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Master thesis

Conservation and sustainable use of medicinal
plants - a case study on five commercially
important wild species in Nepal

Bevaring og bærekraftig bruk av krydder og medisinerplanter – et casestudie på fem
kommersielt viktige viltvoksende arter i Nepal

Master in Sustainable Agriculture

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List of Abbreviations

ACAP	Annapurna Conservation Area Project
BARDAN	Biodiversity Associates for Research, Development and Action–Nepal
CAMP	Conservation Assessment and Management Prioritisation
CFUGs	Community Forest User Groups
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DADO	District Agriculture Development Office
DFO	District Forest Office
DoF	Department of Forests
DPR	Department of Plant resource
FNCCI	Federation of Nepalese Chamber of Commerce and Industry
GACP	Good Agriculture and Collection Practice
GAP	Good Agriculture Practice
GoN	Government of Nepal
HH	House Hold
HPPCL	Herbs Production & Processing Co. Ltd.
IUCN	International Union for Conservation of Nature
KATH	National Herbarium and Plant Laboratories
MAPs	Medicinal and Aromatic Plants
masl	Meter above sea level
NARC	Nepal Agricultural Research Council
NEHHPA	Nepal Herbs and Herbal Products Association
NGOs	Non-Government Organizations
NTFPs	Non-Timber Forest Products
WHO	World Health Organization

English summary (abstract)

Globally, medicinal and aromatic plants (MAPs) are considered as valuable sources for producing drugs. However, wild populations are vanishing at a high speed due to destructive harvesting and habitat destruction. The study focuses on conservation and sustainable use of such plants in Nepal, focusing on five commercially important wild or semi-wild species: *Ophio-cordyceps sinensis*, *Nardostachys grandiflora*, *Dactylorhiza hatagirea*, *Rauvolfia serpentina*, and *Cinnamomum tamala*. The objectives were twofold. Firstly, to map the status and challenges in the conservation and use of the targeted plants in concerned districts. Secondly, to highlight the importance of conserving indigenous knowledge on the plants and their habitats. Despite the presence of various sets of recommendation and strategies for conservation and sustainable use, governmental and non-governmental organizations have failed to make a significant impact on the topic. Wild medicinal plants are still threatened in Nepal, although there are various conservation actions, i.e. botanic gardens and natural reserves. Conservation of traditional knowledge through documentation and oral transfer from one generation to the next is important. In this way, people can actively take part in the conservation of the plants. Questionnaires, group discussions and interviews were conducted in three regions of Nepal and included 80 stakeholders and 10 experts involved in conservation, harvesting, cultivation and trade of MAPs. In addition, a review of databases, reports and scientific papers was included. The results emphasized that conservation strategies like (i.e. *In-situ*, *Ex-situ* and cultivation practices) and resource management approaches (i.e. GACP and sustainable use method) should be applied for the conservation and sustainable use of the targeted medicinal plants. A biotechnical approach like *In-vitro* technique can play an important role by complementing conservation actions but also by helping commercial cultivation by providing mass disease free planting material. Such biotechnical approach can be used to more species and could be especially valuable in a country like Nepal, which is poor and generates considerable amount of income through MAPs trade. Moreover, advantage of diverse climatic condition and profound diversity in the MAPs can help the country and the MAPs stakeholders to generate economic profit through commercialization of the plants.

Keywords: conservation strategies, cultivation, in vitro technique, medicinal and aromatic plants, natural reserves, over harvesting, rotational harvesting, sustainable use, traditional knowledge.

Norwegian summary

Globalt sett oppfattes krydder og medisinvekster (ofte kalt aromatiske vekster, også forkortet MAP) som verdifulle for framstillingen av medisin. Men ville populasjoner av plantene forsvinner i rask takt, mye på grunn av destruktiv høsting og ødeleggelse av naturlig vokseplasser. Denne oppgaven fokuserer på bevaring og bærekraftig bruk av denne typen viltvoksende planter i Nepal og med fokus på fem arter som er kommersielt viktige i landet: *Ophio-cordyceps sinensis*, *Nardostachys grandiflora*, *Dactylorhiza hatagirea*, *Rauwolfia serpentina*, and *Cinnamomum tamala*. Målet med oppgaven er todelt. For det første, å kartlegge status og utfordringer knyttet til bevaring og bruk av nevnte plantearter i utvalgte områder i Nepal. For det andre, å løfte fram betydningen av tradisjonell kunnskap knyttet til bevaring og bruk av viltvoksende planter som finnes hos lokalbefolkningen i landet. Til tross for at anbefalinger og strategier for bevaring og bærekraftig bruk finnes, har ikke offentlige og frivillige organisasjoner lykkes med å endre på forholdene. Viltvoksende populasjoner er fortsatt truede i Nepal, selv om det skjer noe, for eksempel gjennom bevaring i botaniske hager og naturreservater. Bevaring av tradisjonell kunnskap via dokumentasjon og muntlig overlevering fra en generasjon til neste er viktig. På denne måten kan folk ta aktiv del i bevaringsarbeidet. Spørreundersøkelser, gruppediskusjoner og intervjuer ble gjennomført i tre regioner i Nepal og inkluderte 80 lokale aktører og 10 eksperter involvert i bevaring, høsting (innsamling), dyrking og handel med krydder og medisinvekster. I tillegg ble det gjennomført et litteraturstudie av databaser, rapporter og vitenskapelige artikler. Resultatene understreker at både bevaringsstrategier (som *in situ*, og *ex situ* bevaring men også aktiv dyrkning) og god ressursforvaltning (som bærekraftig høsting) burde inngå i arbeidet med bevaring og bærekraftig bruk av de aktuelle planteartene. Bioteknologiske metoder som *in-vitro* teknikk burde kunne bidra positivt ved å fremme en kommersiell produksjon og oppformering av sykdomsfritt plantemateriale. Slike metoder burde kunne brukes til mange arter og kan være særlig aktuelt i et land som Nepal som er fattig og hvor handel med aromatiske planter har stor betydning. Videre finnes et stort spenn i klimatiske soner og en utstrakt variasjon av aromatiske plantearter, noe som skulle kunne hjelpe landet og involverte aktører i dra nytte av dette til å generere økonomisk profitt gjennom kommersialisering.

Nøkkelord: aromatiske planter, bevaringsstrategier, bærekraftig bruk, dyrking, *in vitro* teknikk, medisinplanter, naturreservat, overhøsting, rotasjonshøsting, tradisjonell kunnskap

1. INTRODUCTION

1.1 Background

Nepal is a landlocked mountainous country between China and India, covering 14.7 million hectares of land with 800-850 km from east to west and 140-240 km from north to south, with latitudes from 26 to 30° N and 80 to 88° E. The land is very variable with elevation ranging from 59 m a.s.l. in the lowland of Terai to 8848 m a.s.l. at the Mt. Everest, this only within a 150-200 km distance. Nepal is divided into five physiological zones; Terai (lowlands), Siwaliks (hills), Middle-mountains, High-mountains and High-Himalayan range (Kanel, Kunwar, Bhattarai, & Baral, 2017). Due to this big variation, Nepal, compared to its size, is rich in biological diversity. The country covers a significant share of the global diversity despite having only 0.09% of the global land area (Bhujju, Shakya, Basnet, & Shrestha, 2007; Shrestha, Shrestha, & Shrestha, 2010).

1.2 Importance of medicinal plants

“Medicinal plants have been the subjects of man’s curiosity since time immemorial” (Constabel, 1990). Globally, medicinal plants are considered important sources for producing new medicines (Chen et al., 2016; Nalawade, Sagare, Lee, Kao, & Tsay, 2003). In Europe more than 1300 medicinal plants are used and 90 % of the medicinal plants are harvested from the wild. Natural sources also play crucial role in the United States medical field, where out of top 150 prescribed drugs 118 are based on natural sources (Balunas & Kinghorn, 2005; Chen et al., 2016). Similarly, 80 % of the human population in the developing countries fully rely on herbal medicine for primary health care, while in the developed nations 25 % of prescribed drugs are extracted from wild plants (Chen et al., 2016; Hamilton, 2004). Furthermore, 85 % of the traditional medicines used in developing countries are from plant extracts (Vieira & Skorupa, 1992). The traditional medicinal formulation comprises of medicinal plants that can be used either directly or in the form of powder, decoctions, juice and pastes. Depending upon the disease treated, they are either administered orally or topically (Rahmatullah et al., 2011). For e.g. *Ophiocordyceps sinensis* is popular in traditional Chinese medicine and traditional Tibetan medicine (Chen et al., 2010). The major traditional medicinal system in Nepal is Ayurveda. People in rural areas of Nepal use *Ophiocordyceps sinensis* with milk and honey as tonic and aphrodisiac. Meanwhile, some twelve years back in time, 80 %

of the people in Nepal relayed upon local healers and Ayurvedic medicine, and the main reasons were that these treatments were cheaper and more easily available than modern pharmaceuticals and health care (Kunwar, Nepal, Kshhetri, Rai, & Bussmann, 2006).

