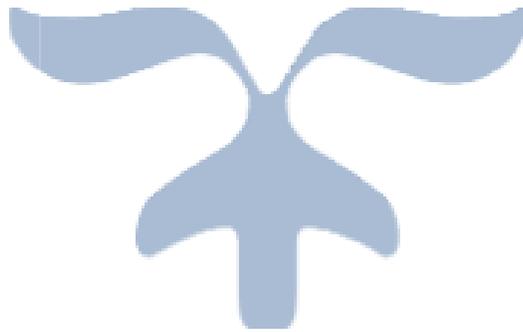


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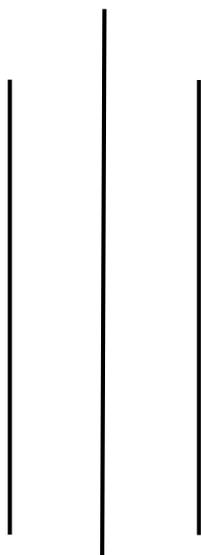
**Research on Current Status, Distribution and Marketing of  
Rato Chyau in Karnali Province, Nepal**

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**Forest Research and Training Center Birendranagar, Surkhet**  
Jun 2024

# Research on Current Status, Distribution and Marketing of RatoChyau in Karnali Province, Nepal



*Submitted by*

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Karnali Province Government  
Ministry of Industry, Tourism, Forests and Environment  
**Forest Research and Training Center**  
Birendranagar, Surkhet  
Jun, 2024

## Abstract

Karnali Province is hub of Non Timber Forest Product such as medicinal plants and varieties of mushroom. This study was conducted to assess the current status of red mushroom (*Ganoderma lucidum*), to investigate the existing harvesting practices of this mushroom, to identify the key stakeholders involved in red mushroom production, to prepare the distribution map / habitat suitability map of this species, to analyze the environmental factor influencing the distribution of this species, to examine the current marketing channels and strategies and to assess the economic impact of red mushroom on local communities in the Karnali Province. Although, intensive field survey was conducted in Jumla and Kalikot Districts, the study covers whole Karnali Province. First of all, the social data were collected to identify the potential habitats, harvesting practices, marketing status, economic contributions and problems related to the red mushroom in Karnali Province, Nepal. Then field survey was conducted to collect the presence points and to understand the ground reality related to this species. Topographic, vegetation-related, anthropogenic and climatic variables were collected from open sources. Maximum Entropy (MaxEnt) software was used to model the distribution/suitable habitat of this species. Furthermore, the jackknife and response curves were used to identify the influencing environmental factors to distribution of the red mushroom. This study identified 1773.15 km<sup>2</sup> area as distribution area/suitable

habitat of this species in Karnali Province. Jumla, Mugu, Dolpa, Rukum West, Jajarkot and Kalikot Districts are good habits of this species. Land use land cover, annual mean precipitation, annual mean temperature, elevation and forest are influencing the distribution of red mushroom in the study area. Distribution is concentrated to the area of dense needle leaved forest, 600 mm annual mean precipitation, eight degree centigrade annual mean temperature, and 2600 m elevation. Forest fire control and market guarantee of collected products are recommended for the conservation and marketing of red mushroom in Karnali Province.

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During the data collection study team got valuable and meaningful direction from Mr. Rajendra Kumar Basukala, director of FRTC, Karnali Province, Birendranagar, Surkhet. Similarly study team got friendly support from Mr. Kamal Raj Aryal, forest research officer (now under secretary in Ministry of Forest and Environment, Kathmandu, Nepal). We are equally thankful for their valuable support during the data collection phase. Without their support, this study wasn't possible.

Lastly, we are grateful to all the field staffs and support staffs for the unrelenting effort they put to generate quality data from the field.

Thank you very much.

**Team leader of study team**

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# **1. Introduction**

## **1.1 Background**

### **1.1.1 Non timber forest product**

Non-timber forest products (NTFPs) are forest products which are not wood. NTFPs contribute significantly to both society and the national economy. They provide critical resources for millions of people, particularly in rural and indigenous communities, by serving as essential sources of food, medicine, and raw materials for traditional crafts and construction. Economically, NTFPs support livelihoods by creating income-generating opportunities, especially for marginalized populations who rely on the sustainable harvesting and trade of these products. NTFPs also play a crucial role in national economies by contributing to export revenues, promoting biodiversity conservation, and encouraging sustainable land use practices. By reducing pressure on timber resources and fostering ecological stability, NTFPs help to maintain the integrity of forest ecosystems, thus supporting long-term environmental sustainability and resilience. Karnali Province is hub of NTFP. Medicinal and Aromatic Plants (MAPs) in Karnali Province generated economic output equivalent to NPR 160738 million (USD 1.39 billion) or 1.03% of GDP of Karnali Province and 0.02% of the National GDP in the

fiscal year 2019/2020 (Aryal et al., 2023). Furthermore, Jajarkot District on average exported 1,590,681.72 kg NTFPs worth NRs. 3,819,271.6 (equivalent to USD 32,081.88) from the year 2015 to 2020 to the national economy through royalty (Lamichhane et al., 2021).

### **1.1.2 Wild mushroom**

Wild mushrooms hold significant importance across various dimensions, including ecological, economic, and cultural aspects. Ecologically, they play a crucial role in forest ecosystems as decomposers, breaking down organic matter and recycling nutrients that enrich soil health and support plant growth. Economically, wild mushrooms are a valuable resource for many rural and indigenous communities, providing a source of income through their collection and sale. The Dipterocarp inhabiting mycoelements like *Scleroderma texense* has been used both for food and medicine in Rupendehi District, Nepal (Aryal & Budhathoki, 2014). They are highly sought after in both local and international markets, particularly gourmet varieties like chanterelles and morels, which are prized for their unique flavors and nutritional value. Including wild mushroom a total of 261 wild edible plant species from 101 families were found to be consumed by 23 ethnic groups of Nepal (Miya et al., 2021). The wild mushrooms are good sources of vegetable in rural areas.

*Laetiporussulphureus* was identified as edible wild plants in Nepal (Miya et al., 2021). Among wild species, *Laetiporussulphureus* has drawn concern of people for its versatile food and medicinal values (Mishra & Mishra, 2013).

Culturally, wild mushrooms have long been a part of culinary traditions and medicinal practices in many societies, offering diverse uses from enhancing food dishes to serving as natural remedies. Their sustainable harvesting also promotes forest conservation by highlighting the importance of maintaining natural habitats for future generations. Wild morels (*Morchella* spp.) are harvested commercially and exported extensively from west Nepal especially from Karnali Province which share 58% of total national output (Raut et al., 2019).

### **1.1.3 Red mushroom**

The red mushroom, particularly species like the reishi (*Ganoderma lucidum*) or other culturally significant varieties, holds profound importance for many ethnic groups around the world. For numerous indigenous and ethnic communities, these mushrooms are deeply embedded in traditional medicine, spiritual practices, and cultural heritage. Red mushroom / Katcheyau (*Ganoderma lucidum*) is used for the ignition of cigarettes in Lumle area of Kaski District, Nepal (Adhikari et al., 2006).

Red mushrooms are often revered for their medicinal properties, believed to boost immunity, enhance longevity, and treat a variety of ailments. *Ganodermalucidum* is being traded by Sherpa community in street of Itahari, Sunsari District of Nepal and used as medicinal purposes (S. Thapa, 2021).

They are integral to traditional healing practices, where they are used in remedies for physical and spiritual well-being. Ganoderma is good source of fat and fiber (Pandey et al., 2023). Furthermore, Ganoderma is potential NTFP of Simbhanjyang, Makawanpur (Khadka & Aryal, 2020). Culturally, red mushrooms symbolize health, resilience, and connection to nature, playing a key role in rituals and ceremonies that reinforce community identity and continuity. The mushrooms credited with success against cancer belong to the 20 genus including Ganoderma (Patel & Goyal, 2012). Economically, these mushrooms contribute to the livelihoods of ethnic groups by providing a source of income through local trade and, increasingly, international markets. The sustainable harvesting of red mushrooms also encourages the preservation of traditional knowledge and practices, supporting the cultural and environmental sustainability of ethnic communities. Ganoderma is being collected in large quantities (about 4-10 tons per year) from Nepalese forests to meet its rising demand and is mostly sold to China in crude form.

