Sustainable harvesting plan of Yarsagumba (*Ophiocordyceps sinensis*) in Api-Nampa Conservation Area (ANCA)

Submitted to

Api Nampa Conservation Area

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Executive Summary

Nepal is blessed with natural endemic biodiversity. About 2000 plants among enlisted plants of Nepal are recognized as non-timber forest products (NTFP) of which 1624 plant species are being used as medicines currently. Medicinal and Aromatic Plants (MAPs) has been recognized as life line for Himalayan people which are essential for fulfillment of their substantial basic needs. MAPs are collected and traded from all over the country but Himalayan regions are considered important for high value MAPs. NTFPs collection and trade plays crucial role as source of income to hill and mountain farmers in Nepal and sometimes it comprises up to 50% of household incomes. *Ophiocordyceps sinensis* is a fungus that parasitizes larvae of ghost moths and produces a fruiting body valued as an herbal remedy found in mountainous regions of India, Nepal and Tibet. Yarsagumba plays has played vital role in sustaining and also enabling rural economy in Himalayan region particularly high mountain areas as Dolpa, Mugu, Humla, Bajhang and Darchula in Nepal. Collection, transportation, use or trade of Yarsagumaba was totally banned in Nepal until 2001. But following its popularity and lobbying by various organization, government lifted the ban. Following the lift of ban Yarsagumba collection increased dramatically in Nepal and Himalayan areas. Yarsagumba generated the highest amount of revenue among 62 NTFP species traded, sharing 41% of the total revenue from NTFPs in 2011. Increasing global demand and increasing price of yarsagumba has led to over harvesting of the species. To ensure the sustainability of the species, GoN has prepared Yarsagumba Management Guideline in 2073. According to the guideline, in order to harvest and trade yarsagumba it is necessary to have sustainable harvesting plan of the species. Therefore, the study was conducted to prepare the sustainable harvesting plan of yarsagumba. In order to prepare the sustainable Yarsagumba (*Ophiocordyceps sinensis*) harvest plan, resource inventory was conducted in ANCA to estimate the density, frequency, total yield and allowable harvest. First potential area of yarsagumba in six VDCs of ANCA was delineated based on the altitudinal range and land use map using ArcGIS 10.3. The total potential area of yarsagumba in ANCA was estimated 32009.11 ha. Stratified Random sampling method was used to collect field data. Six potential VDCs were considered as strata and out of which only three strata (Ghusa, Rapla and Khandeswori) were selected for inventory because of the time and resource constraints. Altogether, 94 sample plots were randomly distributed in three strata. The total number of 8479 individuals were engaged in collection last year in different sites of ANCA. The issues and challenges of yarsagumba collection included over harvesting, illegal harvesting, poor trail conditions, unmanaged camping, waste management at camping sites, lack of health services and natural problems like untimely snowfall. On other hand ANCA has

been facing challenges of grassland management, waste management, royalty collection, market management at local level due to less number of human resources.

Based on the inventory, density, frequency and abundance of the Yarsagumba in each stratum were estimated. The overall density of Yarsagumba in ANCA was estimated 85 piece/ha while frequency and abundance was estimated 38.59% and 70.51 per ha respectively. The total yield was estimated 911.71 kg. The lowest yield was estimated in Guljar (47.92 kg) and highest yield in Ghusa (343.21 kg). The number of Yarsagumba collection per day per person range from 2 to 7 with average of 5 piece (4.7 gm). The average number of Yarsagumba collection is 30 days.

Based on the limited information available on the ecology and life cycle of Yarsagumba, harvesting plan has defined rotation age of one year. The Yarsagumba collection period set 2nd week of Jestha to end of Ashar allowing a collector to collect for maximum of 30 days. The annual harvestable amount of Yarsagumba is restricted to 90% total yield. Annual harvestable amount of Yarsagumba estimated is 820 kg per year from ANCA. To collect the total harvestable amount of Yarsagumba, ANCA can issue 17114 collection permits and an individual can have one permit annually.

Harvesting plan also has provision for habitat management activities which includes; regulating the number of harvester in 13 collection site; use of proper instrument for harvesting (hoe and knife); allocating camping site; waste management at camping sites; grassland management activities. In coordination with local institutions conservation area will also ensure temporary health and security post, drinking water management at camping sites. The ANCA together with Council, User Committee will regularly monitor harvesting sites to control illegal harvest and over harvesting; activities forbidden by Yarsagumba management guideline, 2073. For collection of Yarsagumba, ANCA will issue collection permits to individuals. Three types of permits will be issued; Green permit for residents inside ANCA at NRs 500/person; yellow permits for residents of Darchula district outside ANCA at NRs 2000/person; and red permits for residents of other districts at NRs. 3000/person. The permit will allow collection for 30 days and an individual will not be issued more than one permit. ANCA in coordination with local institutions will monitor the harvesting sites and keep records of annual harvest.

Acronyms and Abbreviation

NTFPs : Non Timber Forest Products

DoF : Deparment of Forests

ANCA : Api-Nampa Conservation Area

B.S. : Bikram Sambat

Sq.mi. : Square Miles

Ft. : Feet

KSL : Kailash Sacred landscape

m. : meters

MAPs : Medicinal and Aromatic Plants

VDCs : Village Development Committee

ACAP : Annapurna Conservation Area Project

USD : Us Dollars

°C : Degree Celsius

Mm : Millimeters

GPS : Global Positioning System

CF : Community Forest

Kg : Kilograms

Gm : Grams

Ha: hectare

In: Inch

DHM: District Hydro Metrology

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Chapter One: Introduction

Background

Blessed with natural endemic biodiversity, Nepal harbors 6500 flowering plants (Angiosperms) and 4064 non-flowering plants (Gymnosperms). Government of Nepal has enlisted these plants in government document through own efforts. Among all enlisted plant species, approximately 2000 are recognized as non-timber forest products (NTFP) out of which 1624 plant species are being used for medicines purposes. Since the beginning of human civilization NTFPs have been used traditionally. NTFPs have been used as the sources of food, medicine, cosmetic, ritual uses among others. Global NTFPs consumption as medicines is similar to Nepal. More than 60% of the world's population and 80% of the developing countries are directly dependent on plants for medicinal purposes.

NTFP plays important part of household income for farmers in hilly and mountain region of Nepal (Olsen, 1997). Edwards (1996) reported income from NTFPs sometimes constitutes of 50% of household income. This highlights the importance of NTFPs in household income. About 1,600 to 1,900 plant species are used as traditional medicine in Nepal (Baral 2006; Ghimire 2008). However, Nepalese rural families are seasonally engaged in NTFPs business for subsistence only without any intention of sustainable enterprise development. The average annual royalty collected from 80 NTFPs was estimated 25 million per year (DoF, 2013).

Api Nampa Conservation Area (ANCA) was established in 2010 by Government of Nepal based on National Parks and Wildlife Conservation Act, 1973 (2029 BS) clause 3. This conservation area is named after the two famous peaks Api and Nampa. ANCA covers an area of 1,903 km2 (735 sq mi) extending in 18 Village Development Committees and 1 Municipality of Darchula district bordered by the Mahakali River in west, international boundary with Tibet in North and adjacent to Bajhang, Lasku and Naugad rivers in south and Baitadi districts in east. ANCA's elevation ranges from 518 to 7,132 m (1,699 to 23,399 ft) at Mt. Api.

The main objective of establishing ANCA was to conserve the unique biodiversity and cultural heritage found in the area. The mammalian species found in conservation area are; snow leopard, Himalayan black bear, red panda, common langur, Himalayan tahr, Himalayan musk deer, goral and serow. While birds species include Himalayan monal, snow cock and blood pheasant. Diverse climatic conditions and altitudinal variation of the area provides suitable habitats for many rare and threatened wildlife species including the snow leopard and the musk deer. ANCA aims to conserve pristine nature of the conservation area while addressing the

needs of local peoples. ANCA seeks to involve local peoples in its overall management. Such approaches are commonly known as participatory conservation model. Limited number of tourists visit conservation area due to remoteness.

They major livelihood of local people are dependent on agriculture, collection of medicinal and aromatic plants as well as artisan productions. The community of the Byash, for example, still practices a nomadic lifestyle. They move between the high altitude grasslands in the summer months and the lower valleys close to Darchula town in the winter.

Diversity in physiographic and climatic conditions in the area offers a possibility of the existence of variety of vegetation. Out of 35 forest types identified by Stainton (1972), this region represents sixteen (16) forest types. The major species in the region constitute Chir pine (Pinus roxburghii), *Alnus spp., Pinus patula*, Blue pine (*Pinus wallichiana*), *Rhododendron spp*., *Cedrus deodara*, *Quercus lanata*, *Q. semicarpifolia*, *Abies spp., Birch spp*., *Juniperous spp*. and moist alpine scrubs. The region is origin of valuable NTFPs and Medicinal and Aromatic Plants (MAPs), extracted and traded in local, national and international market every year. The main NTFPs traded from the regions are Yarshagumba (*Ophiocordyceps sinensis*), Chiraito (*Swertia ciliata*), Majhito (*Rubia cordifolia*), Allo (*Girardinia diversifolia*), Jatamansi (*Nardostachys grandiflora*), Panchaunle (*Dactylorhiza hatagiera*), Ritha *(Mukurossa spendis)*, Dhupi *(Juniperus spps*.), Rock honeybee and several others.