According to the World Health Organization (WHO), medicinal plants have a high demand in the world at present, estimating the economic value of the plant products to about US \$ 14 billion/year (Sharma & Thokchom, 2014). The demand for raw material is growing at the rate of 15-25 % yearly and WHO has estimated that the demand for medicinal plants is probably going to cross US \$ 5 trillion in 2050 (ibid). Medicinal and aromatic plants (MAPs) plays a crucial role in Nepalese economy, with its export of the plants to countries like India, China, Singapore, Japan, Germany, France, Switzerland, Netherlands, Canada, USA and others. Thus, MAPs have a potential to contribute to the local economy and to improve livelihood. However, there are challenges in the natural resource management. Here, the economic value of MAPs may serve as a driving force for a proper conservation of the plants but the economic value can also be a treat causing overutilization of local habitats and biodiversity (Subedi, 1997; Subedi, 2004). A sustainable use is a prerequisite for a positive development. Due to increasing demand of natural products (i.e. plant based cosmetics, dyeing and colouring agents, food supplements, drugs, etc.), both from inside the country and from the international market, especially from Indian and Chinese aromatic and pharmaceutical industries, the value and volume of MAPs trade is rapidly increasing in Nepal. The national export value of MAPs and products is estimated to more than US \$ 30 million (Kanel et al., 2017; Olsen, 2005). Annual income of MAPs collectors in Nepal is estimated roughly to range from 11 million US \$ to 35 million US \$ (ibid). Around 470,000 households are involved in collection of wild plants in Nepal, generating 8-25 % of these households' incomes (Kanel et al., 2017; Olsen, 1998). Due to such an importance, MAPs have been identified as potentially high value products in Nepal, having huge prospects for the development of the country. Thus, the government of Nepal (GoN) has given priority to the MAPs subsector in its policies and programs by setting an aim to minimize poverty while conserving biodiversity. In this regard, GoN has prioritized around 30 species of MAPs that are having high commercial or development value for the country (MoFSC, 2017).

1.3 Worldwide diversity

On a global scale, more than 10 % of the plant species are used for medicinal purpose, i.e. for drugs and health product, which means that more than 50,000 species around the world are being used in one way or another as medicine. Nevertheless, there is non-uniformity in the distribution of medicinal plants (Chen et al., 2016; Huang, 2011; Rafieian-Kopaei, 2012). China and India have the highest number of plant species identified to be used as medicine, with around 11,000 and 7500 such species found within its borders, respectively, Also Colombia and a few other countries, including Nepal, have a high number of medicinal plants (Figure 2). The percentage of medicinal plants (among all species) is ranging from 7 % to 44 %, with the highest percentages for India (Chen et al., 2016). Certain families of plant have high numbers of medicinal plants and also a high number of threatened species compared to other families (Huang, 2011). In Nepal, more than 700 plant species are considered to have medicinal value. Among them, 238 are in active use and 100 of these are of commercial value and are extensively traded (Kunwar, Ansari, & Luintel, 2009; Shrestha & Das, 2008; Subedi, 2006).

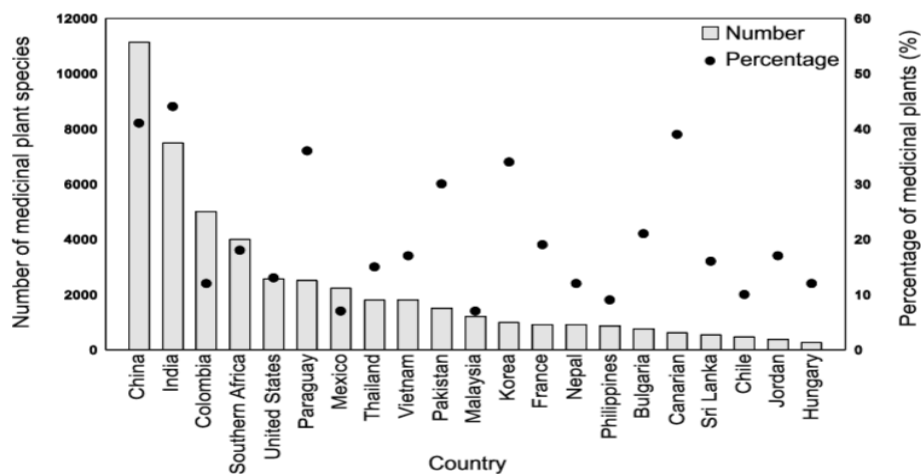


Figure 1 Medicinal plant species of different countries with number and percentage. The dot represents the % of medicinal plants compared with the total no. of plant species and the light bars represent the no. of medicinal plant species. (Source: (Chen et al., 2016).)

1.4 Need for conservation

The current estimated loss of plant species is known to be 100 – 1000 times higher than the natural extinction rate and humankind is losing at least one potentially important drug every second year (Pimm, Russell, Gittleman, & Brooks, 1995). According to the study of International Union for Conservation of Nature (IUCN) and the World Wildlife Fund (WWF), globally there are 50,000 – 80,000 flowering plants that are having medicinal use. Among these, due to habitat destruction and overharvesting, about 15000 species are being subjected towards threatened category, and many of them with the risk of extinction (Bentley, 2010). Due to growth in human population and in plant consumption, it is estimated that 20% of the wild plant resources are in danger (Ross, 2005). Although such threats have been known for long time, the world is unable to halt the loss of species and habitat destruction. The process has led to extinction of medicinal plants, particularly in China (Heywood & Iriondo, 2003; Nalawade et al., 2003), but also in India (Hamilton, 2008; Heywood & Iriondo, 2003), Nepal (Hamilton, 2008), and Kenya, Tanzania and Uganda (Zerabruk & Yirga, 2012). Similarly, the volume of harvested plant mass taken from wild population is increasing. In recent decades, the amount has increased by 8-15 % in North America, Europe and Asia (Bentley, 2010; Ross, 2005). If the population of any species goes below threshold level, then the reproductive capacity gets irreversibly reduced (Semwal, Saradhi, Nautiyal, & Bhatt, 2007; Soulé, Estes, Miller, & Honnold, 2005). Therefore, a specific conservation approach should be applied for specific species in due time before it is too late.

1.5 Conservation strategies

Different conservation strategies have been formulated for the conservation of medicinal plants. These are briefly described below.

1.5.1 *In situ* conservation

Most of the medicinal plant species are endemic in nature and the characteristic they possess are due to the secondary metabolites present in them with respond to stimuli present in the natural environment, which may be difficult to express in culture conditions (Coley et al., 2003; Figueiredo & Grelle, 2009). *In situ* (on site) conservation of entire communities or populations is important because it helps us to protect complex network of relationship in the environment, including indigenous species and natural communities (Gepts, 2006). It also

increases the diversity in the habitat (Forest et al., 2007) and strengthen the relationship between conservation of the plant resources and a sustainable use of the same resources (Long et al., 2003). Up to date, focus has been given towards establishing protected areas and following ecosystem-oriented conservation rather than species-oriented conservation (Ma, Rong, & Cheng, 2012). Several authors highlight that successful *in situ* conservation must be determined by national or local rules and regulation but also potential adherence of plants in the growing habitats (Soulé et al., 2005; Volis & Blecher, 2010).

Natural reserves and wild nurseries are two typical examples of *in situ* conservation (Coley et al., 2003; Sheikh, Ahmad, & Khan, 2002).

Natural reserves: They are components of protected areas established to preserve and rehabilitate biodiversity of important wild resources (Rodríguez, Brotons, Bustamante, & Seoane, 2007). Globally, at present there are more than 100,000 such protected areas, covering 12 % of the earth's land surface (Chape, Harrison, Spalding, & Lysenko, 2005). Government of Nepal (GoN) has focused on *in situ* conservation by inaugurating new protected areas and expanding geographical areas of current protected sites (MoFSC, 2002). Even though more than 23 % of Nepal's area is under legal protection, the country is unable to protect all ecosystems, including all the different forest and vegetation types (Oli & Dhakal, 2018).

Wild nurseries: The main aim of establishing wild nurseries is to conserve by species-oriented cultivation and domestication of threatened and endangered plants. This can be done in or close to their natural habitat, for example in protected areas or nearby from where plant grows naturally (Balunas & Kinghorn, 2005; Chen et al., 2016). Due to habitat degradation, overexploitation and invasive species a lot of wild species population are under high pressure. So, wild nurseries can become an effective approach to conserve medicinal plants that are endangered, endemic and in high demand (Chen et al., 2016; Li & Chen, 2007).

1.5.2 ***Ex situ* conservation**

Ex situ conservation is an effective complement to the *in-situ* conservation when it comes for the conservation of medicinal plants which are endangered and overexploited along with low abundance, slow growth and high susceptibility towards replanting diseases (Hamilton, 2004; Havens, Vitt, Maunder, Guerrant, & Dixon, 2006). It helps in continual survival of threatened species. Sometimes *ex situ* conservation can be combined with production of large volume planting material to produce drugs. So, it is often considered as an immediate action to sustain

the survival of threatened medicinal plant species (Chen et al., 2016; Swarts & Dixon, 2009). The environment may be far away in this case and different from naturally growing habitats. Furthermore, within-species genetic diversity is a challenge to maintain in small garden systems. Nevertheless, their reproductive materials can be selected and stored for future replanting (Hamilton, 2004).

Botanic gardens: They play vital role in *ex-situ* conservation (Havens et al., 2006) and can maintain the ecosystem to strengthen the survival of threatened and endangered species (Chen et al., 2016). It involves a broad variety of species grown together under same conditions, consisting of ecologically and taxonomically diverse flora (Primack & Miller-Rushing, 2009). Conservation of medicinal plants can be achieved through botanical garden by developing protocols for propagation and cultivation. They can also initiate programs for variety breeding and domestication (Maunder, Higgins, & Culham, 2001). In Nepal there is such activities for example in the botanical garden in Godawari, Lalitpur. The National botanical garden (KATH) is also actively involved in conserving plant genetic resources and research (Kanel et al., 2017).

