POPULATION STATUS AND HARVEST PRACTICE OF *Nardostachys jatamansi* (D.Don) DC. IN JUMLA DISTRICT, KARNALI, NEPAL

A THESIS

SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER DEGREE IN BOTANY

Submitted to:

DEPARTMENT OF BOTANY

AMRIT CAMPUS

TRIBHUVAN UNIVERSITY

KATHMANDU, NEPAL

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T.U. Reg. No. 5-2-214-354-2015

Exam Roll No. : 928/077

May, 2024

DECLARATION

The thesis entitled, "**Population Status and Harvest Practice of *Nardostachys jatamansi* (D.Don) DC. in Jumla District, Karnali, Nepal**" presented to the Department of Botany, Amrit Campus, Thamel, Kathmandu, Nepal for the Master's degree in Science (MSc.) in Botany has been supervised by Assist. Prof. Dr. Baburam Paudel, Department of Botany, Amrit Campus. This is my original work and has never been deposited before, in full or in part, for the purpose of earning a degree at this or any other educational institution or university.

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ACKNOWLEDGEMENTS

I am sincerely grateful to my research supervisor Assist. Prof. Dr. Baburam Paudel for his guidance, inspiration and skillful supervision with great enthusiasm during my research work and the preparation of the thesis.

I am thankful to Dr. Jaya Prakash Hamal, Head of Department, Assist. Prof. Dr. Laxmi Joshi Shrestha, Program Coordinator and Assoc. Prof. Dr. Shila Singh, Former Head of Department of the Department of Botany, Amrit Campus, Tribhuvan University, for their guidance and administrative support.

This thesis work was supported by an Innovative Research Grant (Grant number: TU-NPAR-078/79-4-04) of the Research Directorate, Rector office, Tribhuvan University.

I acknowledge Assist. Prof. Dr. Chandra Kanta Subedi for his technical support and guidance throughout the completion of thesis.

My special thanks goes to Dr. Suresh Kumar Ghimire for helping me in plant identification. I appreciate my friends Asmita Adhikari, Sagar Kafle for their assistance in the field. Additionally, I would extend my acknowledgement to Sujan Acharya, Reema Sapkota, Rajani Pandit and Samikshya Paudel for their support and encouragement to complete my work.

My sincere gratitude is extended to my parents and all of my family members for their unwavering love, support, and encouragement in every circumstance throughout my research work.

Finally, but just as importantly, I would like to express my profound gratitude to all the people and institutions that helped me in any way during my research.

Priscilla Gautam

ABSTRACT

Nardostachys jatamansi (D.Don) DC. is a herbaceous medicinal plant that has high market demand and is listed as critically endangered in the IUCN red list and given priority to research and development by Government of Nepal. Indiscriminate harvesting practices, unmanaged grazing, overexploitation, and other factors are responsible for the decline of the population of *N. jatamansi*. To know the real-time population status of *N. jatamansi*, the study was conducted in two different sites in Jumla district (Tilkholesh- 3,300 to 3,450masl and Derabanga- 3,550 to 3,700masl). Altogether, 60 and 66 quadrats of 2m×2m were laid in Derabanga and Tilkholesh respectively. The first quadrat was laid randomly at the start of the population and then successive quadrats were laid in every 20m both vertically and horizontally. Geographical location, altitude, slope, aspect, number of study species and associated species and disturbance level were assessed in each quadrat. Different population parameters (density, frequency, abundance and IVI) were estimated. The density of *N. jatamansi* was higher in Derabanga than in Tilkholesh. The distribution was not affected by altitude, slope and aspect within their range. Grazing and trampling was found as major anthropogenic disturbance on the study site. Generalized linear model showed that disturbance caused significant effect on the distribution of *N. jatamansi* ($P<0.05$). Abundance frequency ratio revealed that *N. jatamansi* was contagiously distributed in both study sites. The most common species associated with *N. jatamansi* were *Anaphilis* sp., *Fragaria* sp., *Rhododendron setosom, Impatiens* sp., *Bistorta amplexicaulis* and *Gnaphalium* sp. *N. jatamansi* were found to be used by local people to boost the immunity of their cattle when they suffer from cough and cold. It had not been collected for commercial purposes but had been harvested indiscriminately with other grasses as fodder. It could be possible to stop the eventual loss of this medicinal plant from its natural habitat by educating the local residents about its ecology and significance.

Keywords: Population parameters, Questionnaire, Disturbance, Distribution

सोध सार

Nardostachys jatamansi (D.Don) DC. एक वनस्पतिय जडिबुटी हो, जसको बजारमा धेरै माग छ । यसलाई IUCN ले अति संकटापन्नको सूचीमा राखेको छ साथै नेपाल सरकारले यसलाई अनुसन्धान र विकासको लागि प्राथमिकतामा राखेको छ । मनपरी उत्खनन्, अव्यवस्थित चरिचरण, अत्याधिक दोहन जस्ता कारकहरु यसको संख्या घट्नुमा जिम्मेवार छन् । यसको वर्तमान् अवस्थाको जनसंख्याको स्थिती थाहा पाउनको लागि जुम्ला जिल्लाको दुई फरक ठाउँ (तिलखोलेस-३३०० देखि ३४५० मि. र डेराबाङ्गा-३५५० देखि ३७०० मि.) मा अध्ययन सम्पन्न गरियो । दुई वर्ग मिटरको ६० वटा quadrat डेराबाङ्गामा र ६६ वटा quadrat तिलखोलेस गौडामा राखिय । पहिलो quadrat जटामसी पाउन थालेपछि randomly राखियो र त्यसपछि ठाडो र तेर्सो रूपमा प्रत्येक २० मिटरमा राखिएको थियो। प्रत्येक quadrat को भौगोलिक स्थान, उचाई, ढलान, पक्ष, जटामसी र त्यसको साझेदार बोटविरुवाहरुको संख्या र अवरोधको स्तर टिपोट गरियो । जटामसीको घनत्व तिलखोलेसमा भन्दा डेराबाङ्गामा बढि पाइयो । जटामसीको वितरणलाई यसको सीमा सम्ममा उचाई, ढलान र पक्षले प्रभाव नपारेको पाईयो । चरिचरण र खुदाई त्यस ठाउँको मुख्य मानवीय अवरोध थियो । ती अवरोधहरुले जटामसीको वितरणमा सार्थकरुपमा प्रभाव पारेको थियो । जटामसी दुवै ठाउँमा लगातार रूपमा वितरण भएको पाइयो । जटामसीसँग सबैभन्दा बढि साझेदारका रुपमा पाइएका बोटविरुवाहरु *Anaphilis* sp., *Fragaria* sp., *Rhododendron setosom, Impatiens* sp., *Bistorta amplexicaulis* र *Gnaphalium* sp. थिए । जटामसीलाई त्यहाँका स्थानियहरुले गाईवस्तुलाई खोकी र चिसोलागेको बेला खुवाउने गरेको पाइयो । यसलाई व्यवसायिक प्रयोजनको लागि संङ्कलन नगरिएको पाइए तापनि घाँस काट्दा सँगै काटिने गरेको पाइयो । स्थानीय बासिन्दाहरूलाई यसको पारिस्थितिकी र महत्त्व बारे शिक्षित गरेर प्राकृतिक बासस्थानबाट यो औषधीय वनस्पतिको अन्ततः क्षति रोक्न सम्भव छ।

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ACRONYMS AND ABBREVIATIONS

A	Abundance
a.s.l.	above sea level
BCC-CSM1	Beijing Climate Center Climate System Model
BS	Bikram Sambat
CECI	Centre d'étude et de coopération international
CFUG	Community Forest User Groups
CITES	Convention on International Trade in Endangered Species of Wild Fauna andFlora
D	Density
DoFSC	Department of Forests and Soil Conservation
E	East
eSDM	Ensemble Species Distribution Modelling
F	Frequency
GCM	Global Circulation Model
GDP	Gross Domestic Products
GLM	Generalized Linear Model
GoN	Government of Nepal
GPS	Global Positioning System
HMG	His Majesty's Government
IUCN	International Union for Conservation of Nature
IVI	Important Value Index
m	meter
MAPs	Medicinal And Aromatic Plants
MoICS	Ministry of Industry, Commerce and Supplies
MPs	Medicinal Plants
N	North
NPR	Nepali Rupees

NTFPs	Non-timber Forest Products
RA	Relative abundance
RD	Relative Density
RF	Relative Frequency
USD	United States Dollar
VDC	Village Development Committee

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1 INTRODUCTION

1.1 Background

Nepal's vast range of elevations and monsoon-driven climate result in a diverse range of ecosystems, ranging from lowland tropical forests with evergreen understory in the Terai to evergreen and deciduous forests of temperate, coniferous forests, and finally forests reaching the tree line. Above this, rhododendron scrubland rises to high alpine meadows, where plant life disappears and is replaced by snowcapped summits. These diverse ecosystems are home to a great number of flora contributing to 2% of flowering plants, 3% of pteridophytes and 6% of bryophytes of the World's flora (MoFSC, 2014). With an estimated 6,653 types of flowering plants, Nepal is ranked tenth among the Asian nations for diversity of flowering plants, out of these, 1,762 are medicinal plants (Kunwar *et al.,* 2010 ; Kunwar *et al.,* 2022).

Medicinal plants are those plants which have been used from pre-historic times for the treatment of various health issues. In addition to serving as traditional medicine, medicinal plants are valuable commodities in trade, satisfying the need for novel drug development in distant markets (Jamshidi-Kia *et al.,* 2018). Medicinal plants are distributed throughout the tropical, sub-tropical, temperate, and alpine zones of the country. An altitude of 1100 m a.s.l. Nepal has the greatest richness of medicinal plant diversity (Acharya *et al.,* 2009). The forests and grasslands of Northern Nepal are home to most of the highly valued medicinal plants found in the country (MoICS, 2023).

About 100 species of medicinal plants are traded annually, but only 20 species account for 80% of the total trade in terms of volume and value in Nepal (Chhetri *et al.,* 2021). Non-timber forest products (NTFPs) or Medicinal and Aromatic Plants (MAPs) contribute around 5% of the Gross Domestic Product (GDP) of Nepal (CECI, 2006). Mid and far-western regions of the country provide 85% of Nepal's MAPs collections (MoICS, 2023). Although MAPs of Nepal have reached the markets of 50 countries, Indian markets are still the top importers and Chinese markets have an interest in highly valued MAPs of Nepal (Ghimire *et al.,* 2016). Thus, the volume and value of trade have rapidly expanded in response to rising demand from outside markets, particularly from China. The estimates of MAPs trade in Nepal, which are primarily centred on the Indian market, do not accurately reflect the trade situation (Pyakurel & Oli 2013).

Local people's livelihood in Nepal primarily depends on forest products, mainly on medicinal plants for their household needs (Shrestha *et al*., 1995). A study claimed that medicinal plants contribute up to 42% of their annual household cash income (Olsen & Larsen, 2003), all showing the importance of medicinal plants in the local livelihoods and national economy. In general, traditional use is not an issue, nevertheless, overexploitation may arise from the commercial collection of particular species to satisfy rising market demand (Uprety *et al*., 2011). Most of the rural people of Nepal who collect medicinal plants, not only have insufficient knowledge of the habitats of those plants and their natural regeneration but also harvest those plants which are prohibited by the Government of Nepal (GoN) for collection and trade (Acharya *et al.,* 2009). Several valuable herbs such as *Valeriana jatamansi, Nardostachys grandiflora, Dactylorhiza hatagirea* and *Rauvolfia serpentina* are in danger of extinction due to unsustainable harvesting practices (Chaudhary, 1998).

Every species has a unique response to a certain environmental niche. Environmental variables control the shift in species composition and have a significant impact on species occupying limited niches. Salick *et al*. (2004) claimed that aspect and slope, together with altitude, are the primary variables that influence plant species richness, diversity, and distributions. Consequently, one of the main elements influencing variations in a variety of characteristics that impact species diversity is an altitudinal gradient (Rahbek,1997; Grytnes and Vetaas,2002; Grytnes, 2003).

Karnali Province is home to more than 400 types of MAPs (Aryal *et al*., 2023). The major economic activities of the province are also dependent upon the harvesting and trade of MAPs. In the fiscal year 2019/2020, MAPs of Karnali province contributed 1.03% of GDP of the province and 0.02% of country's GDP (Aryal *et al*., 2023). Jumla is one of the districts that lies in Karnali province which is rich in medicinal plants and the local livelihood depends upon the wild plants for their food and medicinal values. The collection of NTFPs is the major source of income for the arrangement of food for more than 90% of people are under the food deficit (Paudel, 2009). Altogether 110 medicinal plants are found in Jumla district. Out of which *N. jatamansi* contributes about 50% of the total trade value of NTFPs traded from Jumla (Thapa, 2010).

Nardostachys jatamansi (D.Don) DC commonly known as 'Jatamansi' is a highly valued medicinal herb with a high market demand. It is the only species in the genus *Nardostachys* with other synonyms such as *N. grandiflora*, *N. gracilis* Kitam and *N. chinensis* Batalin (https://powo.science.kew.org/). The plant's major commercial portion is its rhizome, which can be used in place of valerian and whose extracts are utilized in more than 26 Ayurvedic treatments

(Purohit *et al.,* 2012). When it comes to the amount of *N. jatamansi* exported, Nepal leads the world with 82±5%, followed by India with 13±5% and Bhutan with 5±4% (Chauhan, 2021). According to CITES Export Permit Record of DoFSC, Nepal exported 3,284kg of *N. jatamansi* oil and 180.88 metric tons of *N. jatamansi* rhizomes/roots residue (marc) in 2023 (DPR,2024). India is the top country to import both marc and oil from Nepal. Due to its medicinal value and rate of population decline, International Union for Conservation of Nature (IUCN) categorized *N. jatamansi* as a critically endangered species (Chauhan, 2021). It is also listed in CITES Appendix II (https://checklist.cites.org/). Except for the processed product with approval from the Department of Forest exporting it beyond the nation is prohibited (DoFSC, 2019). Anthropogenic pressure such as the collection of forest biomass for energy source and fodder, deforestation, unsustainable harvesting, overgrazing, expansion of agricultural land and forest fires are likely to pose threats to the plant (Khuman *et al*., 2011; Ved *et al*. 2015).

1.2 Rationale of the study

Threatened species with limited populations and specialized habitats are more concerned about global conservation in the Anthropocene age due to their increased risk of extinction (Wani *et al*., 2021). The likelihood of over-exploitation of many valued species has increased due to the recent trend of large-scale commercial extraction of medicinal plants to satisfy the expanding demand of herbal enterprises. It is well documented that the pace, depth, and size of human impacts in the Himalaya have put ecological strains on life support ecosystems in addition to individuals and communities of medicinal plants. Different problems arise in the conservation of medicinal plants due to various factors like unscientific harvesting, habitat degradation and climate change. There could be unreported population decreases of *N. jatamansi* throughout its whole spectrum of distribution (Chauhan, 2021). So, there is an urgent need for the assessment of *N. jatamansi* in its natural habitat. The Government of Nepal has also prioritized *N. jatamansi* with other 33 medicinal plants for research and economic development of the country (DPR, 2024). Jatamansi Conservation Action Plan (2081-2090) has also aimed to conserve the natural habitat of Jatamansi, to increase its availability, number and distribution, to survey it's population in the entire country and to involve local people in the conservation and to contribute to the economic prosperity of local people through the conservation and promotion of Jatamansi (DPR, 2024).