In Nepal, the conservation of red mushrooms, particularly species like *Ganodermalucidum*, faces significant challenges. The primary concern is habitat loss

due to deforestation and land use changes, which threaten the natural environments where these mushrooms grow. Unsustainable harvesting practices, driven by high demand and lack of effective management, lead to the depletion of mushroom populations. There is also a scarcity of comprehensive research on the ecological role and distribution of red mushrooms, which hampers effective conservation strategies. The lack of awareness and understanding among local communities about the importance of these species further exacerbates their vulnerability, making it difficult to implement conservation measures that balance ecological preservation with community needs.

The harvesting of red mushrooms in Nepal is fraught with difficulties that stem from both ecological and socio-economic factors. Overharvesting, spurred by the lucrative market for these mushrooms, has led to a decline in wild populations, putting pressure on the species' sustainability. Traditional harvesting methods, often practiced without modern scientific knowledge, can be detrimental, damaging the delicate mycelial networks that are crucial for mushroom regeneration. Additionally, there is a lack of regulated harvesting protocols and insufficient enforcement of existing rules, which leads to illegal and unsustainable collection practices. This situation is compounded by limited access to training and resources for sustainable harvesting techniques, which could otherwise help in balancing mushroom collection with ecological conservation.

The marketing of red mushrooms in Nepal faces numerous obstacles, ranging from logistical challenges to market access barriers. The remote and often mountainous regions where these mushrooms are found make it difficult to transport them to markets, leading to significant post-harvest losses due to spoilage. The lack of proper storage facilities and cold chain infrastructure exacerbates this issue, reducing the quality and market value of the mushrooms. Furthermore, there is a lack of market information and knowledge among local harvesters about potential buyers and price trends, which often results in exploitation by middlemen who buy the mushrooms at low prices. This economic disparity discourages sustainable harvesting practices and reduces the economic benefits that could incentivize conservation. Moreover, the regulatory environment for mushroom export is cumbersome, with bureaucratic hurdles and limited support for small-scale producers, making it challenging to access international markets where demand for red mushrooms is high.

Karnali Province, situated in the rugged landscapes of north-western Nepal, is characterized by its rich biodiversity and ecological diversity. Amidst this enchanting province lies a fascinating aspect yet to be comprehensively explored: the cultivation and marketing potential of red mushrooms. These distinctive fungi not only contribute to the local economy but also hold ecological significance. The enigmatic allure of red mushrooms, known for their unique flavors and potential

health benefits, beckons us to understand the dynamics of their cultivation within the unique environmental context of Karnali. By unraveling the complexities surrounding their growth, mapping their natural habitats, and examining the economic dimensions associated with their marketing, this research seeks to contribute valuable insights to local farmers, businesses, and policymakers.

In recent years, red mushrooms have garnered attention not only for their culinary appeal but also for their potential to bolster local economies and provide sustainable livelihoods.

## **1.2 Objective**

The general objective of the study was to identify the current status, distribution and marketing of RatoChyau (*Ganoderma lucidum*) in Karnali Province, Nepal.

Specific objectives were

- To assess the current status of red mushroom in Karnali Province, Nepal
- To investigate the existing harvesting practices of red mushroom in study area
- To identify the key stakeholders involved in red mushroom production in study area
- To prepare the distribution map / habitat suitability map of red mushroom in study area

- To analyze the environmental factor influencing the distribution patterns of red mushroom in study area
- To examine the current marketing channels and strategies employed for red mushroom products in study area
- To assess the economic impact of red mushroom on local communities

### **1.3 Rationale of the study**

Mushrooms are not only important for national and local economy but also important for the rural people for food and medicine. These mushroom should be conserved and managed for the betterment for people and environment. Conservation of these species is a key action of biodiversity conservation. For conservation and management, basic data are crucial. Information related to distribution and habitat of mushroom are crucial to document. The rationale for conducting this study lies in the profound significance these plants hold for healthcare, economic development, and biodiversity conservation.

Investigating the current status, distribution, and marketing of red mushrooms, particularly species like *Ganoderma lucidum*, in Nepal is crucial for several compelling reasons. First, these mushrooms are ecologically significant, playing a vital role in

forest ecosystems by contributing to nutrient cycling and soil health. Understanding their distribution can provide insights into ecosystem dynamics and help in biodiversity conservation efforts. Second, red mushrooms are of immense cultural and economic importance to many local and indigenous communities, who rely on them for traditional medicine and as a source of income. However, the lack of comprehensive data on their current status poses a threat to their sustainable use. Third, the growing national and international demand for red mushrooms presents significant economic opportunities, yet the absence of structured marketing channels and inadequate market information leads to inefficiencies and economic loss for local collectors. By studying their distribution, we can identify critical habitats and populations at risk, which is essential for developing effective conservation strategies. Additionally, a detailed analysis of the marketing dynamics can help in formulating policies that support sustainable harvesting, fair trade practices, and economic development. Overall, this study aims to bridge knowledge gaps, promote sustainable management, and enhance the socio-economic benefits of red mushroom resources in Nepal.

#### **1.4 Limitation of the study**

The limitations of a scientific study refer to the constraints or restrictions that affect the scope, accuracy, or applicability of the research findings. These

limitations can arise from various factors, including the study's design, methodology, sample size, and external influences. One common limitation is the sample size, which, if too small, may not accurately represent the broader population, leading to results that lack generalizability. Methodological limitations can include biases in data collection, measurement errors, or the use of inadequate tools and techniques that might affect the validity and reliability of the results.

Although, this the provincial level study, majority of biophysical and data were collected from Jumla and Kalikot Districts. Also, field visits for the social survey was conducted mostly on these district. Data of other district were collected from the phone interviews and indirect sources. Annual reports of divisional forest offices and other study reports were analyzed for the required data. For the study purpose, indirect interviews were conducted with collectors and traders of the red mushroom.

Limited budget for the study was another major limitation of the study. This study demands more budget for the comprehensive field work and consultation. This study was conducted with very limited budget so data were collected from some part of the province and only some community. Furthermore, time limitation was also another limitation. Due to lack of time, this study couldn't collect the multi-season data from the field. This study collected field data during the spring and pre-

monsoon season. To be honest, this season is not best for the field data collection of red mushroom. Therefore, this study couldn't capture the information related to seasonal variability of the presence of red mushroom.