Seed banks: This is a way of storing and preserving the genetic diversity of plants in form of seeds stored under optimal conditions (usually ultra-dried seeds kept in sealed bags at sub-zero temperatures). The system was established for conservation of the diversity of crop plants used in agriculture but has also been used for wild plants (Li & Pritchard, 2009; Schoen & Brown, 2001). The most notable seed bank for wild plants is the Millennium Seed Bank located in Britain (Schoen & Brown, 2001). It provides relatively fast access to the plant samples to evaluate their properties and gain useful information for the conservation of persisting natural populations (Li & Pritchard, 2009; Schoen & Brown, 2001). The most challenging job of seed banks is to reintroduce plant species back into natural habitat and help in the restoration of wild population (Li & Pritchard, 2009). So far, there are few seed banks doing such restoration actions.

***In vitro* culture and cryopreservation:** Though conservation of species is most effective via *in-situ* conservation, there are many medicinal plants that either do not produce seeds or the seeds are too small or weak to germinate under natural conditions. In addition, plant produced from seeds are most likely to be highly heterozygous, that leads to big variation in properties such as size, shape and colour. For production purposes, and for some plants, such variation is not acceptable in commercial markets. Most plants are not susceptible to vegetative

propagation, thereby limiting the mass multiplication of desired plant types. On the top, many plants propagated by vegetative methods contain systemic bacteria, viruses and fungi that may have negative impact on the quality and appearance of nominated items (Sharma & Thokchom, 2014). To overcome these disadvantages, *in vitro* technique can be implemented to complement *in situ* conservation methods, and in some cases it can be the only option (Negash, Krens, Schaart, & Visser, 2001; Sarasan et al., 2006).

Since the 1960s, the use of *in vitro* culture has been popular around the world but the start of *in vitro* culture in Nepal began after the establishment of Tissue Culture Laboratory under Department of Plant Resource (DPR) in 1976, at Godawori, Lalitpur. Later, in 2000 Biotechnology laboratory was established in DPR Thapathali, Kathmandu. Since then only 111 economically important medicinal, ornamental, horticulture and tree species have been propagated by *in vitro* labs in Nepal. Among them there were only 13 medicinal plants involved (DoPR, 2013).

Cryopreservation is the technique to preserve structurally intact living cells and tissue by using very low temperatures (Morris, 1981). Cryopreservation of plant cells, tissues, meristem and other organs represents an important technique for the long term preservation of experimental material and plant germplasm without alteration in the genetic makeup (Sakai, Kobayashi, & Oiyama, 1990). So far, cryopreservation is not common, neither in Nepal, nor in most other countries, but the technique should be applied for the long storage of culture materials (Sarasan et al., 2006).

1.5.3 Cultivation practice

Although quality of medicinal plants produced from cultivation may be less efficacious than from wild, cultivation is widely popular and generally an accepted practice (Chen et al., 2016; Gepts, 2006). By using different cultivation techniques, problems like misidentification of botanical origin, level of toxic components, low content of active ingredients, or pesticide contamination can be solved. Cultivation of medicinal plants under controlled growth conditions can ameliorate the yields of active compounds and create production stability. It also decreases the pressure on wild plant populations, which will give such populations time for recovery. Successful production will also most likely decrease the market price of the plants (Chen et al., 2016).

Good agricultural practices (GAP) for medicinal plants have been implemented in different countries around the world. It covers broad items like ecological environment of production sites, cultivation, collection, germplasm, quality aspects of detecting pesticides, macroscopic/microscopic authentication, inspection of metal element and chemical identification of bioactive compounds. The GAP approach, if correctly carried out, should ensure high quality products, regulate production, and facilitate a standardization of herbal drugs by using available knowledge (ibid). In Nepal, Good agriculture and collection practices (GACP), i.e. combining GAP and Good collection practices (GCP), have been developed for some medicinal plants to help and promote farmer and entrepreneur in commercialization of the plants.

1.5.4 Sustainable use

Destructive harvesting causes resource exhaustion and may even result in species extinction, particularly for those medicinal plants with slow growth and low abundance (Larsen & Olsen, 2007). Therefore, sustainable use of medicinal plants and good harvesting practice should be established. Harvesting can be really destructive when medicinal plants roots are harvested (Manandhar, 1990). An approach where leaves are harvested, instead of roots or the whole plants, can be a sustainable strategy. For e.g. a study discovered that the pharmacological activities are same for ginseng extracts from root parts and ginseng extracts from leaves and stems. Therefore, harvesting and using wild ginseng leaves and stems and not the roots could act as a potentially sustainable resource management practice (Wang, Peng, & Xie, 2009). Such an approach is one of the most important conservation strategies for many of the wild harvested species. Strategies like selective harvesting (only 50-75 % of the stock), post matured harvesting and rotational harvesting (5 years) are other strategies for sustainable harvesting (Kanel et al., 2017). The concept of dividing a plot or area into five blocks and harvesting the subsequent block year wise is shown in Figure 2.

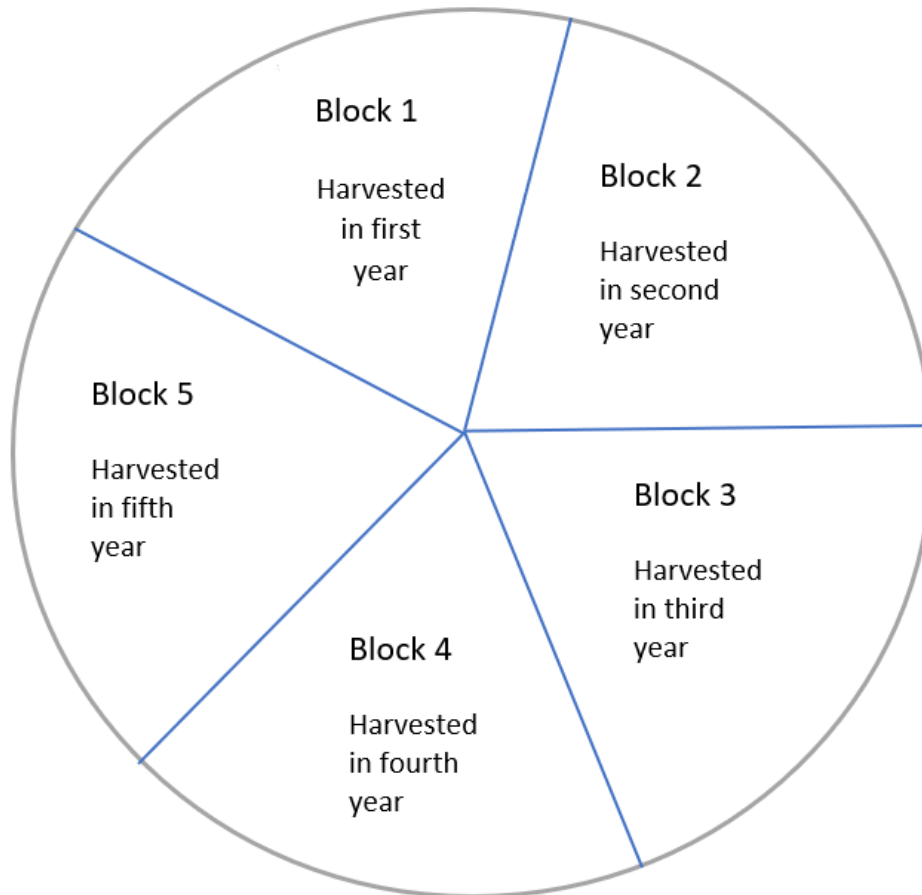


Figure 2 Rotational harvesting guide Reconstructed from (Pyakurel & Baniya, 2011).

1.6 Rationale of the study

Nepal is rich in biodiversity and there are significant plant species that are harvested for medicinal purpose. Due to the commercial value of medicinal plants they are overharvested in the wild. Different problems arise in conservation of medicinal plants due to various factors like destructive harvesting, habitat degradation and climate change. Despite, the presence of many conservation strategies prevalent in Nepal, GoN has failed to make significant impact in the conservation of threatened medicinal plants. So, the study mainly focused on the factors that create problems in conservation and strategies in action by GoN to conserve threatened medicinal plants. By selecting five commercially important medicinal plants, the study tries to depict the true picture of all threatened medicinal plants in Nepal. The objectives were set accordingly, so that the study can be beneficial for developing future strategies for the sustainable conservation of medicinal plants.

1.7 Objectives and research questions

The main objectives of the study were:

- i) To map the status, challenges and to find the optimal conservation strategies (*In-situ* and *Ex-situ*) of targeted medicinal plants in concerned districts and other part of the country, and
- ii) To highlight the importance of conserving indigenous knowledge towards conservation of plant genetic resources from local people in Nepal.

The study was conducted to give information on one main research question: What should be done for the effective conservation of threatened medicinal plants in Nepal? The sub-questions were:

- a. What approaches are taken into action by GoN to conserve threatened species of medicinal plants?
- b. Which strategical improvements are necessary to take for an effective conservation of medicinal plants?
- c. How do stakeholders look upon challenges in conservation and use of the plants in a sustainable way?
- d. How can traditional knowledge be beneficial for the effective conservation of medicinal plants?