In General, this study can provide valuable information regarding the distribution, present status and the role of this commercially valuable medicinal plant in the livelihood of local people. The significance of the study can be helpful for formulation of future strategies for the sustainable conservation, and management of medicinal plants.

1.3 Research questions

i. What is the population status and distribution patterns of *N. jatamansi* in its natural habitats in two different populations of Jumla district?
ii. How do different abiotic factors affect the population status of this medicinal plant?
iii. What is the current harvest practice and contribution of this medicinal plant to the livelihood of local communities?

1.4 Objectives

The present study aims to determine the population status of *N. jatamansi* and its role in the local livelihood of the Jumla district.

Specific objectives:

i. To determine variations in different population parameters (frequency, density, abundance and IVI) of *N. jatamansi* among different abiotic factors (elevation, slope and aspect).
ii. To test if the distribution (No. of individual species) of *N. jatamansi* is affected by various factors (elevation, slope, aspect and disturbance).
iii. To know the the harvest practice of *N. jatamansi* and its contribution in local livelihood.

1.5 Limitations and Delimitations

i. Althouth *N. jatamansi* is known to be occurred at several places of Jumla district such as Dillichaur, Chhumchaur, Patmara, Guthichaur, Garjyangkot, Lamra, Haku etc. the present study was confined only to Patmara and only based on two populations so the results cannot be used in the generalization of the population status of *N. jatamansi* in the entire district because the plant is known to be occurred also on other parts of the districts.
ii. Only limited factors (elevation, slope, aspect and disturbance) were considered in the study, but the population of the species can also be influenced by other factors such as land use type, forest fire, pH, moisture and nutrient content of the soil.

2 LITERATURE REVIEW

Scientific studies on Nepalese Medicinal plants have been a matter of great interest to various researchers since the beginning of the 19th century. It started during 1802-1803 when Francis Buchanan started to collect the plants of Nepal and recorded the uses of some medicinal plants followed by Nathaniel Wallich (Rajbhandari, 2001).

2.1 General studies on medicinal plants of Nepal

Banerjee (1957) published a paper on food and medicinal plants from eastern Nepal which was the first research of Nepal to be published on medicinal plants. According to His Majesty Government (HMG) Nepal (1970), the book 'Medicinal Plants of Nepal' contained details on the medicinal uses and distribution of 393 species, and was first published by the Department of Medicinal Plants (currently Department of Plant Resources) in 1970 A.D. Later in 1984 A.D., by publishing a supplementary volume 178 species of plants were added.

According to IUCN (2000), IUCN Nepal published a National Register of Medicinal Plants first time in 2000 A.D. which contained the description, conservation status and traditional uses of medicinal plants in Nepal. Later in 2004 A.D., it was revised describing 187 MPs (IUCN, 2004). Subedi (2006) reported that 161 NTFPs were collected for commercial purposes; of these, more than 50% are mainly utilized for medicinal purposes, and roughly 7% are used to make essential oils.

Devkota (2009) studied seven population of *Neopicrorhiza scrophulariiflora* in two villages Walangchung Gola and Ghunsa in Taplejung district and studied the population structure on the lower and upper alpine habitats. Very young and reproductive adult ramets were poorly represented in populations from the Walangchung Gola sector, which had greater numbers of juvenile and vegetative adult ramets. Conversely, populations from the Ghunsa sector had nearly similar numbers of juvenile, vegetative adult, and young ramets. Additionally, compared to Walangchung Gola groups, the proportion of mature reproductive ramets in Ghunsa populations was much higher. Along with population size and structure, altitude was also linked to the inter-population variation in other plant performance parameters. Populations in the lower alpine regions had high rates of sexual allocation and sexual reproductive effort.

Humagain and Shrestha (2009) selected the 12 most traded species and assessed the trade pattern and economic contribution of important medicinal plants in the livelihood of local people of

Chilime VDC in Rasuwa District and found that 90% of the collection used for trade and the selected medicinal plants contribution to the family income of the livelihood was 40% with the profit of NPR 9,000 annually.

Chapagain (2014) studied the population structure of *Juniperus indica* which is used in traditional medicine along elevation gradient in Manang district and found that it preferred to grow on South east to south west facing slopes on dry, rocky habitats. He also found that the population density is affected by the elevation. The adult plant showed higher density in low elevation band (3350-3580 m) while the juveniles and seedlings of the plant showed higher density in mid elevation band (3650-3880 m).

Ghimire *et al.* (2016) assessed the volume and value of medicinal plants traded from Nepal and found that 13.23 thousand tons of MAPs were exported annually for 10 years (2005 to 2014) which worth USD 39.34 million for average trade in the same 10 years.

Paudel (2016) conducted a study in Nepal and assessed the habitat of a medicinal plant *Roscoea alpine* that is endemic to Himalayas and found that they prefer to grow mostly on open alpine grasslands. The main risks to the plant were determined to be road construction and ecotourism-related habitat degradation, early and indiscriminate harvesting for fodder, pressure from grazing, and other human disturbances to the ecosystem.

Subedi (2016) aimed to study the population structure and performance of a medicinal plant *Juniperus squamata* along three elevation bands in Manang district at mid elevation (3,700-4,000m) all of the life stages i.e. (seedling, juvenile and adult) showed high density. The population structure in the studied area displayed a reverse J-shape, suggesting a healthy state of regeneration.

Khanal *et al.* (2018), published a handbook of Pharmacognosy "Medicinal Plants in Nepal" in which they have described 30 medicinal plants with their general description, uses, distribution, chemical constituents, conservation status and microscopic characters and organoleptic characteristics.

Shrestha (2018) performed a study in Panchase Protected Forest of Central Nepal and found that the population of *Taxus wallichiana* is higher in northern aspect than in southern aspect and were confied to a narrow altitudinal belt (2200 to 2500m). She also attempt to assess the potential distribution of the plant through species modeling and found that the plant may be possibly distributed in the high altitude of Eastern part of Nepal than Western Nepal.

Paudel and Poudel (2019) assessed the habitat of *Satyrium nepalense* at Deorali pass, above Nangethati in Kaski district and found to be growing mostly on open grassy meadows. Their study revealed that population parameters like frequency, density and abundance is not affected by the elevation within their study site. The plant was found to be reandomly distributed and that population does not fall into any category of IUCN threat category.

Pyakurel *et al*. (2019) analyzed the data collected through structured pretested questionnaires from 113 sub-local traders, 105 local traders, and 75 central wholesalers for the case year 2014–2015 and found that 300 species of MAPs are being traded. The vulnerability assessment tool revealed that *Nardostachys jatamansi*, *Rheum australe*, and *Neopicrorhiza scrophulariiflora* are commercially the most vulnerable medicinal plants.

Khadka (2022) intends to find the population structure of *Rhododendron arboreum* in Rainaskot Lamjung in a mixed forest. She found that *R. arboreum* is the most frequent species having high density and IVI. However, IVI was higher on high altitudes (1600 -1653m) than at low altitude (1200-1400m). She revealed that the soil's properties, biological diversity, and human disturbances are responsible for the forest's variations in population and regeneration attributes.

Parajuli (2023) evaluated the population density and structure of *Paris polyphylla* across lower, mid and upper temperate region in Dolakha district and found that juveniles had the lower density than vegetative and reproductive adults in all of the assessed populations. He also found that human disturbances i.e. harvesting and trampling and topographic features were the main environmental variables influencing the plant's variability in performance and density. The ability of the plant to persist and thrive will be influenced by how well policies are implemented to prevent overharvesting and premature rhizome harvesting, as well as to conserve younger life stages.

2.2 Studies related to *Nardostachys jatamansi*

Ghimire *et al.* (1999) assessed the population distribution and density, biomass production and regeneration of five different MAPs (*N. grandiflora, Picrorhiza scrophulariiflora, Rheum australe, Dactylorhiza hatagirea* and *Aconitum orochryseum*) in three different sites of Gyasumdo Valley, Manang District and found that the frequency of *N. grandiflora* is low in the study area while density was found to be higher in Ponger lake site in comparison with other studied MAPs. They also found that the regeneration of *N. grandiflora* was higher compared to other studied MAPs in the Ponger lake site. On the Ponger Lake site and Yamra, *N. grandiflora* contributed the most for underground biomass, 65.82% and 72.4% respectively.

Airi *et al*. (2000) investigated the availability and preferred habitats of *N. jatamansi* in the west Himalayas of India. They discovered that the plant primarily favoured damp boulders and moss-covered rocks. West-facing slopes were found to have higher densities than east-facing slopes. Altitude showed a strong positive correlation with the frequency and density of the plant. Below-ground biomass was found to be positively connected with biological traits such as plant density, plant height, and above-ground biomass, as well as environmental features such as moisture content and soil nitrogen.

Larsen (2002) selected three different sites which are half-day, one-day and one and half days away from nearby villages in Chaudabise Valley, Jumla and intended to compare the abundance of *N. grandiflora.* She considered density and dry root biomass as the abundance of the plant and came to know that abundance is greater in the area with no disturbance than in the area with disturbance. A similar result was found in the case of the length of the rhizome.

Chauhan and Nautiyal (2005) cultivated *N. jatamansi* under various treatments at different elevations (1800m, 2200m and 3600m) applying vegetative propagules and seedling transplantation procedures. They found that yield increased with the increase in the amount of manure added and elevation in comparison with the control. The crop that was planted as seedlings and grown vegetatively in a polyhouse at 3600m yielded the highest profit.

Ghimire *et al.* (2005) investigated the effect of selective and unselective harvesting practices on the density of ramets of *N. grandiflora* in SPNP and its buffer zone and found that the density increased after two years of harvesting at 10% and 25% levels and reached the density before harvesting after four years of harvesting for 10% level. While the density decreased continuously for 50% and 75% levels of harvesting during the study period (1999-2002).

Larsen (2005) conducted a study in Gorkha district and applied several harvesting treatments and found that the no. of individuals of *N. grandiflora* is high in those plots in which 50% harvesting and 100% harvesting with replanting was applied. The diameter of the rhizomes was found to be high in the plots with 50% harvesting followed by 100% harvesting with replanting. The result was also similar for the dry weight of the rhizomes.

Ghimire *et al.* (2008) found that the flowering stage of Jatamansi was more prevalent in alpine meadows than in rocky outcrops. Similarly, population growth rates was also found to be higher in alpine meadows which was unharvested population than rocky outcrop habitat in which control treatment was applied. In both alpine meadows and rocky outcrops habitat, survival rate for adult was higher which is followed by juvenile and seedlings in the unharvested subplots. They also used Matrix modeling for the prediction of recovery time of the pre-harvest value and found that it requires 5 years for the recovery of outcrops population in which 10% harvesting level was applied. While, it requires 17 years for the 25% harvesting and 33 years for the 75% harvesting. On the other hand, the estimated recovery time was 6 years for the population of meadows that were commercially harvested (with harvesting levels above 25%).

Kadel (2011) compared essential oils extracted from rhizomes collected from Humla and Jumla and found that rhizomes from Humla contains 1.9% of essential oil with royal green color and the rhizomes from Jumla contains 1.52% of essential oil with greenish brown color.

Shrestha and Shrestha (2012) assessed the vulnerability of 21 medicinal plants by the Rapid Vulnerabiluty Assessment method in Langtang National Park and found that, three species were assigned to the Category I, 12 species in Category II, 6 species in Category III and any species doesn't fall in Category IV. *N. grandiflora* is the highly vulnerable species being placed in Category I. The main reason of their threat is due to parts of the plant used, overexploitation due to market pressure and population size.

Lakey and Dorji (2016) performed the ecological study of 16 species prioritized by collectors and experts in Lingshi Dungkhag which is located in Jigme Dorji Wangchuck National Park of Bhutan. They found that *N. grandiflora* is distributed broadly in between 3824 to 4664 m.a.s.l and have high average density (8.9/m^2).

Rana *et al*. (2020) intends to find out the climatically suitable zone for the plantation of six commercially important MAPs using ensemble species distribution modelling (eSDM). All of the selected MAPs showed their preference in the central region of Nepal at an altitude ranging from 1800 to 4200 m a.s.l. Whereas, *N. jatamansi* showed high preference at mountainous region from east to west of Nepal. Considering current and future climatic conditions, Global circulation model (GCM), BCC-CSM1.1.was used and found that the predicted zone of *N. jatamansi* overlapped highly with *D. hatagirea* and *N. scrophulariiflora* in western region of Nepal.

Sharma *et al.* (2021) conducted a study on Manedada, which lies in Gaurishankar Conservation Area to determine the distribution of *N. jatamansi* and found that *N. jatamansi* is most frequent with high density ($64/m^2$ to $84/m^2$) and IVI (140.9 to 151.8). They also found that the sample of rhizomes had an average essential oil concentration of 0.9%.

Kunwar *et al.* (2023) used occurrence points of different medicinal plants, 19 bioclimatic variables and elevation and analyzed through modeling and predicted that suitability zone for *N. jatamansi* will be increased 12.45% in 2070. By 2070, under current and future climatic conditions, *N. jatamansi* will be found to be largely distributed in Dolpa district and then in Humla district. Although, distribution of *N. jatamansi* will decrease in Jumla district. The suitable habitat for *N. jatamansi* is expected to be expanded in the mountainous district of west to central Nepal. Altitude contributed for the distribution of *N. jatamansi* by 42.77%.

Khakurel *et al.* (2024) conducted vulnerability assessment of 19 medicinal plants in Annapurna Conservation Area and found that, five species fall in Category I, 12 species under category II and two species under Category III. Category I, II and III indicates the most vulnerable, highly vulnerable and least vulnerable respectively. In their study, rhizomes were the most used part by the local people. *N. jatamansi* fall under category I in their study.

Research Gap

Althouth there are many studies conducted on population status of several medicinal plants (Devkota, 2009; Chapagain 2014; Subedi, 2016; Khadka, 2022; Parajuli, 2023), the real time population status of *N. jatamansi* is still lacking. This study intends to find the real time population status of *N. jatamansi* in its two poplation in Jumla district.

3 MATERIALS AND METHODS

3.1 Ethical consideration

All required approvals for research were acquired (Figure 1A, Figure2A). It was made clear to each participant in the questionnaire survey the aim of the study as well as the utilization of their contributions. All respondents provided their prior, informed consent before taking part.

3.2 Study area

The present study was conducted at two different populations of *N. jatamansi*, one in the north direction and another in the southwest direction, 1.55km and 1.66km from the Patmara village respectively. Patmara village, a village of Patarasi Rural Municipality, ward number -7, of Jumla district lies at an altitude of 3,008m. Jumla district is situated in the Karnali province of Western Nepal and is surrounded by Dolpa district in the east, Kalikot in the west, Mugu in the north and Jajarkot in the south. The district covers an area that lies in the altitudinal range of 2076-6387 m.a.s.l. and experiences dry and subhumid temperate climates (Paudel, 2009; Bhattarai *et al*., 2023) The average summer temperature in Jumla ranges from 18°C to 30°C, while the wintertime average is -14°C to 8°C. The average annual precipitation is 1343.0 mm (http://rapnepal.com/district/district-profile-12).