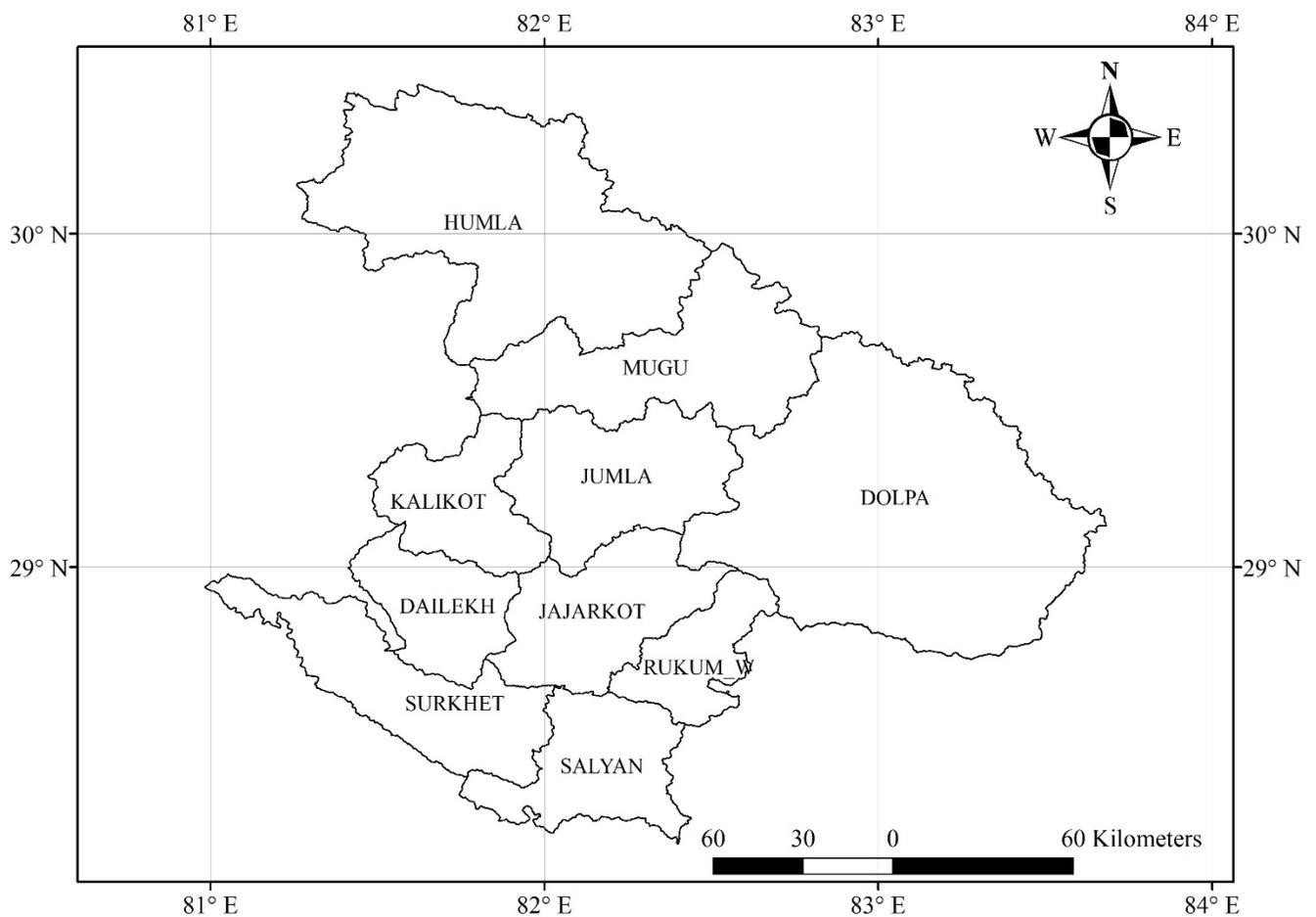
## **2. Methods and materials**

### **2.1 Study area**

#### **2.1.1 General description**

The study was conducted in the Karnali Province of Nepal. Karnali, the largest province in Nepal, boasts an expansive area of 30,211 km<sup>2</sup> (11,664.5 sq mi). Bounded by Lumbini Pradesh to the southeast and south, Sudurpashchim Pradesh to the west, and the Tibet Autonomous Region of China to the north, its

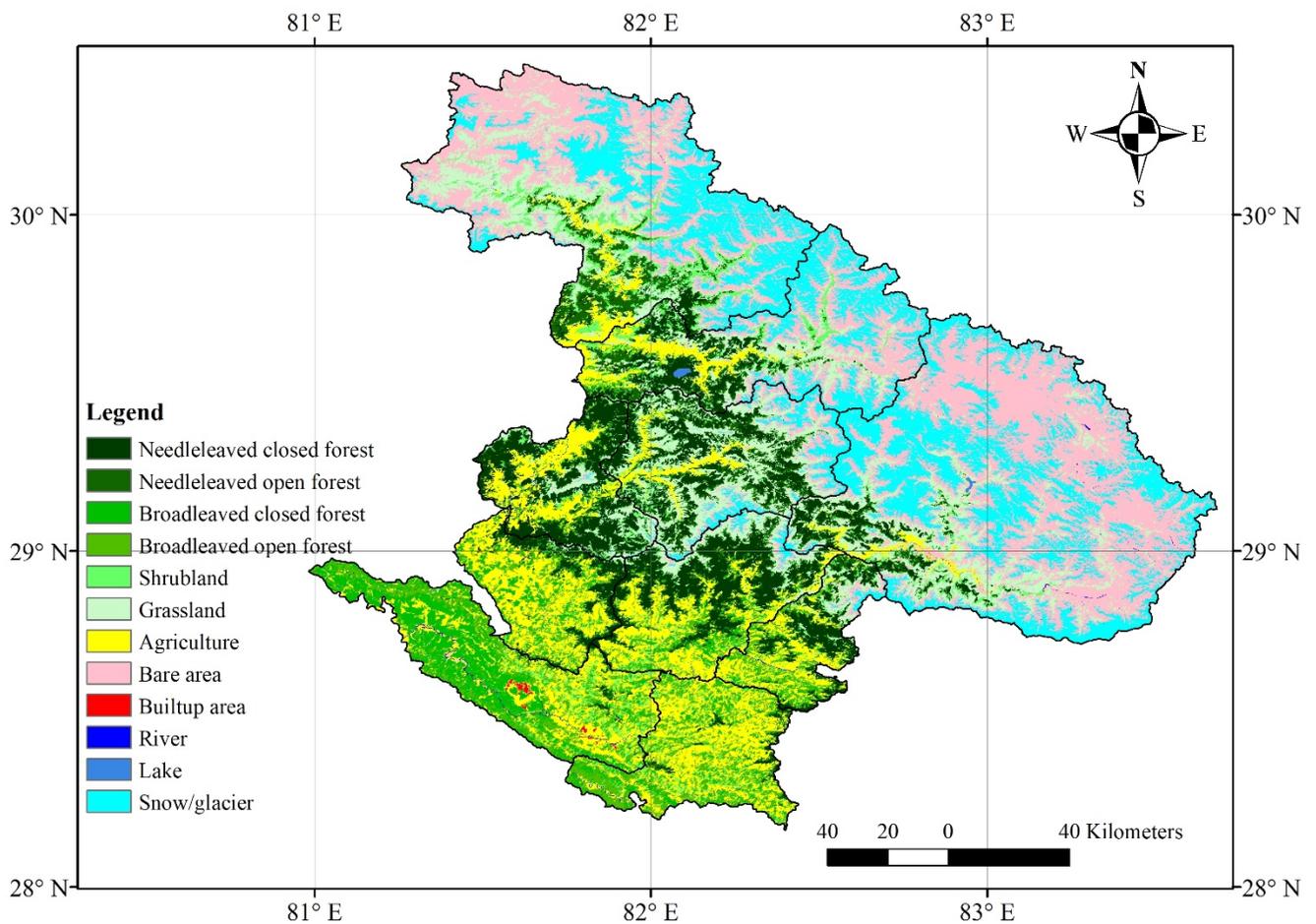
geographical coordinates range from 28.16 to 30.44 N and 80.98 to 83.68 E. Encompassing ten districts—Dailekh, Dolpa, Humla, Jajarkot, Jumla, Kalikot, Mugu, Rukum (west), Salyan, and Surkhet (**Figure 1**). Karnali Province is characterized by diverse landscapes and ecosystems.