Rationale

It is evident that many fungi are vanishing from nature due to factors like habitat alteration, climate change, landslides, grazing, deforestation, slash and burn, unscientific harvesting, etc. Those species having selective niche are particularly affected by human induced activities. The high market demands or some of the species annually attracts large number of people for extensive collection of the product with primitive means and methods that may be perceived as one of the principal causes for rapid resource degradation. However, negligible efforts have been realized so far in Nepal towards the conservation of fungal diversity and their natural habitat. While discussing conservation of fungi insights over some parasitic fungi that are beneficial to human beings are also important to consider. The parasitic fungi such as Yarsagumba (*Ophiocordyceps sinensis*) are economically important for some Himalayan communities. Their conservation through scientific management of natural habitats is ultimately required for sustainable harvest of the product from nature in perpetuity. As a poorest country in the world, Nepal should at least be in the position of in situ scientific

management of the product while other countries in the world have started domestication. The frequency and exact distribution of the fungi in natural ecosystem is unknown. Its economic survey and mapping is necessary for scientific management. Although few studies on wild status of some medicinal plants have been carried out, several others, particularly at the high altitude species, is yet to be evaluated (Shrestha and Joshi, 1996; IUCN, 2000; Lama et al., 2001).

Conservation of any fungi requires niche protection i.e. the management of ecological habitat and the accompanying biodiversity. Habitat protection for fungi conservation in wild means preserving soils constituents such as structure, texture, debris, organic matter, moisture, associated flora and fauna as well as maintaining air and solar elements and the surrounding biological diversity. Identification of appropriate time of maturity of spores is necessary to ensure sufficient regeneration via dispersal of matured spores. Though rainy season (between July and October) is the favorable time for *Ophiocordyceps sinensis* collection, the exact duration of fungal maturity of the herb is yet to be explored. The season of fungal maturity and optimum production is still unknown and identification of appropriate timing of collection is greatly felt. The host caterpillar of *Ophiocordyceps sinensis* thrives in sub alpine and alpine grasslands, meadows and open dwarf scrub lands near to the potential tree line.

On the one hand *Ophiocordyceps sinensisis* perishable item so its scientific harvesting in the season of appearance is necessary for wise use while on the other hand it is general conception that stock of *O. sinensisis* diminishing all along Nepal as with other medicinal plants in lack of serious attempt to conserve them. It is assumed that the frequency and availability of the species vary notably from region to region. The product deserves high potential to generate income opportunities, enhance rural income and raise the national revenue. Hence wise collection and habitat management is necessary for the resource sustainability.

Government of Nepal had imposed a ban on collection, use, sale, distribution, transportation and export of Yarsagumba till the year 2001 (HMG/N 2001). After lifting the ban on collection and trade of yarsagumba in 2001, the collection and trade has increased significantly in Nepal which has led to over harvesting, immature harvest and habitat disturbance. Though, the collection of yarsagumba in the forests of Api Nampa Conservation Area has been performed legally in some extent. However, collection method needs scientific manner for the sustainable and perpetuity of species. Yarsagumba have been harvested without knowing their sustainable harvestable quantity as well as illegal harvesting prior to maturity of fungus. This could lead to the situation of either under harvesting or over harvesting of Yarsagumba. The inventory helps to develop a sustainable management plan

wise use. Hence, Yarsagumba Management guideline, 2073, has been developed by GoN to ensure the sustainability of the resource. Therefore, this sustainable harvesting plan has been prepared to sustainably harvest Yarsagumba without damaging its natural habitat and pristine ecosystem of ANCA.

Objectives

Prime objective of the harvesting plan is to ensure sustainable harvest of Yarsagumba in ANCA. The harvesting plans specific objectives are:

- Regulating quantity of harvestable Yarsagumba from different regions of ANCA.
- Regulating the Yarsagumba harvesting time in ANCA.
- Improving habitat of Yarsagumba.

Limitations

As extensive inventory of NTFPs demands more time and resources, these are adjusted with respect to sample size and sampling design. The study faced variability in seasonal availability of

NTFPs and thus there were chances of absence of some NTFPs during inventory of these resources. On the other hand, randomly selected sample plots were allocated to accessible terrain and topography. Due to scattered availability of NTFPs, there might be some degree of error in taking representatives of effective area. In order to reduce the error, attempts are made to identify this effective area with help of local experiences of local users. Similarly, study area of the ANCA are confined to six VDCs which were identified as potential site for Yarsagumba in ANCA management plan.

Chapter Two: Scenario Analysis of Yarshagumba

Ophiocordyceps sinensis a fungal parasite of larvae (caterpillars) which belongs to the ghost moth genus Thitarodes (Hepialidae, Lepidoptera). It is widely distributed in the montanae grasslands of Tibetan plateau and Himalayas. It has been recorded from Bhutan (Namgyel and Tshitila 2003), China (Pegler et al. 1994; Winkler 2005), India (Sharma 2004; Winkler 2005) and Nepal (Devkota 2006). The fungus is distributed at an altitudinal range of 3,000 and 5,000 m (9,800 and 16,400 ft) (Zhang et al. 2009; Devkota 2010; Winkler, 2009).

The caterpillars prone to be infected by *O. sinensis* generally live 15 cm (5.9 in) underground. The fungus germinates in the living larva, kills and mummifies it, and then the stalk-like fruiting body emerges from the corpse. It is known in English colloquially as caterpillar fungus, or by its more prominent names *Yartsa Gunbu.* The fungus consumes its host from inside out as they hibernate in alpine meadows. Usually the larvae are more vulnerable after shedding their skin, during late summer. The fungal fruiting body disperses spores which infect the larvae. The infected larvae tend to remain vertical to the soil surface with their heads up. The fungus then germinates in the living larva, kills and mummifies it, and then the stalk-like fruiting body emerges from the head and the fungus finally emerges from the soil by early spring. Fifty-seven taxa from several genera (37 *Thitarodes*, 1 *Bipectilus*, 1 *Endoclita*, 1 *Gazoryctra*, 3 *Pharmacis*, and 14 others not correctly identified to genus) are recognized as potential hosts of *O. sinensis*.

Table 1: Scientific classification of Ophiocordyceps sinensis

Scientific classification	
Kingdom:	Fungi
Division:	Ascomycota
Class:	Sordariomycetes
Order:	Hypocreales
Family:	Ophiocordycipitaceae
Genus:	*Ophiocordyceps*
Species:	***O. sinensis***

Yarsagumba (Ophiocordyceps sinensis Berk.) has been one of the most valuable traditional Chinese and Tibetan medicine. Literally Yartsagunbu (Yarsagumba in Nepali menas "Summer grass and winter worm" (Holliday and Cleaver 2008).

O. sinensis parasitizes underground dwelling larvae of moths (Lepidoptera), especially species of *Thitarodes* (*Hepialus*) spp., *Hepialiscus* spp., *Forkalus* spp., *Bipectilus* spp. etc (Shrestha 2011). The fungus uses the body of the host as a substrate to form the mycelium, which is finally converts into sclerotium, leaving the exoskeleton intact. The stroma of the fungus grows from the sclerotium and emerges above the ground, it is then collected with the sclerotium as a whole for medicinal use (Ghimire *et al*. 2008, Li *et al*. 2011). The host insect larvae lives underground throughout larval stage for three to four years or longer. The larvae infected by the fungus usually die in the winter and the fungal stroma comes out in the spring or summer of the following year.

The fungus has a small solitary spike with dark brown fructification and yellowish white stalk. The size of the fungus is about 4-10 cm in length and 0.14-0.4 cm in girth. The natural distribution of fungus is limited by strict host specificity on moth insects, confined geographical distribution and over exploitation by humans in recent decades (Ghimire *et al*. 2008, Li *et al*. 2011). It grows in highland meadows and alpine slopes covered by snow for at least 4-5 months in a year and which have less than 350mm rainfall per year (Winkler 2005). It is distributed in trans-himalayas of Nepal in Dolpo, Darchula, Bajhang, Mugu, Humla, Jumla, Rukum, Manang, Mustang, Gorkha, Lamjung, Dhading and Rasuwa districts (Bhattarai and Ghimire, 2006).

Yarsagumba (*Ophiocordyceps sinensis*) has gained the center stage among rural people, businessmen, researchers, conservationists, and policy makers in last few years in Nepal. It has been popular for extensive medicinal use, extraordinary life cycle, and as one of the most valuable biological resources in the world (Shrestha 2012; Shrestha and Bawa 2013). Yarsagumba generated the highest amount of revenue among 62 NTFP species traded in Nepal which was 41% of the total revenue from NTFPs in 2011 (GoN, 2011). In 2011, the market price of Yarsagumba was USD 25,000 per kg in Kathmandu, Nepal whereas it was traded in USD 100,000 per kg in China — the major international trade destination for Yarsagumba (Agile News cited from Shrestha and Bawa 2013).

