Threats and Conservation of *Paris polyphylla*: Vulnerable Medicinal Plant in Panchase Protected Forest, Nepal

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Abstract : Government of Nepal has enlisted *Paris polyphylla* as the priority medicinal and aromatic plant (MAPs) for the economic development of the country due to its high market price and demand. But in Panchase Protected Forest (PPF) its value is not well recognized. Therefore, this study aimed to explore the distribution of the plant, assess threats and interventions for conservation and promotion in Bhadaure Tamagi area of Kaski district. Participatory resource mapping, semi-structured questionnaire and key informant survey were carried out for data collection. The plant was distributed at nine different patches of the forest at moist, fertile, and sloppy sites in Northern and Eastern aspects, and spotted only at two patches. Among 10 threat factors, illegal collection with Relative Threat Factor Severity Index (RTFSI) value of 0.90 was the major threat to the plant, and forest fire with value of 0.25 was the least impacting threat. Poor management and institutional factors were not understood by local people directly. Though the plant has high market value, only 6% of the locals used the plant for direct income whereas the rest used for the household purpose as they have no idea of the market. It is recommended to empower and support local people for commercial cultivation and trade, sustainable harvesting techniques, and to bring all the concerned stakeholders of PPF together to work effectively to conserve and promote this wonder herb.

Key words: Threat factors, medicinal and aromatic plant, interventions for conservation, illegal collection, forest fire, harvesting techniques, impacting threat

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Introduction

Medicinal and aromatic plants (MAPs) are botanical raw materials that are essentially used for therapeutic, aromatic and/or culinary purposes as components of cosmetics, medicinal plants, health foods and other natural health products In Nepal, around 2000 species of plants are commonly used for medicinal purposes (Shrestha et al. 2000). It has been estimated that out of 15% contribution of forestry sector to the national GDP, 5% is contributed by NTFPs (Malla et al. 1995).

Paris polyphylla (English name: Love Apple, Local name: Satuwa), Family: Melanthiaceae, is an important perennial medicinal plant growing under the canopy of moist temperate forest of Nepal (Madhav et al. 2010). Among the 138 native vascular plants taxa threatened in Nepal and over 50 species of medicinal plants (Tandon et al. 2001), *P. polyphylla* is listed under Vulnerable Category (V) CAMP. It is distributed in the Himalayan region, and is native to Assam, Bangladesh, China North-Central, China South-Central, China Southeast, East Himalaya, Laos, Myanmar, Nepal, Taiwan, Thailand, Tibet, Vietnam and West Himalaya. Throughout Nepal, it is distributed in Eastern, Mid and Western regions between 1800-3300 m elevation associated with Rhododendron species, *Daphniphyllum himalense* (IUCN 2004). This species is the most popular among 138 medicinal plant species in the Panchase Protected Forest (PPF) area. Shah et al. (2012) reviewed the various medicinal properties of *P. polyphylla* and categorized the species as the "jack of all trades". Rhizome of this plant is widely used in Nepal as an antihelminthic, antispasmodic, digestive stomachic, expectorant and vermifuge (Bhattarai, Ghimire 2006; IUCN 2004).

Demand for *P. polyphylla* in the international market is in increasing trend, especially in China due to its high use in Chinese medicine (Roy et al. 2018; Negi et al. 2014). The market has been increase by 400-fold between 1980s and 2017 (Cunninghamm et al. 2018), and Nepal is of the *P. polyphylla* exporting nation to both China and India. As the growing market of medicinal plants increases the level of extraction and threatens its sustainability (Jamba, Kumar 2018), the species has been endangered in the neighboring countries (Bhat, Mayirnao, Fayaz 2017). Till today, the Department of Forest (DoF) and PPF Program Office has not carried out any inventory on the status of this particular species in the Panchase area. Conservation and wise- utilization of the invaluable medicinal species like *P. polyphylla* has been a major challenge in PPF mostly due to over exploitation, illegal collection, open grazing, etc. (K.C., Phoboo, Jha, 2010) Therefore, this research aims to map distribution of *P. polyphylla* in PPF area and identify factors of threats and its conservation measures.

Materials and Methods

Study Area

PPF with an area of 57.76 km² was gazetted in 2012 as a "Protected Forest" under the Article 23 of the Forest Act 2002. It lies between 83°45" to 83°57" E. longitude and 28°12" to 28°18" N. latitude. Its altitude varies from 900 m to 2517 m. Bhadaure Tamagi area belonging to ward number 4 in Annapurna Rural Municipality and ward number 23 in Pokhara Municipality was selected for the study. The criteria for selecting it were ethnic group residence, local level collection and trade, prevalence of local healing practice, availability of highest density of *P. polyphylla,* and majority of PPF area lying in these wards. Location map of the study area is presented in Figure 1.