**Figure 1: Karnali Province**

### 2.1.2 Land use land cover

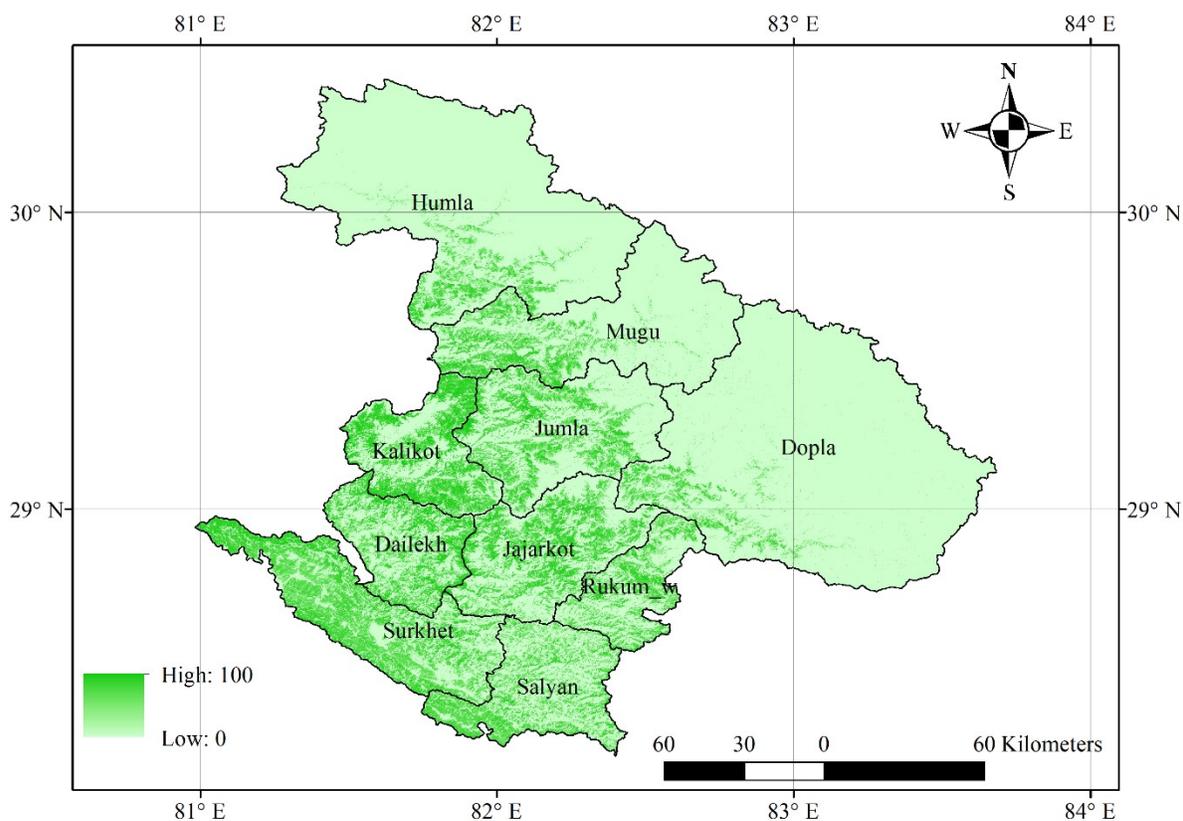
More than half the province's land surface (51%) is covered by vegetation, which includes forest (30%), shrub land (3%) and grassland (18%) (Acharya & Paudel, 2020; Uddin et al., 2015). Most of the area is covered by snow/glacier and bare area in upper parts of the province (**Figure 2**). Lower parts of this province is covered by agriculture lands and broadleaved forests. Needle leaved forest are presented in the middle parts of the province.



**Figure 2: Land Cover of Karnali Province**  
©ICIMOD/Uddin et.al.2015.

### 2.1.3 Forest cover

Forest cover is low in Humla, Mugu and Dopl Districts of the province. But the forest cover is relatively more in Surkhet and Salyan Districts. Rest of the districts have moderate forest cover (**Figure 3**).

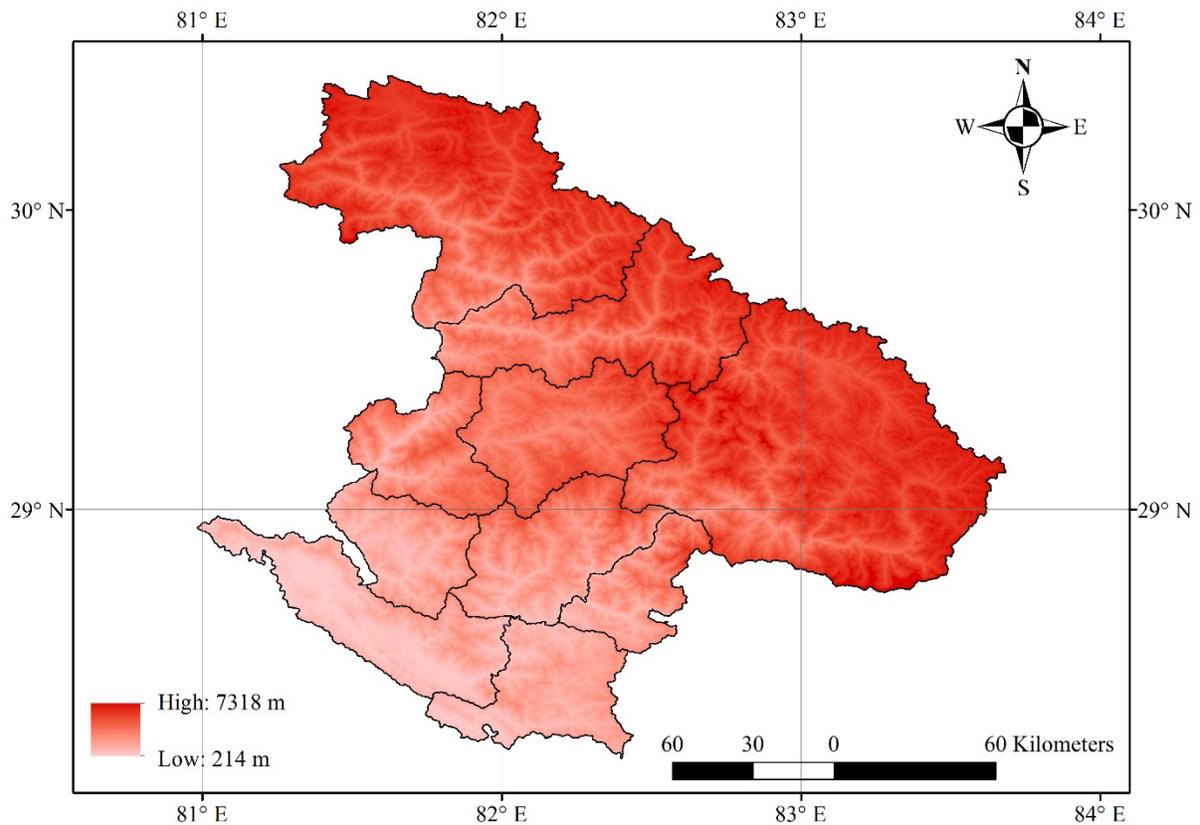


**Figure 3: Forest cover of Karnali Province**

### 2.1.4 Elevation

The Karnali Province has diverse altitudinal range. This province covers 214 m to 7, 318 m digital elevation model (elevation of the 30 m X 30 m pixel value).

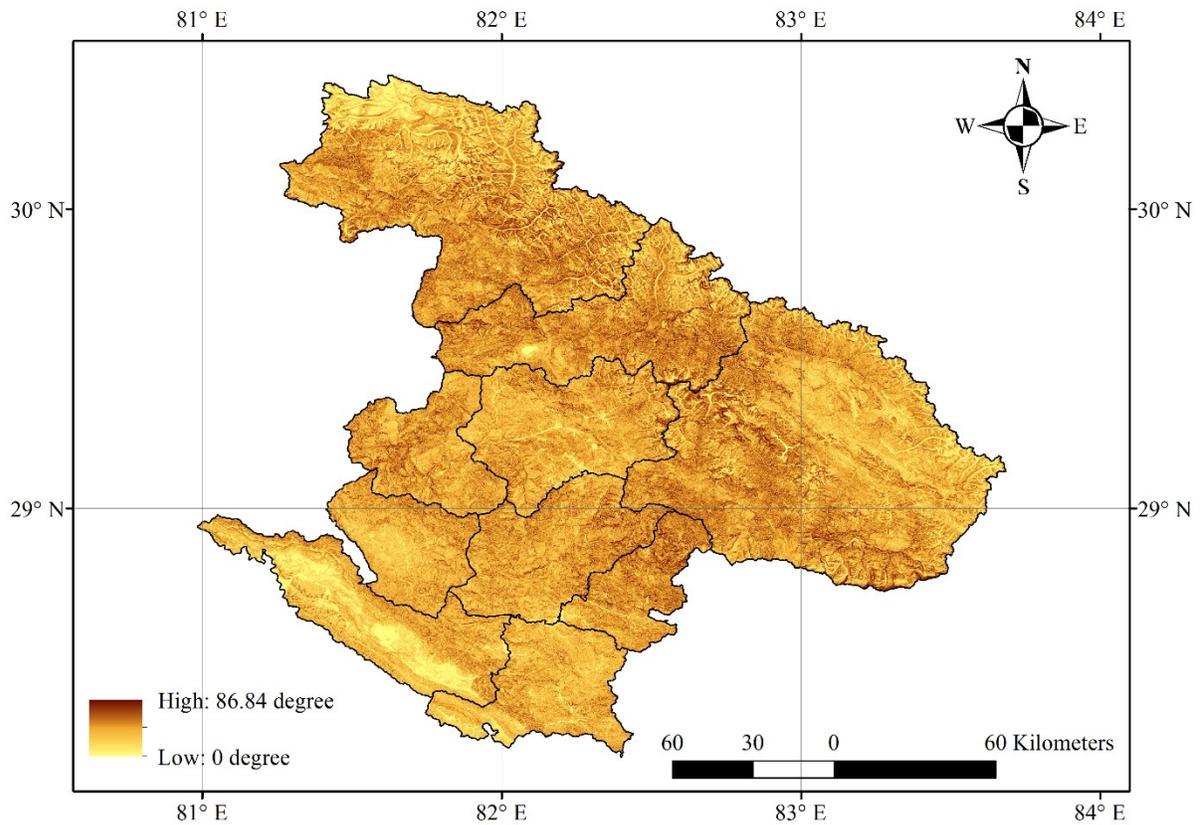
Southern part of the province has low elevation and northern part of the province has high elevation (**Figure 4**). The highest peak point of the Province is ChurenHimal (7348 m). LimiValley in Humla District of the province lies at an altitude above 4,000 meter.