2. MATERIALS AND METHODS

2.1 Selection of target species

Five medicinal herbs and plants found in wild condition in Nepal were selected for the study; i.e. *Ophio-cordyceps sinensis*, *Nardostachys grandiflora*, *Dactylorhiza hatagirea*, *Rauvolfia serpentine*, *Cinnamomum tamala*. The species were selected because they are commercially important MAPs of Nepal, and with population that is expected to be decreasing in the wild. In addition, one semi-wild species, *Cinnamomum tamala*, was selected to provide a clear difference in the conservation approach compared to the wild species.

2.1.1 *Nardostachys grandiflora* Wall. ex DC.

Nardostachys grandiflora (family Caprifoliaceae) commonly known as “Spikenard” is herb found from 3200-5000 masl. Roots and rhizome are the used parts for medicinal purpose. It is the only species found in Nepal under this genus and popularly known as “Jatamansi” (Kanel et al., 2017).

2.1.2 *Dactylorhiza hatagirea* (D.DON) Soó

Dactylorhiza hatagirea (D.DON) Soó (family Orchidaceae) commonly known as “Marsh Orchid” is a perennial herb found from 2800-4600 masl. It is popular by the name “Panchaule” in Nepal. Tuberous root is the used part for medicinal purpose (Kanel et al., 2017).

2.1.3 *Ophiocordyceps sinensis* (Berk.) G.H.Sung, J.M.Sung, Hywel-Jones & Spatafora

Ophiocordyceps sinensis (family Ophiocordycipitaceae) commonly known as “Chinese Caterpillar Fungus” or “Yartsa gunbu” (meaning winter worm and summer grass in Tibetan language) is found from 3500-5200 masl. It is a combined life form of caterpillar and fungus (the base is the caterpillar and upper part is the fungus). The life cycle is quite complex. When a matured fungus spore infects the caterpillar of ghost moth in soil (in August) and it grows under snow in winter, the fungus will fill the caterpillar core by budding and give rise to cylindrical stroma of fungus above the ground in early spring (Sigdel, Rokaya, Münzbergová, & Liang, 2017). There are 310 species of cordyceps found in the world, but only 3 has

medicinal importance (*C. sinensis*, *C. militaris*, *C. barnesi*). Nepal has only 3 species of cordyceps and popularly known as “Yarsagumba” (MoFSC, 2017).

2.1.4 *Rauvolfia serpentina* (L.) Benth. Ex Kurz

Rauvolfia serpentina (family Apocynaceae) commonly known as “Devil Pepper” or “Snakeroot” is found from 100-900 masl. Root, root with bark and leaves are the used parts for medicinal purpose. It is popularly known as “Sarpagandha” in Nepal. (Shrestha, Swar, & Bhattarai, 2013).

2.1.5 *Cinnamomum tamala* T.Nees & Eberm

Cinnamomum tamala T.Nees & Eberm (family Lauraceae) commonly known as “Cinnamon Leaf” or “Indian Bay Leaf” is found from 100-2500 m a.s.l. in Nepal. Bark and leaves are the used parts for spices and medicinal purpose. It is popularly known as “Tejpat” or “Dalchini” in Nepal. It is available from east to west in Nepal and in many parts of the country it is commercially cultivated (MoFSC, 2017).

2.2 Site selection

Three districts; Jumla (Chandannath 3 and 4), Mustang (Thini and Syang village), and Chitwan (Bijayanagar and Bangai village) were selected for the study of these targeted species. They are represented by green, yellow and red dots in the map (Figure 3), respectively. Two village from each district were selected for the study.



Figure 3 Map of Nepal showing the study district (Source: ("Nepal administrative and political province vector map with flag", 2018).)

Jumla is one of the districts from province no. 6, which is located between $82^{\circ}57'E - 82^{\circ}18'E$ longitude and $28^{\circ}58'N - 29^{\circ}30'N$ latitude and is in the Mid-Western region of Nepal. It is a mountainous region where the elevation ranges from 2134 to 6424 masl. (MoAD, n.d.).

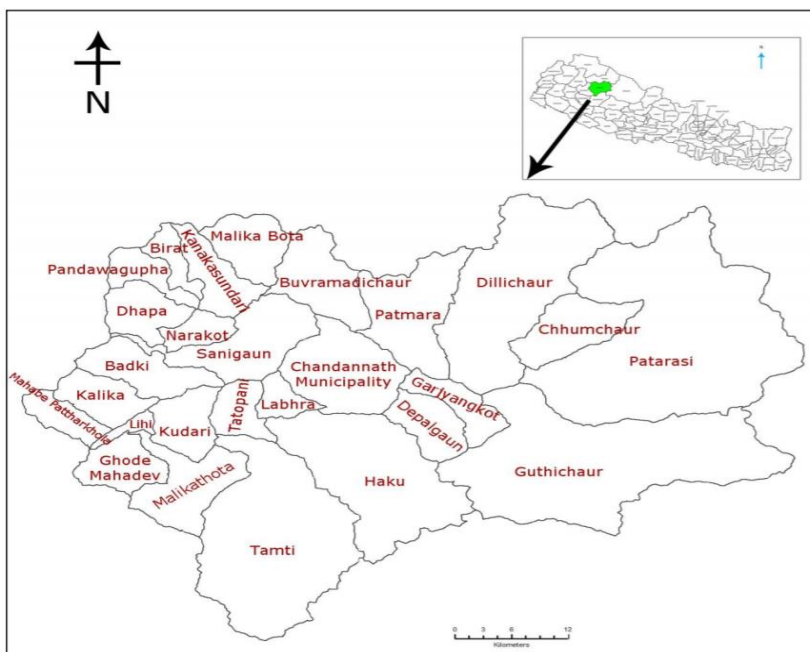


Figure 4 Map of Jumla District (Source: (MoAD, n.d.))

Chitwan is one of the districts from province no. 3, which is located between 27°21'N - 27°52'N latitude and 83°55'E - 84°48'E longitude. It occupies an area of 2,218 km². The elevation ranges from 144 – 1945 masl. (ibid).

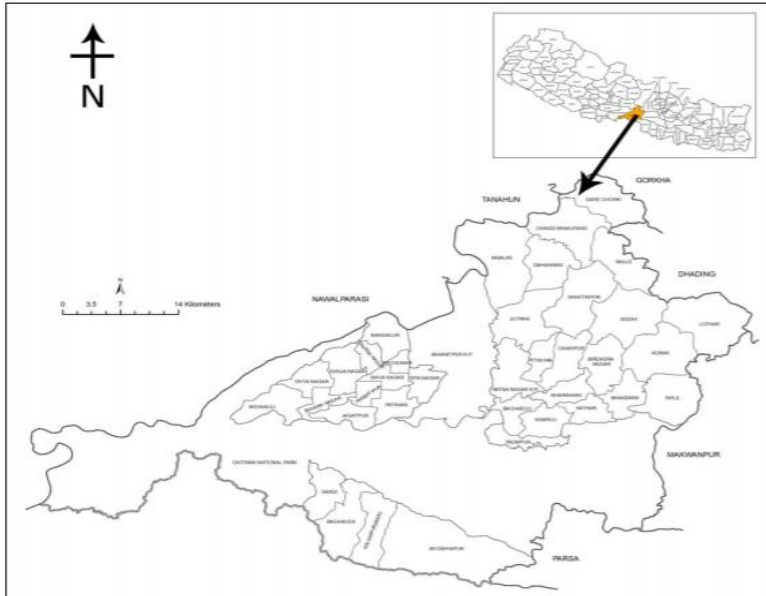


Figure 5 Map of Chitwan District (Source: (ibid))

Mustang is one of the districts from province no. 6, which is located between 28°20'N - 29° 05'N latitude and 83° 30' to 84° 15' E longitude. It occupies an area of 3573 km². The elevation ranges from 2000 - 8,167 (to the highest peak of Mt. Dhaulagiri) masl. (ibid).

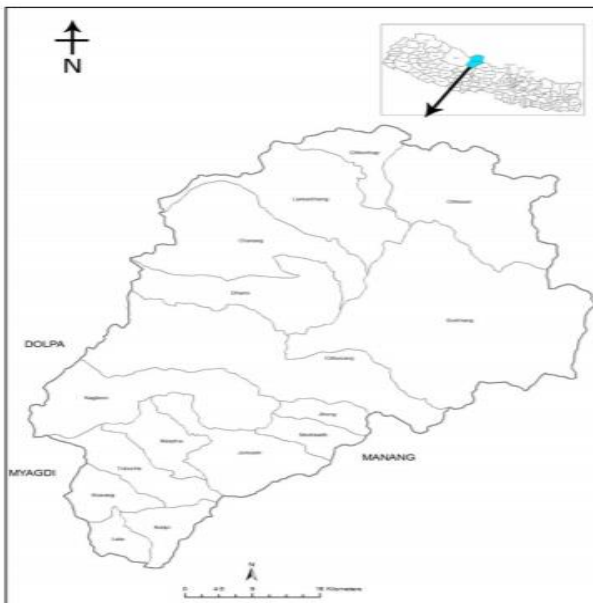


Figure 6 Map of Mustang District (Source: (ibid))

2.3 Sampling methods and data analysis

A simple random sampling method was used in the survey to sample the n population from the entire population of the targeted area. In total, 80 farmers/households (HH) (i.e. 21 HH from Chitwan, 25 from Jumla and 34 from Mustang) were randomly selected for the survey. In addition, 10 agricultural or botanical experts from different institutions (mainly governmental) in Nepal were interviewed. The institutions involved were Department of Plant Resource (DPR), 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).

Data collection: Various techniques and sources were used to collect necessary information. Both the primary data and secondary data were collected and analysed in this study.