Chapter Three: Methodological Approach

Study area description:

The study was conducted in Api-Nampa Canservation Area (ANCA) of Darchula district in far-western Nepal. Api Nampa Conservation Area (ANCA) is the most recent CA that covers the northern Darchula, bordering with two big land masses viz. China in North and India in

West. This is also an important part of trans-boundary Kailash Scared Landscape (KSL). ANCA was established in 2010 with an area of 1,903 km^2. ANCA borrowed its name from Api (7,132 m) and Nampa (6,757 m) mountains which are situated in the region. Spatially ANCA extends from 80°22' to 81°09'longitude and from 29°30 to 30°15' latitude. Northern border extends up to autonomous region of Tibet while its Southern border extends up to Lasku and Naugad khola of Darchula district. The eastern border extends up to Bajhang district and its western border extends up to Mahakali river which separates it from India.

Figure 1: Location map of ANCA (Source: ANCA 2008)

ANCA is spread over wide range of altitude variation of 539m to 7,132m elevation. ANCA is gifted with mountains higher than 6000m, such as Api (7,132 m), Nampa (6,757 m) and Byas (6,670 m). Soils in the middle mountains are moderately acidic, medium- to light- textured coarse grained sand and gravel (ANCA 2008). The region possesses fragile geology as result of crash between Indian subcontinent plate and Tibetan plate. The areas is formed of rocks like Schist, Gneiss, Limestone and Sediment, so they are highly sensitive to landslide and flooding in during rainy season.

2.2 CLI MATE

The climate of the greater Kailash landscape is primarily governed by the monsoon in the southern part (Greater and Lesser Himalayan Zones), by the rain shadow zone (cold desert

conditions) over the crest of the Himalayas (Trans-Himalayan zone), and continental and Central Asian climatic conditions drive climate in Tibetan Plateau (Zomer and Oli, 2011). Due to variations in altitude and topography, the climate of the region varies widely from subtropical to temperate, alpine, and cold high altitude desert types.

In the Southern Himalayas, The average temperature is around 18°C with minimum temperatures of 7°C, and average rainfall in excess of 2,100 mm .Temperature and rainfall patterns of the southern Himalayan ranges are tropical to subtropical up to 2,000 masl; and temperate up to above 3,000masl (Ibid). In these locations an increase in minimum temperatures has been recorded since the 1970s (Zomer and Oli, 2011).

ANCA has diverse climatic conditions due to variation in altitude and topography. South-eastern and valleys of ANCA have sub-tropical climate while temperate and alpine climatic conditions are dominant in the middle mountains and high Himalayas. Subtropical climate is found in southern part of Latinath, Tapoban, Sipti, Khar and Kante VDCs whereas temperate to alpine climate occurs Byas, Rapla, Ghusa and Khandeswori VDC which are situated at higher altitude (ANCA Mgt. plan, 2010-2014).

Average annual minimum and maximum temperature of the region is recorded 13.69 °C (Figure 2a)and 27.78 °C (Figure 2b) respectively with the lowest monthly average minimum temperature recorded in December, January and February (Figure 3a) and highest monthly average maximum temperature recorded in May, June and July (Figure 3b).

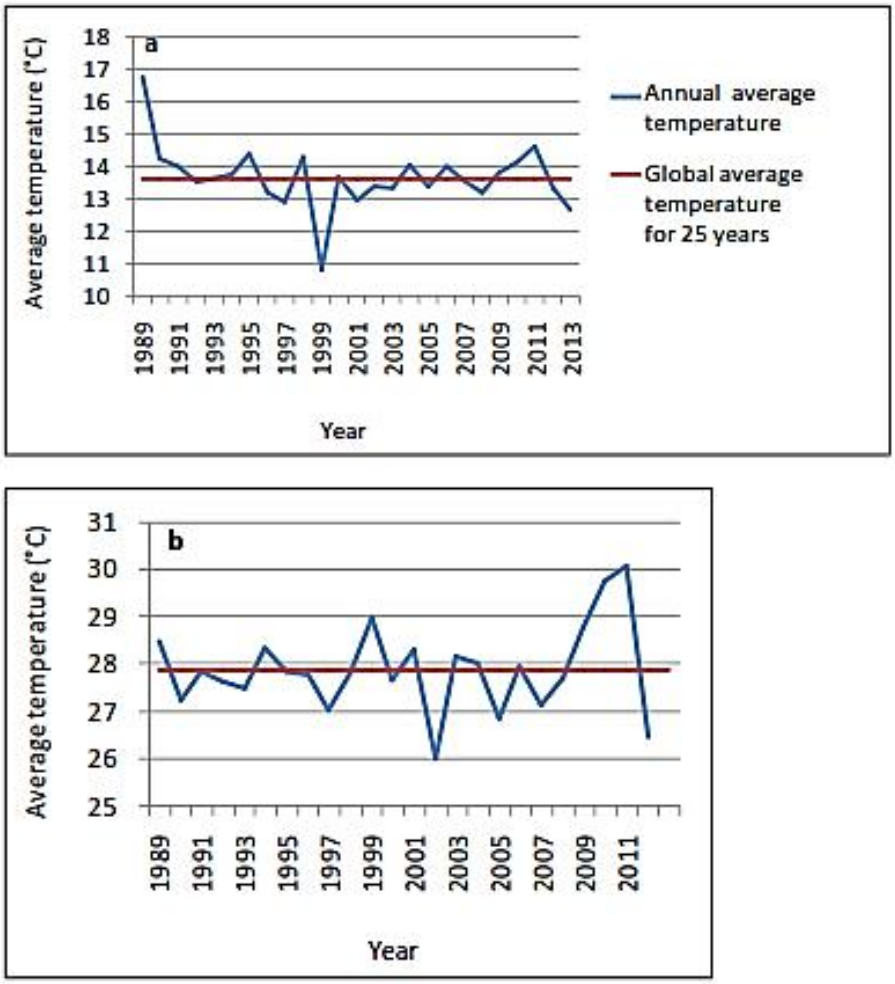

Figure 2: Average annual minimum (2a) and maximum temperature (2b) over 25 years (1989-2013) (Source: DHM, 2014)

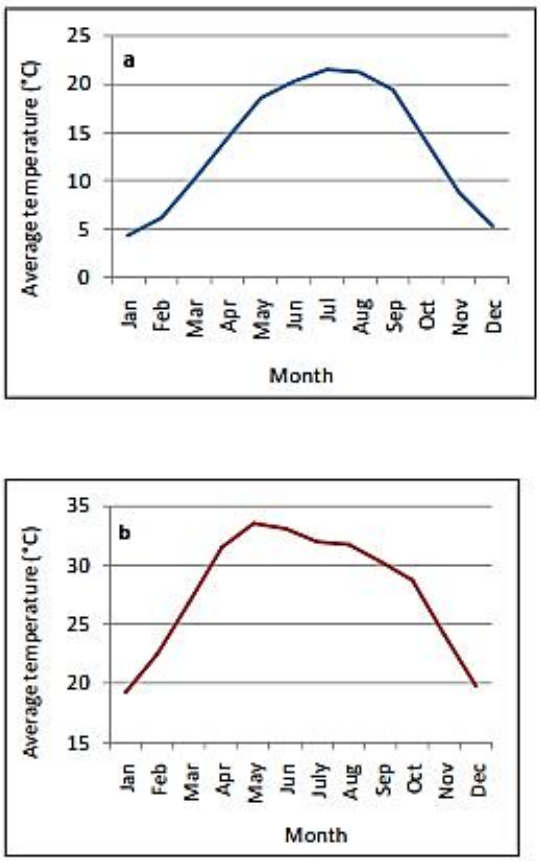

Figure 3: Average monthly minimum (3a) and maximum (3b) temperature over 25 years (1989-2013) (Source: DHM, 2014)

The average annual precipitation was recorded to be 209.4 mm (Figure 2**a)** with highest rainfall in the months of July and August and the least from November to April (Figure 4**b).**