**Figure 4: Elevation range of Karnali Province**

### 2.1.5 Slope

Karnali Province covers flat land to 86.84 degree slope range (**Figure 5**). Most part of the Surkhet District is covered by the flat land. Slope is increasing on northern side of the province.

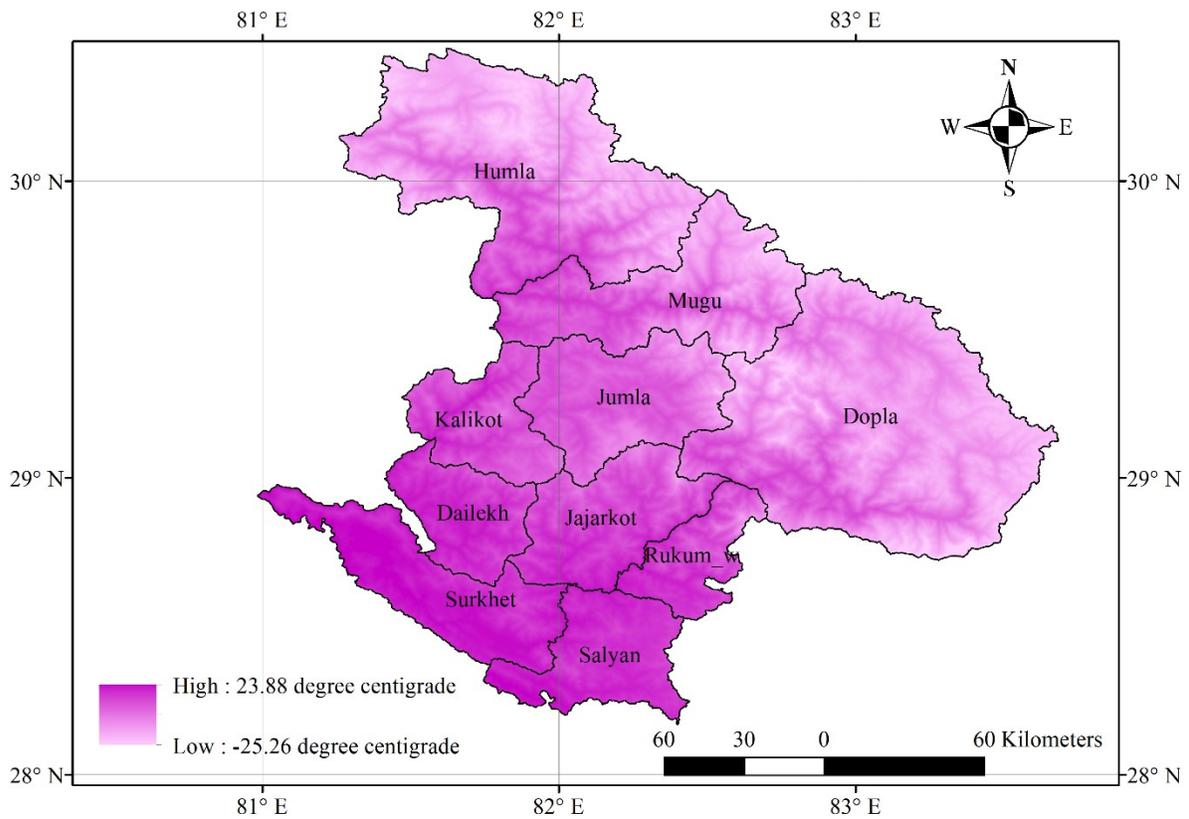


**Figure 5: Elevation range of Karnali Province**

## 2.1.6 Climate

Due to large variation in elevation range this province has diverse climate. Annual mean temperature of the province range from -25.26 to 23.88 degree centigrade

(Figure 6). This province is drier than other provinces. Normally, this province is receiving the smaller amount of precipitation in comparison to the other provinces of Nepal.



**Figure 6: Annual mean temperature of Karnali Province**

### 2.1.7 Non timber forest product in Karnali Province

Karnali Province is famous for the NTFP and MAPs. MAPs in Karnali Province generated economic output equivalent to NPR 160738 million (USD 1.39 billion)

or 1.03% of GDP of Karnali Province and 0.02% of the National GDP in the fiscal year 2019/2020 (Aryal et al., 2023). Almost all of Nepal's Ganoderma comes from natural stands, with the bulk coming from the Karnali (46%) and Far West (50%) Provinces (Raut et al., 2022). Furthermore, wild morels (*Morchella* spp.) are harvested commercially and exported extensively from west Nepal especially from Karnali Province which share 58% of total national output (Raut et al., 2019).

## **2.2 Data collection**

### **2.2.1 Social data collection**

Possible habitats of red mushroom plant were identified through the consultation with staffs of the Divisional Forest Offices and member of the community forests users groups, key informants, collectors and traders. Then these area were visited to collect the following information related to

- Red mushroom collection season
- Location of habitat of red mushroom
- Suitable climate for red mushroom
- Suitable tree species on which this species can grow
- Uses of red mushroom
- Red mushroom harvesting methods and practices
- Problems related to the red mushroom harvesting

- Legal aspects associated with red mushroom harvesting
- Existing practices and problems associated with marketing of red mushroom
- Economic contribution of red mushroom

## **2.2.2 Biophysical data collection**

Possible habitats of red mushroom were identified during the social data collection. The study team visited all potential habitats of this species during the spring to pre-monsoon season of 2024 throughout the study area. The study team conducted intensive survey in Jumla and Kalikot Districts. Global Positioning System (GPS) points, photos and other details of red mushroom were collected during the field survey. During the data collection process, the villagers/herders who helped to show the habitats benefited from wages. Nepal Herbs and Herbal Products Association (NEHHPA) publish “Identification Manual of Commercial Medicinal and Aromatic Plants of Nepal” (Gurung & Pyakurel, 2017). The study team used this manual during the field data collection.

## **2.2.3 Collection of environmental layers**

### **2.2.3.1 Topographical variables**

The topographical variables were used for the habitat modeling of the species for 20 years (Osborne et al., 2001). Digital Elevation Model (DEM) of 30 m resolution was downloaded from USGS website (<https://earthexplorer.usgs.gov/>), and slope

as well as aspect were calculated from the DEM using ArcGIS software (ESRI, 2017). Furthermore, shapefile of waterways were obtained from the Geofabrikwebsite (<https://www.geofabrik.de/data/shapefiles.html>). Then distance raster file was created by the help of ArcGIS software (ESRI, 2017).