Primary data collection: The primary data that are required for the study were obtained from the HH survey and the expert interviews, using two different sets of semi-structured questionnaires, one for the HH survey and one for the expert interviews (Appendix 5.2). The semi-structured questionnaires were prepared, pretested in the periphery of proposed VDCs, then the questionnaire was improved and finalised. A focus group discussion (FGD) was conducted in each study site after the completion of the survey to verify the results obtained from the survey and to provide supplement to the data. The FGD comprises of people from different ethnic groups, different ages and different genders, focusing on major variables like level of knowledge on medicinal plants, use of targeted medicinal plants for prevention and treatment purposes, harvesting patterns, harvesting purposes, conservation efforts from their level, challenges to conserve the targeted species, things to be done to overcome these challenges etc. The people who were collectors and were interested in the discussion were selected for FGD. Some people from the survey and some not involved in the survey were included in the discussion.

Secondary data collection: Secondary data were collected from different publications, research papers and global databases as GBIF (2018). Additional information's were collected from Central Bureau of Statistics (CBS), Department of Forest (DoF), District Forest Office (DFO), Ministry of Agriculture and Livestock Development (MoALD).

Data analysis: The collected data were coded, entered in Excel spreadsheets (Microsoft, USA), and analysed through chi-square tests using the relevant functions in the software. The chi square tests were carried out in eight different analysis to test the various hypothesis. Null hypothesis (H0) and alternative hypothesis (H1) were formulated to check the independence of the variables involved in the test through chi-square statistics. Level of significance was set to 0.05. where the chi square value in each test was compared with the critical value (taken from the chi square distribution table at the given number of degrees of freedom and at the given significance level).

3. RESULTS AND DISCUSSION

3.1 Survey results

Below follow the main results from the survey of the 80 persons involved in the harvesting and use of medicinal plants in three regions in Nepal. The results are presented in summary tables referring to how many respondents that replied within each of the categories. The results from the statistical analysis are given as chi-square values (X^2), degrees of freedom (DF), and the P-values from each of the chi-square tests.

3.1.1 Knowledge on medicinal plants

Table 1. Level of knowledge on medicinal plants related to age of the people.

	No	Little	Moderate	High	Very high	Sum
<i>Age category</i>						
<30	3	2	0	0	1	6
30-45	10	19	0	0	0	29
45-60	4	27	2	2	0	35
>60	0	6	3	1	0	10
Sum	17	54	5	3	1	80

Although very few respondents said they had moderate, good or very good knowledge on medicinal plants, the level of knowledge was significantly related to the age of the people ($X^2=36.3$, $DF=12$, $P=0.0003$, Table 1). In general, older people in the target regions had comparatively more knowledge about medicinal plants than the younger.

Table 2. Knowledge on benefits of using medicinal plants related to age of the people

age category	knowledge on benefit of using medicinal plants					SUM
	No	Little	Moderate	High	Very high	
<30	3	2	0	0	1	6
30-45	9	19	1	0	0	29
45-60	4	27	2	2	0	35
>60	0	6	3	1	0	10
Sum	16	54	6	3	1	80

Although, very few respondents said that they had moderate, high and very high knowledge on benefit of using medicinal plants, the knowledge on benefit of using medicinal plants was significantly related to the age of the people ($X^2= 32.4$, $DF= 12$, $P= 0.0011$, Table 2). In general, older people had more knowledge on benefit of using medicinal plants in the target region than the younger.

Similar results were stated in other studies (Estomba, Ladio, & Lozada, 2006; Monteiro, de Albuquerque, de Freitas Lins-Neto, de Araújo, & de Amorim, 2006; Rajakumar & Shivanna, 2010; Upadhyay, Roy, & Kumar, 2007). A study done in Chhotta Bhangal in Western Himalaya also stated that the knowledge on medicinal plants were confined to older age (Uniyal, Singh, Jamwal, & Lal, 2006).

3.1.2 The use of medicinal plants

The use of medicinal plants could be divided into two, for prevention or for treatment.

Prevention use

Table 3. Prevention use of *Ophiocordyceps sinensis* in terai and mountain regions

Region	Use	No use	Sum
Terai	0	21	21
Mountain	7	52	59
Sum	7	73	80

Mountain = Jumla and Mustang, Terai is Chitwan

Although few respondents from mountain region used this species for prevention purpose, the analysis showed that, there was no significant relationship between two variables i.e. availability region does not influence the use of the species for prevention purpose ($X^2= 2.73$, $DF= 1$, $P= 0.098$, Table 3). Though the plant grows in high mountain areas, very few use it for prevention purpose, even in the mountain region. The reason could be the price of the plant that is very high, as stated by respondent Y from Jumla region:

“Before 1992 CS cost 5 Rs/piece (i.e. 0.13 USD) ,2005 62 Rs/piece (i.e. 0.87 USD), now it is 600 Rs/ piece (i.e. 5.88 USD) and People prefer to buy medicines from medical shop over using them for prevention purpose”.

Back in 2012 the cost of *Ophiocordyceps sinensis* (Yarshagumba) was NRs 8-10 lakhs/kg, i.e. around 9000 USD/kg when compared to US dollar (Pyakurel & Oli, 2012). But according to the survey and respondents the recent price could range from around 12,000-14,000 USD/kg in Nepal. In China the cost is approximately 20,000 to 40,000 USD and is known as “soft gold” (Lo, Hsieh, Lin, & Hsu, 2013).

Table 4. Prevention use of *Dactylorhiza hatagirea* in terai and mountain regions

Region	Use	No use	Sum
Terai	0	21	21
Mount	1	58	59
SUM	1	79	80

Mount = Jumla and Mustang, Terai is Chitwan

The result showed that, there was no significant relationship between two variables i.e. availability region did not influence the use of DH for prevention purpose in the targeted region ($X^2= 0.36$, $DF= 1$, $P= 0.54$, Table 4). Though it is found in high mountain areas, negligible number of people use it for prevention purpose. The high price could explain the result. In addition, the plant is sold through illegal channels and it is banned for collection, use and trade in Nepal (MoFSC, 2017).

As demonstrated, very few people use *Ophiocordyceps sinensis* and *Dactylorhiza hatagirea* for prevention, and there was no significant difference between regions in such a use. The same result was observed for the tree and other species (detailed results not shown). Among the answered, they used *Ophiocordyceps sinensis* to give energy and as aphrodisiac, *Dactylorhiza hatagirea* to prevent from worsening the wound, *Nardostachys grandiflora* to prevent from cold and high-altitude sickness and *Cinnamomum tamala* to prevent from cold and as a stimulant). Use of *Cinnamomum tamala* for prevention of cold and as a stimulant was also stated in GACP of *Cinnamomum tamala* (Shrestha, Joshi Bhatta, & Sharma Dhakal, 2015), although *Cinnamomum tamala* is more commonly used as a spice than a medicine (ibid). However, there is no clear-cut differences between spices and medicinal plants, and sometimes also not between prevention and treatment. Many species are used to prevent diseases, and respondents mentioned that *Allium wallichii* Kunth (Ban lasun) is used for gastritis (mentioned by respondents in Mustang and Jumla). Also, *Swertia chirayita* (Roxb. ex Fleming) Karsten (chiraito), *Neopicrorhiza scrophulariiflora* (kutaki), *Acorus calamus* (bojho), Nas (surti+ simpati+ tito) was mentioned as used for common cold, and *Paris*

polyphylla Smith (satuwa) was used against inner pain and asthma. Furthermore, *Artemisia vulgaris* (titepati) was mentioned used for pest control in agriculture (surya mahat).

Use of medicinal plants for treatment purposes

In this section, the use of targeted plants for treatments is in focus.

Table 5. Use of targeted medicinal plants for treatment in different region.

Region	Targeted	No use	Sum
Chitwan	5	16	21
Jumla	22	3	25
Mustang	23	11	34
Sum	50	30	80

The result showed that, there was significant relationship between two variables, which means that the use of targeted medicinal plants for treatment was influenced by region ($X^2= 20.73$, $DF= 2$, $P= 3.14^{E-05}$). The number of respondents that used the plants for treatment were higher for treatment use than for prevention use. The regional differences in treatment use can be explained in different ways. Jumla and Mustang are rural areas lying in the high mountains and in areas less developed in aspects like health facility, transportation etc. The number of collectors were high in these areas, and there was a general lack of employment opportunities and a lower purchasing power of people there. Furthermore, most of the targeted species are found in Jumla and Mustang. The result is in line with other studies that have shown that the use of traditional medicine is more common in rural areas compared to more urban areas (Hossan et al., 2010; Rahmatullah et al., 2009).