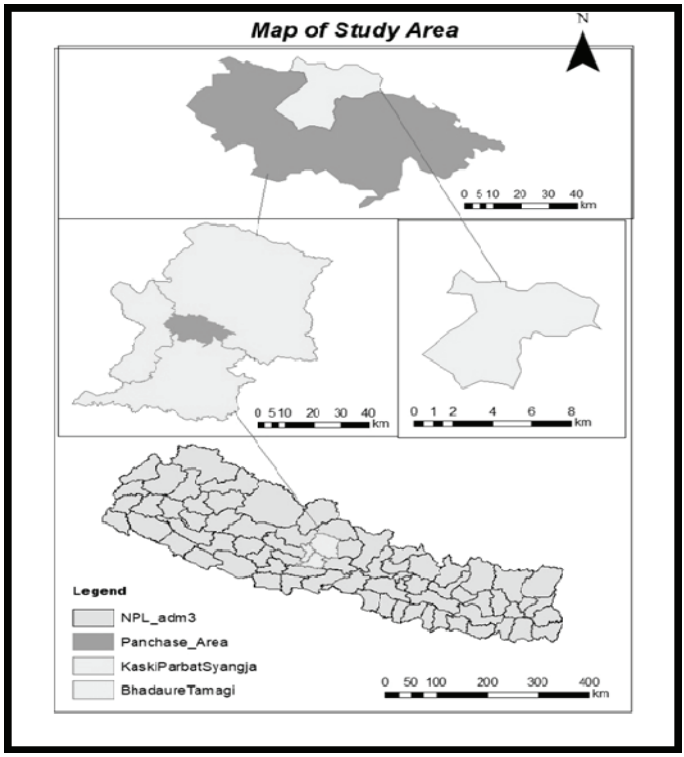

Figure 1 : Location Map of Study Area

Methods

Data Collection

Both primary and secondary information sources were used for data collection. Participatory Resource Mapping was done to prepare the distribution map of the plant. Direct field observations and GPS mapping were done in the forest to

study the habitat nature of *P. polyphylla* and mapping the existing distribution of this plant with the help of local key informants and DFO staff. Household survey with semi-structured questionnaire was carried out with 15% of households, i.e. 115 households out of 762 selected randomly to understand local people's knowledge on harvesting techniques, average collection and availability of *P. polyphylla* in the forest. Key informants interviews were conducted with the local traders, political leaders, local healer, Machhapuchhre Development Organization (MDO) office staffs, executive members of PPF Council, field staffs and Community Based Anti-Poaching Unit (CBAPU) members to obtain information regarding threats and possible intervention measures for *P. polyphylla* conservation and promotion. A ranking system based on Relative Threat Factor Severity Index (RTSFI) following Kiringe and Okello (2007) was used for the assessment of threats. The following formula was used to prioritize the threats to define RTFSI:

Mean score of each threat factor = (sum of all the scores for that particular threat factor) / (the total number of respondents)

Relative Threat Factor Severity Index, RTFSI = (the mean score for a particular threat factor) / (the maximum possible score)

International and national documents related to the subject, policy documents, reports, research articles, etc. were reviewed to gather background information.

Results and Discussion

Distribution Map of Paris polyphylla

In the study area, the plant was found in patches rather than in a single large habitat in the altitudinal range from 1800 to 2350 ma.s.l.in Northern and Eastern aspects. It prefers mostly the moist areas with brown to black fertile soil full of humus and other organic materials under the full or partial shade of trees with minimum requirement of light. Similarly, the plant was visible at the bank of big and small streams, springs in the forest in a damp condition and slightly sloppy to steep sloppy areas ranging from 30° to 75°. It existed in difficult terrains, nooks and corners of the forest, which had tough accessibility. Also, the plant was found growing at the middle of the stream above the rocks where mud was collected. The plant did not exist in dry and open areas of the forest. Similar type of occurrence of the plants was observed in Arunachal Pradesh, India, and were found growing in the altitudinal range between 1000 to 3500 masl in moist and shady areas of forest, rocky slopes and water channel with rich humus soil (Paul et al. 2015) in rhododendron and bamboo forest with low light intensity and sloppy areas near stream side (Roy et al. 2018). The associated species of *P. polyphylla* observed in the field were *D. himalense, Rhododendron species*, *Daphne bholua, Adiantum caudtum, Arisaema intermedium, Swertia chiraita, Rubia cordifolia*,

etc. However, *D. himalense* and *Arisaema intermedium* were dominant. Similar species were found to be dominant in Ghandruk Village Development Committee in mid- hills of Nepal where *Arisaema intermedium* was used as an indicator for presence or absence of *P. polyphylla* (Madhav et al. 2010). Distribution of *P. polyphylla* in the study area is shown in Figure 2.

