IJBSAT

ISSN: 0975 - 4539
IJBSAT (2020), 11(2):8-18

DOI: http://doi.org/10.5281/zenodo.4133192

Sustainable Harvesting and Cultivation of Endangered Himalayan Wild Plants

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ABSTRACT
Endangered wild species with high commercial interests are at risk of being extinct. This study focuses on traditional Asian medicinal species, one fungus, *Ophio-cordyceps sinensis*, three wild plants *Nardostachys grandiflora, Dactylorhiza hatagirea, Rauvolfia serpentina*, and one semi-cultivated plant, *Cinnamomum tamala*. Information on traditional use and of gathering methods were surveyed from local collectors and stakeholders involved in trade of wild plants, and from conservation and management experts. All target species are popular and prices are high. We found that old people had more knowledge about the plants than young do and people in rural mountainous areas use the plants more frequently than in the more central urban areas. People involved in gathering are likely to be illiterate but they have good knowledge on wild species. Our study emphasized that local stakeholders should be included in the conservation work and with sustainable harvesting methods. In addition, cultivation of the plants could be a way forward. All target species except *Cinnamomum tamala* have decreasing or threatened wild populations, thus can serve as an example of a native species that is being cultivated and where cultivation go hand in hand with conservation interests.

Keywords: Dactylorhiza hatagirea; Nardostachys grandiflora; Ophio-cordyceps sinensis; Rauvolfia serpentine

INTRODUCTION

On a global scale, more than 10 % of the plants, or around 50,000 species are used as herbal drugs or spices [1-3]. In developing countries like Nepal, 80 % of the population relay on traditional medicine for their primary health care [4]. China and India have the highest numbers of utilized medicinal and aromatic plants and most of these species are harvested from the wild [1, 5]. Nepal, especially compared to its size, is also rich, with 700 plants considered to have medicinal value, where 238 are in active use and 100 are of commercial value [6-8]. According to the World Health Organization, medicinal plants have an economic value of more than 14 billion US $ a year and the demand for raw material is steadily growing [9]. Due to both local use and export, such plants plays a crucial role in the Nepalese economy. However, there are challenges. The high value causes overutilization and is a risk for biodiversity loss [10, 11]. The International Union for Conservation of Nature (IUCN) is a global authority that uses a set of criteria to evaluate the extinction risk of species and subspecies. To date, 95,000 species have been assessed, and around 25,000 of these have been found to be threatened. The IUCN Red List is recognized as the most authoritative guide to the status of biological diversity.

The aim of our study was to assess the conservation status of wild medicinal species in the Himalayan region, to capture stakeholders' perceptions of the situation and find ways forwards. The material included data from both local collectors and dealers and experts involved in nature conservation and management. The study clearly highlighted the challenge of over-utilizing commercially interesting wild plants. On the other hand, we also identified solutions and actions needed to sustain the plants.

MATERIALS AND METHODS

Study sites and methodology

A mixed methodology approach [12] was applied compiling data from surveys and focus group discussions with stakeholders involved in gathering and trade of medicinal plants and expert interviews. Three study sites were

IJBSAT

ISSN: 0975 - 4539
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selected and these were Jumla (Chandannath village 3 and 4), Mustang (Thini and Syang village), and Chitwan (Bijayanagar and Bangai village). Jumla is in a mountainous region in the Mid-Western region of the country, 2100-6400 m a.s.l. and at 28-29°N, 82-83°E. Mustang is in the high mountainous Western region, 2000-8000 m a.s.l. and at 28-29°N, 83-84° E. Chitwan is more in the central lowland, 44 to 1945 m a.s.l and at 27-28°N, 83-84°E. For the surveys, a simple random sampling method was applied with 80 farmers/households (HH), 21 from Chitwan, 25 from Jumla and 34 from Mustang, respectively.

Ten experts were interviewed for complementing information, especially related to conservation status and efforts. The experts were from Department of Plant Resource (DPR), District Forest Office (DFO), Nepal Agriculture Research Council (NARC), Herbs Production & Processing Co. Ltd (HPPCL), Department of Forests (DoF), National Herbarium and Plant Laboratories (KATH) at Godawari (Lalitpur), Annapurna Conservation Area Project (ACAP), District Agriculture Development Office (DADO).