The respondents in the study areas highlighted the following purposes for using the targeted medicinal plants as treatments:

Targeted species	Medicinal use
<ul style="list-style-type: none"> • <i>Ophiocordyceps sinensis</i> 	Weakness and aphrodisiac
<ul style="list-style-type: none"> • <i>Nardostachys grandiflora</i> 	fever, cough, headache, indigestion, high altitude sickness, dried leaves as incense (tenzin xekyap)

-
- *Dactylorhiza hatagirea* diarrhoea, dysentery, aphrodisiac, control bleeding and as disinfectant in wounds, stomach trouble
 - *Rauwolfia serpentina* stomach pain, maintain high blood pressure, kill worms and snake bite
 - *Cinnamomum tamala* stomach pain, diarrhoea, piles, scabies (Z respondent, Jumla)

Among the free answers, where the respondents could mention other medicinal plants and their use, the following was the commonly used medicinal plants in the study areas:

- *Pleurospermum hookeri* C.B. Clarke (Ganaino) - diarrhoea and indigestion
- *Gossiypium arboretum* (Ruwa saag) – diabetes, common cold, excessive bleeding
- *Iris decora* Wall. (Ninaijadi) - gum pain
- *Aconitum bisma* (Bikhama) - pain (boil and daily use for 4-5 days)
- *Taxus wallichiana* (Lauthsalla) - used as tea leaves and its oil for cancer
- *Swertia chirayita* (Chiraito) - common cold
- *Neopicrorhiza scrophulariiflora* (Kutaki) - common cold, cough, asthma

The use of *Ophiocordyceps sinensis* for weakness and as aphrodisiac was also mentioned in other studies (MoFSC, 2017; Wang & Yao, 2011; Yong, 2018; Zhu, Halpern, & Jones, 1998). The use of *Nardostachys grandiflora* for the treatment of the above diseases had also been mentioned in the study conducted in Nepal (Kanel et al., 2017). Use of *Nardostachys grandiflora* for indigestion was also mentioned in other study conducted in Nepal (MoFSC, 2017). The similar use of *Nardostachys grandiflora* as incense was also reported (Raina, 2013). The use of *Dactylorhiza hatagirea* as incense was mentioned in (IUCN, 2000; Kanel et al., 2017), and *Rauwolfia serpentina* was mentioned to have a similar use (Shrestha et al., 2013). Use of *Rauwolfia serpentina* for controlling high blood pressure was reported in one of the study conducted in Nepal (Joshi, Dhakal, & Saud, 2017; MoFSC, 2017). The similar use of *Cinnamomum tamala* was mentioned in other study conducted in Nepal (Shrestha et al.,

2015). The use of *Cinnamomum tamala* in Nepal mainly for spice was mentioned in other study (MoFSC, 2017).

3.1.3 Harvesting practice

Table 6. Harvesting versus education level

Education	Harvest	No harvest	Sum
Literate	15	19	34
Illiterate	34	12	46
Sum	49	31	80

The result showed that there was significant relationship between two variables, i.e. harvesting was influenced by education level ($X^2= 7.31$, $DF= 1$, $P= 0.0068$, Table 6). We can see that more illiterate people are involved in the harvesting of medicinal plants than literate. This can be explained by a general lack of employment opportunities for illiterate people in the study area. They may not have alternative sources of income and collect plants to sustain themselves and their families. Various other studies have shown that the poor people are the most dependent one collecting MAPs to sustain their living (Das, 2005; Dold & Cocks, 2002; Quang & Anh, 2006; Sandemose, 2009).

Table 7. Harvester type versus education level

	Sustainable harvesting	Commercial harvesting	Sum
Literate	1	14	15
Illiterate	6	28	34
Sum	7	42	49

The result showed that harvesting type is not influenced by education level ($X^2= 1.02$, $DF= 1$, $P= 0.31$, Table 7). An interesting observation was that the illiterate people were involved in sustainable harvesting, i.e. selective harvesting like harvesting plant parts, harvesting after maturity, leaving some portion of rhizome or root in the soil etc. It may be so due to the transfer of indigenous knowledge about the importance and use of medicinal plants from generation to generation. Furthermore, some people in the study sites were traditional health practitioner commonly known as “Lama” or “Jhakri” in Nepal, who treat patient with traditional/indigenous knowledge. The result correspond well with another study that also

showed that the people having indigenous/traditional knowledge follow a sustainable approach by using selective harvesting rather than the commercial harvesting methods that are more destructive (Ghimire, McKey, & Aumeeruddy-Thomas, 2005). On the other hand, almost every collectors/harvester follow seasonal harvesting patterns for targeted species. This creates a high harvesting pressure to the natural populations for a certain period of the year, and this again may create difficulties for a sustainable harvesting management approach.

3.1.4 Conservation efforts

Table 8. Conservation effort versus medicinal knowledge

	Conservation effort		
	Yes	No	Sum
Pmk	41	22	63
Pnmk	3	14	17
SUM	44	36	80

Pmk- People with medicinal knowledge, Pnmk- People with no medicinal knowledge

The result showed that there was a significant relationship between conservation effort and people's knowledge on medicinal plants, i.e. people with medicinal 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 8). The result was in line to other study which had shown similar result (Lama, Ghimire, & Aumeeruddy-Thomas, 2001). Sustainable harvesting can be linked with conservation effort to conserve targeted medicinal plants. A study reported that people with medicinal knowledge are more likely to follow a sustainable harvesting approach to maintain plants population densities (Ghimire et al., 2005).

3.2 Species information

The following section deals with the conservation status of five selected species and the conservation efforts that has been carried out to conserve them from government level. The information's are based on experts' interviews and literature review.

3.2.1 *Nardostachys grandiflora*

Conservation status

Nardostachys grandiflora Wall. ex DC. is listed as rare by IUCN (2001) and vulnerable by CAMP (2001). There has been a ban on export in unprocessed form of the plant since 2001 by GoN and the plant is listed in Appendix II by CITES. According to the District forest officer from Jumla and ACAP project officer from Mustang, they reported that the trend in the wild population is in decreasing order in the study site. Out of the 62 georeferenced occurrence worldwide, around half of them (30 occurrences) are from Nepal, indicating that the plant is endemic to the area (GBIF, 2018).

Conservation effort

GoN has conservation of the species in protected areas like in Rara National Park in Jumla and Annapurna Conservation Area in Mustang. *In-situ* conservation is also done through protection of forest and grassland and by handing over harvesting rights in governmental forest to communities. Awareness program is also launched by GoN for preventing early harvesting in the wild.

Ex-situ conservation is initiated by GoN through cultivation trials ongoing in Rasuwa, Jumla and Sankhuwasaba districts of Nepal. Non-governmental organizations (NGOs) in Jumla had conducted cultivation trials at low altitude, but they failed. Germplasm of the species is preserved in the gene bank of Nepal. Commercial cultivation and *in vitro* culture are lacking for this species in Nepal.

Similar result for the conservation status and cultivation trial of *Nardostachys grandiflora* has been reported in the study conducted in Nepal (Kanel et al., 2017) and the plant was assessed as vulnerable (Tandon, Bhattarai, & Karki, 2001). The current study showed decreasing trend in wild population in the study sites (Jumla and Mustang). It may be due to overharvesting and habitat destruction. The similar reasons were mentioned in other study about declining population of the species (Raina, 2013). High price of *Nardostachys grandiflora* leads to overharvesting and a population decline in their natural habitats. This is a common reason for overharvesting also for other species (Shrestha & Bawa, 2013). Negative effect on population densities due to overharvesting was also mentioned in one of the study (Ghimire et al., 2005). A study showed that the largest amount of *Nardostachys grandiflora* is harvested from Jumla

district (Kanel et al., 2017). It was also reported that more than 80%, and up to 95 % of the total global export of *Nardostachys grandiflora* is from Nepali origin (Pyakurel & Oli, 2012). However, a study conducted in 20 districts of Nepal showed that there is adequate stocking of *Nardostachys grandiflora* and about 950 tons can be harvested annually, and yields of *Nardostachys grandiflora* rhizomes can increase from 2-2.8 gm/plant to 3.86 gm/plant when CFUG follows a two years rotational harvesting system (Kanel et al., 2017).

To summarize, a detailed status, distribution and stocking population study of *Nardostachys grandiflora* is required throughout the country so that the government can make a concrete decision on conservation, harvesting and trade of the species. This will in the long-run benefit the stakeholders related to MAPs.

3.2.2 *Dactylorhiza hatagirea*

Conservation status

Dactylorhiza hatagirea (D.DON) Soó is listed in Appendix II (CITES), endangered by (CAMP), under forest act 1993 crude drugs are ban for collection, use, sale, distribution and transportation. According to the District forest officer from Jumla and an ACAP project officer from Mustang, they reported that the trend in the wild population is in decreasing order in the study sites. Out of 193 georeferenced occurrences reported worldwide, Nepal is third in the list, covering 25 of the occurrences. There are two botanical types under this species; i.e. *D. hatagirea* var. *doniana* (Soó) Soó and *D. hatagirea* var. *schlaginweitii* (Soó) Soó (GBIF, 2018).

Conservation effort

GoN has followed conservation of the species in protected areas like Rara National Park in Jumla and Annapurna Conservation Area in Mustang. *In-situ* conservation is also done through protection of forest and grassland and by handing over of forest and grassland to communities.

Ex-situ conservation: GoN has made initiatives in *ex-situ* conservation of the species by preserving germplasm in the national gene bank. GoN has also initiated commercial cultivation in Humla, as well as cultivation trails in Jumla, Terathum, Rasuwa and Sankhuwasaba districts. *In vitro* culture is lacking for this species in Nepal.

A recent update of the national conservation status and the various cultivation trials of the species is reported in one of the report (Kanel et al., 2017). Though it is banned for harvesting and trade, it is reported from the experts, that the trend in the wild population is in decreasing order in the study sites. It may be due to illegal harvesting and habitat destruction. Other study has shown that *Dactylorhiza hatagirea* is threatened and the anthropogenic factors (grazing, trampling etc.) have significant negative effects in the habitations (Bhattarai, Pandey, Gautam, & Chhetri, 2014). However, one study showed that there is adequate stocking of *Dactylorhiza hatagirea* in Nepal and that around 17 tons a year can be at a harvested with sustainable harvesting methods without damaging the populations (Kanel et al., 2017). 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 *Dactylorhiza hatagirea*.