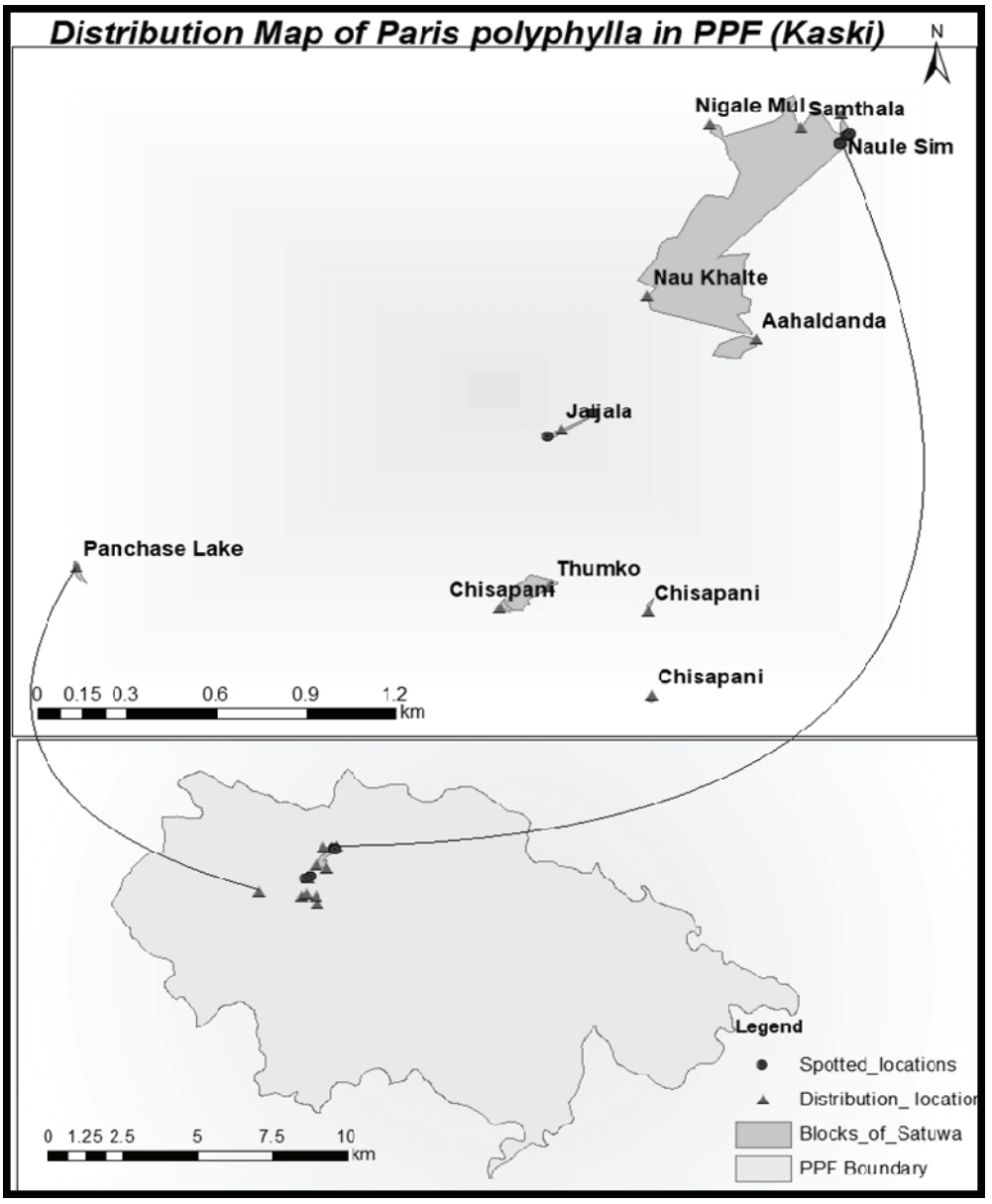

Figure 2 : Map Showing Distribution of *P. polyphylla* in the Study Area

Based on the field visit and the local level knowledge, nine sites of the forest, namely, Naulesim, Samthala, Jaljala, Nigalemul, Naukhalte, Aahaldanda, Thumko, Chisapani and the periphery of Panchase lake were suitable existing habitat of *P. polyphylla.* Among these sites, Naulesim, Samthala, Nigalamul, Naukhalte and Chisapani were the fringe areas whereas Jaljala, Aahaldanda, Thumko and the periphery of Panchase lake lie in the core area of PPF. But the plant was spotted only at two sites: Naulesim and Jaljala. At Naulesim, 11 plants at one spot and 5 plants at another spot whereas at Jaljala, 2 at one spot and 1 at another spot were spotted. Though the rest of the sites were suitable, the plants were not found in other areas. As per the local people, the availability of the plant has declined at high rate due to which it is now very rarely available, which was once abundant.

Factors for Decline in Availability of Paris polyphylla

Based on the respondent's view, activities for the decline of availability of *P. polyphylla* were grouped into four different factors, human being the major factor for the decline. Human factor accounted for 76.0% followed by environmental factors at 14%, management and institutional factor at 9.0% and others at 1% of the total share for decline (Figure 3). The list of activities for each factor is presented in Table 1.

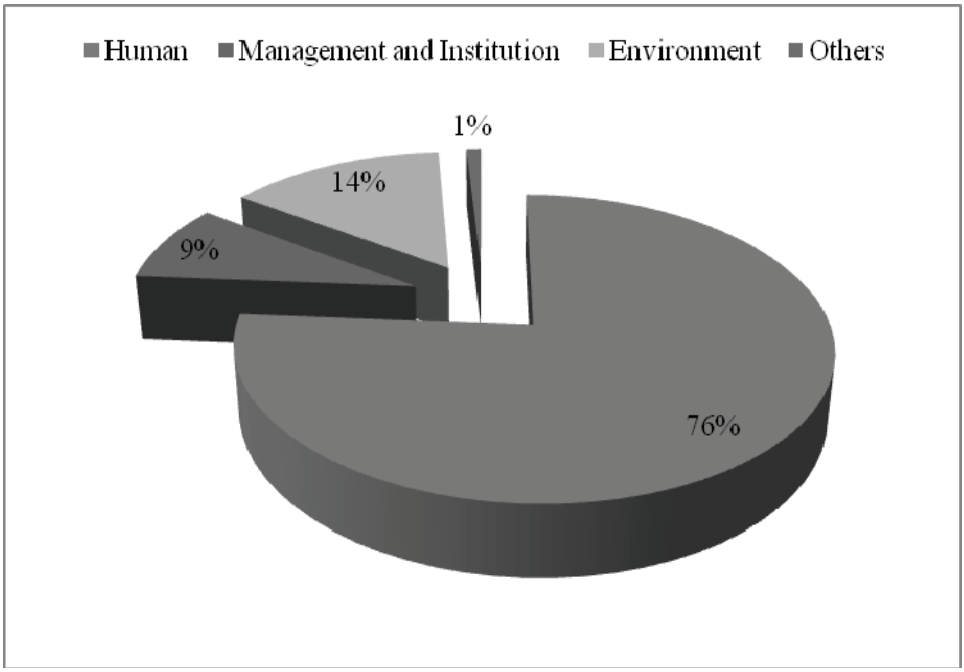

Figure 3 : Factors for Decline in Availability of *P. polyphylla*

Table 1 : List of Activities for Each Factor (Based on Respondents' Views) in Percentage

Human factor (76%)	Environmental factor (14%)	Management and institutional factor (9%)	Others (1%)