The study site is present at the sub alpine region of the northern part of district which contains more vegetation than the southern part. Forest of *Abies spectabiliis*, *Betula utilis* and *Rhododendron campanulatum* are found on the steep slopes of high altitude. The transition of forests and meadows is the habitat for medicinal plants like *R. anthopogon*, *N. jatamansi* and *Iris nepalensis*. Other species like *Dactyllorhhiza hatageria*, *Rheum australe* and *Neopicrorhiza scrophulariiflora* are found in the upper region of alpine meadows (Thapa, 2010).

The quadrat survey was conducted on two different sites namely Derabanga and Tilkholesh Gauda. Derabanga lies in the western Himalayan subalpine scrub and meadows eco-region and Tilkholesh Gauda lies in the western Himalayan subalpine conifer forests eco-region of the Karnali Province. The study sites were selected in such a way that they lie in between different elevation range The people who live in the Patmara area heavily utilize the open conifer forest of Tilkholesh Gauda for collection of fodder, fuel woods and grazing cattles. While local people depend on Derabanga only for collection of fodder. The questionnaire survey was performed at Patmara village with the local people.

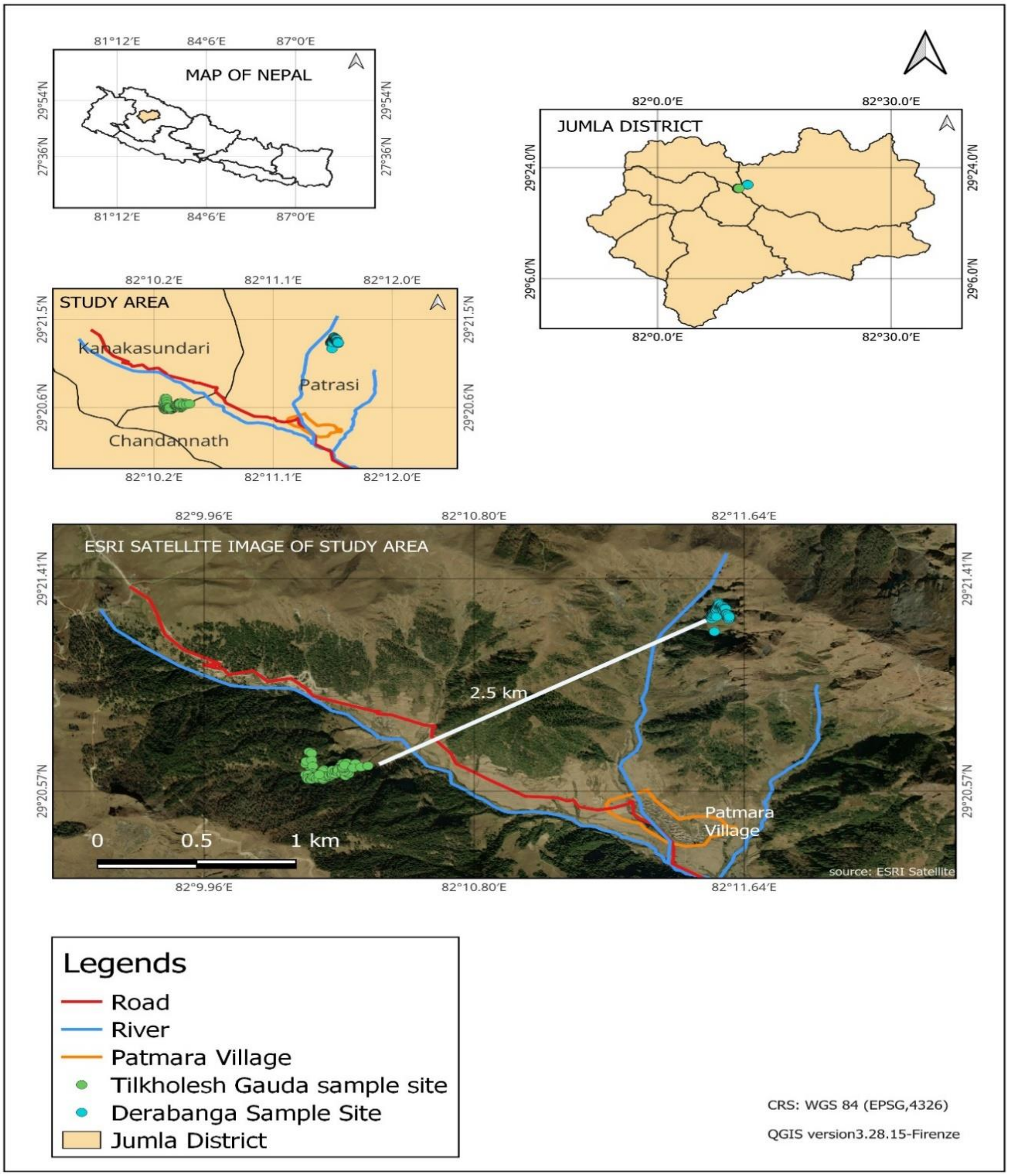

Figure 1: Map showing the both study sites Derabanga and Tilkholesh Gauda

3.3 Study species

3.3.1 Plant description

The highly valued medicinal and aromatic herb *N. jatamansi* (D.Don) DC was formerly placed in the family Valerianaceae but according to the Angiosperm Phylogeny Group (APG) system of classification of plants, it is placed in the family Caprifoliaceae (DPR, 2024). In Nepali, it is called as ‘Bhultya’. It is also known as Balchar, Indian spikenard, Indian valerian or Jatamansi (Singh *et al*., 2013). It is a small, perennial and rhizomatous plant which prefers to grow on moss-laden rocks, moist boulders, rocky-outcrop, steep areas, undisturbed meadows and forests (Airi *et al*., 2000; Chauhan & Nautiyal 2005; Ghimire *et al*., 2008; Ugyen & Dorji, 2021). The plant is 10 to 70cm tall and has a long, woody, rhizomatous, tail-like rootstock that is covered with reddish-brown hairs or the tufted fibrous leftover of the petioles of its wilted leaves (Goyal & Rath, 2021). Leaves are radical, entire and 1 or 2 in pairs. The inflorescence can have three to seven terminal and axillary clusters, or one terminal capitate cluster, often with broad oval bracts (Amatya & Sthapit, 1994). Flowers are actinomorphic and calyx is made up of five well-developed dentate lobes, which are green in the middle and violet at the rims. These lobes persist long after the seed reaches maturity. Petals are partially joined into a tube with five lobes. At anthesis, they are pinkish red, but as they mature, they turn bluish and change color when they shed (Chauhan *et al*., 2008; Gautam and Raini, 2013). Fruits are single-seeded achenes with tiny white hairs and calyx teeth on top (Amatya and Sthapit 1994; Ghimire *et al*., 2005). In nature, only 10% to 20% of seeds germinate, and plants usually multiply vegetatively by their rhizomes and ramets, creating thick clumps (Nautiyal *et al*., 2003).

Figure 2: *Nardostachys jatamansi* in its natural habitat in Derabanga

3.3.2 Distribution in the world

Nardostachys jatamansi is native to Himalaya regions of Myanmar, Bhutan, Nepal, India, Pakistan and China at an altitude of 3000 to 5000m (Ghimire *et al*., 2008; Chauhan, 2021; Goyal & Rath, 2021).

3.3.3 Distribution in Nepal

Nardostachys jatamansi is found in every province of Nepal except Madhesh Province. It is distributed throughout 30 mountainous districts which extend from western to eastern Nepal (DPR, 2024) (Table 4A). In comparison to the eastern region of Nepal, the distribution is both wider and higher in the western regions mainly higher mountainous regions in Karnali Province (DoFSC, 2019).

3.3.4 Phenology

Seed germination and emergence of leaves of *N. jatamansi* occurs from April to June (Nautiyal *et al*., 2003). Flowering time is between July to August (Chauhan *et al*., 2008). From September to October, the plant bears fruit and ripened. Every leaf turns yellow at the start of October. The herb loses all of its leaves in the winter, becomes buried in the snow, and goes dormant and resume its growth in the early summer after the snow melts (Kadel, 2011). Jatamansi rhizome can therefore be harvested around October after the seeds have been ripened.

3.3.5 Uses

For centuries, *N. jatamansi* has been utilized in the Ayurvedic, Unani and Amchi systems of traditional medicine (Jain, 1994; Ghimire *et al*., 2005). It is used in the treatment of digestive, circulatory, respiratory, urinary, reproductive, and nervous system-related diseases (Jain, 1994; Kaur *et al*., 2020). Its roots and rhizomes are mostly known to treat mental illness, hysteria and syncope epilepsy (Sahu *et al*., 2016). Jatamansi root's extract promotes hair growth in patients with hair fall due to cancer treatment (Goyal & Rath, 2021). In Nepal, high-grade incense made from the rhizomes of Jatamansi are used by Buddhist as well as Newar communities (Mulliken & Crofton, 2008). Additionally, it is utilized to make premium dyes, perfumes and hydrosoles which makes it commercially valuable (DoFSC, 2019).

3.3.6 Chemical compositions

Both volatile and non-volatile components are found in Jatamansi, mainly Sesquiterpenes and coumarins. The main Sesquiterpene is Jatamansome (Thakur *et al.*, 2021). Other phytochemicals found in Jatamansi are alkaloids, sesquiterpenoids, lignans and neoloignans (Kaur *et al*., 2020).

3.4 Sampling method and habitat assessment

A systematic purposive sampling method was adopted for the quadrat survey. The requisite size of 2m×2m quadrat was used for the study. After laying the first quadrat randomly from the start of the population, other quadrats were laid systematically both vertically and horizontally from the initial reference point maintaining a gap of 20m between the quadrats.

The geographical location, altitude, and aspect of each plot were recorded using the global positioning system (GPS). The slope was measured using the clinometer application on the phone. Jatamansi is a rosette-growing plant. Therefore, each adult with a root system and leaf rosette was regarded as an individual. The number of individuals of study species and associated species inside the plot were counted and some samples were collected and preserved for further identification.

3.5 Population status

Frequency, density, abundance, IVI and A/F ratio were considered as the proxy measure of the population status of *N. jatamansi.* Frequency, density and abundance were calculated following the method of Curtis and McIntosh (1950). Relative frequency, relative density, relative abundance and IVI were calculated by the method given by Curtis (1959). The abundance frequency ratio (A/F) was calculated to determine the distribution pattern of *N. jatamansi*. According to the criteria set by Kershaw (1973), the value of an A/F ratio less than 0.025 shows regular, 0.026 to 0.050 as random and more than 0.050 as contiguous type of distribution. To assess the potential variation in the population status of *N.jatamansi* across different topographic factors, frequency, density, abundance and IVI of *N. jatamansi* were estimated across different ranges of elevation, slope class, and aspects by using the formula below:

Frequency (F):

Frequency indicates how often a plant species occurred in the studied quadrats. It is expressed in percentage.

Frequency $= \frac{Number\ of\ quadrat\ in\ which\ species\ occurred}{total\ number\ of\ quadrats\ studied} \times 100\%$

Relative frequency $= \frac{Frequency\ of\ the\ individual\ species}{total\ frequency\ of\ all\ species} \times 100$

Density/m^2 (D):

Density indicates the total number of individual of a species that occur within a given sample unit or study area. It is expressed in terms of plants per unit area.

Density$= \frac{Total\ number\ of\ individual\ of\ a\ species\ in\ all\ quadrats}{total\ number\ of\ quadrats\ studied\ \times size\ of\ the\ quadrat}$

Relative Density $= \frac{Density\ of\ the\ individual\ species}{total\ density\ of\ all\ species} \times 100$

Abundance (A):

Abundance indicates the relative representation of a species in its community.

Abundance $= \frac{Total\ no\ of\ individuals\ of\ a\ species\ in\ all\ quadrats}{Number\ of\ quadrat\ in\ which\ the\ species\ occured}$

Relative abundance $= \frac{Abundance\ of\ the\ individual\ species}{total\ abundance\ of\ all\ species} \times 100$

Important value index (IVI)

IVI refers to the relative importance of a species in its community. IVI was determined by using the formula (Curtis,1959) :

IVI=RD+RF+RA

Similarity index

Sørensen similarity index was calculated to know the similarity between associated species of the study sites.

Sørensen index (%) = $\frac{2c}{a+b} \times 100$

Where, a = number of species recorded in site A, b = number of species recorded in site B and c = Common species of both sites

Disturbance

A species' population may naturally be small in some circumstances, or it may drop as a result of human pressure such as grazing, trampling, and extraction (Uniyal *et al*., 2002). Although, there are several disturbance types, only three types i.e. grazing, trampling and harvesting were considered in this study. The pressure from disturbances was quantified on a 3-point scale as adopted by Larsen (2002). On the 3- point scale, 1 represents the least disturbance, 2 represents medium disturbance and 3 represents high disturbance.

Statistical analysis

T-test was performed to compare the population parameters (density and abundance) between the two study sites. One way ANOVA was applied to determine the effects of different topographic factors (elevation, aspect and slope) while Generalized linear model was applied to analyze the effect of disturbance on the distribution (no. of individuals) of *N. jatamansi*. All the statistical analyses were performed in R (R Core Team, 2021).

3.6 Identification of associated species

Herbarium of study species together with its associated species were prepared in order to identify them. Expert consultation was used to identify those herbarium species and also compared with the specimens from the National Herbarium and Plant Laboratories (KATH), Godawari. The herbarium specimens were deposited on Tribhuvan University Central Herbarium and Ascol Herbarium.

3.7 Current harvest practice and Role of *Nardostachys jatamansi* in the livelihood of local people

A Questionnaire survey was conducted to know the role of *N. jatamansi* in the livelihood of local people as well as the harvesting practices. Altogether 34 people including farmers and medicinal plant collectors were interviewed in such a way that a respondent from each household was included. A set of open-ended questionnaires was prepared to collect the data and opinions of local people regarding harvesting stages, amount of rhizomes of plant harvested last year, trade, uses and threats to the plant (Table 3A).

4 RESULT

4.1 Habitat type and Population status of *Nardostachys jatamansi*

In Derabanga, *N. jatamansi* was found under the canopy of mixed forest of *Rhodondendron campanulatum, Betula utilis* and *Arundinaria* sp. in the north and west facing slopes, while in the south and east facing slopes, it was found under the canopy of scrub of *Rhododendron setosum, Cotoneaster mycrophyllus* and *Gaultheria* sp. In some places, *N. jatamansi* was also found on open grassy slopes. Whereas, in Tilkholesh Gauda *N. jatamansi* occurred in *Abies spectabilis* forest in moist and shady place. In both sites, *N. jatamansi* mostly occurred on mossy rocks. In Derabanga, *N. jatamansi* was found distributed from 3550 to 3700 m elevation while in Tilkholesh Gauda it was found between the elevation of 3300 to 3450 m.

Among the 60 and 66 studied quadrats, *N. jatamansi* occurred in 24 quardrats at both Derabanga and Tilkholesh Gauda. The density of *N. jatamansi* in Derabanga and Tilkholesh Gauda was $4/m^2$ and $2/m^2$ respectively (Table 1 and 2). T-test performed revealed that the density differs significantly ($P<0.05$) between two sites. Frequency of *N. jatamansi* was higher in Derabanga i.e. 40% than in Tilkholesh Gauda (36.36%). Similarly, abundance was also higher in Derabanga i.e. 38.17 than in Tilkholesh Gauda (21), but do not differ significantly ($P>0.05$) between both sites. In, both sites the A/F ratio is higher than 0.05 which shows that *N. jatamansi* is distributed contagiously at both sites (Table 1 and 2).