The IUCN Red List of Threatened Species database was retrieved to trace information on conservation status on wild medicinal species in Nepal. In addition, regional or national assessments were examined, where the national list for Nepal [13] was a key source. Also, the Convention on International Trade in Endangered Species of Wild Fauna and Flora was accessed, as were Conservation Assessment and Management Prioritisation (CAMP), Central Bureau of Statistics (CBS), Department of Forests (DoF), District Forest Office (DFO), Ministry of Agriculture and Livestock Development (MoALD) and Department of Plant Resource (DPR).

Target species

Five commercially important species were extracted as key target species but we could have included more species. They were selected as due to their high economic value (commercial interests) but also as we expected the species to be threatened or at least have decreasing populations.

The first wild species was *Nardostachys jatamansi* DC. (synonyms *Nardostachys grandiflora* Wall. ex DC. or *Nardostachys gracilis* Kitamura), known as muskroot or spikenard, locally called "Jatamansi", is an herb found on medium high altitudes in the Himalayas. Roots and rhizomes are gathered and used for medicinal purposes [14, 15] but the plant is classified as critically endangered on a global scale [11] and in Nepal [16]. The second species was *Dactylorhiza hatagirea* (D.Don) Soó, (synonym *Orchis hatagirea* D.Don), known as marsh orchid or locally as "Panchaule", is a perennial herb found at medium to high altitudes (2800-4600 m a.s.l.).Tubers are gathered and used for medicinal purposes [15]. The third species was *Rauvolfia serpentina* (L.) Benth. Ex Kurz (syn. *Ophioxylon serpentinum* L.), devil pepper or snakeroot, popularly known as "Sarpagandha" in Nepal, grows in the lowland and hill areas in South- and Southeast Asia. Root, bark and leaves are gathered and used for medicinal purposes. Because of the high demand, it became nearly extinct in some areas in South Asia. To provide enough roots some hospitals set up small gardens for cultivation of the species [17]. The fourth wild species included in this study was *Ophiocordyceps sinensis* (Berk.) G.H.Sung, J.M.Sung, Hywel-Jones & Spatafor termed "Chinese caterpillar fungus" or "Yartsa gunbu" in Tibetan language, meaning winter worm and summer grass. Scientific synonyms are *Cordyceps sinensis* (Berk.) Sacc. and *Sphaeria sinensis* Berk. The fungus grows on the larva of the ghost moth (*Hepialus humuli*) and the life cycle is quite complex. In autumn, spores infect the larva, which at that time of the year stay in the soil. The spores develop over the winter, fill the larva core, and in early spring give rise to cylindrical stroma above the ground [18], which is used as tonic and aphrodisiac in traditional Chinese-Tibetan medicine and in the Nepal Ayurveda system [19-22]. In the study sites the species is used with milk and honey. The cost of *Ophiocordyceps sinensis* (Yarshagumba) was

IJBSAT

ISSN: 0975 - 4539
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NRs 8-10 lakhs/kg, i.e. around 9000 USD/kg when compared to US dollar [23]. In China, the cost is approximately the double [24].

The last species was *Cinnamomum tamala* T.Nees & Eberm, (syn. *Laurus albiflora* Wall.), commonly known as cinnamon leaf or Indian bay leaf, locally known as "Tejpat" or "Dalchini" in Nepal, is a perennial plant growing wild in the mountain slopes in Nepal, India, Bhutan and some other Asian countries. People use the dried bark medicinally, especially to treat stomach problems. The plant is commercially cultivated and easily available throughout Nepal [19, 25].

The species were included in the questionnaires and the further database and literature research. The Global Biodiversity Information Facility [26] was used to trace georeferenced occurrences of the species. These are records from herbaria, inventories, and living collections reported to the facility. GBIF serves as an international network and provides open access to data about all types of life. Amongst others, the Himalayan Uplands Plant Database and many of the national universities report to GBIF.

Statistical analysis

Survey questions were related to knowledge and use of medicinal plants, gathering pattern, and conservation efforts and semi-structured questionnaires were applied. The results from the statistical analysis are given as chi-square values (X2), degrees of freedom (df), and the P-values from each of the chi-square tests. Focus group discussions were conducted in each study site after completion of the survey, to verify the data and provide additional information and people from various ethnic groups, ages, and gender took part.

Table 1. Number of respondents in each category based on self-assessment of their general knowledge on medicinal plants and their knowledge on benefits of using such plants. Results related to age category of the respondents.