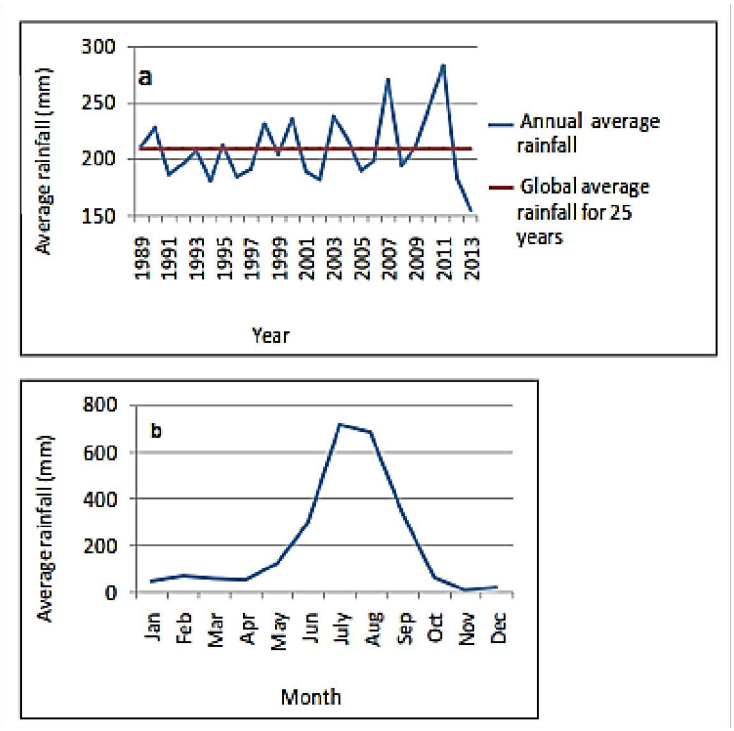

Figure 4: Average annual (4a) and monthly (4b) rainfall over 25 years (1989-2013) (Source: DHM, 2014)

Land use classification of ANCA:

Out of total area of ANCA, forest area covers highest area (30.08%) followed by barren land (28.78%), grassland (23.98%). Lowest area is covered by ponds/lake (0.02%) and water bodies (0.22%). The river cuttings/cliffs covers 0.48%, whereas sandy areas, glacier, cultivated land shrubland occupies 2.13%, 3.28%, 4.91% and 6.12% respectively. The land use map and details of area covered by different land use is presented in the

Figure 5 and Table 2: Land use of ANCA showing area (km2) of different land useTable 2.

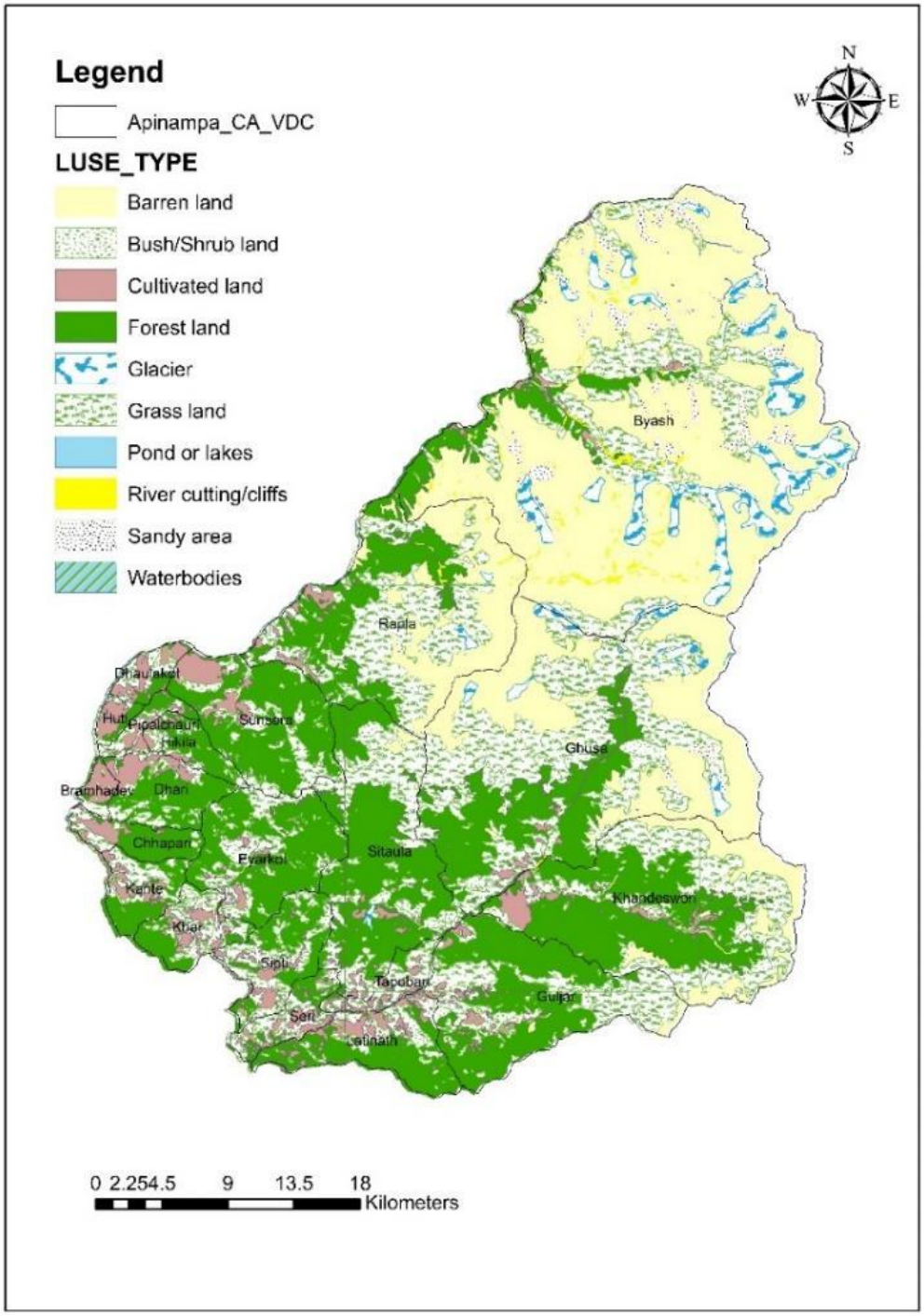

Figure 5: Land use map of ANCA (Source: DNPWC 2017)

Table 2: Land use of ANCA showing area (km^2) of different land use

Lanuse_Type	Area_Sq_km	Area_ha	Percentage of ANCA area
Barren_land	547	54735	28.78
Grassland	456	45597	23.98
Bush_shrubland	116	11639	6.12
Cultivated land	93	9343	4.91
Forest land	573	57200	30.08
Glacier	62	6243	3.28
Ponds_lakes	0	31	0.02
River cuttings/cliffs	9	915	0.48
Sandy area	40	4043	2.13
Water bodies	4	412	0.22
Total	**1903**	**190159**	**100**

Sampling design and plot design

Sampling design defines how the observation unit are selected and number of sample plots. The sampling method and the design used in an inventory depend on the distribution of the species, the resource availability and the objectives of the inventory.

Sampling design, plot design and data collection for this study was based on Participatory Inventory of Forest Resource (ANSAB, 2010) and NTFP Resource Inventory Guideline, 2069 (DoF, 2069).

ANCA covers 21 VDCs of Darchula districts and management plan of ANCA has identified six potential VDCs for Yarsagumba where this study was concentrated. Thus, study area was stratified into six strata based on VDC boundary and randomly selected three VDCs, namely; Ghusa, Rapla and Khandeswori. Effective areas of Yarsagumba in each VDCs were delineated using ArcGIS 10.2 and sample plots of $25m^2$ were randomly selected in each strata.

Circular fixed area sample plots of $25m^2$ were deployed in sampling. Altogether 94 random plots were distributed in three strata. The detail of plot design is presented in Table 3

Table 3: Effective area of strata and number of plots in three strata.

Strata	Effective area of strata (Ha)	No. of plots	Area of Plot (m^2)	Remarks
Ghusa	10094.8	30	25	Circular plot
Rapla	5056.46	34	25	Circular plot
Khandeswori	4333.66	30	25	Circular plot
Total	**19484.92**	**94**		

Pre-field work

Literature review:

Peer reviewed literature and scientific papers related to the Yarsagumba were reviewed thoroughly in order to facilitate sampling design to administer inventory. ANCA annual reports, management plan and relevant reports of past studies were reviewed. Based on the literatures, annual reports, NTFP resource inventory guideline and relevant report sampling design, plot design, field plans, and inventory protocol were developed.

3.4.3 Effective area delineation and sample plot lay out

Yarsagumba are restricted to high altitude of the Himalayas and Tibet. In Nepal Yarsagumba is found in alpine and sub-alpine pastures above tree line at altitude of 3540-5050 m (Devkota, 2010).

Therefore, in order to delineate potential area of Yarsagumba, digital layer of contour map and land use map were analyzed through ArcGis 10.2 software. First altitudinal range of Yarsagumba was found out through literature and then altitudinal range was extracted from contour map through "select by attribute" tool of the software. This extracted layer was then intersected through "geoprocessing tool" with land use map containing layers of forest, pasture and shrub land. Then the extracted layer was converted to raster data and again the raster data was converted to polygon feature and finally it was dissolved by pasture. Thus the potential area of Yarsagumba was found out considering its altitudinal range and existence of the species on pasture layer of land use map. The potential area was then checked whether the coordinates of sample plots containing individual species were overlaid or not.

Number of sample plots was determined based on area of the polygons, budget and time availability for field work. Circular sample plots of $25m^2$ were randomly laid out within the polygons and centroid's coordinates of each sample plot were calculated through ArcGIS 10.2

for navigation by global positioning system (GPS). The distance between plots to plot were adjusted to at least 100 meter.