4.1.1 Community composition

In total, 32 plant species belonging to 17 families were recorded in Derabanga and 23 plant species from 17 families were recorded in Tilkholesh Gauda as the associated species of *N.jatamansi* (Table 1 and 2). In Derabanga, Asteraceae was the dominant family having highest number of species i.e. 11, while in Tilkholesh Gauda, family Rosaceae was dominant with four plant species. Sørensen index revealed that 52.83% of associated species were similar between the two study sites.

In Derabanga, *N. jatamansi* had the highest IVI (31.82) followed by *Anaphilis triplinervis* (21.13), *Fragaria* sp. (19.64), *Rhododendron setosom* (19.4) and *Gnaphalium affine* (11.96). However, *A. triplinervis* and *R. setosum* were the two dominant associated species on the basis of frequency (Table 1).

Table 1: Community composition of *N. jatamansi* in Derabanga

Name of plant species	Family	Total number of individuals	Total number of quadrats in which species occurred	D(/m²)	RD(%)	F(%)	RF(%)	A	RA(%)	A/F ratio	IVI
***Nardostachys jatamansi*(D. Don) DC**	Caprifoliaceae	916	24	3.82	24.82	40	6.88	38.17	0.13	0.95	31.82
***Adenostyles* sp.**	Asteraceae	28	2	0.29	1.89	8.33	1.43	14	0.05	1.68	3.37
***Adiantum* sp.**	Pteridaceae	62	5	0.65	4.2	20.83	3.58	12.4	0.04	0.6	7.82
***Ainsliaea aptera* DC.**	Asteraceae	4	1	0.04	0.27	4.17	0.72	4	0.01	0.96	1
***Anaphilis triplinervis*(Sims. CB. Clarke)**	Asteraceae	153	15	1.59	10.35	62.5	10.74	10.2	0.03	0.16	21.13
***Artimisia dubia* Wall. ex Besser**	Asteraceae	12	1	0.13	0.81	4.17	0.72	12	0.04	2.88	1.57
***Arundinaria* sp.**	Poaceae	58	3	0.6	3.92	12.5	2.15	19.33	0.07	1.55	6.14
***Aster diplostephioides* (DC.) Benth ex C.B.Clarke**	Asteraceae	13	3	0.14	0.88	12.5	2.15	4.33	0.01	0.35	3.04
***Aster stracheyi* Hook.f.**	Asteraceae	7	2	0.07	0.47	8.33	1.43	3.5	0.01	0.42	1.92
***Betula utilis* D. Don.**	Betulaceae	7	5	0.07	0.47	20.83	3.58	1.4	0	0.07	4.06
***Bistorta amplexicaulis* (D. Don.) Greene**	Polygonaceae	41	5	0.43	2.77	20.83	3.58	8.2	0.03	0.39	6.38
***Caragana* sp.**	Fabaceae	11	3	0.11	0.74	12.5	2.15	3.67	0.01	0.29	2.91
***Cirsium nishiokae* Kitam.**	Asteraceae	11	4	0.11	0.74	16.67	2.87	2.75	0.01	0.17	3.62

***Cotoneaster mycrophyllus* Wall. ex Lindl.**	Rosaceae	10	3	0.1	0.68	12.5	2.15	3.33	0.01	0.27	2.84
***Cyananthus microphyllus* Edgew.**	Campanulaceae	36	5	0.38	2.44	20.83	3.58	7.2	0.02	0.35	6.04
***Epibolium wallianum* Hausskn**	Onagraceae	2	2	0.02	0.14	8.33	1.43	1	0	0.12	1.57
***Fragaria* sp.**	Rosaceae	152	13	1.58	10.29	54.17	9.31	11.69	0.04	0.22	19.64
***Gaultheria* sp.**	Ericaceae	68	9	0.71	4.6	37.5	6.45	7.56	0.03	0.2	11.07
***Gerbera nivea* (DC.) Sch.Bip.**	Asteraceae	8	1	0.08	0.54	4.17	0.72	8	0.03	1.92	1.28
***Gnaphalium affine* (D. Don)**	Asteraceae	81	9	0.84	5.48	37.5	6.45	9	0.03	0.24	11.96
***Hydrocotyl* sp.**	Araliaceae	30	1	0.31	2.03	4.17	0.72	30	0.1	7.2	2.85
***Jasminum humile* Gueldenst.**	Oleaceae	5	1	0.05	0.34	4.17	0.72	5	0.02	1.2	1.07
***Podophyllum hexandrum* Royle**	Berberidaceae	1	1	0.01	0.07	4.17	0.72	1	0	0.24	0.79
Polygonatum cirrhifolium	Asparagaceae	54	4	0.56	3.65	16.67	2.87	13.5	0.05	0.81	6.57
***Potentilla eriocarpa* Wall. ex Lehm.**	Rosaceae	24	1	0.25	1.62	4.17	0.72	24	0.08	5.76	2.42
***Potentilla argyrophylla* Wall. ex Lehm.**	Rosaceae	6	1	0.06	0.41	4.17	0.72	6	0.02	1.44	1.14
***Rhodiola sinuata* (Royle ex Edgew.) S.H.Fu**	Crassulaceae	5	1	0.05	0.34	4.17	0.72	5	0.02	1.2	1.07

***Rhododendron campanulatum* D. Don.**	Ericaceae	9	4	0.09	0.61	16.67	2.87	2.25	0.01	0.14	3.48
***Rhododendron setosom* D. Don**	Ericaceae	138	14	1.44	9.34	58.33	10.03	9.86	0.03	0.17	19.4
***Rosa* sp.**	Rosaceae	18	5	0.19	1.22	20.83	3.58	3.6	0.01	0.17	4.81
***Senecio wallichii* DC.**	Asteraceae	52	4	0.54	3.52	16.67	2.87	13	0.04	0.78	6.43
***Synotis penninervis* (H.Koyama) T.J.Tong**	Asteraceae	5	3	0.05	0.34	12.5	2.15	1.67	0.01	0.13	2.49

Here, D=density, RD= Relative Density, F=Frequency, RF= Relative Frequency, A= Abundance, RA= Relative Abundance, IVI= Importance Value Index, total quadrats studied=60

In Tilkholesh Gauda, *N. jatamansi* had the highest IVI (39.86) followed by, *Fragaria* sp. (35.37), *Impatiens* sp. (26.85) and *Bistorta amplexicaulis* (22.81). However, *Fragaria* sp. and *Bistorta amplexicaulis* were the major dominant associated species on the basis of frequency in this site (Table 2).

Table 2: Community composition of *N. jatamansi* in Tilkholesh Gauda

Name of plant species	Family	Total number of individuals	Total number of quadrats in which species occurred	D(/m²)	RD(%)	F	RF(%)	A	RA(%)	A/F ratio	IVI
***Nardostachys jatamansi* (D.Don) DC**	Caprifoliaceae	504	24	1.91	20.47	36.36	9.73	21	9.67	0.58	39.86
***Abies spectabilis* (D.Don) Mirb.**	Pinaceae	5	4	0.05	0.56	16.67	4.46	1.25	0.58	0.08	5.59
***Adiantum* sp.**	Pteridaceae	98	8	1.02	10.94	33.33	8.92	12.25	5.64	0.37	25.5
***Anaphilis triplinervis*(Sims. CB. Clarke)**	Asteraceae	29	3	0.3	3.24	12.5	3.34	9.67	4.45	0.77	11.03
***Arundinaria* sp.**	Poaceae	15	3	0.16	1.67	12.5	3.34	5	2.3	0.4	7.32
***Betula utilis* D. Don.**	Betulaceae	2	1	0.02	0.22	4.17	1.11	2	0.92	0.48	2.26
***Bistorta amplexicaulis* (D. Don.) Greene**	Polygonaceae	74	10	0.77	8.26	41.67	11.14	7.4	3.41	0.18	22.81
***Caragarna* sp.**	Fabaceae	2	1	0.02	0.22	4.17	1.11	2	0.92	0.48	2.26
***Centella asiatica* (L.) Urb.**	Apiaceae	10	1	0.1	1.12	4.17	1.11	10	4.6	2.4	6.83
***Epibolium wallianum* Hausskn**	Onagraceae	1	1	0.01	0.11	4.17	1.11	1	0.46	0.24	1.69
***Fragaria* sp.**	Rosaceae	142	13	1.48	15.85	54.17	14.49	10.92	5.03	0.2	35.37
***Galium* sp.**	Rubiaceae	44	4	0.46	4.91	16.67	4.46	11	5.06	0.66	14.43
***Gerbera nivea* (DC.) Sch.Bip.**	Asteraceae	27	4	0.28	3.01	16.67	4.46	6.75	3.11	0.41	10.58
***Impatiens* sp.**	Balsaminaceae	45	1	0.47	5.02	4.17	1.11	45	20.71	10.8	26.85
***Potentilla eriocarpa* Wall. ex Lehm.**	Rosaceae	29	2	0.3	3.24	8.33	2.23	14.5	6.67	1.74	12.14
***Potentilla argyrophylla* Wall. ex Lehm.**	Rosaceae	19	4	0.2	2.12	16.67	4.46	4.75	2.19	0.29	8.77
***Rhodiola sinuata* (Royle ex Edgew.) S.H.Fu**	Crassulaceae	44	4	0.46	4.91	16.67	4.46	11	5.06	0.66	14.43
***Rhododendron lepidotum* Wall. ex G.Don**	Ericaceae	15	4	0.16	1.67	16.67	4.46	3.75	1.73	0.23	7.86
***Rosa* sp.**	Rosaceae	1	1	0.01	0.11	4.17	1.11	1	0.46	0.24	1.69
***Saxifraga parnassifolia* D.Don**	Saxifragaceae	28	3	0.29	3.13	12.5	3.34	9.33	4.3	0.75	10.77

***Senecio wallichii* DC.**	Asteraceae	44	4	0.46	4.91	16.67	4.46	11	5.06	0.66	14.43
***Swertia speciosa* D.Don**	Gentianaceae	24	2	0.25	2.68	8.33	2.23	12	5.52	1.44	10.43
Unknown	Apiaceae	14	3	0.15	1.56	12.5	3.34	4.67	2.15	0.37	7.05

Here, D=density, RD= Relative Density, F=Frequency, RF= Relative Frequency, A= Abundance, RA= Relative Abundance, IVI= Importance Value Index, total quadrats studied=66

4.1.2 Density, frequency and abundance of *N. jatamansi* based on different topographic factors

In Derabanga, density and abundance were highest at an elevation zone of 3550-3600m while frequency was highest at elevation zone of 3600-3650m (Table 3; Figure 3). No individuals of *N. jatamansi* were recorded above 3700m at that place.

Table 3: Frequency, density and abundance of *N. jatamansi* along the elevation range in Derabanga

Elevation zone (m)	3550-3600	3600-3650	3650-3700
Density(/m²)	5.82	3.95	2.32
Frequency(%)	42.86	44	33.33
Abundance	54.33	35.91	27.86

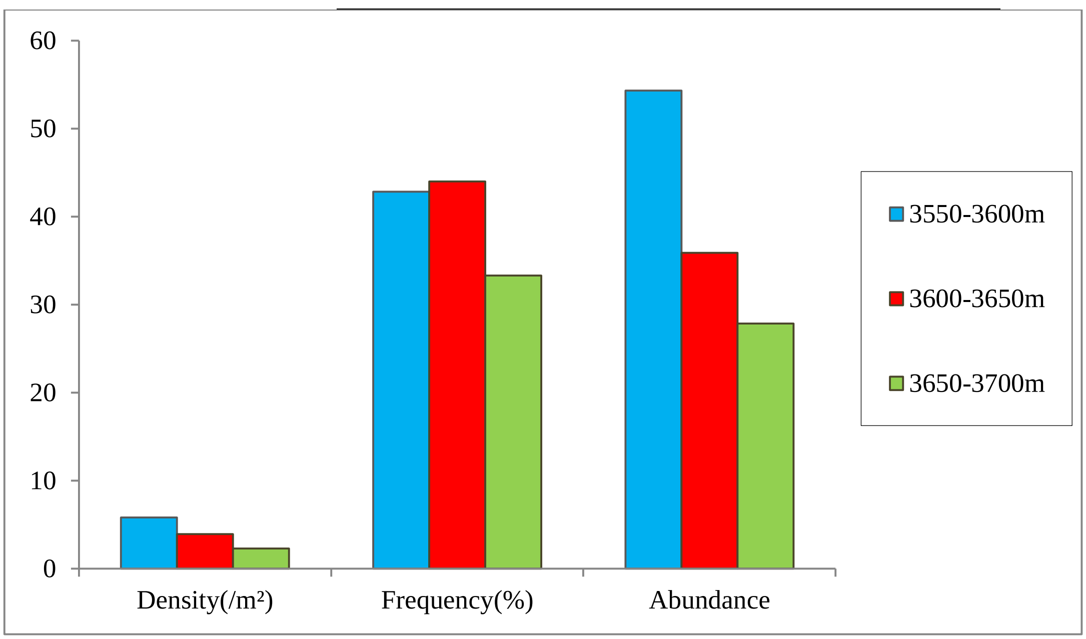

Figure 3: Graph presenting the frequency, density and abundance of *N. jatamansi* along the elevation range in Derabanga

In Tilkholesh Gauda, frequency was highest at an elevation of 3350-3400m while density and abundance were highest at 3400-3450m (Table 4; Figure 4).

Table 4: Frequency, density and abundance of *N. jatamansi* along the elevation range in Tilkholesh Gauda

Elevation zone (m)	3300-3350	3350-3400	3400-3450
Density(/m²)	1.43	2.08	2.21
Frequency(%)	38.89	50	25.93
Abundance	14.71	16.67	34.14

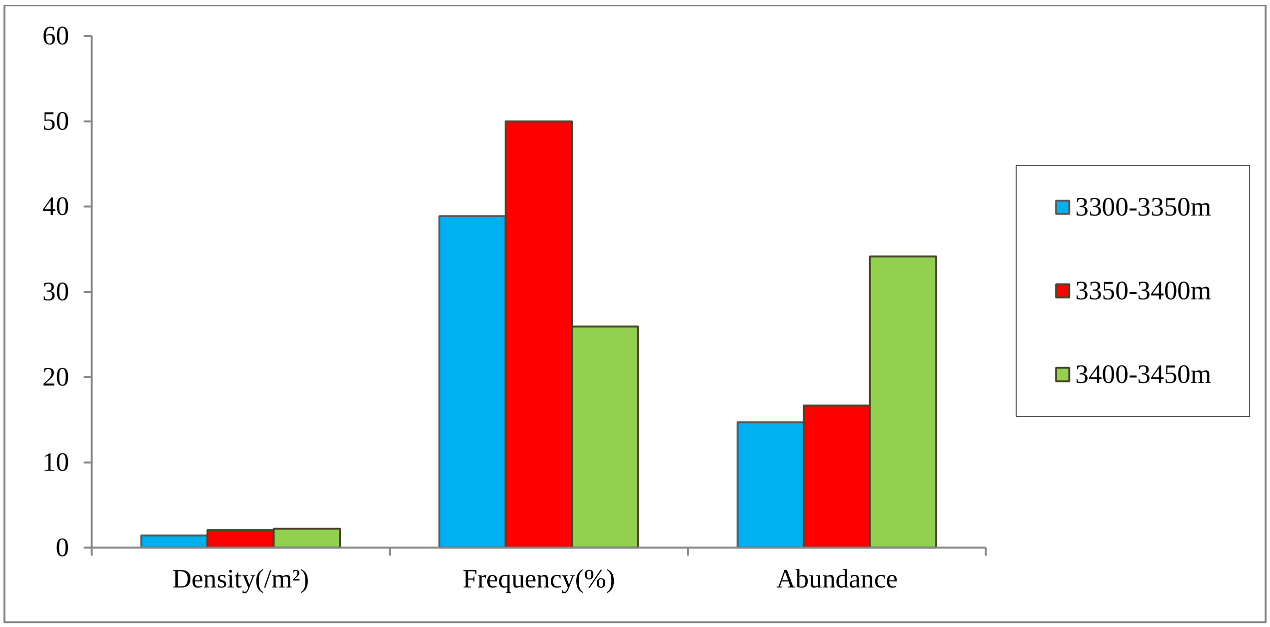

Figure 4: Graph presenting the frequency, density and abundance of *N. jatamansi* along the elevation range in Tilkholesh Gauda

In Derabanga, density and abundance of *N. Jatamansi* were higher on west facing slopes but frequency is highest on east facing slopes (Table 5; Figure 5).