			General knowledge		
Age	No	Little	Moderate	High	Very high
<30	3	2	0	0	1
30-45	10	19	0	0	0
45-60	4	27	2	2	0
>60	0	6	3	1	0
			Knowledge on benefits medicinal plants		
Age	No	Little	Moderate	High	Very high
<30	3	2	0	0	1
30-45	9	19	1	0	0
45-60	4	27	2	2	0
>60	0	6	3	1	0

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Table 2. Number of respondents that said they are using the five targeted medicinal species in treating diseases and the numbers of respondent that use of *Ophiocordyceps sinensis* for prevention purposes in the lowland (Chitwan) and the mountain (Jumla and Mustang), respectively.

	Using targeted plants in treating diseases	
Region	Yes	No
Terai (Chitwan)	5	16
Mountain (Jumla + Mustang)	45	14

	Prevention use *Ophiocordyceps sinensis*	
Region	Yes	No
Terai (Chitwan)	0	21
Mountain (Jumla + Mustang)	7	52

Table 3. Number of respondents involved in gathering/harvesting of medicinal plants and what methods they use among literate and illiterate (no or very little formal education) people in the study sites.

	Involved in gathering	
Education level	Yes	No
Literate	15	19
Illiterate	34	12
	Gathering methods	
Education level	Sustainable	Commercial
Literate	1	14
Illiterate	6	28

Table 4. Conservation involvement versus knowledge on medicinal plants

	Involved	Not involved
Some knowledge	41	22
No knowledge	3	14

RESULTS AND DISCUSSION

Knowledge and use of medicinal plants

The survey included 80 farmers/households involved in gathering and use of medicinal species. Overall, the majority of the respondents assessed their level of knowledge to be low, both on general knowledge of medicinal plants and knowledge related to the use of the same plants (Table 1). We found that knowledge could be linked to age, where older people had comparatively more knowledge about medicinal plants than the younger ($X^2=36.3$, DF=12, P=0.0003). The older people had more knowledge on the benefits of using

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ISSN: 0975 - 4539
IJBSAT (2020), 11(2):8-18

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medicinal plants than the younger (X^2= 32.4, DF= 12, P= 0.0011).

Regarding use, few respondents said they use medicinal species for preventive purposes, but they rather use them for direct treatments. Regarding use for treatment, a significant difference was detected between Jumla and Mustang on one side and Chitwan on the other (X^2= 20.73, DF= 2, P<0.001, Table 2). Jumla and Mustang are remote, mountainous areas with limited access to health facilities and transportation, and in these areas, thus we believed the use of medicinal plants is more common than in the more central region, represented by Chitwan. The number of collectors is also higher in the mountainous areas. For prevention purposes, we could not find a similar pattern as in all sites, the use for prevention was limited, although there was a tendency to more frequent use of *Ophiocordyceps sinensis* in the mountainous sites (X^2= 2.73, DF= 1, P= 0.098, Table 2). Although this species grow in high mountain areas, very few also in Jumla and Mustang use it regularly for prevention purposes. The reason could be the high price of the species, as stated by one of the respondents from Jumla. "Before 1992, this costed 5 Rs/piece (i.e. 0.13 USD), in 2005, the cost was 62 Rs/piece (i.e. 0.87 USD) but now it is 600 Rs/ piece (i.e. 5.88 USD)." Translated to SI units, the recent price could range from around 12,000-14,000 USD/kg in Nepal.

For *Dactylorhiza hatagirea*, the survey also showed no significant relationship between availability in the region and the use for prevention purposes (X^2= 0.36, DF= 1, P= 0.54). This plant is gathered in high mountain areas, but a negligible number of people also in the mountainous sites use it for prevention purposes. High price, illegal trade, and a strict regulation for collection, use and trade in Nepal [19] could be explaining the result.