Field work

Yarsgumba inventory was conducted based on NTFP resource inventory guideline, 2012. Inventory of NTFP resources has been carried out according to NTFP resources inventory guideline, 2012 produced by Department of Forest (DoF). However some adjustments were made in the prescribed method used in the guideline considering coverage and topography of the target study area because guideline has focused methods applied in CF's NTFP resource inventory and the present study focuses ANCA as a study area. The sample plots of size 25 m^2 was preferred due to ease of laying out plots in the field.

All together 94 sample plots in three strata were laid in the field for inventory purpose. After navigating to the center of sample plots using GPS, 25m^2 sized plots were laid out in the field.

In each sample plot, detailed plot and variables information, such as plot number, altitude, slope, aspect, local name of NTFP species, number of individual species, and fresh weight of individuals, were recorded in inventory sheet. If slope of plot was recorded more than 4.50/10%, slope correction was applied. For field inventory, the field crew consists of forest technician, game scout and local social mobilizer.

Radius correction for fixed area circular plot:

$$SR = \frac{R}{\sqrt{Cos\theta}}$$

Where,

SR=Radius in slope terrain

R=Radius in horizontal plane

Θ=Angle or slope in degree

Post field work

Data compilation

The enumeration sheets were collected, reviewed and cleaned and coded as per required. These data were compiled into Microsoft Excel for further analysis. The following parameters were analyzed which are essential for preparation of harvesting plan.

Frequency

Frequency is the number of sampling units in which the particular species occur, thus it expresses the dispersion of the species in a community. It refers to the degree of dispersion in

terms of percentage occurrence. The following formula were used to calculate species frequency.

$$Frequency = \frac{Number\ of\ sample\ plots\ in\ which\ species\ occurred}{Total\ number\ of\ sample\ plots\ taken} * 100$$

Density

Density expresses the numerical strength of the presence of species in a community. It is the number of individuals per unit area and is expressed as number per hectare. The following formula were used to calculate species density.

$$Density = \frac{Total\ number\ of\ any\ species}{Total\ number\ of\ sample\ plot * area\ of\ sample\ plot} * 10000$$

Yield Calculation

Yield calculation is quantification of the amount of a particular product that can be obtained from certain area. An estimation of the yield of a particular product requires the enumeration of certain characteristics of the individuals making up the parent population. The study used destructive method of NTFP inventory for Yarsagumba and fresh weight of samples were recorded from each sample plots. Hence, yield per hectare and total yield were calculated using following formula:

$$Yield\ (gm\ per\ ha) = Density * Average\ weight\ of\ an\ individual$$

$$Yield\ (kg\ per\ ha) = \frac{Total\ yield\ (gm\ per\ ha)}{1000}$$

$$Total\ yield\ from\ area\ (ha) = Total\ yield\ \ per\ ha(kg) * total\ area\ (in\ ha)$$

Conversion Factor

The conversion factor is ratio of dry weight to green weight. The conversion factor is used to estimate per hectare dry weight and total yield of the area. The green weight of the individual was calculated recorded in the field while dry weight of Yarsagumba was taken from *Sigdel et al. 2017*. The dry weight estimated by *Sigdel et al, 2017* ranges from 0.2 to 0.5 gram.

$$Conversion\ factor = \frac{Dry\ Weight}{Green\ weight}$$

Correction factor:

Since the fresh of Yarsagumba were taken in field without cleaning, therefore it also included the weight of soil attached to it. If we donot reduce the weight of the soil from fresh weight of Yarsagumba, yields will be overestimated. Therefore, it is necessary to apply correction factor to fresh weight. Since there is no standard correction factor for soil weight, it was assumed 10% of total fresh weight. Hence, correction factor of 0.9 was used to adjust fresh weight of Yarsagumba from inventory.

Chapter Four: Results

This chapter presents the results derived from the Yarsagumba resource inventory, social survey and the document analysis. The results were analyzed and discussed in relation to the study objectives.

Potential area of Yarsagumba:

Potential area of Yarsagumba was calculated for each potential VDCs based on the altitude and land use of the study area.

Figure 6 shows the potential Yarsagumba area in Byas VDC. The total area of VDC is estimated 56392.67 ha while Yarsagumba potential area covers 8800.05 ha. Yarsagumba potential area covers 15.6% of total VDC area and 4.6% of total ANCA area.

Figure 6: Potential area of Yarsagumba in Byash VDC

Figure 7 presents the Ghusa VDC (32003.52 ha) with potential Yarsagumba distribution areas which covers 10094.8 ha area. Out of total VDC area, potential Yarsagumba area is 31.54% and 5.31% of total ANCA.

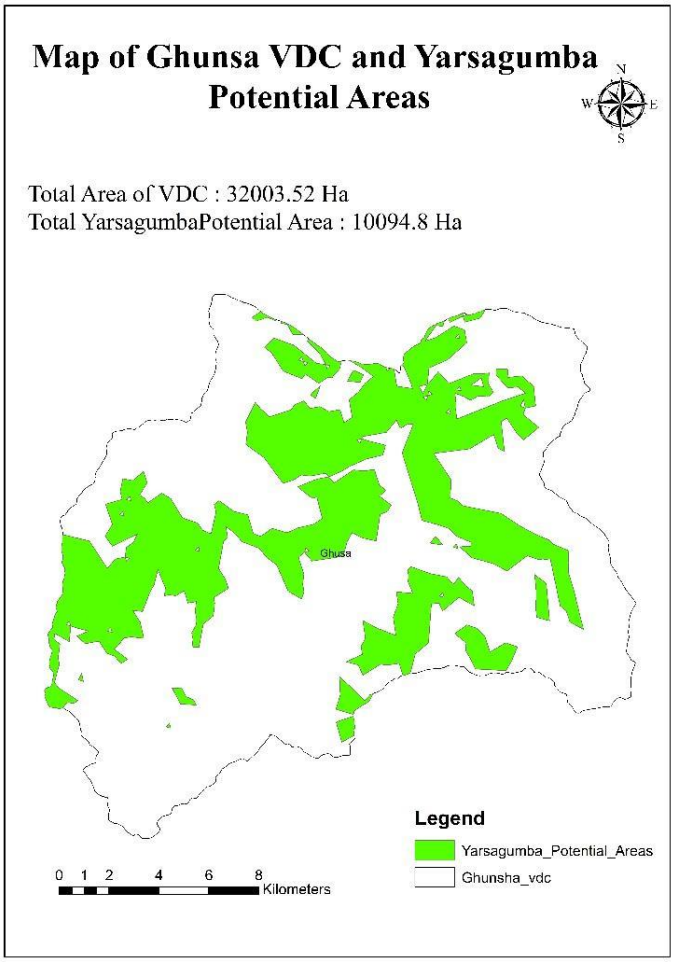

Figure 7: Potential area of Yarsagumba in Ghunsa VDC

Guljar VDC covers an area of 11504.56 ha, of which 1756.10 ha (15.26%) area is potential for Yarsagumba and the potential area is 0.92% of total ANCA (

Figure 8).

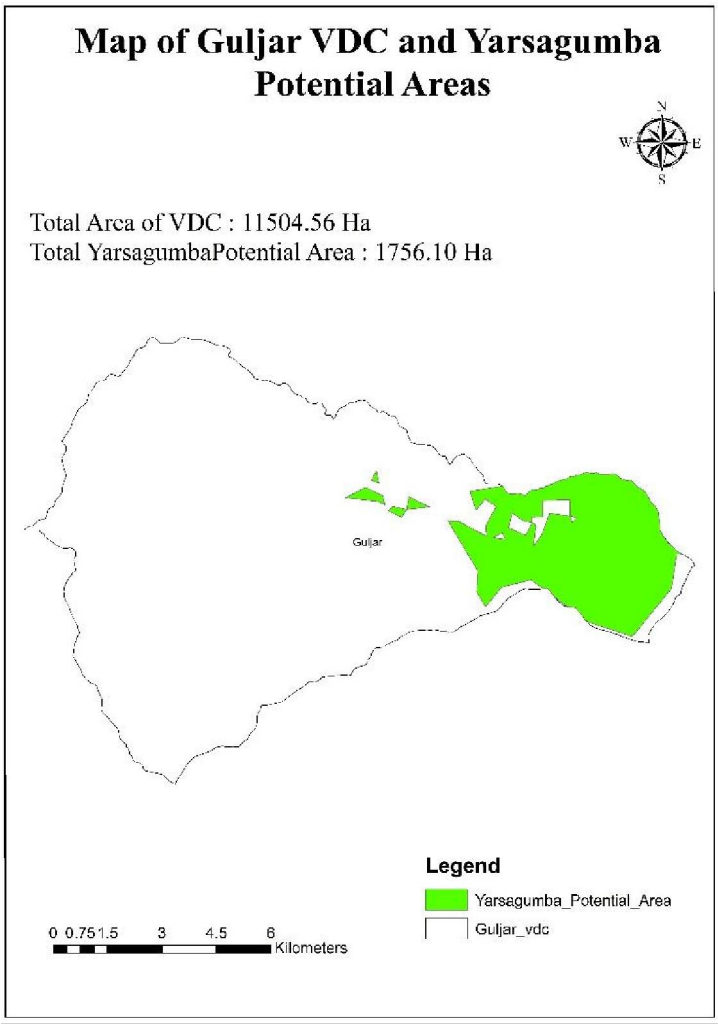

Figure 8: Potential area of Yarsagumba in Guljar VDC

Similarly

Figure 9 shows potential area for Yarsagumba in Khandeswori VDC. Of total area of the VDC (17978.74 ha) 24.10% (4333.66 ha) is Yarsagumba potential area which represents 2.28% of ANCA.