Table 5: Frequency, density and abundance of *N. jatamansi* along different aspects in Derabanga

Aspect	East	West	North	South
Density(/m²)	3.42	5.53	3.61	1.78
Frequency(%)	66.67	40	46.88	20
Abundance	20.5	55.25	30.8	35.67

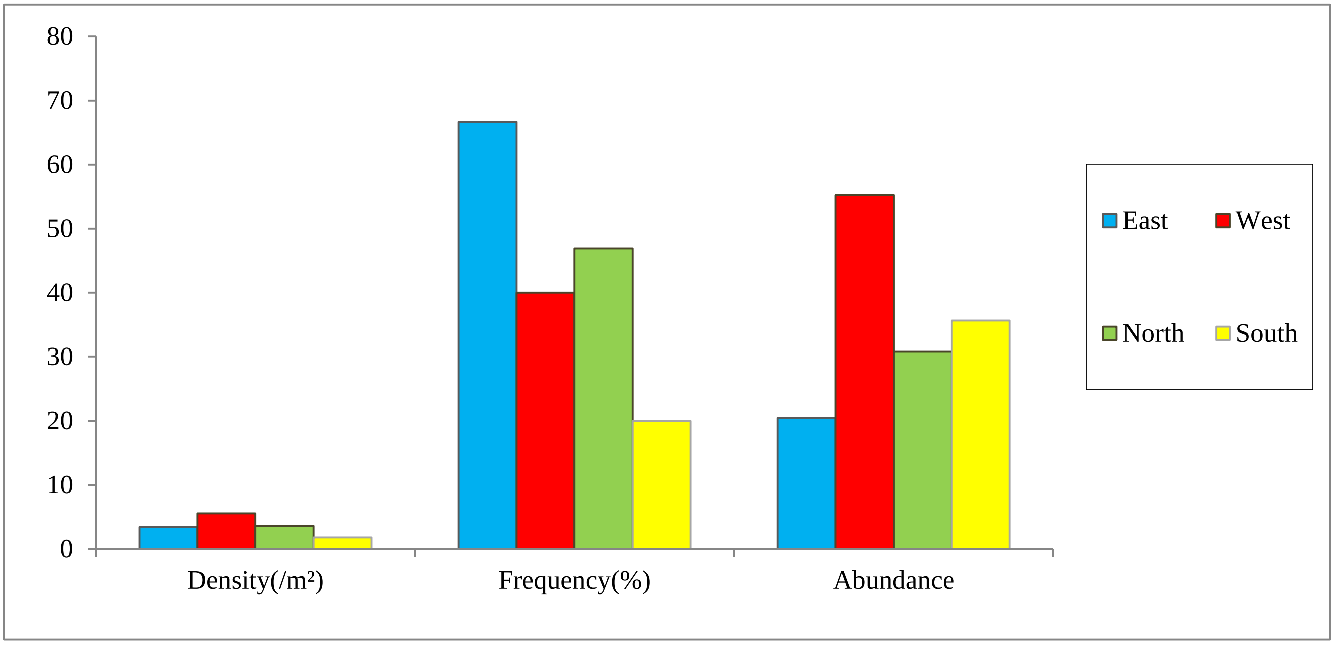

Figure 5: Graph presenting the frequency, density and abundance along different aspects in Derabanga

In Tilkholesh Gauda, density, frequency and abundance are found to be highest on west facing slopes (Table 6; Figure 6).

Table 6: Frequency, density and abundance of *N. jatamansi* along different aspects in Tilkholesh Gauda

Aspect	East	West	North	South
Density(/m²)	0.18	4.15	2.04	1.96
Frequency(%)	20	60	37.78	33.33
Abundance	3.5	27.67	21.59	23.5

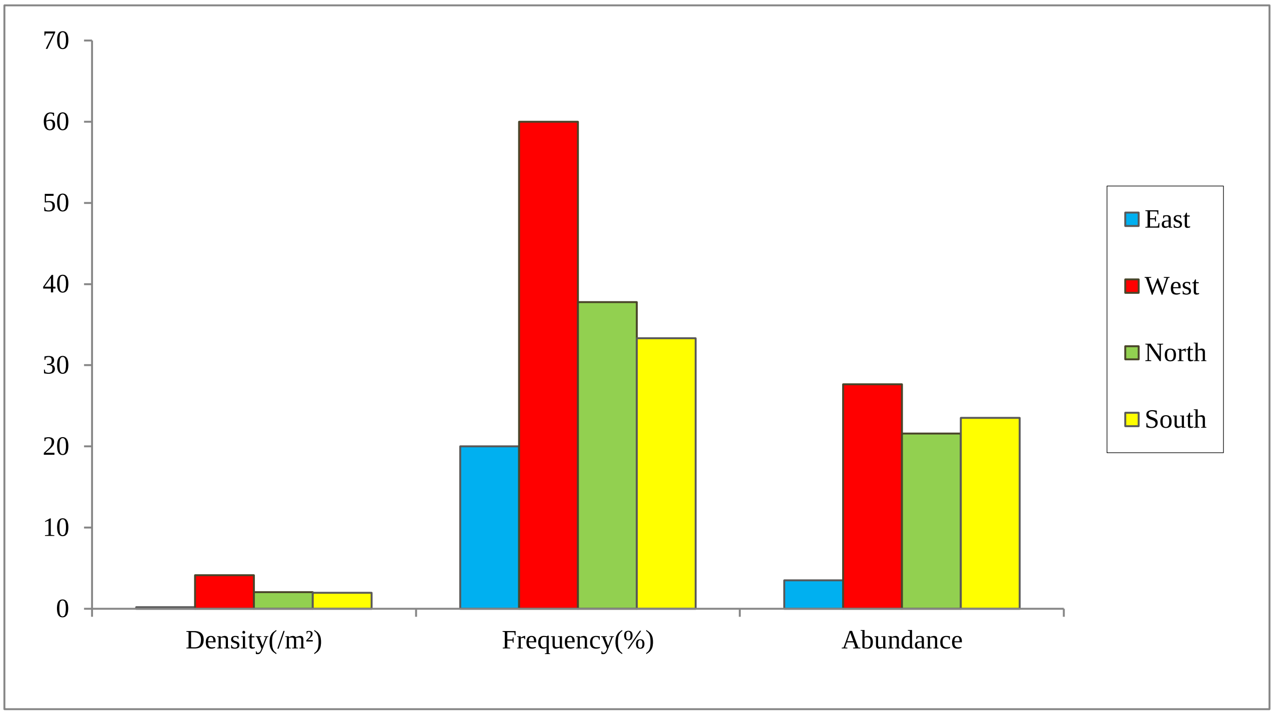

Figure 6: Graph presenting the frequency, density and abundance along different aspects in Tilkholesh Gauda

In Derabanga, no any individual were recorded at 10-20⁰ slope, the density and abundance were highest on 30-40⁰ slope and frequency was highest at 20-30⁰ slope (Table 7; Figure 7).

Table 7: Density, frequency and abundance of *N.jatamansi* in Derabanga along different range of slopes in Derabanga

Slope	0º-10º	10º-20º	20º-30º	30º-40º	40º-50º	50º-60º	60º-70º	70º-80º	80º-90º
Density(/m²)	10.58	0	10.5	11.75	0.89	3	3.85	3.75	5.58
Frequency(%)	66.67	0	100	66.67	25	37.5	30	54.55	50
Abundance	42.33	0	42	70.5	14.25	32	51.33	27.5	44.67

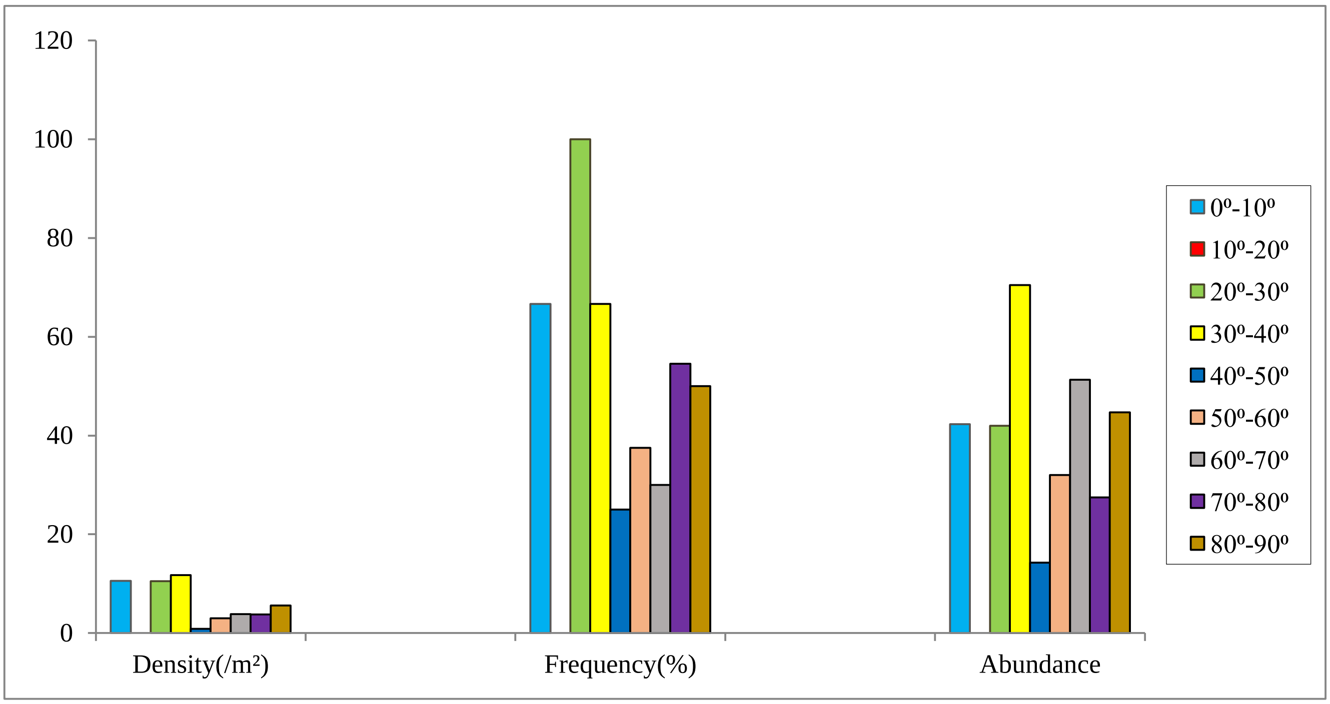

Figure 7: Graph presenting the frequency, density and abundance along different range of slopes in Derabanga

But in Tilkholesh, density and abundance were highest at 20º-30º slope and frequency was highest at 80º-90º slope in Tilkholesh Gauda (Table 8; Figure 7).

Table 8: Density, frequency and abundance of *N.jatamansi* in Derabanga along different range of slopes in Tilkholesh Gauda

Slope	10º-20º	20º-30º	30º-40º	40º-50º	50º-60º	60º-70º	70º-80º	80º-90º
Density(/m²)	1.83	4.25	3.95	2.33	1.59	0.28	0.5	3.25
Frequency(%)	66.67	42.86	40	50	18.18	5.88	50	85.71
Abundance	11	39.67	39.5	18.67	35	19	4	15.17

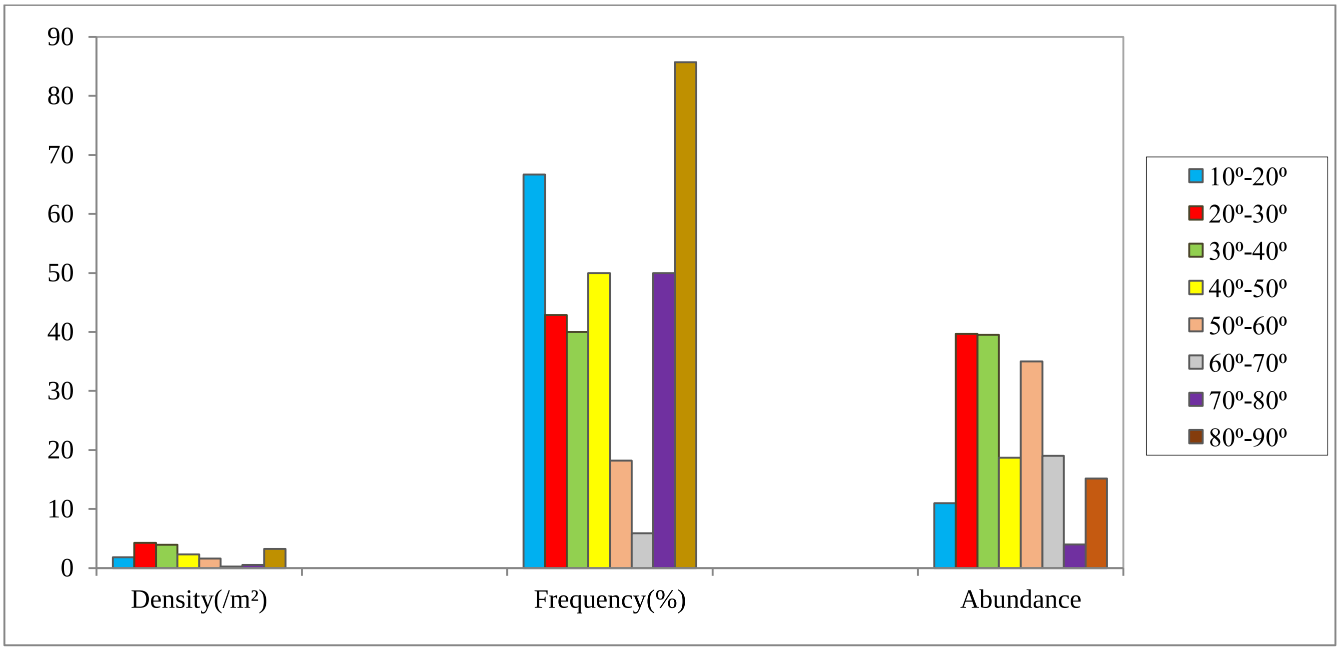

Figure 8: Graph presenting the frequency, density and abundance along different range of slopes in Tilkholesh Gauda

4.1.3 Effects of elevation, aspect, slope and disturbance on the distribution of *N. jatamansi*

One way ANOVA performed revealed that at both sites, all the assessed factors, i.e., altitude, slope and aspect had no significant effect on the distribution of *N. jatamansi* (p-value > 0.05) (Table 9).