The respondents were given the opportunity to specify for which purposes they use the species. Some mentioned that *Ophiocordyceps sinensis* was used for giving energy and aphrodisiac effects, *Dactylorhiza hatagirea* to cure wound, *Nardostachys jatamansi* to prevent against cold and high-altitude sickness, *Rauwolfia serpentina* against stomach pain, maintain blood pressure and kill worms and *Cinnamomum tamala* to prevent cold and as generally have stimulant effects. Other species mentioned by the respondents were *Allium wallichii* Kunth (Ban lasun) used for gastritis, *Acorus calamus* (bojho) used against common cold, *Paris polyphylla* Smith (satuwa) used against inner pain and asthma, *Pleurospermum hookeri* (Ganaino) used against diarrhoea and indigestion, *Gossiypium arboretum* (Ruwa saag) used against diabetes, common cold, and excessive bleeding, *Iris decora* Wall. (Ninaijadi) used against gum pain, *Aconitum bisma* (Bikhama) used against pain, Taxus wallichiana (Lauthsalla) used against cancer, *Swertia chirayita* (Chiraito) used against common cold, and *Neopicrorhiza scrophulariiflora* (Kutaki) used against common cold, cough, and asthma. Furthermore, *Artemisia vulgaris* (titepati) was used for pest control in agriculture (respondent from Jumla). Other studies [20, 22] have mentioned the use of *Ophiocordyceps sinensis* for weakness and as aphrodisiac and *Nardostachys jatamansi* for the same [15] but also for indigestion [19] and as an incense [30]. The use of *Dactylorhiza hatagirea* as an incense is also known [13, 15], and *Rauwolfia serpentina* has been reported to have a similar use. *Rauwolfia serpentina* is used for controlling high blood pressure [16]. Similar use of *Cinnamomum tamala* has also been reported [19].

Sustainable gathering and maintenance

The survey showed that people involved in gathering of medicinal plants are likely to be illiterate (X^2=7.31, DF=1, P=0.0068, Table 3). People with no or little formal education have few alternative sources of income and collect plants to sustain themselves and their families 31-34. The result further showed that the way they gather/harvest the species is not

IJBSAT

ISSN: 0975 - 4539
IJBSAT (2020), 11(2):8-18

DOI: http://doi.org/10.5281/zenodo.4133192

influenced by education level (X^2=1.02, DF=1, P=0.31, Table 3).

People with no or little formal education said they practice sustainable gathering methods as people with more education. Sustainable gathering could be harvesting after maturity, harvesting only some plant parts, and leaving a portion of the rhizomes/roots back in the soil. People without formal education may have learned the importance of maintaining wild habitats through a transfer of indigenous knowledge from generation to generation. Some people in the study sites were traditional health practitioner, commonly known as "Lama" or "Jhakri" in Nepal, who treat patient with plants/medicines known from traditional, indigenous knowledge. They may not have formal education but have based their knowledge on traditions. For the targeted species, almost every collectors/harvester followed a seasonal harvesting pattern, which means there is a high pressure on the habitats at certain periods of the year. This again could be a bottleneck in sustaining the habitats. The survey showed that there was a significant relationship between conservation effort (participation in conservation) and people's knowledge on medicinal plants, i.e. people with medicinal plant knowledge were more ahead towards the conservation of medicinal plants than the people having less such knowledge (X^2= 12.16, DF= 1, P= 0.00048, Table 4).

Conservation status

Only one of the selected target species have been assessed by IUCN. *Nardostachys jatamansi* was latest assessed in 2014 [35] and found to be critically endangered on a global scale and is listed as such on the IUCN Red List of Threatened Species. GBIF (2018) has 674 records of the species, of which 412 are georeferenced, most of them from mountainous areas in China, Bhutan and Nepal. According to recent information, more than 80% of the total global export of the plant is from Nepal [23]. Although there has been a ban on export in unprocessed form of the plant since 2001 and the plant is listed in Appendix II by CITES 16. The expert interviews, according to district forest officer from Jumla and an ACAP project officer from Mustang, showed that the trend in the wild population is in a decreasing order, which supports that the species is endangered. Declining population has also been reported by [30, 36]. High price is a driving force to over-harvesting [37]. A recent study showed that the largest amount of *Nardostachys jatamansi* is harvested from the Jumla district [15]. The same study however showed that there was an adequate stocking and about 950 tons can be harvested annually in Nepal, if they follow a two years rotational sustainable harvesting system. The expert interviews also showed that the government of Nepal has conservation actions of *Nardostachys jatamansi* in protected areas in Rara National Park in Jumla and Annapurna Conservation Area in Mustang. Awareness programs have also been launched, aiming at preventing early and destructive harvesting. Cultivation trials is ongoing in Rasuwa, Jumla and Sankhuwasaba districts. The trials, at least at low altitudes, have failed. Germplasm of the species is preserved in the national gene bank, but commercial cultivation and in vitro culture programmes are lacking.