Illegal collection	Drying up of water resources	Insufficient staff recruitment	Consumption of whole plant and seeds by wild animals and birds
Unscientific harvesting	Natural hazards	No inclusion of MAPs related activities in the new OP of PPF	Pressure from unmanaged fallen trees and logs
Careless forest products collection	Invasive species	No approval of the OP	
Tourism impact	Competition among species	CBAPU not working effectively	
Open grazing			
Developmental activities			
Forest fire			

People were the major factor resulting in the decline of availability of *P. polyphylla* with activities, such as its illegal collection, unscientific harvesting, careless forest products collection, tourism impact, open grazing, developmental activities and forest fire (Table 1). The environmental factors included drying up of water resources, natural hazards, invasive species, competition among species, etc. Besides, management and institutional factors contributed to the decline of the plant as no any intervention for the protection, conservation and promotion of the plant had been carried out, which have indirect and hidden impact on decrease in its availability. These factors included insufficient staff recruitment, no inclusion of MAPs related activities in the new Operational Plan (OP) of PPF Management Plan and even no approval of OP, and CBAPU not working effectively. The policy of PPF included provision for sustainable conservation, utilization, promotion and marketing of MAPs including *P. polyphylla* through people's participation, which at the field level was not in implementation. Similarly, other factors included consumption of whole plant and seeds by wild animals and birds, pressure from unmanaged fallen trees and logs, etc. In addition, it is inherently slow growing and poorly regenerating

species due to dormancy of its seeds and rhizomes, and its restricted local distribution.