3.2.3 *Ophiocordyceps sinensis*

Conservation status

According to the District forest officer from Jumla and an ACAP project officer from Mustang, *Ophiocordyceps sinensis* (Berk.) G.H.Sung, J.M.Sung, Hywel-Jones & Spatafora is conserved but the wild populations of the species are decreasing in the study sites. Out of the 28 georeferenced occurrences reported worldwide, Nepal covers only 2 of the occurrence, which means it is not endemic to Nepal (GBIF, 2018).

Conservation effort

GoN has initiated conservation of the species through protected areas like Rara National Park in Jumla and Annapurna conservation area in Mustang. *In-situ* conservation is also done through protection of forest and grassland. GoN has initiated awareness program against immature collection and GoN has banned export of the species without special authorization and steaming and proper packaging.

Ex-situ conservation: GoN has preserved germplasm in the national gene bank. Research is carried out for promoting *in vitro* culture of the species but so far, this has been unsuccessful in Nepal. There has been successful fungal growth in the laboratory but not any fruiting bodies (Baral & Maharjan, 2012).

Ophiocordyceps sinensis was reported to be not threatened in two of the study sites (Jumla and Mustang) but still the wild population was reported to be decreasing by the experts of concerned districts. 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 (Shrestha & Bawa, 2015). For such a reason, overharvesting can be a treat (Shrestha & Bawa, 2013, 2015; Yong, 2018).

3.2.4 *Rauvolfia serpentina*

Conservation status

Rauvolfia serpentina (L.) Benth. Ex Kurzis listed as endangered (IUCN) or critically endangered (CAMP), Appendix II (CITES). District forest officer from Chitwan reported that the trend in the wild population is decreasing in that study site. Out of the 299 georeferenced occurrences reported worldwide, Nepal covers only 9, meaning that the species is not endemic to Nepal. There are two distinct botanical types of the species; i.e. *Rauvolfia serpentina* var. *gracilis stapf* and *Rauvolfia serpentina* var. *obversa* (Miq.) Bakh.fil. (GBIF, 2018).

Conservation effort

GoN has initiated conservation of the species in protected area like in Chitwan National Park. The *in-situ* conservation is done through protection of forest and handing over of forest to communities. GoN has initiated an awareness program to prevent early or destructive harvesting and export of the plant is banned without further processing.

GoN has preserved germplasm in the national gene bank. Experimental plots have been carried out in KATH Godawari Lalitpur to develop more efficient production of planting materials and initiatives on 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.

Similar result for the conservation status of *Rauvolfia serpentina* has been found in a recent report (Barakoti, 2013). According to the DFO officer, the trend in wild population of the species is decreasing in one of the study sites (Chitwan) and other part of Terai landscape, and this is mainly due to overharvesting and habitat destruction. High price leads to overharvesting and therefore population is declining (Shrestha & Bawa, 2013). Similarly, a study conducted in

India reported that *Rauvolfia serpentina* is threatened with extinction risk due to overharvesting (Dey & De, 2010).

3.2.5 *Cinnamomum tamala*

Conservation status

Cinnamomum tamala T.Nees & Eberm. is a semi-wild species in contrast to the above mentioned four species. Cultivation of *Cinnamomum tamala* is an important source for harvesting plant material in contrast to the four other species. Still, the plant also grows wild and people are harvesting wild populations. 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. Out of the 162 georeferenced occurrences reported worldwide, Nepal covers 37 of the occurrences. There are three botanical types under this species; *C.t. var. tamala*, *C.t. var. albiflorum meisn*, and *C.t. var. elliptifolium Baruah & S.C.Nath* (GBIF, 2018).

Conservation effort

GoN has followed *in-situ* conservation of the species through protected area like in Chitwan National Park. *In-situ* conservation is done through protection of forest and handing over of forest to the communities.

GoN has preserved the germplasm in the gene bank. Commercial cultivation has started in many districts, especially in the Hilly and Terai regions many farmers cultivate the plant.

The study showed that *Cinnamomum tamala* is conserved and the trend in wild population is expected to be increasing. The reason behind this may be due to increasing commercial cultivation. However, a detailed status study should be carried out. Data collected 25 years ago stated that out of 75 districts in Nepal, the plant was commercially harvested from wild populations in 33 districts (Bhattarai, 1996). It is specially cultivated for commercial purposes in Udayapur and Palpa districts of the country (Shrestha et al., 2015).

3.3 Conservation status and challenges

Based on the literature review and the expert interviews, important results related to conservation status could be drawn.

Comparison between domesticated and wild plants

One can trace a difference in the conservation status and its availability between the domesticated species *Cinnamomum tamala* and the four targeted wild species. All five species are however included in the governmental list of prioritized MAP species for research and development (MoFSC, 2017). Four of them (*Nardostachys grandiflora*, *Rauvolfia serpentina*, *Ophiocordyceps sinensis* and *Cinnamomum tamala*) are prioritized by private sector for business promotion by BARDAN, with the support of FNCCI/NEHHPA in their latest five years NTFPs/MAPS Business Promotion Strategy (Pyakurel & Oli, 2012). Despite the concern from Government of Nepal and the private sector, one cannot see an improvement in the conservation status of the four-wild species, but we can see it for *Cinnamomum tamala*. The four wild species are commercially valuable, but their populations and habitats are threatened. It is time to act upon them. The government and private sector should collaborate and focus on research and development. The species can generate high income and help to achieve government objective of reducing poverty through MAPs trade. So, it's time to work for commercial cultivation of other targeted species like it has been done for *Cinnamomum tamala*. This should be done on a national basis. *In-vitro* culture can be an effective technique to support the conservation and commercialisation of the targeted species.

Challenges in conserving targeted species

Challenges related to the conservation of the targeted species could be grouped into economic factors, social factors, environmental factors, awareness, technological development and policy related issues:

Economic factors: 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.

Social factors: The study identified a general lack of awareness among many of the people involved in harvesting MAPs and that poverty drives for collection of the plants (i.e. haphazard and over harvesting).

Environmental factors: 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 challenges that also represent a treat to MAPs.

Awareness: 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 organisations.

Technological development: Ten out of ten experts reported about lack of tools and technologies in the conservation of NTFP and lack of good laboratory facilities for research purposes. One out of ten experts reported that there is a lack of research in identification of MAPs diseases, and that there are insufficient studies in the life cycles of NTFP and its pest.

Policy level: Ten out of ten experts reported about failures in regulation and policy implementation as a challenge. A forest officer reported that one general policy is not suitable for all geographical regions in Nepal and requested a more regional regulation opportunity. Two out of ten experts reported of a lack of a central government authorised board to look after overall management and development of MAPs in Nepal. In one of the report similar policy level challenges have been stated (Kanel et al., 2017). 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.

The majority of the challenges that were identified in the current study have also been stated in other conducted studies (Barakoti, 2013; Kanel et al., 2017).

3.4 Key issues for an effective conservation of targeted species

Status, distribution and stock population of targeted species should be studied. Public participation in the conservation of protected areas should be strengthened and raising the awareness about the importance of medicinal plants could be one way forward. Strong policies

and implementation to attract serious collectors and small scale NTFPs entrepreneur should be made. Inventorying and monitoring of species populations is important. DFO should have an eye on illegal harvesters. 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 of MAPs. Detailed studies on life cycles of NTFPs/MAPs and its pests could be a step forward to increase production and minimizing yield losses. Increased production through cultivation trials and the use of *in vitro* technique should be taken into action. Some of the above mentioned points was also mentioned in a recent study that included 20 districts in Nepal (Kanel et al., 2017).

3.5 Sustainable harvesting

Awareness programs have been lunched in many districts of Nepal to prevent early and destructive harvesting of medicinal plants in the wild. For the sustainable harvesting of *Ophiocordyceps sinensis*, GoN has formulated concrete guidelines. To minimize the volume of harvest (over-harvesting), GoN has included a royalty system in its policies on the collection of MAPS from wild. Due to the successful result of handing over national forests to local communities, GoN has accelerated the work of handing over of forests to communities now familiar with community forests. For the sustainable harvesting, GoN has banned export in crude form for many of the threatened species. Declaration of national park and wildlife conservation as protected areas has helped in some way to protect threatened species. GoN has formulated block-wise rotational harvesting, an NTFP inventory guideline was formulated in 2012 and a sustainable harvesting plan for Annapurna conservation area. Rotational harvesting of two blocks in two subsequent year has been followed in Jumla recently.

3.6 Training of the people

Despite a recognition of the economic importance of MAPs, such plants have not received special attention from the government of Nepal. It is still a debate on the responsibility of the plants, if they belong to Ministry of Forest or Ministry of Agriculture. MAPs are included in the syllabus of both, however most of the work is carried out by the Ministry of Forest. But according to what experienced from this study, the work is not satisfactory carried out. For example, very few institutions are involved in training and there is a lack of awareness of

training the local people. Many of the collectors in the study were frustrated about this; as exemplified by respondent X from Jumla who said: *“Training is made not to reach the poor people; only elite group receive such training”*.

Based on the study, the following governmental and non-governmental institutions are involved:

- a) DPR is totally based on research and does not provide training.
- b) DFO also do not provide training because of huge mass of people involved in collection.
- c) National herbarium (KATH) at Godawari provide training to students who come to visit in plant conservation on a one-day basis.
- d) NARC provide very limited training, i.e. when groups of people show their common interest in certain medicinal plants.
- e) HPPCL- only provide training to collector who have got a PAN No., which means a lot of collectors who don't have PAN No. misses this opportunity.