Dactylorhiza hatagirea is a plant that has not yet been assessed by IUCN, but it is listed in Appendix II (CITES) [16] and judged to be endangered by (CAMP) [38]. On a global scale, 194 occurrences are reported to GBIF (2018) of which 122 are georeferenced and these are found in mountainous areas of India, Pakistan, Nepal, and China. Under the forest act of 1993, crude drugs from the species are ban for collection, use, sale, distribution and transportation in and from Nepal. According to the District forest officer from Jumla and an ACAP project officer from Mustang, the trend in the wild population is in decreasing order. It may be so due to illegal harvesting and habitat destruction. Other factors such as grazing and trampling have negative effects [38]. However, one study showed that there is adequate stocking of *Dactylorhiza hatagirea* in Nepal

IJBSAT

ISSN: 0975 - 4539
IJBSAT (2020), 11(2):8-18

DOI: http://doi.org/10.5281/zenodo.4133192

and that around 17 tons a year can be harvested with sustainable harvesting methods without damaging the populations [15]. The same study reported that 15 tons of *Dactylorhiza hatagirea* is illegally traded in Nepal. Due to conflicting reports, a detailed status, distribution and stocking population study of the species is required throughout the country to help authorities to make a concrete decision. In this way, the stakeholders can benefit by policies regarding to harvest and trade of the plant. Conservation is followed in protected areas like Rara National Park in Jumla and Annapurna Conservation Area in Mustang. Germplasm is conserved in the national gene bank and GoN has also initiated commercial cultivation in Humla, as well as cultivation trails in Jumla, Terathum, Rasuwa and Sankhuwasaba districts [15]. In vitro culture is lacking for this species.

Ophiocordyceps sinensis is a species geographically linked to high altitudes in Himalaya (Nepal, Bhutan and China). The IUCN Red List of Threatened Species does not include the species in their database. According to the District forest officer from Jumla and an ACAP project officer from Mustang wild populations are decreasing. The reason behind decreasing population could be a combination of climate change and overharvesting. This species is one of the world's most expensive biological resources [39]. For such a reason, overharvesting can be a treat [21, 37, 39]. GoN has initiated conservation in protected areas. GoN has initiated awareness program against immature collection and GoN has banned export of the species without special authorization and steaming and proper packaging. Germplasm is preserved in the national gene bank and research is carried out for promoting in vitro culture of the species but so far, this has been unsuccessful [40]. Fungal growth is shown but not with fruiting bodies.

Rauvolfia serpentina is listed as endangered in Nepal [13] or critically endangered (CAMP) and in Appendix II (CITES). Out of the 297 occurrences reported worldwide, only 32 are georeferenced and these are spread over a large area in Asia 26. According to a district forest officer from Chitwan the wild population is in a decreasing order. For this species, high price is also a driving force for over-harvesting [37]. Similarly, a study conducted in India reported that *Rauvolfia serpentina* is threatened with extinction risk due to overharvesting [41]. GoN has initiated conservation of the species in protected area like in Chitwan National Park. GoN has initiated an awareness program to prevent early or destructive harvesting and export of the plant is banned without further processing. Germplasm is preserved in the national gene bank. Experimental plots have been carried out in KATH Godawari Lalitpur to develop more efficient production of planting materials. Initiatives on of cultivation is going on in Banke, Bardiya, Jhapa and Sarlahi districts in Nepal. In vitro culture is currently possible for multiplication of planting material and for backup ex situ preservation.

Cinnamomum tamala is a semi-wild species in contrast to the above mentioned purely wild species. Out of the 150 occurrences worldwide [26, 42] were georeferenced, many of them to Nepal or nearby countries. According to District Forest Officers from Jumla and Chitwan districts, the species is conserved and the trend in the wild population is expected to be increasing. Cultivation is an important source for harvesting plant material in contrast to the four other species. Still, the plant also grows wild and people are gathering from wild populations. Cultivation for commercial purposes is mainly done in Udayapur and Palpa districts of the country. GoN has preserved the germplasm in the gene bank. Commercial cultivation has started in many districts, especially in the hilly Terai region many farmers cultivate the plant.

Key issues for conservation and sustainable use

One can trace a difference in the conservation status and its availability between the

IJBSAT

ISSN: 0975 - 4539
IJBSAT (2020), 11(2):8-18

DOI: http://doi.org/10.5281/zenodo.4133192

domesticated species *Cinnamomum tamala* and the four targeted wild species. All five species are however included in the governmental list of prioritized species for research and development [19, 23]. Despite the concern from the government and from the private sector, we cannot see an improvement in the conservation status of the four-wild species, but we can see it for *Cinnamomum tamala*. Cultivation or a sustainable management of wild population could generate high income and help to reduce poverty in rural areas. Commercial cultivation has so far only been done for *Cinnamomum tamala*.