Threat Factors for Paris polyphylla with their Perceived Threat Index and Prevalence

P. polyphylla was faced by several threat factors operating at relatively higher relative threat factor severity index (RTFSI) level of 0.90 with a range of 0.25 to 0.90 as shown in Table 2.

Table 2 : List of Threat of *Paris polyphylla* and RTFSI

S.N.	Threat Factor	Mean Threat Factor Score (Mean ± SE)	Relative Threat Factor Severity Index (RTFSI)
1	Illegal collection	4.50 ± 0.08	0.90
2	Unscientific harvesting	4.16 ± 0.08	0.83
3	Open grazing	3.76 ± 0.13	0.75
4	Management and institutional provision	3.45 ± 0.10	0.69
5	Impacts of climate change	3.05 ± 0.11	0.61
6	Forest products collection by local users	2.92 ± 0.15	0.58
7	Developmental activities	2.64 ± 0.10	0.53
8	Natural hazards	2.63 ± 0.08	0.53
9	Others (eaten by wild animals, invasive species, etc.)	1.66 ± 0.08	0.33
10	Forest fire (man induced)	1.24 ± 0.06	0.25
	Mean value (±SE)	3.00 ± 0.10	0.60 ± 0.02

(RTFSI value of illegal collection was the highest (0.90) followed by unscientific harvesting 0.83, open grazing 0.75, management and institutional provision 0.69, impacts of climate change 0.61, forest products collection by local users 0.58, developmental activities 0.53, natural hazards 0.53, others 0.33 and forest fire the least (0.25).

Illegal collection of the rhizome was done for domestic, medicinal and income generation purposes by the local users of three districts, i.e. Kaski, Parbat and Syangja residing in the areas within the distance ranging from 1 hr to 6-7 hrs from the forest. Tourists, researchers from the foreign countries and tourist guides in the name of meditation in the Panchase Peak would stay in the forest for 15-30 days, and when they return back they would carry the valuable MAPs. There was increasing encroachment in PPF for poaching and unsolicited collection of MAPs and NTFPs. Premature harvesting of the rhizomes was

another threat due to which the seeds could not disperse naturally for the regeneration in a larger area. The scientific harvesting period of *P. polyphylla* is October (Kartik) when the seeds mature, but in PPF, people collected the plant earlier in May and June. Similarly, people were unaware about the scientific sustainable harvesting of the rhizomes because of which they uproot the whole plant and harvest rhizomes leaving the aerial parts. Random collection by uprooting the young or mature plant, which sprouted from either seeds or fragmented rhizomes, was one of the key factors for downsizing the population of *P. polyphylla* (Deb et al. 2015).

Open grazing was ranked as third relative threatening factor. As per KIs, there were around 6,000 livestock from three districts left openly in the PPF at the time of declaration of Protected Forest, and still today there are around 1,000 to 1,200 in the forest. The local people left them for more than a year where some even reproduced in the jungle. Those livestock ate the whole plant of *P. polyphylla* along with the rhizomes on one hand, and on the other hand, their foot stepping destroyed the whole plants. Several internal and external issues at policy, institutional and operating level have also direct and indirect impacts on the threat of *P. polyphylla* as no any intervention has been taken yet for its conservation and promotion. Also, ***"Chori Sikari tatha Jadibuti Taskari Niyantran Ikai"*** (CBAPU) is not working effectively, there are no sufficient staffs in PPF committee, no forest guards, no inclusion of MAPs related activities in Operational Plan of PPF and even no approval of the new OP instead of the former OP, which expired in 2073 B.S., no knowledge of the main stakeholders like MDO, PPF officers about the existence of *P. polyphylla* in PPF, etc. There was no co-ordination among the concerned stakeholders to carry out the NTFPs and MAPs related interventions. As included in the management plan of PPF, the resources in the core area shall be strictly protected and that in the fringe area, the benefit would be shared among the concerned stakeholders. But in reality, there is no such mechanism prevailing and people openly collect the rhizomes of *P. polyphylla* from both the core and fringe areas. No any legal permit is required for collection of rhizomes. Local people are not much aware of the value of the species. The local youths do not seem to have sufficient knowledge about the various NTFPs. Generally speaking, medicinal plants issues are low among the priorities of the responsible agencies (Jain 2000).