Despite MAPs 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 (Pyakurel & Oli, 2012).

4. CONCLUSION AND RECCOMENDATIONS

Despite the presence of various sets of recommendation and strategies, governmental and non-governmental organizations have failed to make a significant impact on the conservation and sustainable use of medicinal plants resources in Nepal. So far, little has been done on conventional conservation, i.e. in botanic gardens (*ex situ*) and natural reserves (*in situ*). *In-vitro* technique can play an important role for the conservation of medicinal plants by complementing *in-situ* conservation and helping in commercial cultivation by providing mass disease free planting materials. Conservation of traditional knowledge through documentation and oral transfer to the successive generation is important to safeguard. General awareness among the collectors about specific species is necessary to develop. Guidelines for sustainable harvesting of every threatened species is necessary to develop and teach out. Employment opportunities and value addition within the MAP sector should be prioritized, especially in rural areas where people also could actively be involved in the conservation of medicinal plant resources.

The study showed that there are several challenges related to the conservation and use of medicinal plants in Nepal as it stands today. The following recommendations could be highlighted based on the findings from the survey, the group discussions, the expert interviews and the literature review:

- a) There is a need for a detailed study about the status, distribution and stock population of the target species in the country. It is necessary to formulate effective conservation strategies.
- b) A national approach for the conservation of medicinal plants should consider geographical differences within the country.
- c) An official marketing channel should be establishment so that the collector receives more benefit by reducing the number of middlemen.
- d) Provision of adequately trained forestry staff should be prioritized so that they can have eye on illegal harvesting/collection and provide technical knowhow and skills to the collectors and CFUGs members about the medicinal plants.
- e) Sample MAPs species illustrations should be provided in the national checkpoints, at customs offices and at the various offices of DFO.
- f) A national database system for all the work in MAPs sector should be developed and made available to the public.

- g) Focus should be given to cultivation of the species including *invitro* culture with a well- equipped laboratory with infrastructures and extension service.
- h) Approaches like block wise five years rotational harvesting, selective harvesting and post matured harvesting should be followed for sustainable use of wild medicinal plant populations.
- i) Research should be carried out, focusing on identification of diseases of MAPs, MAPs life cycle and pest problems.

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APPENDIXES

Detail analysis of chi-square test

Table 1.

H0: level of knowledge is independent to age

H1: level of knowledge is related to age

$\alpha = 0.05$

$df = (5-1)(4-1) = 4*3$

12

χ^2

36.33347571

p value

0.000286323

Since, the p-value is less than the alpha (α) value 0.05 we reject the null hypothesis

Table 2.

H0: knowledge on benefit is independent to age

H1: knowledge on benefit is related to age

$df = (4-1)(5-1) = 12$

12

p value

0.001199011

χ^2

32.40245089

Since, the p-value is less than the α value 0.05 we reject the null hypothesis.

Table 3.

H0: use of cs for prevention is independent to region

H1: use of cs for prevention is influenced by availability region

DF: (2-1)(2-1)

1

$\alpha = 0.05$

P VALUE

0.09845223

χ^2

2.730438821

Since, p-value is higher than 0.05 we fail to reject the null hypothesis.

Table 4.

H0: use of DH for prevention is independent to region
 H1: use of DH for prevention is influenced by availability region
 DF: (2-1) (2-1)
 1
 $\alpha = 0.05$
 P VALUE
 0.548263263
 X^2
 0.360437674

Since, the p-value is more than 0.05 we fail to reject the null hypothesis.

Table 5.

H0: use of targeted plants for treatment is independent to region
 H1: use of targeted plants for treatment is influenced by region
 DF: (3-1) (2-1)
 2
 $\alpha = 0.05$
 P VALUE
 3.1469E-05
 X^2
 20.73301214

Since, the p-value is less than 0.05 we reject the null hypothesis.

Table 6.

H0: harvesting is not related to education
 H1: harvesting is related to education
 Df
 1
 p value
 0.006847569
 $\alpha = 0.05$

 x^2
 7.312523888

Since, the p-value is less than 0.05 we reject the null hypothesis.

Table 7.

H0: harvester type is not influenced by education

H1: harvester type is influenced by education

df: (2-1) (2-1)

1

p-value

0.311374495

$\alpha = 0.05$

χ^2

1.024836601

Since, the p-value is more than 0.05 we fail to reject the null hypothesis.

Table 8.

H0: conservation effort is not influenced by people with medicinal knowledge

H1: conservation effort is influenced by people with medicinal knowledge

df: (2-1) (2-1)

1

p-value

0.000485773

$\alpha = 0.05$

χ^2

12.1695008

Since, p-value is less than 0.05 we reject the null hypothesis.

Questionnaires involved in the survey

Questionnaire for Farmers/Harvesters

1. Farmer Details

Name:

Address:

Education:

Sex:

Age:

Family size:

Occupation:

2. How do you grade your **general level of knowledge** on medicinal plants?

No Little Moderate High Very high

3. How do you grade your **knowledge on the benefits of using** medicinal plants?

No Little Moderate High Very high

4. Have you used medicinal plants **to prevent** diseases on yourself or in your family?

YES NO

If yes, how often:

Plant	Less than once a year	Once or twice a year	Almost every month	Almost every week	Almost every day
<i>Ophiocordyceps sinensis</i>					
<i>Nardostachys grandiflora</i>					
<i>Dactylorhiza hatagirea</i>					
<i>Rauvolfia serpentine</i>					
<i>Cinnamomum tamala</i>					

Other plants: free answer

5. Have you used medicinal plants **to treat** diseases?

YES NO

If yes, how often:

Almost never Once a year Once a month Once a week Almost every day

If yes, against which diseases you use the following medicinal plants?

Plants	Which diseases	Parts used
Cordyceps sinensis		
Nardostachys grandiflora		

Dactylorhiza hatagirea		
Rauvolfia serpentine		
Cinnamomum tamala		

Others: free answer

6. Have you **harvested** targeted medicinal plant species from the **wild/forest**?

YES NO

If yes, for what purpose:

Plant	For own/family use	Sell on the local market	Sell to dealers
Cordyceps sinensis			
Nardostachys grandiflora			
Dactylorhiza hatagirea			
Rauvolfia serpentine			
Cinnamomum tamala			

How often do you harvest targeted species from the wild/forest?

Plant	Less than once a year	Once or twice a year	Almost every month	Almost every week	Almost every day
Cordyceps sinensis					
Nardostachys grandiflora					
Dactylorhiza hatagirea					
Rauvolfia serpentine					
Cinnamomum tamala					

7. How do you harvest?

Sustainable harvester (take some leaves or plant parts but not most of it)

Commercial harvester (take it all)

8. What type of harvesting pattern you follow? Like seasonal harvesting or according to life stages.
9. What you know about sustainable harvesting?
10. Have you received any training/classes from governmental or non-governmental organizations highlighting about the importance, use and need for conservation of medicinal plants?

Training on the use of medicinal plants Yes No

Training on conservation of medicinal plants Yes No

Comments:

11. If you have not received such training would you like to take such trainings in near future?

Yes No

12. What have you done from your position to protect/conservate the endangered species mentioned above?
13. In your opinion what are the major challenges to conserve endangered medicinal plants?
14. In your opinion what should be done to overcome these challenges?

Questionnaire for experts

1. Expert details

Name:

Age:

Address:

Occupation:

Working experience:

sex:

Education:

2. What is the conservation status and trends in wild populations of targeted medicinal plants?

- a. *Ophiocordyceps sinensis*
 - Conservation status:
 - Trends in wild populations
 - b. *Nardostachys grandiflora*
 - Conservation status:
 - Trends in wild populations
 - c. *Dactylorhiza hatagirea*
 - Conservation status:
 - Trends in wild populations
 - d. *Rauvolfia serpentina*
 - Conservation status:
 - Trends in wild populations
 - Cultivation
 - e. *Cinnamomum tamala*
 - Conservation status:
 - Trends in wild populations
 - Cultivation
3. Do you provide any training to highlight the importance of medicinal plants to general people? If yes, then how often?

YES NO

If yes, how and how often....

4. What approaches have you followed to develop sustainable harvesting from wild populations?
5. What has been done from your institutions to conserve the targeted species?

Plants

In-situ

Ex- situ

- a. *Cordyceps sinensis*
- b. *Nardostachys grandiflora*
- c. *Dactylorhiza hatagirea*

-
- d. Rauvolfia serpentina
 - e. Cinnamomum tamala

6. What are the challenges in conserving targeted species?

Provide details under each point

Policy level

Economic

Social

Biological

Environmental

Awareness

Smuggling

Technology

What is the major challenge according to your opinion:

7. Are you getting enough budget to conserve endangered medicinal plants? Yes No

8. What is the trend of budget allocation in your district/institution?

Increasing

Decreasing

Constant

9. How do you allocate the budget?

Research

Forest management

10. In your opinion what should be done for effective conservation of targeted species?

Some glimpses during the survey



Photo 1. Respondent from Jumla



Photo 2. Dried root of *Dactylorhiza hatagirea*



Photo 3. Dried *Ophiocordyceps sinensis*



Photo 4. On the way to survey site: Thini, Mustang



Photo 5. Surveying farmer in Jumla



Photo 6. Surveying oldest respondent (Lama) in Mustang



Photo 7. Department of Forest, Ministry of Forest and Soil Conservation, Kathmandu



Photo 8. Collector of Medicinal herbs in Jumla, showing homemade medicine (Nas) in his left hand