### **2.2.3.2 Vegetation-related variables**

Distribution of mushrooms is depend on vegetation-related variables. For instance, some species are light demanders, whereas others are shade demanders. Therefore, the inclusion of vegetation-related variables to predict habitat for this species is a prerequisite for robust modeling.

This study uses the forest cover and Enhanced Vegetation Index (EVI) for modeling purposes. Forest cover prepared by Hansen et al. (2013) was downloaded from the Global Forest Change (GFC) website and used for the modeling. Similarly, EVI time-series data for 2018 and 2019, from images obtained by Landsat 8 were used for the modeling. The EVI was calculated/refined with the help of the Google Earth Engine.

### **2.2.3.3 Anthropogenic variables**

This study incorporated anthropogenic variables into the model. Anthropogenic variables were distance to human paths (used by humans and animals), distance to building, and land use. The location of paths and buildings were obtained from the

Geofabrik website (<https://www.geofabrik.de/data/shapefiles.html>). Distance raster files of paths and buildings were created using ArcGIS (ESRI, 2017). Land cover and land use (LULC) data were downloaded from the International Centre for Integrated Mountain Development website (ICIMOD; <http://www.icimod.org>) (Uddin et al., 2015) and incorporated into the model.

#### 2.2.3.4 Climatic variables

Climatic conditions are most important to the distribution of the plant species. For this study, climatic variables were downloaded from the WorldClim database (<http://worldclim.org/>). Annual mean temperature and annual mean precipitation were used for the modelling purpose.

Topographical, vegetation-related, anthropogenic and climatic variables were downloaded from free sources and pre-processed in ArcGIS (ESRI, 2017) to prepare in the required format (ASCII), extent, and spatial resolution (30 m) (Table 1).

**Table 1: Environmental variables for modeling**

Source	Category	Variable	Abbreviation	Unit
USGS	Topographic	Elevation	elevation	M
		Slope	slope	Degree
		Aspect	aspect	Degree

GEOFABRIK		Distance to water	dist_water	M
Landsat	Vegetation-related	Annual mean EVI	mean_evi	Dimensionless
GFC		Forest cover	Forest	Dimensionless
GEOFABRIK	Anthropogenic	Distance to path	dist_path	M
		Distance to building	dist_build	M
ICIMOD		Land use/land cover	lulc	M
WorldClim	Climatic	Annual mean temperature	mean_temperature	Degree centigrade
		Annual mean precipitation	mean_precipitation	cm

## 2.3 Data analysis

### 2.3.1 Distribution modeling of red mushroom

The Maximum Entropy (MaxEnt) was used to predict the distribution of the species by using the species occurrence points and environmental variables (Elith et al., 2006; Phillips et al., 2006). The MaxEnt is also an established and widely used tool for predicting the distribution of the species in Nepal (A. Aryal et al., 2016; Bista et al., 2018; KC et al., 2019; Panthi et al., 2019; Sharma et al., 2020; Shrestha & Bawa, 2014; A. Thapa et al., 2018). The model used 10 replicates and 1000

background points for the modelling (Barbet-Massin et al., 2012) of distribution of red mushroom in Karnali Province of Nepal.

### **2.3.2 Accuracy assessment of the model**

Assessment of the accuracy is an essential step to validate the models and to understand the performance of the models. A total of 70 % of the occurrence points of red mushroom were allocated for the training dataset, and the remaining 30 % were used as a testing /validation dataset for the modeling of this species. The models were evaluated by the two methods. One method was threshold independent, and another was threshold dependent. In the threshold independent method, the area under the receiver-operator curve (AUC) of models was obtained directly from the model (Phillips et al., 2006; Wiley et al., 2003). The higher the AUC, the higher the model performance (discrimination capacity) is. The AUC <0.7 denotes poor model performance, 0.7–0.9 denotes moderately useful model performance, and >0.9 denotes excellent model performance (Pearce & Ferrier, 2000). Although AUC is a classical and widely used model evaluation parameter, it is criticized by researchers (Lobo et al., 2008). So, threshold dependent accuracy assessment: True Skill Statistic (TSS) was calculated for the model evaluation (Merow et al., 2013). The value of TSS ( $TSS = \text{Sensitivity} + \text{Specificity} - 1$ ) ranges

from -1 to 1, where values less than 0 indicate a performance no better than random and 1 indicates a perfect fit of the model (Allouche et al., 2006). TSS was calculated for all model outputs (0-9 replications), and the final TSS was the average of all 10 replications for all species (Jiang et al., 2014; Panthi et al., 2019). The threshold to maximize the sum of sensitivity and specificity was used to calculate the TSS and to convert the continuous probability map generated by the MaxEnt model to a binary suitable/unsuitable map (Liu et al., 2013).

### 3. Results and discussion

#### 3.1 Current status of red mushroom in Karnali Province

Red mushroom (*Ganoderma lucidum*) is most valuable wild mushroom of Nepal. Almost all of Nepal's *Ganoderma* comes from natural stands, with the bulk coming from the Karnali (46%) and Far West (50%) provinces (Raut et al., 2022). This species is found in Jumla, Kalikot, Humla, Mugu, Dolpa, Rukum West and Jajarkot Districts of the Karnali Province. Ratbhir, Ogla, Bhandari Forest, Jarnage, Khadeni, BhattaKhola, Murkukauli, Tharala, BhitraKhola, PaniKhola of Tatopani Rural Municipality, Kalapatal, RangdangKhola, MotaKharsu, ChandiMela, Koth Forest of Sinja Rural Municipality, upper side of Syalpatal community forest, Sallikandh, GagriKhola, Mandhara, Bhateni forest, Panikhana, Gothaleko forest, upper Kharsu of Bhaleni community forest, upper side of Lamteli community forest, Naiberi to Khali area, Khor, Kharseni, Chotteni, Majinya, Majhchhara forest area of Patarasi Rural Municipality of Jumla District, Mahabu, PatalJharana, Shubakalika, Tilagupha, upper side of Khadachaur Rural Municipality of Kalikot are suitable natural habitat of red mushroom. Dead tree of ThingreSalla (*Abies pindron*), Kharsu (*Quercus semecarpifolia*) and Bhanjh (*Q. incana*) are best to grow this species.

### **3.2 Existing harvesting practices of red mushroom**

The red mushroom is typically harvested during the monsoon to post-monsoon season, from Shrawan to Kartik. Local collectors use traditional tools, such as a local knife called an Aasi, though hand collection is also common. While men primarily conduct the harvest, women and children are actively involved in foraging for these wild mushrooms in the forest. However, their harvesting practices do not account for the sustainability of the resource, as they tend to collect all mushrooms they find without regard for conservation.

### **3.3 Key stakeholders involved in red mushroom production**

Local people are the key stakeholders involved in red mushroom production in Karnali Province. To be specific, main stakeholders involved in red mushroom production in Karnali Province are as follows