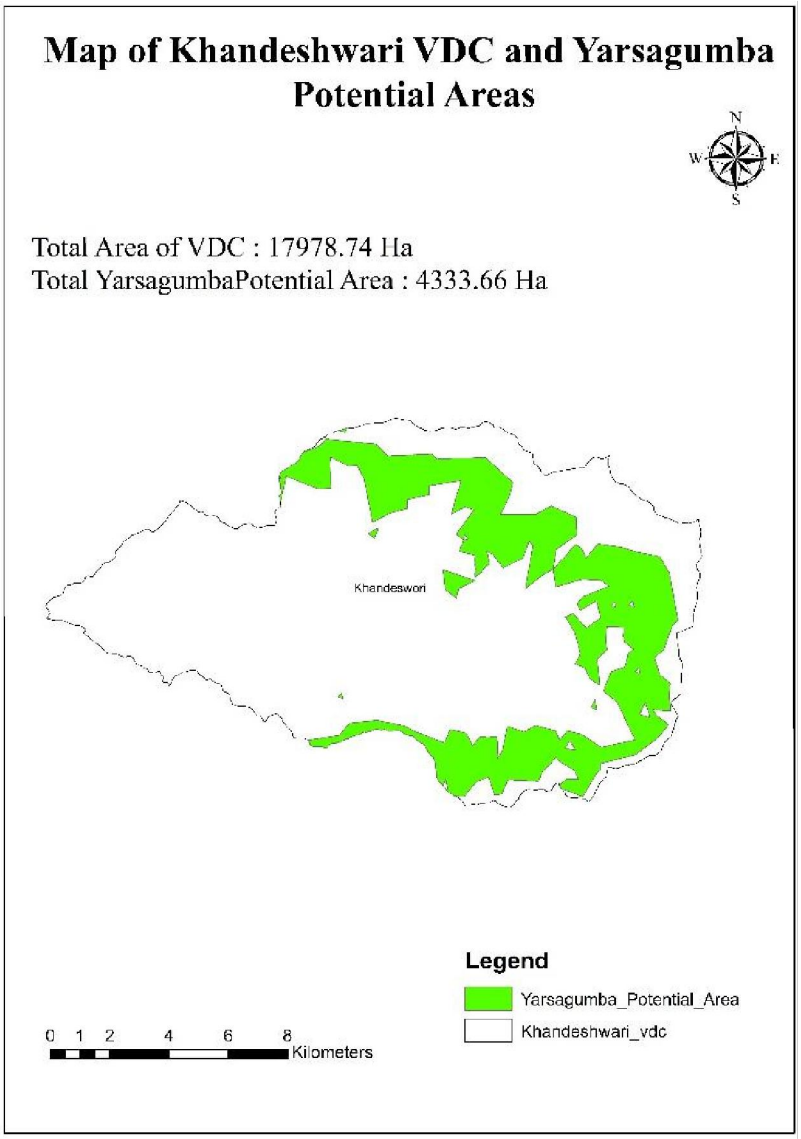

Figure 9: Potential map of Yarsagumba in Khandeswori VDC

Rapla VDC covers total area of 17882.71 ha, of which 28.28% of VDC area is potential for Yarsagumba and the area makes 2.66% of ANCA. Map of Rapla VDC with possible Yarsagumba distribution area is shown in

Figure 10.

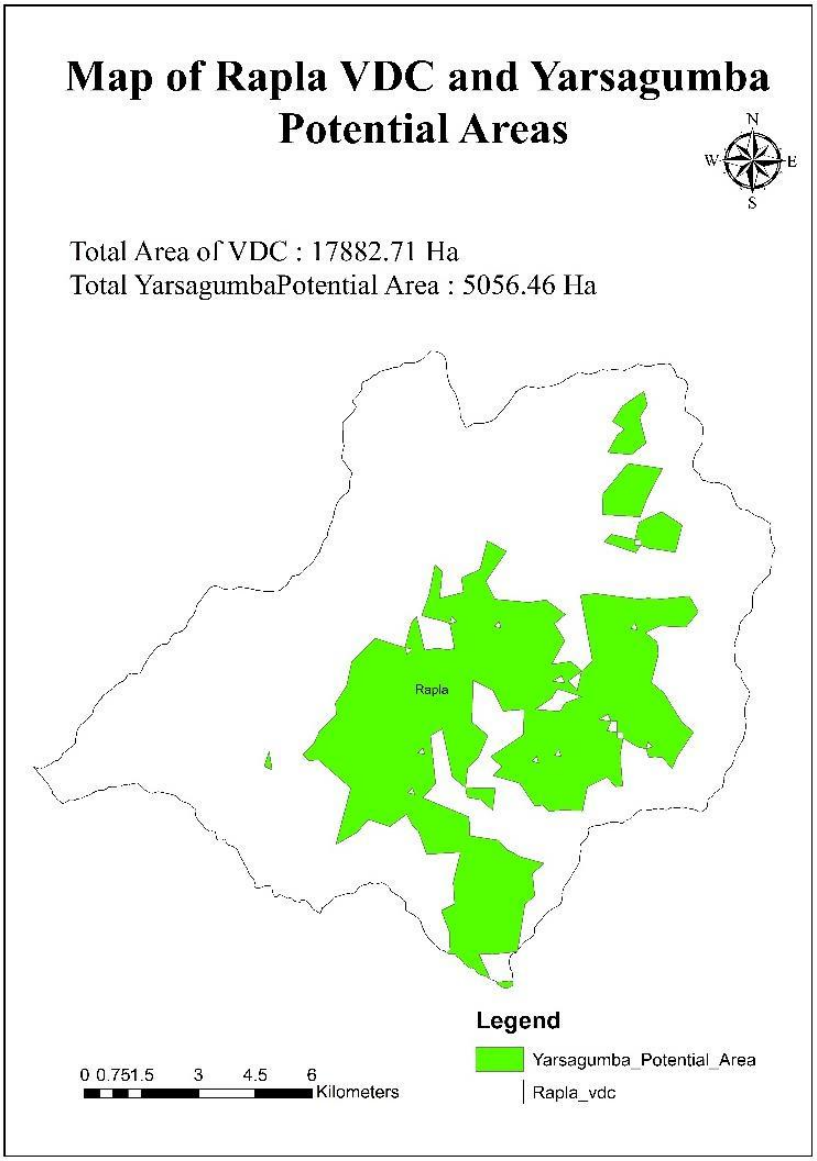

Figure 10: Potential area of Yarsagumba in Rapla VDC

16.09% area of Sitaula VDC (12233.45 ha) is potential for Yarsagumba as shown in Figure 11 which accounts 1.03% of total ANCA.

Total potential area of Yarsagumba is 32009.11 ha in ANCA. Out of total area of six VDCs, 21.63% area is potential for Yarsagumba which is 16.83% of total area of ANCA.

