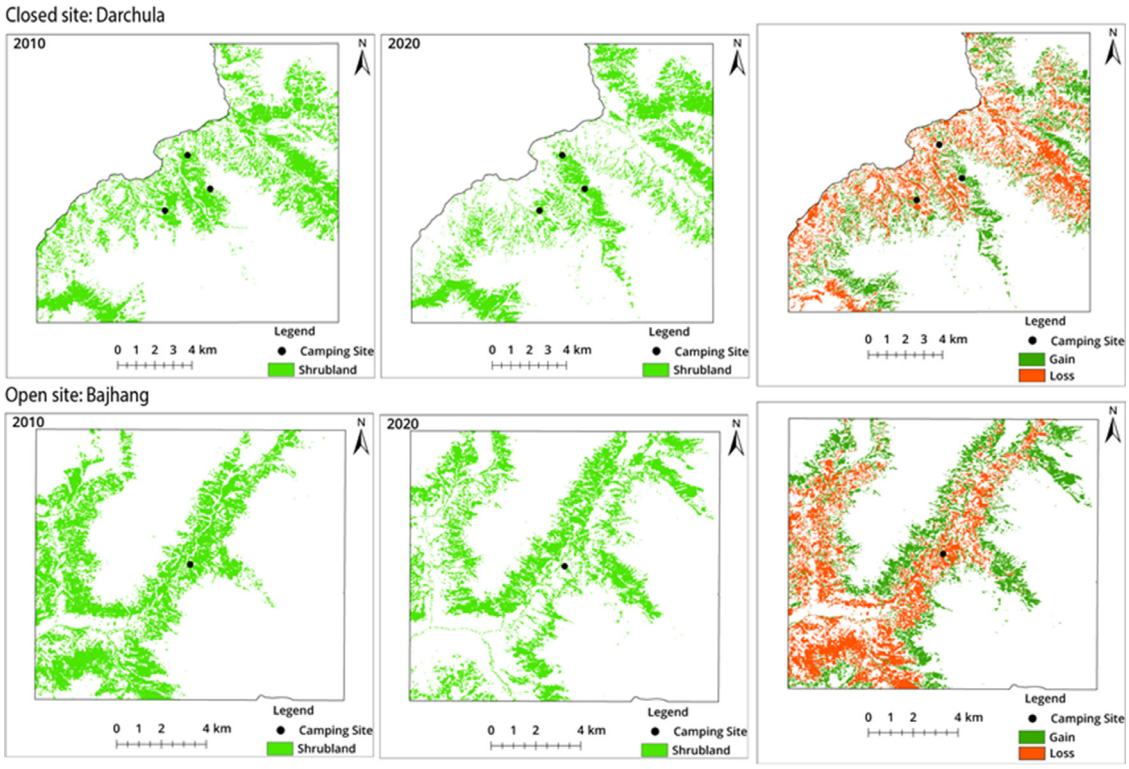

Fig. 3. Decadal change in shrub vegetation cover at closed (Darchula) and open (Bajhang) access sites of caterpillar fungus collection. The study area for Darchula and Bajhang were selected within 6 km from the camping sites. The green color represents shrub vegetation, and red color represents loss of shrub vegetation.

pressure on resources. On the other hand, the lesser number of people in a tent at the closed-access site is explained by the restricted access to the harvest sites. The closed-access site falls within the Api Nampa Conservation Area, whose resource utilization is governed by the Caterpillar fungus Management Guidelines (MFSC, 2017). The collection of caterpillar fungus at this site appears regulated and sustainable due to regulated access, which is an essential prerequisite to sustainable resource management (Hutton and Leader-Williams, 2003).

3.2. Vegetation cover affected by collectors and duration of stay

The vegetation at Bajhang was dominated by juniper trees, while the vegetation at Darchula was dominated by rhododendron shrubs. In general, trees and shrubs are lopped and collected from the downhill areas near settlements before being carried to the campsites. Fuelwood is collected while collectors traveled to and from fungus collection sites. No specific travels were made to collect fuelwood.

The more collectors and extended stay have likely contributed to more fuelwood consumption at the open-access site in Bajhang (Fig. 2). Closer scrutiny of satellite images revealed a decadal decline in vegetation cover by 9% at the closed site and 11% at the open site (Fig. 3). The open-access site had a daily fuelwood consumption of about 6.0 kg, while it was about 4.5 kg at the closed-access site. The amount of fuelwood consumed daily at the open site is relatively lower than the 8.0kg fuelwood consumed by a household in the high-altitude of the Western Himalaya (Joshi et al., 2020), but stands far greater than the amount of fuelwood consumed by a large family in a village in Nepal (Fox, 1984). Besides fuelwood, most juniper species at the open site are also sources of incense and forage for mountain livestock and wildlife (Farjon, 2018), which exacerbates its exploitation. The disproportionate exploitation of juniper species across the globe was a reason earlier for its decline, prompting the International Union for Conservation of Nature (IUCN) to place it on the "Red List of Threatened Species" in 1998 (Conifer Specialist Group, 1998).

3.3. Duration of stay and fuelwood consumed by different tent categories at open and closed access collection sites

All tent categories at the open-access site in Bajhang had a longer duration of stay (Table 1). The average duration of stay was 38 days at the open-access site and 30 days at the closed-access site. The duration of stay at the open-access site far exceeded the recommended collection period of one month (Government of Nepal, 2017). The rationale behind limiting the collection to about a month is to ensure that enough sporulating caterpillar fungi live undisturbed in the ground for sustainable spore production in the next season (Winkler, 2011). Irrespective of categories, a longer duration of stay for all tents at the open-access site in Bajhang suggests tremendous pressure on caterpillar fungus and fuelwood resources.