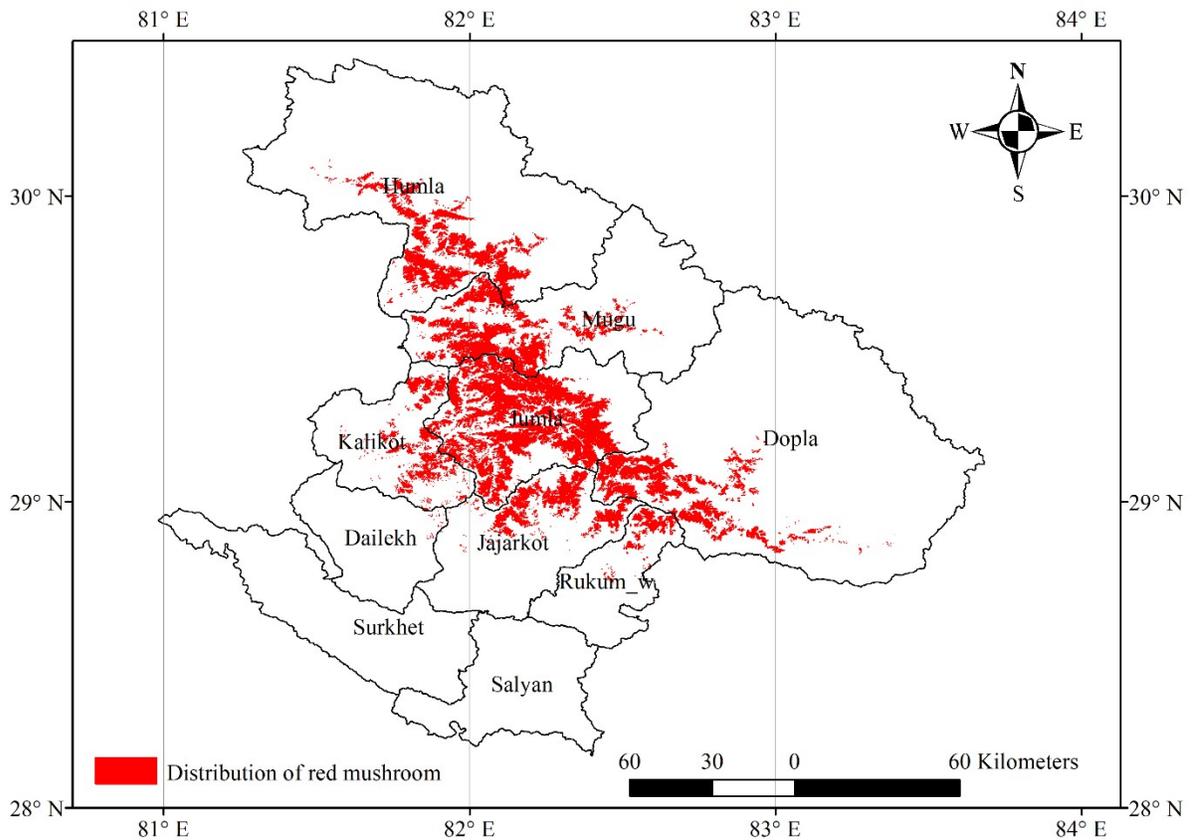
- Local people: men, women, children
- Herders
- Ethnic groups
- Community forests
- Local traders

- National traders
- Division forest offices
- Researchers
- Academicians: lectures, students

These stakeholders are key stakeholders related to the red mushroom in Karnali Province.

### **3.4 Distribution / habitat suitability of red mushroom**

Result of the MaxEnt model shows that Jumla District is best habitat of red mushroom. Additionally, Jumla, Mugu, Dolpa, Rukum West, Jajarkot and Kalikot Districts are good habits of this species. Dailekh, Surkhet and Salyan Districts are not habitat of this mushroom (**Figure 7**). In total 1773.15 km<sup>2</sup> area was identified as distribution area/suitable habitat of this species in Karnali Province.



**Figure 7: Distribution/suitable habitat of red mushroom in Karnali Province**

Threshold 0.184 was used to convert the continuous MaxEnt output into the binary map. The model has good accuracies (TSS=0.900, AUC=0.963). Details of accuracies of every 10 run are shown in table 2.

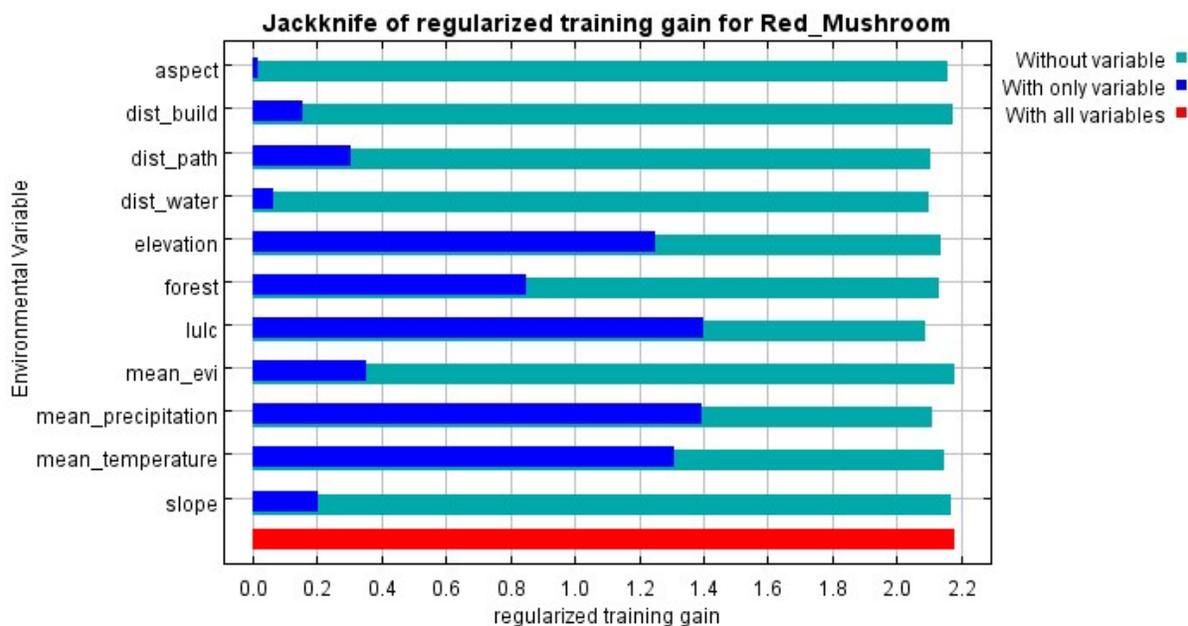
**Table 2: Accuracies of the models**

Replicates/Run	Threshold	AUC	TSS
0	0.260	0.973	0.946
1	0.090	0.967	0.911
2	0.240	0.960	0.951
3	0.200	0.969	0.937

4	0.140	0.960	0.924
5	0.090	0.955	0.918
6	0.150	0.965	0.929
7	0.090	0.966	0.911
8	0.500	0.955	0.677
9	0.080	0.960	0.901
Average	0.184	0.963	0.900
Standard deviation	0.129	0.006	0.080

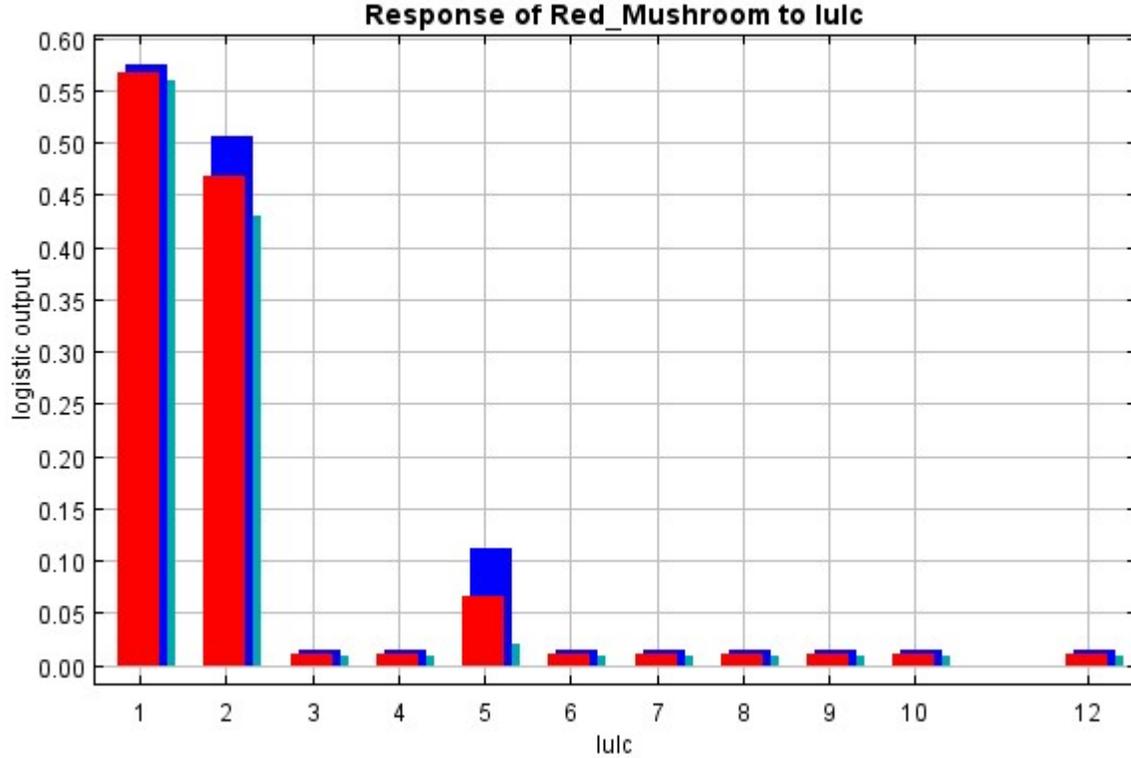
### 3.5 Environmental factor influencing the distribution patterns of red mushroom