P. polyphylla is found at the periphery of big and small springs, streams and wells in PPF. But, the springs, streams and wells were drying up due to which the moist environment favorable for *P. polyphylla* was disturbed (Chaudhary, Aryal 2009). On the other hand, altitudinal change in habitat of the plant has been recorded in the area. The plant was available even in the lower altitudinal range of forest in the past, but now-a-days, it is found only in the higher altitudinal

range. The unpredictable weather/climate pattern has also affected the regeneration, growth and viability of the plant. Unhealthy competition with the other invading species brought due to climate change was also another threat. The species exhibit poor adaptability to change environment and susceptible to climatic conditions for reproductive vigor (Deb et al. 2015).

The local users of the forest caused destruction to the small plants of *P. polyphylla* during the collection of fodder, fuel wood, grass, dry leaves, timber, etc. knowingly or unknowingly. The ignorance and negligence of youths in cutting and damaging the plants during fodder collection, fuelwood collection and timber extraction, logging, dry leaves collection, etc. have caused exploitation of the plants. Developmental activities like construction of roads, small trails, trekking paths, ring roads, etc. have caused habitat fragmentation of *P. polyphylla.* Similarly, the connectivity of roads from three districts has made the people from distant areas access easy to the forest for collection of rhizomes. The entry roads from three districts at different points have eased the illegal collectors. Since *P. polyphylla* is found at the periphery of springs, streams, wells, etc. natural hazards like landslide, soil erosion, falling of stones, etc. were much noticeable due to which the habitat was adversely affected. The water induced disasters caused serious impacts to the plants which were noticeable both before and after the declaration of protected forest.

PPF being rich in biodiversity including wild animals and birds, the number of wildlife has increased, which has resulted in increased damage to the NTFPs including *P. polyphylla*. The seeds of *P. polyphylla* are eaten by birds, the whole plant including rhizomes by deer, bear, hare, etc. Decrease in its associated species like *Pinus roxburghi, Rhododendrons arboreus, Quercus* species, *Taxus bacata, Bamboos,* etc. has caused threat to the plant (PPF Annual Progress and Learning Report, Fiscal Year 2069/2070 B.S.). Once abundant 4-D trees, i.e. dead, diseased, decaying and dying trees, which were laid down on the forest caused its destruction. On the other hand, the invasive species like *Ageratina adenophora, Ageratum houstonianum, Lantana camara,* etc. have almost covered the lower portion of the forest, and are slowly spreading towards the higher altitude. Forest fringes, roadsides and fallow lands in Panchase area are dominated by the invasive species mainly due to impact of climate change and unmanaged road construction (Baral et al. 2017). Though forest fire occurred frequently in PPF in the past, this problem is less frequent these days and so, this impact has the least Relative Threat Index (0.25). Because of preference of *P. polyphylla* for the moist habitat fire could not spread easily around the areas where the plants grow.

Preference of the Local People for the Conservation and Promotion of Paris polyphylla

Table 3 depicts the result of Friedman Non-Parametric test showing preference of the local people for the conservation and promotion of *P. polyphylla* in PPF (N = 105, $\chi 2 = 286.326$, df = 5 and p = 0.000). First preference of the respondents was for Medicine and Healing purpose with the mean rank value 1.80. Since the past, people were utilizing *P. polyphylla* for gastro intestinal, dermatological, immune system, ear, eyes, nose and throat diseases, veterinary diseases, poisonous, respiratory, anti-pyretic diseases, etc. They considered the plant as being useful like honey.

Table 3 : Friedman Non-Parametric Test Showing Preference of the Local People for the Conservation and Promotion of *P. polyphylla*

Preferences	**Mean Rank**
Medicine and Healing	1.80
Cultural and Familial Traditions	2.67
Household Income	2.95
Ecological Balance	3.64
Raw Material for Industries	4.16
Others (Tourism promotion, Panchase Protected Forest identity, etc.)	5.78

The second priority was given to Cultural and Family Traditions. Since most of the community residing there are Gurungs who have the culture of consumption of local alcohol use to keep *Satuwa* in their mouth to upset the harmful effect of alcohol in their bodies. Similarly, *Satuwa* was used by local healers, *Dhamis, Jhakris* with the belief for treatment of infliction by witch (*Boksi lageko, Lago lageko*). *P. polyphylla* rhizomes were used to perform *Harelo pooja* during Shrawan and also in the funeral ceremony.