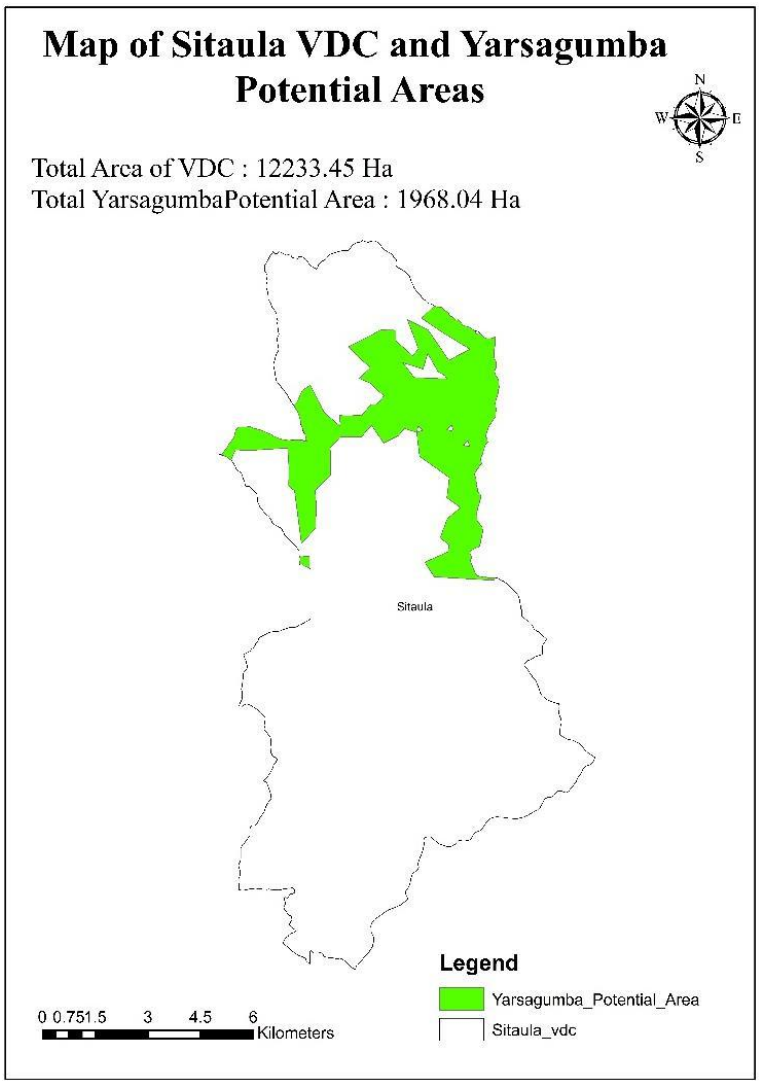

Figure 11: Potential area of Yarsagumba in Sitaula VDC

Frequency, Density and Abundance

Table 4 presents estimated frequency, density and abundance of Yarsagumba in study VDCs (Strata) and overall ANCA. The frequency of Yarsagumba ranged from 30.36 (Khandeswori) to 43.44 (Ghusa) percent and overall frequency is estimated to be 38.46%. Density per hectare ranged from 66.46 to 106.38 in Khandeswori and Ghusa respectively, while overall density of

Yarsagumba in ANCA is estimated 85.39 individuals per hectare. The abundance in overall ANCA is estimated 70.50 per hectare and lowest is estimated in Rapla (54.39 per ha) and highest in Khadeswori (97.96 per ha).

Table 4: Result of Yarsagumba frequency, density and abundance in three strata

Strata	Frequency (%)	Density (individual per ha)	Abundance (per ha)	Remarks
Ghusa	43.33	106.38	59.17	
Rapla	41.59	83.33	54.39	
Khandeswori	30.36	66.46	97.96	
Overall ANCA	**38.46**	**85.39**	**70.50**	

Total Yield

Potential area of Yarsagumba (ha) and total yield (in pieces and KG) are given in the Table 5. Total Yarsagumba yield of ANCA was estimated 911.71 Kg. The lowest yield was estimated in Guljar (47.92 kg) while highest yield of 343.21 kg was estimated in Ghusa. It is obvious that total yield is the highest in the VDC whose area was the largest (10094.8 ha) and the lowest in VDC which has least area because the total yield is product of density and area.

Table 5: Result of potential area, total yield (pieces and KG)

Name of VDC	Potential Area of Yarsagumba (Ha)	Total yield (*1000 pieces)	Total Dry Yield (KG)
Rapla	5056.46	421.3548	134.21
Ghusa	10094.8	1073.8848	343.21
Khandeswori	4333.66	288.0150	92.05
Byash	8800.05	751.4362	240.16
Sitaula	1968.04	168.0509	53.71
Guljar	1756.1	149.95337	47.92
Total	**32009.11**	**2852.6954**	**911.71**

Average number of Yarsagumba collection per day per person:

It is estimated that average number of Yarsagumba collection per day per person was 5 piece (4.7 gm fresh weight). Average collection per day per person ranged from 2 to 7 piece (1.88 to 6.58 gm fresh weight). Harvesting in ANCA in 2017 started from May and harvesting period was estimated to last for 30 days. Average number of people involved in collecting Yarsagumba was estimated 8479 individuals.

Number of harvesters in Different collection sites:

The number of harvesters collecting Yarsagumba in different sites of six VDCs are given in Table 6.

Table 6: Number of collectors in different collection sites of six VDCs

S.N.	VDC	Collection site	Number of collectors
1	Ghusa	Lolu	527
		Rokhapu	631
2	Byas	Budi	947
		Api	735
		Bolin	427
		Kuntisau	735
3	Sitaula	Chaimatela	1065
		Satganga	338
4	Rapla	Dudiban	857
		Humdumti	379
		Galgasya	468
5	Khandeswori	Dharamghar	623
6	Gulzar	Dharamghar	747
Total			**8479**

Annual Allowable Harvest (KG) and Collectors:

A species is considered as overharvested when the harvest rate of any given natural populations of that species exceeds its natural replacement rate (Peres 2010). However, the impacts of this massive-scale harvesting on natural populations of Chinese caterpillar fungus and associated ecosystems are largely unknown. Nor do we know the natural replacement rate of Chinese caterpillar fungus. Thus, the assumptions of overharvesting and the variation in overharvesting

across space and time remain to be validated. Therefore, to ensure the sustainable harvest of the Yarsagumba, it is recommended that allowable harvest should be restricted to 90% of total yield (ANSAB, 2010). The overall harvestable amount (KG and piece) from different potential area and number of harvester allowable are tabulated in Table 7.

Table 7: Annual Allowable Harvest (piece and KG) of Yarsagumba and number of allowable harvesters

Name of VDC	Potential Area of Yarsagumba (Ha)	Total Yield (KG)	Allowable harvest (KG)	Allowable harvest (piece)	Number of allowable harvesters
Rapla	5056.46	134.66	121.19	379197	2528
Ghusa	10094.8	343.21	308.89	966501	6443
Khandeswori	4333.66	92.05	82.84	259202	1728
Byash	8800.05	240.16	216.14	676291	4508
Sitaula	1968.04	53.71	48.34	151253	1008
Guljar	1756.1	47.92	43.13	134951	899
Total	**32009.11**	**911.71**	**820.53**	**2567395**	**17114**

The harvestable amount of Yarsagumba is 820.53 kg based on the field study and according to the ANCA official records average Yarsagumba released annually amounts 858.4 Kg. Therefore, total annual harvestable amount may range 820.53 Kg to 858.4 Kg.

Issues and challenges of Yarsagumba harvesting:

In the perception of the harvester, the problems during harvesting period include illegal collection, over harvesting, poor trail condition, lack of health posts/services, unmanaged wastes in camping sites and security. The natural problems like untimely snowfall were also reported.

While the challenges ANCA has been facing are grassland management (including fire), waste management at camping site, Yarsagumba market management at local level, royalty collection, and fixing camping sites. The issues/problems of Yarsagumba harvesting faced by harvesters are listed below:

- Illegal collection of Yarsagumba
- Over harvesting and premature harvesting
- Improper market price at local level
- Fire on grassland in dry season
- Poor trail conditions
- Unmanaged Camping
- Lack of waste management in camping site
- Untimely snowfall
- Lack of health post/services

The challenges of related to Yarsagumba by ANCA are:

- Market management
- Grassland management
- Waste management in camping sites
- Royalty collection
- Monitoring of Yarsagumba harvesting due to insufficient human resource and harsh terrain.

Chapter Five: Yarsagumba harvesting Plan

Apart from over harvesting, premature harvesting, and climate change, there could be several other anthropogenic and natural drivers of Chinese caterpillar fungus decline. Population fluctuations of food plants can cause fluctuations in populations of host caterpillar and ultimately the Caterpillar fungus. Thus, long-term monitoring of the natural populations of Chinese caterpillar fungus and its host to track the impacts of harvesting is necessary.

Due to limited information on ecology and natural history, the high economic value of the fungus, and massive scale of harvesting, there is no single overarching solution for sustainable management of this resource. In order to deal with multiple factors that might be responsible for decline in populations, a number of steps might be required to manage the Chinese caterpillar fungus populations. The collection of the fungus is done from de acto open access pasture land. Thus, it is highly likely that the resource will be further depleted if the pressures continue and there is no response to prevent further depletion, leading to Hardin's (1968) 'tragedy of the commons' situation. There are a number of conservation measures that needs to be adopted.

Rotation period of Yarsagumba:

Due to limited knowledge of natural history and regeneration process of the species, it is hard to determine the rotation age of the Yarasgumba. However, Chakraborty et al., 2014 has stated the life cycle of Yarsagumba needs one year to complete. In spring and summer it grows out of the host larva and forms a mushroom fruiting body above the ground, but grows inside the host larva during autumn and winter. Therefore, the rotation period of the Yarsagumba should be fixed one year.

Time period of harvesting

It is necessary to initiate conservation efforts by enforcing harvest and trade. If collection duration is fixed and the specimens regenerated later are prevented from extraction, populations may sustain for a long time. A similar perception among Chinese caterpillar fungus harvesters in China was documented by Weckerle et al. (2010). Currently, Yarsagumba management guideline 2073 have fixed calendar date of 2nd Week of Jestha to Ashar for harvesting, allowing collectors to extract Yarsagumba freely anytime. The Yarsagumba collection permit will be valid for 30 days and a person can have single permit at a time (Yarsagumba Management Guideline, 2073).

Habitat Management

Yarsagumba habitat management from unintended activities of harvesters during harvesting period includes solid waste management, control of excessive grazing, and reduction of adverse impacts on landscape (soil, water, and forests) during harvest.