So far, awareness programs have been lunched in some districts to prevent early and destructive harvesting, for example for *Ophiocordyceps sinensis*. To minimize over-harvesting, GoN has included a royalty system in its policies on the collection of medicinal species from the wild. We recommend continue handing over national forests to local communities as this has been successful regarding local involvement. Community forests are now being familiar at many sites. For sustainable harvesting, a block wise rotational harvesting has been developed in Jumla district, including an NTFP inventory guideline and sustainable harvesting plan in Annapurna conservation area. Still, and despite a recognition of the economic importance of medicinal species, the attention from the government and NGOs is low. For example, there is still a debate on the responsibility of such species, if they belong to Ministry of Forest or Ministry of Agriculture. The current study highlights that there is still a lot to be done. Very few institutions are involved in training and there is a lack of awareness of training to the local people. Many of the collectors in the study were frustrated about this; as exemplified by a respondent from Jumla who said; "Training is made not to reach the poor people; only elite group receive such training". Based on the current study we recognized that the following governmental and non-governmental institutions could be involved: Department of Plant Resource (DPR) is doing research and does so far not provide training to local collectors or traders. District Forest Office (DFO) also does not provide training to local stakeholders. The National Herbarium (KATH) at Godawari provides training in plant conservation day to students who come to visit on a one-day basis. Nepal Agricultural Research Counci (NARC) provides very limited training, i.e. when groups of people show their common interest in certain medicinal plants. Herbs Production & Processing Co. Ltd. (HPPCL) only provide training to collector who have got a PAN number, which means a lot of collectors who don't have this misses the opportunity. Despite medicinal species being a potential sector for the development of the nation, the condition for the sector is not good. This is reflected by low capital investments from both the government and private sectors for an overall development and promotion of the sector [23].

Concluding remarks

The survey showed that many of the farmers who were interested in cultivation of the targeted plants lacked support from governmental institutions. The expert interviews showed that nine out of ten experts said that low funding for research and management was a challenge. Two out of ten experts mentioned that there were lack of value-addition opportunities for the actors involved in the medicinal plant sector. Among social factors, the study identified a general lack of awareness among many of the people involved in the gathering of the wild species. Certainly, poverty drives for collection of the plants and for haphazard and over harvesting. Environmental factors were also identified. Ten out of ten experts, as well as survey respondents, reported that climate change and other anthropogenic factors, including trampling, grazing, deforestation, and monoculture, are serious environmental treats. Almost all the people in the study sites reported, lack of training, and this applied both to governmental and private organisations. They also reported that most of the people in rural areas have been ignored by the

IJBSAT

ISSN: 0975 - 4539
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organisations. Ten out of ten experts reported about lack of tools and technologies in the conservation of threatened species and lack of good laboratory facilities for research purposes. On a political level, ten out of ten experts reported about failures in regulation and policy implementations. One specific challenge related to laws and regulations is smuggling. The study could identify that smuggling is an issue. A porous border with India and China combined with a loose security at check posts encourage for smuggling of the medicinal plants. We recommend that a detailed conservation status, distribution and stock population of targeted species should be initiated. Furthermore, for the threatened species, stakeholders should be involved in the conservation and their participation in protected areas should be strengthened. Strong policies and implementation to attract serious collectors and small-scale entrepreneurs and avoid illegal harvesting and smuggling. The government, through their regional and local networks, should provide species-based training to the collectors, so they prevent early and destructive harvesting. Strict check system in the national check posts is necessary to minimize illegal trade. Increased production through cultivation should be developed.

ACKNOWLEDGMENT:

We are grateful to all the Forest Officers and Agriculture officers of concerned districts, Officer of ACAP project, HPPCL officer, scientists from Department of Plant Resource, National Botanical Garden and Nepal Agriculture Research Council for giving their time for my queries. We are also very grateful to Raj Kumar Rimal for his support and Anup Nainabasti, Deepak Khatri and Kamana Rayamajhi for sharing their hand in the data collection process. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declare that there are no conflicts of interest. The study did not include physical sampling of the plants.

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ISSN: 0975 - 4539
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DOI: http://doi.org/10.5281/zenodo.4133192

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