The third preference was for generating Household Income with the mean rank of 2.95. Most of the people were unaware of the market and its market price in spite of its high demand in international market. Less than half of the respondents have heard about income from the sale of this product. The fourth preference was given for Ecological Balance with the mean rank of 3.64 for the conservation of associated species, conservation of soil and other ecological services. The fifth preference was given to Raw Material for Industries with the mean rank of 4.16. A few respondents heard that the brokers purchased it fresh as well as its dry rhizomes from other villages of Nepal for industries.

The other preferences were for the Tourism Promotion, PPF Identity, Human Existence, Youth Employment and Ultimately Decrease Migration, Mitigate the

impacts of climate change, etc. with the mean rank value of 5.78. These preferences reflect that most of the local people still prefer *P. polyphylla* just for their household purposes rather than commercial cultivation and domestication as no any interventions have been carried out yet.

Interventions for the Conservation and Promotion of Paris polyphylla

Paired comparison by the tools used by Meragiaw et al. (2016) was referred for each threat among four interventions to rank the interventions and identify best among them. 13 KIs were selected for the interview. The interventions for each threat were listed and ranked. As shown in Annex 1, first preference regarding the minimization of Illegal Collection was supporting, motivating and encouraging local people for commercial cultivation, domestication, enterprise development, market potential/ trade followed by regular monitoring and patrolling of the forest by DFO staffs, PPF committee members, CBAPU members, etc., reward and punishment mechanism, and lastly, initiating the legal permit system. From the conservation side, there has been much speculation that NTFP commercialization can provide opportunities for (relatively) benign forest utilization and even create incentives for the conservation of individually valuable species and the environment in which they grow (Belcher, Schreckenberg 2007).

It is clear from Annex 2 that first preference of KIs regarding the eradication of Unscientific/Unsustainable Harvesting was sensitization of the local people through extension programs like training, awareness, orientation, seminars, etc. on how to scientifically cultivate, manage and harvest it followed by participation and co-operation of local people for the implementation of scientific harvesting techniques, establishment of demo plots in the forest where it is abundant and then restriction for the entry and the fourth preference was for keeping stock of seeds in the forest and let them disperse naturally discouraging premature harvesting. Scientific/ sustainable harvesting techniques should be adopted for harvesting the mature rhizomes without affecting the population like viable portion of the rhizome may be left in its natural habitat so that it can regenerate naturally (Paul et al. 2015).

Annex 3 shows that the first preference for controlling open grazing was Effective Implementation of Alternative Programs like plantation of fodder species in CF, construction of improved sheds, etc. so that total dependency of local people on forest decreases, and ultimately, the exploitation of small plants like *P. polyphylla* get reduced followed by Controlled Grazing or Rotational Grazing so that it would not exploit the resources on one hand, and on the other hand, fulfill the needs of local people for grass and fodder, Enrollment of Forest Guards in all entry points and the fourth preference was for Hybridization, i.e. rearing of the improved livestock.

To mitigate the impacts of Climate Change as depicted in Annex 4, the first preference was on Conservation of Water Sources like springs, streams, wells, etc. without letting them to dry and preventing water induced disasters, followed by Plantation of Associated species or Favorable species of *P. polyphylla,* like *Pinus roxburghi, Rhododendron arboreus, Quercus* sps., *Taxus bacata,* Bamboos, etc., controlling Invasive Species on their excessive expansion by utilizing them in the bio-fuel and making manure for organic farming. The fourth preference was on Examination and Use of Indigenous Traditional Knowledge to combat the impacts of climate change.

As the first preference shown in Annex 5, Poor Institutional Mechanism can be improved through Approval of new OP of PPFMC and its proper implementation as the previous OP expired in 2073 B.S. which is still being followed to carry out activities at present. It is followed by Inclusion of MAPs related activities in OP of PPF, "***Chori Sikari tatha Jadibuti Taskari Niyantran Ikai"*** working effectively for the valuable MAPs like *P. polyphylla* and the fourth preference was on Enrollment of Sufficient Number of Staffs and Discouraging High Staff Turnover.