Table 9: Showing the impact of altitude, slope, and aspect on the distribution of *N. jatamansi*

	Derabanga			Tilkholesh		
Factors	df	F value	P-value	df	F value	P-value
Altitude	2	1.097	0.341	3	0.232	0.874
Slope	8	1.6	0.148	7	1.422	0.214
Aspect	3	0.248	0.862	3	1.423	0.245

Generalized linear model showed that disturbance has a significant effect on the distribution of *N. jatamansi* (p-value<0.05). In both sites, the increase in disturbance results in the decrease in the number of individuals (Table 10).

Table 10: Showing the impact of disturbance on the distribution of *N. jatamansi*

	Derabanga			Tilkholesh		
Factors	Estimate	z value	P-value	Estimate	z value	P-value
Trample	-0.214	-6.94	0.0001	-0.5392	-9.244	<0.0001
Grazing	-	-	-	-0.3326	-4.298	0.0001
Trample:Grazing	-	-	-	-0.1397	-3.212	0.00132

4.2 Current harvest practice of *N. jatamansi* and its role on local people livelihood

Questionnaire survey revealed that, out of 34 people, only 19 people family were involved in the collection of medicinal plants. Altogether, 87% of the households of surveyed people were not involved in harvesting the medicinal plants and rest were involved in harvesting the medicinal plants (Figure 9). Most of the people harvest *N. jatamansi* at pre-mature stage (58%) (Figure 10). They perform indiscriminant harvesting practices, not leaving any portion of the plant for further regeneration. On an average, per family harvest is 4.05 Kg. All of the people surveyed use the rhizomes of *N. jatamansi* to feed their cattles to boost the immune system when they are sick.

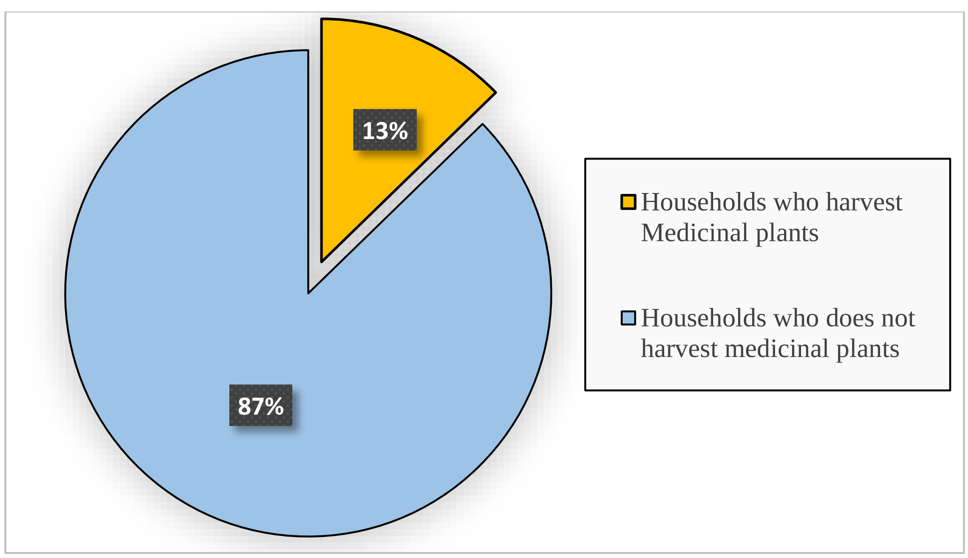

Figure 9: Pie chart showing the percentage of households who harvest and don't harvest medicinal plants.

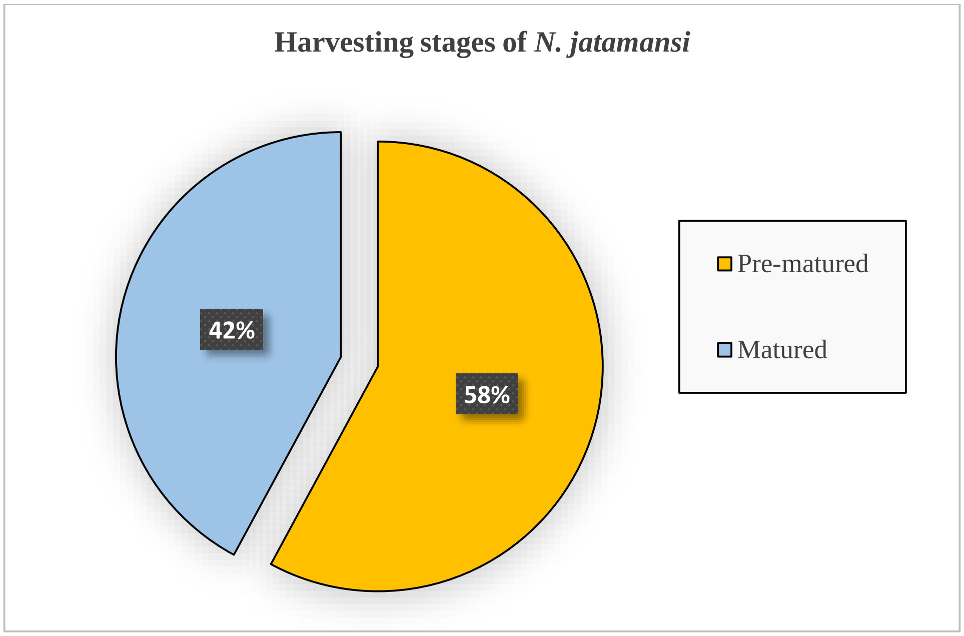

Figure 10: A Pie chart showing the percentage of stage at which *N. jatamansi* is harvested

4.3 Local people's perceptions on possible threats to the population of *Nardostachys jatamansi*

Most people reasoned that overgrazing is the main threats to the population of *N. jatamansi*. 23% reasoned that it may also be due to a lack of proper conservation measures. 19% viewed that it may be due to indiscriminate harvesting (Figure 11).

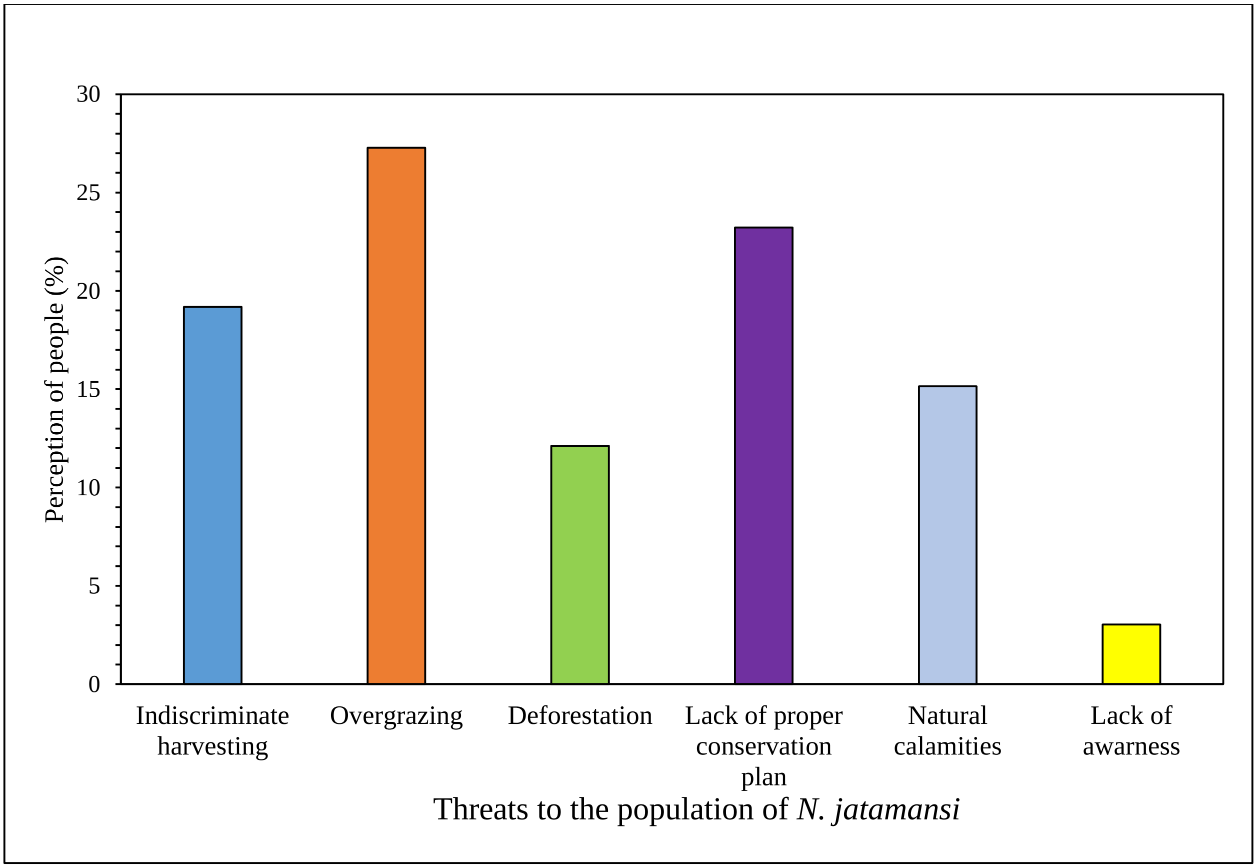

Figure 11: Bar graph showing the perception of local people on the threat to *N. jatamansi*

5 DISCUSSION

5.1 Population status of *N. jatamansi*

Current study shows the low average density ($4/m^2$ and $2/m^2$) and frequency (36.36% and 40%) of *N. jatamansi* in both study sites in comparison with several studies conducted by different researchers in other areas i.e., density of $64\text{-}84/m^2$ and most frequent at GCA (3800 to 3950m altitude) (Sharma *et al*., 2021), average density of $8.9/m^2$ at Jigme Dorji Wangchuck National Park of Bhutan (3824 to 4664m altitude) (Lakey and Dorji, 2016). However, Ghimire *et al*. (1999) found the density to be $14.4/m^2$ in less disturbed area than highly disturbed area where density was $3.06/m^2$ and $3.41/m^2$ in Gyasumdo valley of Manang District. Therefore, the current finding reveals that the population of *N.jatamansi* at both the site is rarer than elsewhere. It could either be the innate rare population or may indicate the recent depletion by multifarous factors. The lower density and frequency of *N.jatamansi* at Tilkholesh Gauda, a location with high levels of anthropogenic activity and overgrazing than in Derabanga, a location with low level of antropogenic disturbance suggest that the population of *N.jatamansi* is being depleted by the anthropogenic encroachment. Because the local people do not know enough about this plant's economic significance and utility, they treat it like any other forest weed and cut it down carelessly with other grasses. This action destroys the plant's aerial portions which ultimately hinders the development of the seed. Consistent to this finding, a previous finding also reports that anthropogenic pressures as well as natural calamities restrict the regeneration of this ecologically sensitive plant conducted in Garhwal Himalayas of Uttarakhand (Purohit *et al*., 2012). Generalized linear regression model revealed that there is decrease in the number of individuals with increase in level of disturbance. But low level of disturbance doesn't affect the availability of *N. jatamansi.* The findings of Larsen (2002) also suggest that abundance of *N. jatamansi* is lower in the area with disturbance than in the area with no disturbance.

The current findings reveals that altitude has no direct impact on the distribution of *N. jatamansi* at both the study site. This result is inconsistent with a previous findings of Airi *et al*. (2000) whose finding suggest the linear replationship between the elevation and density of *N. jatamansi* at Kumaun Himalaya. High density, frequency and abundance of *N. jatamansi* in Derabanga shows that it prefers to grow on open, grassy slopes and on the canopy of scrub of *Rhodondendron setosum, Cotoneaster mycrophyllum* and *Gaultheria* sp. than in the conifers forest. Density is high in west facing slope in both of the sites. But there is no significant difference between number of individuals and aspect of the slope. Ghimire *et al*. (1999) and Airi *et al*. (2000) also found the high density of *N. jatamansi* in the west facing slopes in their study sites. *N. jatamansi* thrives well in west facing slope due to high level of moisture content and low sunlight. Although, number of individuals of *N. jatamansi* is not affected by slope, its frequency, density and abundance was highest in the slope range (20-40°) except for Tilkholesh where frequency was highest in more than 80° slope. This shows the preference of Jatamansi is on steep slopes. Chauhan & Nautiyal (2005) found it to be growing mostly on slope between 40 and 70°.

5.2 Community composition

Only around 53% species are similar in both sites. This may be due to different microhabitats. Derabanga serves as the transition zone between scrub *Rhododendron* forest and alpine meadows while Tilkholesh is a conifers forest. *N. jatamansi* has the highest IVI in Derabanga and also in Tilkholesh. The higher IVI score means that species is using the majority of the resources available to it, with the remaining resources being captured by rivals and associates of that species (Kukshal *et al*., 2009). In both sites, *N. jatamansi* shows contagious type of distribution which may be due to the strategy of vegetative reproduction along with sexual reproduction in addition to the daily and seasonal weather variations and microhabitat preference (Odum & Barrett, 2005; Kukshal *et al*., 2009).

5.3 Harvest practice and role on livelihood of local people

Most of the people of Patmara village are involved in agriculture and livestock rearing rather than collection of medicinal plants. Those who harvest *N. jatamansi,* do not sell it, but use it for domestic purpose mainly as medicine for their cattles. The current harvesting practice is also unsustainable due to the collection of *N. jatamansi* in premature stage and also uprooting the plant entirely to take out the usable part i.e. rhizome. Because they are being gathered haphazardly and without any intention to regenerate, a large number of medicinal plants in the wild are being lost (Sharma *et al*., 2004). Currently, site-specific strategies like informing the locals about the importance of *N. jatamansi* in the generation of income, ecological condition and the need for its conservation could be useful. This is because, communities that receive livelihood benefits from any species are typically inspired to safeguard the species further and practice sustainable management in order to assure long-term returns.

Although, in general the plant should be uprooted entirely due to the use of its rhizome, still some researches (Larsen 2002; Larsen, 2005; Ghimire *et al*., 2008) suggested some practices which can be used to ensure the sustainability. In the study conducted by Larsen (2002), collectors assert that even with their best efforts, they are unable to gather all of the biomass found in a single plant's roots and that tiny bits of root may be all that is needed to ensure regeneration. It is also possible that the plant population will survive to a point when collecting becomes profitable due to seed regeneration, which is ensured by the late start of collection. The majority of the habitat for *N. jatamansi* is found in community-managed forests, and harvesters must obtain a permit from the appropriate Community Forest User Group (CFUG) and weigh their gathered materials to make sure they do not exceed the allowed amount (Woolloff *et al*., 2022). In addition to the managed grazing, sustainable harvesting strategies and giving communities control over harvest management through CFUGs can make a substantial contribution to the preservation of its populations.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Nardostachys jatamansi showed high density in Derabanga than in Tilkholesh Gauda. It is also the most dominant species elevation among its associated species in both sites. However, its distribution was not found to be affected by altitude, slope and aspect in its location of distribution. The population of the plant appears to be declining despite the fact that there is no trade in rhizomes. This may be due to indiscriminate harvesting and anthropogenic pressure resulting in the degradation of the habitat. Local people are unaware of the commercial importance of the plant and hence cut with other grasses as fodder. Therefore, there is urgent need to aware local people on the importance of the plant, its need of conservation and cultivation practices.