We detected a greater fuelwood consumption by bigger tents, similar to the findings of several authors on greater fuelwood collection by large families in the mid-hills of Nepal (Lam et al., 2017; Woodhouse et al., 2014; Webb and Dhakal 2011). However, the average daily per capita consumption of fuelwood across all tent categories at the open-access site was about 1.30 kg, which is a little lower than that of 1.70 kg in the Dolakha district in Nepal (Kandel et al., 2016) and 1.5 kg in developing countries (Win et al., 2018; Wood and Baldwin, 1985). Although total fuelwood collection is not associated with the elevation (Webb and Dhakal, 2011), fuelwood consumption is determined by the lack of other energy sources and by heating requirements (Ranjitkaur et al., 2014). It must be noted here that the fungus collectors at higher elevations have high energy demand without alternative energy sources unlike those in the mid-hills of Nepal where households have more sources of energy. A poor diversity of woody species at higher elevations (Bhat et al., 2020) could partly explain the mounting pressure on fuelwood species at the collection sites. Although the collectors' experience and knowledge could have been useful in selecting fuelwood (Chettri and Sharma, 2007), they were probably futile in a situation, like those found in higher elevations, where the diversity of woody

Table 1
Average duration of stay, fuelwood consumed daily, and the number of people among different tent categories at open and closed access sites of caterpillar fungus collection.

	Duration of stay (days)			Fuelwood consumed daily (days)			People in a tent at open site (no.)		
Tent category	Open site	Closed site	Sig.	Open site	Closed site	Sig.	Female	Male	Sig.
3 people tent	40±8.2	29±1.1	ns	4.0±1.0	4.2±0.6	ns	1.0±0.3	2.0±0.3	*
4 people tent	38±3.3	29±0.7	*	5.2±0.4	4.4±0.5	ns	2.0±0.3	2.0±0.6	ns
5 people tent	39±2.9	31±1.2	*	7.1±0.5	4.5±0.5	*	2.0±0.4	3.0±0.4	*
6 people tent	37±3.0	30±2.4	ns	7.1±0.6	5.0±0.5	*	3.0±0.4	3.0±0.4	ns

* $p<0.05$, ns-nonsignificant

species is poor. Furthermore, unlike mid and lower elevations, the open-access site in Bajhang experiences an alpine climate, and low temperatures limit the growth of trees (Korner, 2003). As reported by Ranjitkaur et al. (2014), the slow plant growth at higher elevations may not have compensated for the rate of fuelwood removal, which probably contributed to the depletion of woody vegetation. *Juniperus indica*, a species common at higher altitudes of Nepal, is negatively affected by altitude (Chapagain et al., 2020), suggesting a mismatch between fuelwood consumption and the growth of juniper trees at the open-access site.

3.4. Future implications of current practices

The contrast in pressures on fuelwood at the open and closed access collection sites demonstrates that access could significantly impact collection pressure on commercially exploited natural resources (Weckerle et al., 2010). The open-access site in Bajhang presents a typical case of open access to resources in combination with increasing resource demand, leading to overexploitation of natural resources. Hence, the current practices of fuelwood removal appear unsustainable in the long run, especially at the open-access collection sites. Without a sound legal framework to instill a sense of ownership, govern the collecting practices, and assure resource sustainability, the current scenario suggests that the open-access harvest site in Bajhang could be heading towards a Tragedy of the Commons (Hardin, 1968). At the current rate of vegetation removal in the open site, which appears higher than its natural regeneration, the fuelwood exhaustion is highly anticipated in a few decades. The Sustainable Harvesting Plan for caterpillar fungus in protected areas of Nepal (Batawaran Samrakhsan Paramarsh Kendra Pvt. Ltd., 2017) does not assure the protection of fuelwood resources, as the plan falls short of specifying the management of shrubby vegetation. As the shrubby vegetation is essential for sound ecosystem health in the mountains, their disappearance could disrupt associated provisioning ecosystem services that mountains provide for sustaining the settlements downstream. Loss of vegetation could invite a series of consequences, including habitat fragmentation, loss of biodiversity, increased greenhouse gas emissions, increased habitat for invasive species, soil erosion, etc. (NSW Scientific Committee, 2019).

The future implications of the current practices are dire. It is necessary to ensure sustainable energy to the fungus collectors through the use of renewable energy, which could also positively impact the ecosystem's health.

4. Conclusions

Open- and closed-access sites of caterpillar fungus collection in the Central Himalaya differ significantly in the tent size, duration of stay, and the amount of fuelwood consumed. The open-access site experiences high pressure on resources as reflected by a more significant number of people in a tent, a longer duration of stay, and a greater amount of fuelwood consumed at the harvest sites. Currently, the collection of fuelwood from shrubby vegetation appears unsustainable at the open-access site in the Bajhang district. The current practices are likely to deplete the fuelwood resource and threaten the sustainability of the caterpillar fungus collection. There is an urgency to replace the current fuelwood resource use practiced by collectors with more sustainable energy systems. Moreover, it is imperative to address this issue holistically through stringent policies that regulate the number of people and days spent at collection sites.

Declaration of Competing Interest

The authors declare that they do not have any form of conflict of interest to influence the content and publication of the manuscript.

Acknowledgments

The authors are thankful to ICIMOD for its encouragement and support. Core funds of ICIMOD supported this study with funds contributed by the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, and Switzerland. We also thank reviewers for their constructive comments and suggestions.

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