Conclusion

P. polyphylla was found distributed in the study site at the altitudinal range of 1800-2350m in a moist, slightly sloppy to steep sloppy sites on the Northern and Eastern aspects. Though nine sites were hot spots from habitat suitability before 10-15 years, the plants were spotted only at two sites. Illegal and unscientific collection, open grazing, poor institutional and management provisions were the major factors for the decline of plants to threatening level. Preference of local people for conservation and promotion of the plant was just for medicinal and healing purposes as majority of them were unaware about market value. Though unseen and misunderstood by the local people directly, poor institutional and management factors were the root causes for no any intervention taken yet for *P. polyphlla* in Panchase. It is the need of time to draw the attention of all the concerned stakeholders about this wonder herb. Immediate approaches are required for the long-term conservation, promotion and utilization of *P. polyphylla*.

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ANNEX 1 : Paired Comparison of the Interventions for Minimizing Illegal Collection

Interventions	Key Informants (KI1- KI13)													Total Score	Rank
	KI1	KI2	KI3	KI4	KI5	KI6	KI7	KI8	KI9	KI10	KI11	KI12	KI13		
1.Legal permit required for collection	2	3	1	1	2	3	1	1	2	1	1	1	4	23	4th
2. Regular monitoring and patrolling of the forest	4	1	4	3	3	1	4	4	3	3	4	3	1	38	2nd
3. Supporting local people (commercial cultivation and domestication)	1	4	3	4	4	2	3	2	4	4	3	4	2	40	1st
4. Reward and punishment mechanism	3	2	2	2	1	4	2	3	1	2	2	2	3	29	3rd

ANNEX 2 : Paired Comparison of the Interventions for Eradication of Unscientific/Unsustainable Harvesting

Interventions	Key Informants (KI1-KI13)													Total Score	Rank
	KI1	KI2	KI3	KI4	KI5	KI6	KI7	KI8	KI9	KI10	KI11	KI12	KI13		
1. Extension activities (Training, Awareness, Orientation)	4	4	3	4	3	2	4	4	3	4	4	3	4	46	1st
2. Demo plot establishment and entry restriction	1	2	1	2	4	1	1	3	4	1	3	4	2	29	3rd
3. Local people participation and co-operation	3	3	2	3	1	4	3	2	2	2	2	1	3	31	2nd
4. Stock of seeds keeping in forest and let disperse naturally	2	1	4	1	2	3	2	1	1	3	1	2	1	24	4th

ANNEX 3 : Paired Comparison of the Interventions for Control of Open Grazing

Interventions	Key Informants (KI1-KI13)													Total Score	Rank
	KI1	KI2	KI3	KI4	KI5	KI6	KI7	KI8	KI9	KI10	KI11	KI12	KI13		
1. Controlled grazing or Rotational Grazing	2	2	4	4	3	3	3	2	3	1	2	3	2	34	2nd
2. Forest guards in all entry points	1	4	2	1	2	2	1	3	2	3	1	4	3	29	3rd
3. Hybridization	3	1	1	2	1	1	4	1	1	2	4	1	1	23	4th
4. Alternative programs (plantation of fodder species in CF, construction of improved sheds, etc.)	4	3	3	3	4	4	2	4	4	4	3	2	4	44	1st

ANNEX 4 : Paired Comparison of the Interventions for Mitigating the Impacts of Climate Change

Interventions	Key Informants (KI1-KI13)													Total Score	Rank
	KI1	KI2	KI3	KI4	KI5	KI6	KI7	KI8	KI9	KI10	KI11	KI12	KI13		
1. Plantation of Associated species or Favorable species	4	1	3	2	4	1	3	4	3	2	4	3	4	38	2nd
2. Conservation of Water Sources	3	3	4	3	1	4	2	3	4	4	3	4	2	40	1st
3. Examination of Indigenous Traditional Knowledge	2	2	1	1	2	2	1	1	1	3	1	2	1	20	4th
4. Control of Invasive species	1	4	2	4	3	3	4	2	2	1	2	1	3	32	3rd

ANNEX 5 : Paired Comparison of the Interventions for Improving Poor Institutional Mechanism

Interventions	Key Informants (KI1-KI13)													Total Score	Rank
	KI1	KI2	KI3	KI4	KI5	KI6	KI7	KI8	KI9	KI10	KI11	KI12	KI13		
1. Approval of OP of PPF Main Council and its proper implementation	4	1	4	2	1	4	1	1	4	2	3	3	4	34	1st
2. Enrollment of sufficient number of staffs and discouraging high staff turn over	1	2	3	1	3	1	4	3	2	3	1	4	2	30	4th
3. Inclusion of MAPs related activities in OP of PPF	3	3	2	3	2	3	3	2	1	4	2	2	3	33	2nd
4. " ***Chori Sikari tatha Jadibuti Taskari Niyantran Ikai"*** working effectively	2	4	1	4	4	2	2	2	3	1	4	1	1	31	3rd