Approved Instruments in harvesting:

The use of small hoe (khurma) and knifes should be used for uprooting of yarsagumba. The instrument other than approved by the conservation are not allowed to carry in the collection site. After uprooting of the yarsagumba, it is necessary to cover the area back in order to protect the soil and conservation of grassland.

Harvesters Camp Management:

Yarsgumba management guideline, 2073 has guided followings topics for management of camps at harvesting sites. Camping sites management should be done in coordination of local institution like, local administration, Nepal Army, Armed police force, Nepal police, District Health Office, Council, Committees and User Committee. The camp management of harvesters should include following activities:

1. Camping site:

   ANCA will identify and fix the camping sites in different rangelands of six VDCs. 13 rangeland as potential collection sites has been identified in ANCA. Therefore, at least 13 camping sites should be fixed for harvesters in ANCA. Conservation area can increase number of camping sites as requirement based on the area of rangeland. Harvester are not allowed to camp out of the area other than specified by ANCA. The ideal camping site should meet following requirements:

   a. Should not damage potential habitat of Yarsagumba.
   b. Should be located in near collection sites.
   c. Should have located in safe location (landslides, animal attacks).
   d. Should be plain and spacious enough to accommodate all harvester.
   e. Should have good drinking water source.

Table 8: Potential Camping sites in six VDCs

S.N.	VDC	Collection site
1	Ghusa	Lolu, Rokhapu
2	Byas	Budi, Api, Bolin, Kuntisau
3	Sitaula	Chaimatela, Satganga
4	Rapla	Dudiban, Humdumti, Galgasya
5	Khandeswori	Dharamghar
6	Gulzar	Dharamghar

2. Drinking water facility management:

   At each camping sites, there should be good supply of water and drinking water should be well managed. Drinking water facilities should be managed in coordination with local institutions, District Drinking water and Sanitation Office and local institutions.

3. Waste management

   Solid waste management is also cited by a significant number of harvesters as a way to conserve Chinese caterpillar fungus as they perceive haphazard solid waste disposal to have an adverse impact on the species. Harvesters have been witnessing the excessive use of fuelwood, open defecation, and accumulation of solid waste in the pristine landscape. Yarsagumba Management Guideline, 2073, has guided that waste at camping site should be managed proper and has banned use and carrying of plastics in collection sites. The collectors are not allowed to litter, fire, dig pits haphazardly. Therefore, proper area should is identified and allocated for dumping and lighting fire.

4. Temporary health facility at camping site

   Temporary health post/camps should be provisioned in each of the collection sites which could provide primary health services to the collectors. At least 13 temporary health camps/post should be established during Yarsagumba collection period in all collection sites.

5. Security at camping site

   In order to control the illegal collection and minimize the crime at camping sites and collection site, security forces should be mobilized in all collection sites. In order to maintain the peace and security at collection and camping site, Nepal Police, Armed

Police Force and Nepal Army should be coordinated and temporary security post should be established.

Regular Monitoring

Yarsagumba Management Guideline, 2073, has forbidden following activities in Yarsagumba collection and camping sites:

a. Camping outside allocated area.
b. Carrying and use of plastic materials.
c. Carrying of other instruments which are not permitted by ANCA.
d. Doing activities that are detrimental to forest and wildlife.
e. Littering, firing and digging pits unsystematically
f. Playing loud music and movies.
g. Using trails other than prescribed by conservation area for taking horse and donkey.
h. Activities that disturbs social peace.
i. Activities that are not permitted by conservation area.
j. Collection of Yarsagumba without permits.
k. Any other activities that are defined illegal by Rule and regulations.

To ensure that collection of Yarsagumba are smooth and legally carried out, regular monitoring will be done by ANCA and local institutions. ANCA and its staffs will monitor collection sites regularly to minimize the occurrence of aforementioned activities. Apart from that, ANCA will monitor if collection are being conducted in specified area and prescribed time period or not.

In order to control illegal harvesting, ANCA can issue collection permits for harvester as prescribed by Yarsagumba Management Guideline, 2073. ANCA can issue three types of collection permits charging applicable fees. Type of the permits that can be issued are:

1. For residents inside ANCA –NRs 500/person. Green colored permit
2. For residents of Darchula district but outside of ANCA-NRs. 2000/person. Yellow colored permit
3. Residents of other districts -NRs. 3000/person. Red colored permit.

Community Engagement

Maximizing benefits to local communities often creates an incentive for conservation of species and results in a win–win situation (Marshall et al. 2006). Therefore, ANCA in coordination with local institutions like Council, Committees and User committee will conduct Yarsagumba collection in conservation area.

Recommendation:

Based on the inventory results and the field observation following are the recommendations:

- Till now no economic survey has been carried out to estimate the exact amount of *O. sinensis* production in ANCA
- The quantitative assessment of the damage to grasslands in Nepal is still lacking. Therefore regular grassland damage assessment should be conducted.
- Conservation education and campaigns among public need to be carried out to ensure that fungi are harvested after sufficient spore dispersal; environmental impacts of unscientific collections, awareness programs on sustainable harvesting, management and utilization of *O. sinensis* at local level need to be conducted for its conservation.
- Further study to identify potential *O. sinensis* areas in ANCA is required for the availability assessment to diversify the collection sites.
- Detailed scientific research should be conducted to monitor ecological factors and regeneration pattern in ANCA area.
- Strong monitoring of *O. sinensis* harvesting is strongly required at local level to ensure sustainable harvesting.
- Government should play proactive initiative role for market promotion (e.g. via cooperative, buyback, etc.)
- Storage and packaging facility of *O. sinensis* should be developed and promoted to facilitate marketing of quality products.
- The present royalty rate of *O. sinensis* needs further review by the government in the changing global context of its market.
- Plantations should be established at lower forests to supplement growing stock depleted by the extraction of fuel wood during collection season.
- Over grazing should be checked for conservation of indicative/ associating flora.
- Community ownership and mobilization should be promoted for effective management of pastures.

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Annex 1: Yarsagumba Collection permit application letter format

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Annex 2: Yarsagumba Collection permit letter format

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==.

tkfOn] o; sfo{nosf] ldlt ==========sf] ;Íng cg'dlt kq g+========== adf]lhd o; sfof{no cGtu{tsf]==========Onfsfaf6==========
==lsnf]u|fd of;f{u'Daf ;Íng ug{' ePsf]n] ;f] jfkt nfUg] b:t"/
?==========-
clf/]kL========== _ bflvnf u/]sf]n] plNnlvt ldlt / kx'Fr :yfg;Dd n}hfgsf] nflu of] cf];/ k;f/ cg'dlt k|bfg ul/Psf] 5 . cf];f/ k;f/ ubf{ k|rlnt sfg"g, o; sfo{fnosf] lgb]{zg tyf zt{x? kfngf ug{' xf]nf .

cg'dltkqhf/L ug]{ clwsf/Lsf]
b:tvtM
gfdM
bhf{M
ldltM

af]wfy{÷ sfof{y{M

>L ========== kf]i6÷;]S6/ Mr]shfFr / b/kL7 u/L 5fl8lbg x'g .

>L========== af6f]df kg]{ r]skf]i6÷sfof{no M ,, ,, ,, .

Annex 4: Yarsagumba harvesting monitoring reporting format

cg';"rL– $

bkmf $-$_ ;Fu ;DalGwt -of;f{u'Daf ;+sng cg'udg kmf/fd_

g]kfn ;/sf/

jg tyf e" ;+/lf0f dGqfno

/fli6«o lgs'~h tyf jGohGt' ;+/lf0f ljefu

==========

s|=;+=	;+sng ug]{ AolSt	;+sng cgd kq g+=	cgdltkq Hf/L ldlt	clGtd ldlt	;+sns ;+Vof	;+sng cgdlt l]fq	of;f{uDaf sf] kl/df0f	s}=

cg'udg ug]{{

clwsf/Lsf]

b:tvtM

gfdM

bhf{M

ldltM

Annex 5: Yarsagumba certification certificate format

cg';"rL– %

lgb]{lzsfsf] bkmf %-!_ ;Fu ;DalGwt -pTklQsf] k|df0f–kq_

g]kfn ;/sf/

jg tyf e" ;+/lf0f dGqfno

/fli6«o lgs'~h tyf jGohGt' ;+/lf0f ljefu

========== sfof{no==========

ljifoM of;f{uDaf pTklQsf] k|df0fkq

>L==========

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tkfOn] o; sfof{nosf] ldlt==========sf] ;Íng cg'dlt–kq g+========== adf]lhd o; ;+/llft lf]q sfof{no cGtu{tsf]==========O{nfsfaf6 ==========lsnf]u|fd÷u|fd -clf/df ==========_ of;f{u'Daf ;+sng ug'{ ePsf] x'Fbf of] pTklQsf] k|df0f–kq lbO{Psf] 5 .

k|df0f–kq hf/L ug]{ clwsf/Lsf]

b:tvtM

gfdM

bhf{M

ldltM