6.2 Recommendations

i. It is necessary to run a conservation and awareness program about the importance of protecting natural habitat, their sustainable use, their management, and the appropriate local harvesting of *Nardostachys jatamansi.*

ii. Due to the population decline of *N. jatamansi,* the study for the cultivation practices need to be done urgently and should be promoted.

iii. More in depth studies are required in order to determine the population status of *N. jatamansi* in other regions of its occurrence.

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APPENDICES

Table 1A: List of species recorded within the quadrat

S.N.	Name of plant species	Family	Locality
1	*Abies spectabilis* (D.Don) Mirb.	Pinaceae	Tilkholesh Gauda
2	*Adenostyles* sp.	Asteraceae	Derabanga
3	*Adiantum* sp.	Pteridaceae	Derabanga, Tilkholesh Gauda
4	*Ainsliaea aptera* DC.	Asteraceae	Derabanga
5	*Anaphilis triplinervis*(Sims. CB. Clarke)	Asteraceae	Derabanga, Tilkholesh Gauda
6	*Artimisia dubia* Wall. ex Besser	Asteraceae	Derabanga
7	*Arundinaria* sp.	Poaceae	Derabanga, Tilkholesh Gauda
8	*Aster diplostephioides (DC.) Benth ex C.B.Clarke*	Asteraceae	Derabanga
9	*Aster stracheyi* Hook.f.	Asteraceae	Derabanga
10	*Betula utilis* D. Don.	Betulaceae	Derabanga, Tilkholesh Gauda
11	*Bistorta amplexicaulis* (D. Don.) Greene	Polygonaceae	Derabanga, Tilkholesh Gauda
12	*Caragana* sp.	Fabaceae	Derabanga, Tilkholesh Gauda
13	*Centella asiatica* (L.) Urb.	Apiaceae	Tilkholesh Gauda
14	*Cirsium nishiokae* Kitam.	Asteraceae	Derabanga
15	*Cotoneaster microphyllus* Wall. ex Lindl.	Rosaceae	Derabanga
16	*Cyananthus microphyllus* Edgew.	Campanulaceae	Derabanga
17	*Epibolium wallichianum* Hausskn	Onagraceae	Derabanga, Tilkholesh Gauda
18	*Fragaria* sp.	Rosaceae	Derabanga, Tilkholesh Gauda
19	*Galium* sp.	Rubiaceae	Tilkholesh Gauda
20	*Gaultheria* sp.	Ericaceae	Derabanga
21	*Gerbera nivea* (DC.) Sch.Bip.	Asteraceae	Derabanga, Tilkholesh Gauda
22	*Gnaphalium affine* (D. Don)	Asteraceae	Derabanga
23	*Hydrocotyl* sp.	Araliaceae	Derabanga

24	*Impatiens laxiflora* Edgew	Balsaminaceae	Tilkholesh Gauda
25	*Jasminum humile* Gueldenst.	Oleaceae	Derabanga
26	*Nardostachys jatamansi* (D.Don) DC	Caprifoliaceae	Derabanga, Tilkholesh Gauda
27	*Podophyllum hexandrum* Royle	Berberidaceae	Derabanga
28	*Polygonatum* sp.	Asparagaceae	Derabanga
29	*Potentila eriocarpa* Wall. ex Lehm.	Rosaceae	Derabanga
30	*Potentilla argyrophylla* Wall. ex Lehm.	Rosaceae	Derabanga, Tilkholesh Gauda
31	*Potentilla eriocarpa* Wall. ex Lehm.	Rosaceae	Tilkholesh Gauda
32	*Rhodiola sinuata* (Royle ex Edgew.) S.H.Fu	Crassulaceae	Derabanga, Tilkholesh Gauda
33	*Rhododendron campanulatum* D. Don.	Ericaceae	Derabanga
34	*Rhododendron lepidotum* Wall. ex G.Don	Ericaceae	Tilkholesh Gauda
35	*Rhododendron setosom* D. Don	Ericaceae	Derabanga
36	*Rosa* sp.	Rosaceae	Derabanga, Tilkholesh Gauda
37	*Saxifraga parnassifolia* D.Don	Saxifragaceae	Tilkholesh Gauda
38	*Senecio wallichii* DC.	Asteraceae	Derabanga, Tilkholesh Gauda
39	*Swertia speciosa* D.Don	Gentianaceae	Tilkholesh Gauda
40	*Synotis penninervis* (H.Koyama) T.J.Tong	Asteraceae	Derabanga
41	Unknown	Apiaceae	Tilkholesh Gauda

Table 2A: Plot wise number of individuals of *Nardostachys jatamansi* along with abiotic factors (altitude, slope, aspect and disturbance) in Derabanga

Plot	No. of individuals of *Nardostachys jatamansi*	Latitude (N)	Longitude (E)	Altitude(m)	Slope(⁰)	Aspect	Trample
Q1	113	29°21.256	82°11.536	3585	37	W	0
Q2	67	29°21.258	82°11.539	3579	62	W	1
Q3	0	29°21.256	82°11.544	3584	51	S	0
Q4	43	29°21.251	82°11.542	3581	55	S	1
Q5	0	29°21.249	82°11.551	3573	49	S	0
Q6	0	29°21.258	82°11.557	3572	65	S	3
Q7	25	29°21.260	82°11.572	3585	70	E	0
Q8	0	29°21.266	82°11.562	3590	68	S	0
Q9	16	29°21.268	82°11.560	3593	88	E	2
Q10	0	29°21.275	82°11.558	3596	60	S	0
Q11	0	29°21.272	82°11.554	3600	58	E	0
Q12	42	29°21.269	82°11.547	3601	28	S	2
Q13	0	29°21.2	82°11.543	3606	12	S	0
Q14	107	29°21.274	82°11.549	3600	5	S	0
Q15	62	29°21.276	82°11.547	3598	72	N	1
Q16	102	29°21.281	82°11.551	3612	82	N	0
Q17	0	29°21.284	82°11.553	3615	17	S	0
Q18	34	29°21.285	82°11.559	3619	66	N	1
Q19	21	29°21.284	82°11.564	3630	71	W	2
Q20	20	29°21.258	82°11.566	3635	6	W	2
Q21	11	29°21.290	82°11.569	3637	42	N	3
Q22	11	29°21.291	82°11.575	3632	52	N	3
Q23	3	29°21.300	82°11.579	3633	45	N	0
Q24	0	29°21.300	82°11.583	3636	43	N	2
Q25	0	29°21.305	82°11.584	3637	45	N	0
Q26	0	29°21.309	82°11.584	3641	42	N	2

Q27	0	29°21.313	82°11.582	3645	43	N	0
Q28	0	29°21.309	82°11.579	3644	45	N	3
Q29	0	29°21.307	82°11.575	3643	42	N	0
Q30	16	29°21.297	82°11.575	3637	49	N	0
Q31	0	29°21.291	82°11.571	3636	7	S	0
Q32	28	29°21.296	82°11.583	3645	32	N	0
Q33	27	29°21.295	82°11.587	3651	45	N	2
Q34	42	29°21.299	82°11.591	3652	54	N	2
Q35	0	29°21.298	82°11.588	3644	42	N	0
Q36	0	29°21.300	82°11.590	3646	43	N	2
Q37	0	29°21.301	82°11.590	3647	43	N	0
Q38	0	29°21.290	82°11.595	3656	72	S	3
Q39	0	29°21.288	82°11.599	3656	34	S	2
Q40	49	29°21.295	82°11.590	3657	72	N	1
Q41	0	29°21.290	82°11.599	3655	67	S	0
Q42	0	29°21.298	82°11.604	3647	78	N	2
Q43	0	29°21.254	82°11.602	3679	73	N	0
Q44	2	29°21.293	82°11.605	3655	71	N	3
Q45	6	29°21.291	82°11.604	3655	76	N	0
Q46	0	29°21.276	82°11.603	3660	57	N	3
Q47	16	29°21.284	82°11.604	3665	82	N	3
Q48	0	29°21.290	82°11.599	3674	88	N	0
Q49	0	29°21.271	82°11.604	3682	88	N	2
Q50	0	29°21.271	82°11.613	3686	85	S	2
Q51	0	29°21.269	82°11.610	3685	77	W	0
Q52	0	29°21.263	82°11.608	3683	72	W	1
Q53	0	29°21.258	82°11.608	3683	68	N	2
Q54	0	29°21.254	82°11.606	3684	62	N	0
Q55	53	29°21.278	82°11.608	3666	62	N	1
Q56	0	29°21.257	82°11.602	3678	52	N	0

Q57	0	29°21.264	82°11.603	3676	61	W	2
Q58	0	29°21.249	82°11.537	3577	45	W	3
Q59	0	29°21.254	82°11.536	3570	48	W	2
Q60	0	29°21.258	82°11.536	3573	51	W	0

Table 3A: Plot wise number of individuals of *Nardostachys jatamansi* along with abiotic factors (altitude, slope, aspect and disturbance) in Tilkholesh Gauda

Plot	No. of individuals of *Nardostachys jatamansi*	Latitude (N)	Longitude (E)	Altitude(m)	Slope(⁰)	Aspect	Grazing	Trample
Q1	1	29°20.682	82°10.389	3349	80	N	0	0
Q2	0	29°20.678	82°10.388	3341	80	N	3	2
Q3	0	29°20.682	82°10.392	3326	55	W	2	3
Q4	0	29°20.685	82°10.403	3323	45	N	2	2
Q5	0	29°20.672	82°10.392	3322	56	N	0	3
Q6	45	29°20.671	82°10.384	3328	32	N	0	0
Q7	4	29°20.661	82°10.375	3330	10	N	3	3
Q8	4	29°20.657	82°10.364	3338	48	N	2	3
Q9	0	29°20.658	82°10.332	3337	12	N	0	2
Q10	0	29°20.643	82°10.330	3336	20	N	3	3
Q11	0	29°20.653	82°10.329	3339	25	E	2	0
Q12	11	29°20.672	82°10.286	3339	85	W	2	1
Q13	35	29°20.681	82°10.276	3342	80	S	1	1
Q14	3	29°20.691	82°10.278	3342	77	N	2	2
Q15	0	29°20.728	82°10.287	3326	60	N	3	3
Q16	0	29°20.722	82°10.295	3351	65	N	2	2
Q17	0	29°20.633	82°10.289	3415	66	N	3	3
Q18	5	29°20.695	82°10.295	3371	75	W	2	2
Q19	34	29°20.672	82°10.298	3398	35	N	1	2

Q20	2	29°20.645	82°10.297	3398	45	E	3	3
Q21	0	29°20.638	82°10.297	3402	35	N	2	3
Q22	42	29°20.623	82°10.289	3436	25	N	0	0
Q23	0	29°20.635	82°10.290	3401	38	S	3	2
Q24	0	29°20.634	82°10.291	3418	66	S	2	3
Q25	12	29°20.626	82°10.300	3450	82	S	3	1
Q26	0	29°20.638	82°10.276	3410	47	S	0	3
Q27	2	29°20.635	82°10.288	3396	18	N	3	2
Q28	0	29°20.630	82°10.285	3422	64	N	3	3
Q29	35	29°20.639	82°10.284	3445	49	N	1	1
Q30	0	29°20.624	82°10.281	3423	49	E	0	3
Q31	0	29°20.620	82°10.284	3428	55	N	2	2
Q32	0	29°20.619	82°10.292	3422	60	N	3	2
Q33	0	29°20.620	82°10.294	3440	75	W	3	3
Q34	67	29°20.630	82°10.299	3432	22	W	0	0
Q35	19	29°20.629	82°10.305	3429	60	N	2	2
Q36	0	29°20.623	82°10.311	3435	50	N	3	2
Q37	0	29°20.623	82°10.318	3438	47	N	3	2
Q38	5	29°20.623	82°10.336	3441	80	E	2	3
Q39	0	29°20.619	82°10.330	3460	55	N	2	3
Q40	0	29°20.623	82°10.329	3459	57	N	2	3
Q41	31	29°20.633	82°10.336	3449	47	N	1	2
Q42	0	29°20.631	82°10.350	3444	65	N	2	2
Q43	0	29°20.636	82°10.350	3437	72	N	2	3
Q44	0	29°20.637	82°10.359	3432	48	N	3	3
Q45	0	29°20.642	82°10.359	3430	24	N	2	2
Q46	0	29°20.641	82°10.367	3426	45	E	3	1
Q47	0	29°20.639	82°10.318	3422	65	E	2	2
Q48	40	29°20.657	82°10.360	3415	52	N	0	1
Q49	0	29°20.653	82°10.369	3405	68	E	2	2

Q50	0	29°20.649	82°10.376	3400	60	E	2	2
Q51	30	29°20.660	82°10.376	3392	58	N	2	1
Q52	0	29°20.656	82°10.378	3391	57	E	3	2
Q53	0	29°20.643	82°10.389	3388	62	N	3	3
Q54	0	29°20.634	82°10.400	3386	60	N	3	3
Q55	27	29°20.642	82°10.410	3371	80	N	1	2
Q56	0	29°20.648	82°10.405	3367	55	N	2	3
Q57	0	29°20.652	82°10.396	3365	68	N	3	2
Q58	0	29°20.662	82°10.394	3362	50	S	2	3
Q59	10	29°20.664	82°10.391	3362	25	N	3	3
Q60	25	29°20.667	82°10.398	3358	45	N	2	2
Q61	0	29°20.668	82°10.392	3359	68	N	2	3
Q62	0	29°20.682	82°10.431	3336	68	E	2	2
Q63	15	29°20.676	82°10.397	3357	46	N	2	1
Q64	0	29°20.665	82°10.424	3322	20	N	3	2
Q65	0	29°20.668	82°10.448	3311	30	N	3	3
Q66	0	29°20.673	82°10.470	3372	62	N	3	2

Table 4A: Province/District wise distribution of *Nardostachys jatamansi* in Nepal (DPR, 2024)

Province	District
Koshi	Taplejung
	Solukhumbu
	Sankhuwasabha
Bagmati	Dhading
	Nuwakot
	Rasuwa
	Sindhupalchowk
	Ramechhap
	Dolakha
Gandaki	Manang
	Baglung
	Myagdi
	Lamjung
	Gorkha
	Mustang
Lumbini	East Rukum
	Rolpa
	Pyuthan
Karnali	Jumla
	Humla
	Mugu
	Dolpa
	Kalikot
	West Rukum
	Jajarkot
	Dailekh
Sudurpaschim	Bajhang
	Bajura
	Doti
	Darchula

Table5A : Questionnaire used for the survey

Questionnaire

Locality……………….. Date……………

Name of respondent……………………….. Age……….. Gender…………

Occupation………….............. Number of family members…………

1. How many of your family members are involved in the harvest of MAPs?
2. How long have you been harvesting the MAPs?
3. How much is your total household annual income (sum up the contribution from agriculture, livestock, wage labor, remittance, MAPs, others)?
4. In which month do you harvest MAPs?
5. At what stage do you harvest *Nardostachys jatamansi*?
6. Do you harvest all parts or leave some portion for regeneration?
7. Do you harvest *Nardostachys jatamansi* for your personal use only or for trade?

Details of *Nardostachys jatamansi* harvest last year (season has not started this year)

SN	MAPs	Volume	Unit price	Sell at
1.	*Nardostachys jatamansi*			

Other information, if any:

In your experience,

(i) What is the current population status of *Nardostachys jatamansi* you harvest? Are they depleting, constant or increasing?

(ii) What are the major disturbance factors/threats to the plant?

Analysis of Variance (ANOVA) statistics

Table 6A: Analysis of variance between different abiotic factors (altitude, slope and aspect) and number of individuals of *Nardostachys jatamansi* in Tilkholesh Gauda

	Degree of freedom	Sum of squares	Means squares	F- value	Pr(>F)
Altitude	2	53	26.62	0.095	0.909
Slope	7	2047	292.4	1.422	0.214
Aspect	3	895	298.4	1.423	0.245

Table 7A: Analysis of variance between different abiotic factors (altitude, slope and aspect) and number of individuals of *Nardostachys jatamansi* in Derabanga

	Degree of freedom	Sum of squares	Means squares	F- value	Pr(>F)
Altitude	2	1825	912.3	0.903	0.413
Slope	8	6539	817.3	0.495	0.849
Aspect	3	588	196.0	0.248	0.862

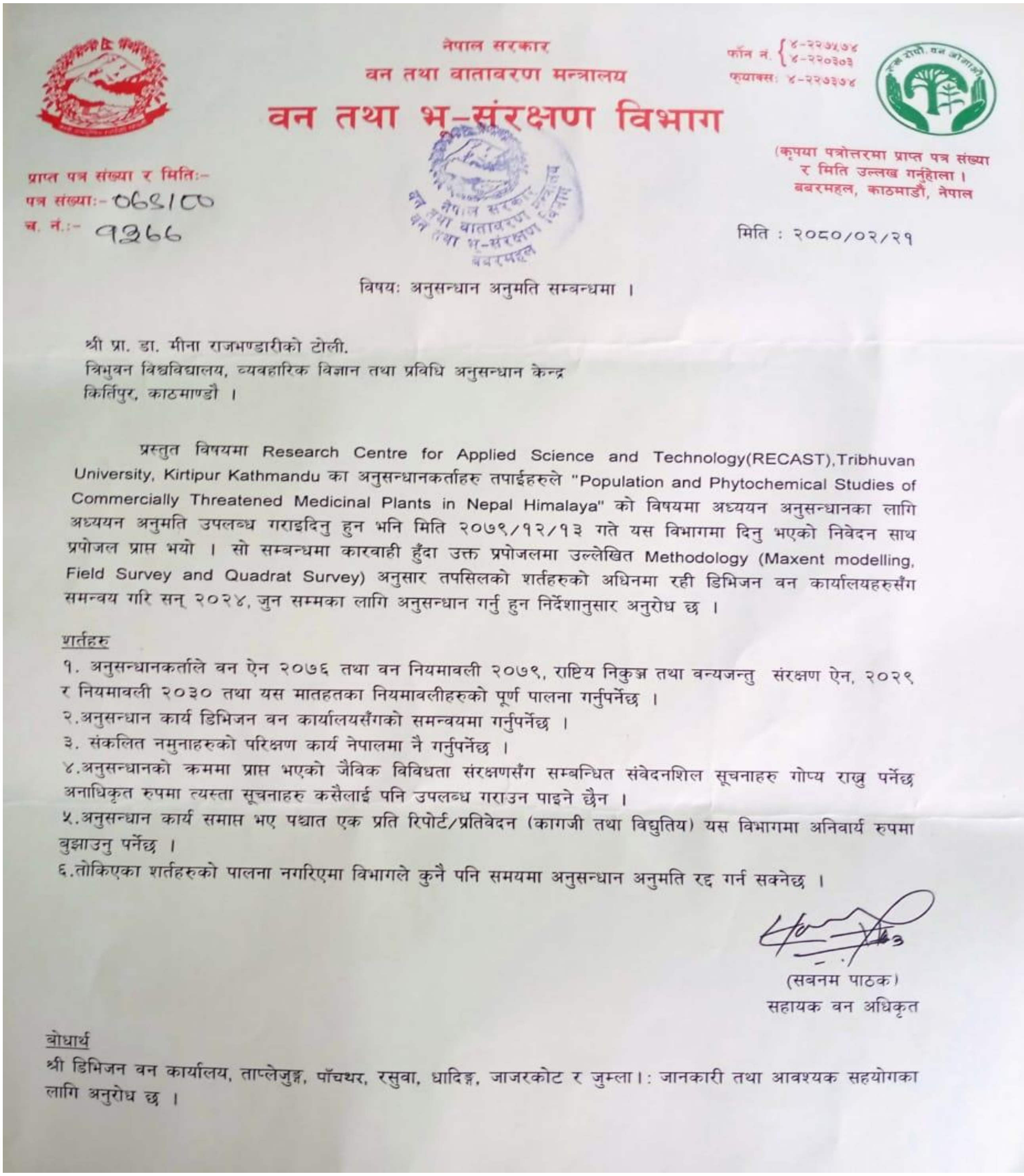
Regression statistics

Table 8A: Regression statistics of Number of individuals of *Nardostachys jatamansi* against disturbance in Tilkholesh Gauda using generalized linear models (GLMs).

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	3.83794	0.07047	54.460	< 2e-16
Trample	-0.53917	0.05833	-9.244	< 2e-16
Grazing	-0.33256	0.07738	-4.298	1.73e-05
Trample:Grazing	-0.13968	0.04349	-3.212	0.00132

Table 9A: Regression statistics of Number of individuals of *Nardostachys jatamansi* against disturbance in Derabanga using generalized linear models (GLMs).

	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	2.93197	0.04187	70.02	< 2e-16
Trample	-0.21403	0.03084	-6.94	3.92e-12



नेपाल सरकार
वन तथा वातावरण मन्त्रालय
वन तथा भू-संरक्षण विभाग

फोन नं. ४-२२७५७४, ४-२२०३०३
फ्याक्स: ४-२२७३७४

(कृपया पत्रोत्तरमा प्राप्त पत्र संख्या र मिति उल्लख गर्नुहोला ।
बबरमहल, काठमाडौं, नेपाल

प्राप्त पत्र संख्या र मिति:-
पत्र संख्या:- ०८९।८०
च. नं.:- ९३६६

मिति : २०८०/०२/२१

विषयः अनुसन्धान अनुमति सम्बन्धमा ।

श्री प्रा. डा. मीना राजभण्डारीको टोली.
त्रिभुवन विश्वविद्यालय, व्यवहारिक विज्ञान तथा प्रविधि अनुसन्धान केन्द्र
किर्तिपुर, काठमाण्डौ ।

प्रस्तुत विषयमा Research Centre for Applied Science and Technology(RECAST),Tribhuvan University, Kirtipur Kathmandu का अनुसन्धानकर्ताहरु तपाईहरुले "Population and Phytochemical Studies of Commercially Threatened Medicinal Plants in Nepal Himalaya" को विषयमा अध्ययन अनुसन्धानका लागि अध्ययन अनुमति उपलब्ध गराइदिनु हुन भनि मिति २०७९/१२/१३ गते यस विभागमा दिनु भएको निवेदन साथ प्रपोजल प्राप्त भयो । सो सम्बन्धमा कारवाही हुँदा उक्त प्रपोजलमा उल्लेखित Methodology (Maxent modelling, Field Survey and Quadrat Survey) अनुसार तपसिलको शर्तहरुको अधिनमा रही डिभिजन वन कार्यालयहरुसँग समन्वय गरि सन् २०२४, जुन सम्मका लागि अनुसन्धान गर्नु हुन निर्देशानुसार अनुरोध छ ।

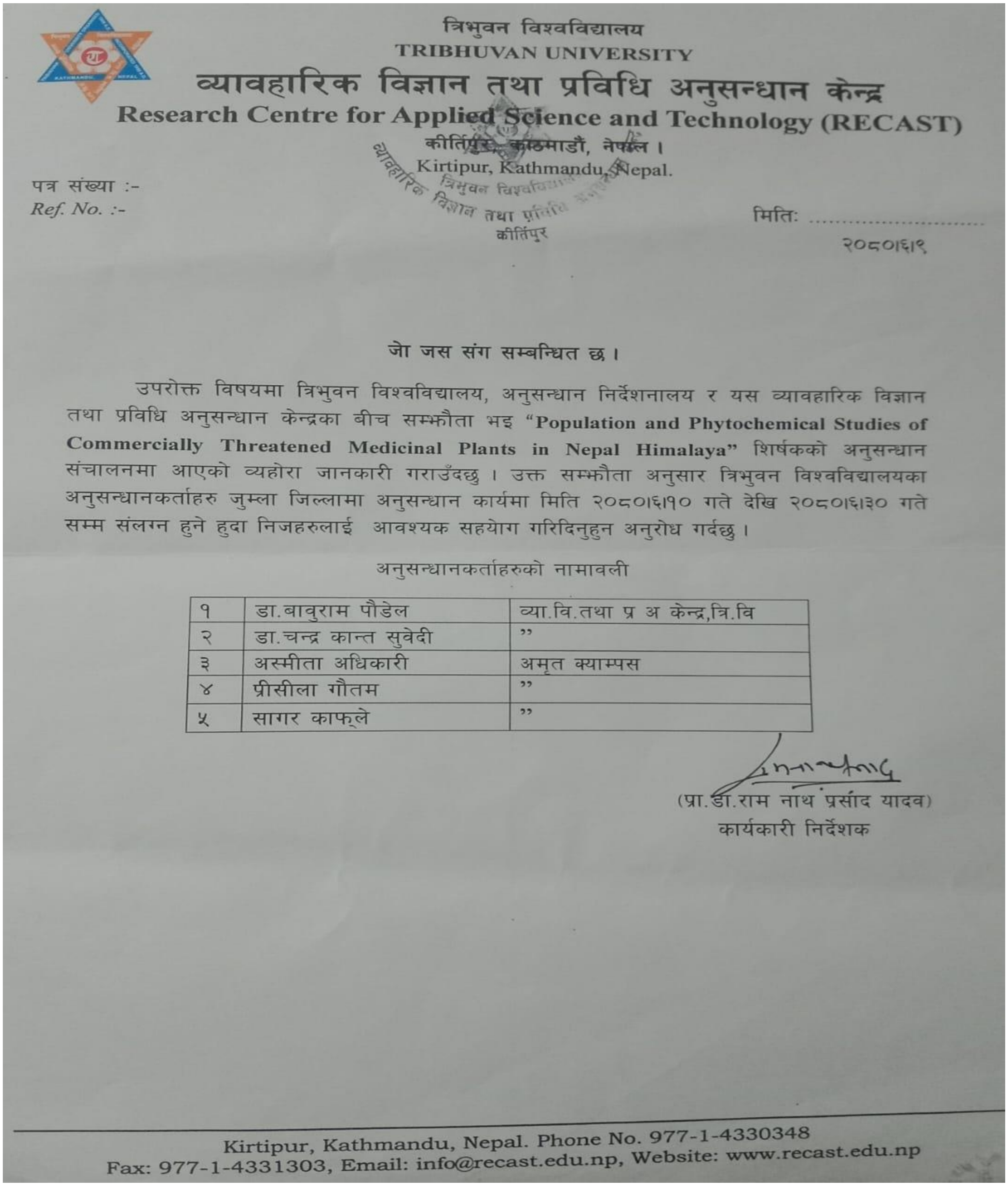
शर्तहरु

१. अनुसन्धानकर्ताले वन ऐन २०७६ तथा वन नियमावली २०७९, राष्टिय निकुञ्ज तथा वन्यजन्तु संरक्षण ऐन, २०२९ र नियमावली २०३० तथा यस मातहतका नियमावलीहरुको पूर्ण पालना गर्नुपर्नेछ ।
२.अनुसन्धान कार्य डिभिजन वन कार्यालयसँगको समन्वयमा गर्नुपर्नेछ ।
३. संकलित नमुनाहरुको परिक्षण कार्य नेपालमा नै गर्नुपर्नेछ ।
४.अनुसन्धानको क्रममा प्राप्त भएको जैविक विविधता संरक्षणसँग सम्बन्धित संवेदनशिल सूचनाहरु गोप्य राख्नु पर्नेछ अनाधिकृत रुपमा त्यस्ता सूचनाहरु कसैलाई पनि उपलब्ध गराउन पाइने छैन ।
५.अनुसन्धान कार्य समाप्त भए पश्चात एक प्रति रिपोर्ट/प्रतिवेदन (कागजी तथा विद्युतिय) यस विभागमा अनिवार्य रुपमा बुझाउनु पर्नेछ ।
६.तोकिएका शर्तहरुको पालना नगरिएमा विभागले कुनै पनि समयमा अनुसन्धान अनुमति रद्द गर्न सक्नेछ ।

(सबनम पाठक)
सहायक वन अधिकृत

बोधार्थ
श्री डिभिजन वन कार्यालय, ताप्लेजुङ्ग, पाँचथर, रसुवा, धादिङ्ग, जाजरकोट र जुम्ला।: जानकारी तथा आवश्यक सहयोगका लागि अनुरोध छ ।

Figure 1A: Letter of Research permission by Department of Forests and Soil Conservation, Ministry of Forests and Environment



त्रिभुवन विश्वविद्यालय
TRIBHUVAN UNIVERSITY
व्यावहारिक विज्ञान तथा प्रविधि अनुसन्धान केन्द्र
Research Centre for Applied Science and Technology (RECAST)
कीर्तिपुर, काठमाडौं, नेपाल ।
Kirtipur, Kathmandu, Nepal.

पत्र संख्या :-
Ref. No. :-

मितिः ....
२०८०।६।९

जो जस संग सम्बन्धित छ ।

उपरोक्त विषयमा त्रिभुवन विश्वविद्यालय, अनुसन्धान निर्देशनालय र यस व्यावहारिक विज्ञान तथा प्रविधि अनुसन्धान केन्द्रका बीच सम्झौता भइ "**Population and Phytochemical Studies of Commercially Threatened Medicinal Plants in Nepal Himalaya**" शिर्षकको अनुसन्धान संचालनमा आएको व्यहोरा जानकारी गराउँदछु । उक्त सम्झौता अनुसार त्रिभुवन विश्वविद्यालयका अनुसन्धानकर्ताहरु जुम्ला जिल्लामा अनुसन्धान कार्यमा मिति २०८०।६।१० गते देखि २०८०।६।३० गते सम्म संलग्न हुने हुदा निजहरुलाई आवश्यक सहयेाग गरिदिनुहुन अनुरोध गर्दछु ।

अनुसन्धानकर्ताहरुको नामावली

१	डा.बावुराम पौडेल	व्या.वि.तथा प्र अ केन्द्र,त्रि.वि
२	डा.चन्द्र कान्त सुवेदी	"
३	अस्मीता अधिकारी	अमृत क्याम्पस
४	प्रीसीला गौतम	"
५	सागर काफ्ले	"

(प्रा.डा.राम नाथ प्रसाद यादव)
कार्यकारी निर्देशक

Kirtipur, Kathmandu, Nepal. Phone No. 977-1-4330348
Fax: 977-1-4331303, Email: info@recast.edu.np, Website: www.recast.edu.np

Figure 2A: Recommendation letter from Research Centre for Applied Science and Technology for research

PHOTO PLATES

Counting the number of *N. jatamansi* inside a quadrat

N. jatamansi on a moss laden rocky slope

Rhizomes of *N. jatamansi*