Land use land cover, annual mean precipitation, annual mean temperature, elevation and forest are influencing the distribution of red mushroom in study area. Aspect, distance to building, mean EVI and slope are less influencing the distribution of this species. Rest variables are moderately influencing (**Figure 8**). In figure 8, variables having short light bar are more important than long light bar. Because, if that variable is not used for the modelling, the regularized training gain of the model will be dropped to that light bar. In figure 8, lulc has shortest light bar. Therefore, lulc is the most important variables to model the distribution of red mushroom.



**Figure 8: Environmental factor influencing the distribution of red mushroom**

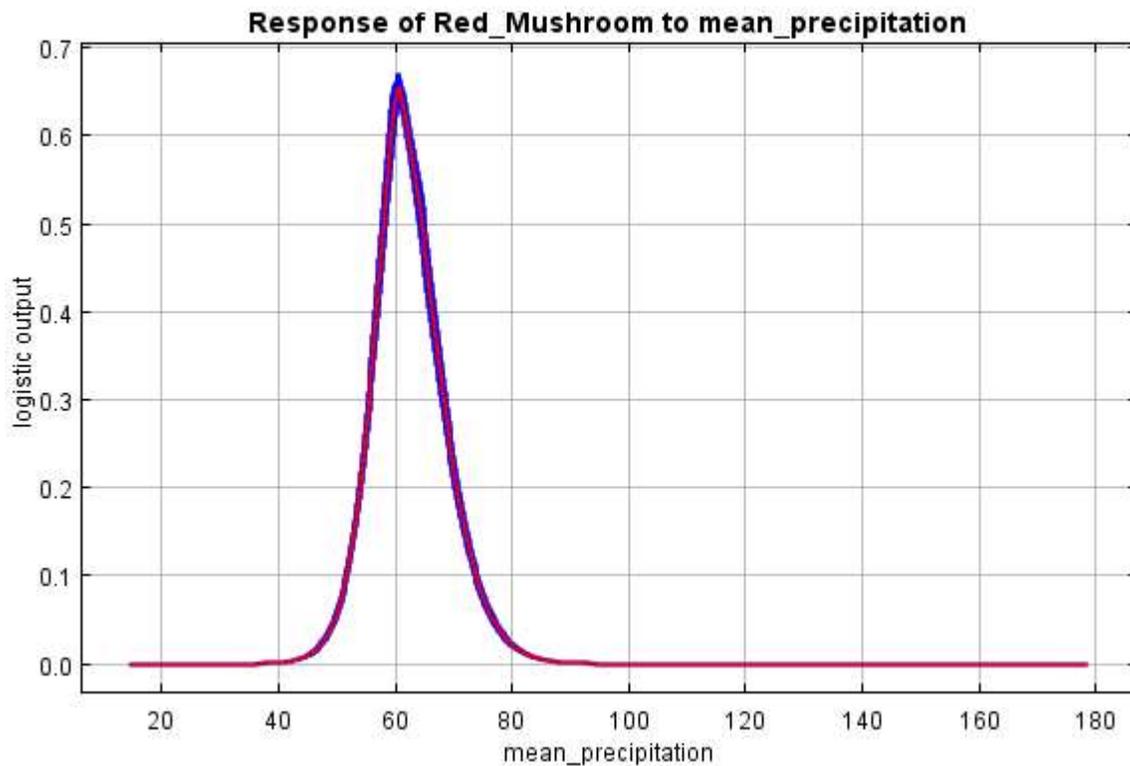
Land use land cover is the most influencing factor to the distribution of red mushroom. Distribution is concentrated to the needle leaved forest. The needle leaved close forest and needle leaved open forest are most suitable habitat of this species (**Figure 9**). Red mushroom can't be grown at other type of land use.



**Figure 9: Response of distribution of red mushroom to land use land cover (LULC)**

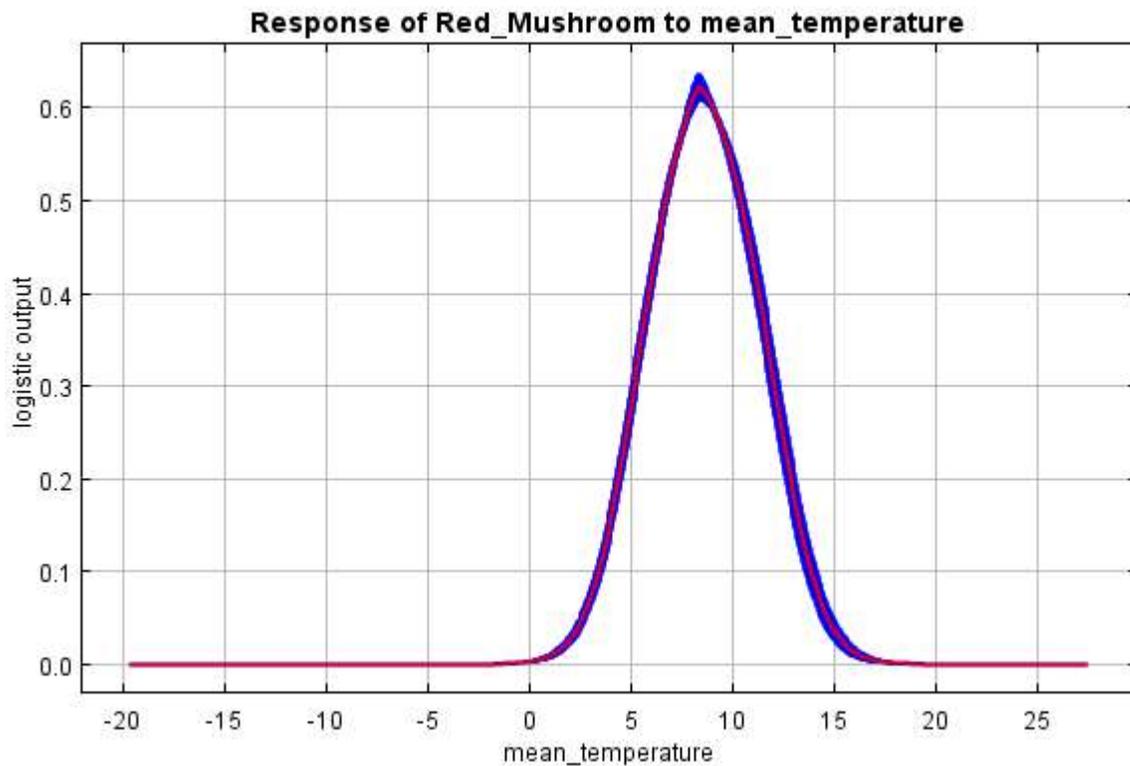
Note: 1= Needle leaved close forest, 2= Needle leaved open forest, 3=Broad leaved close forest, 4=Broadleaved open forest, 5=Shrub land, 6=Grassland, 7=Agriculture, 8=Bare area 9= Built-up area, 10= River, 12= Snow/glacier

Annual mean precipitation is also most influencing factor to the distribution of the red mushroom. 600 mm annual mean precipitation is ideal required precipitation for the suitable habitat of the red mushroom (**Figure 10**). Precipitation less than 400 mm and more than 800 mm is not suitable for the distribution of red mushroom in the study area.



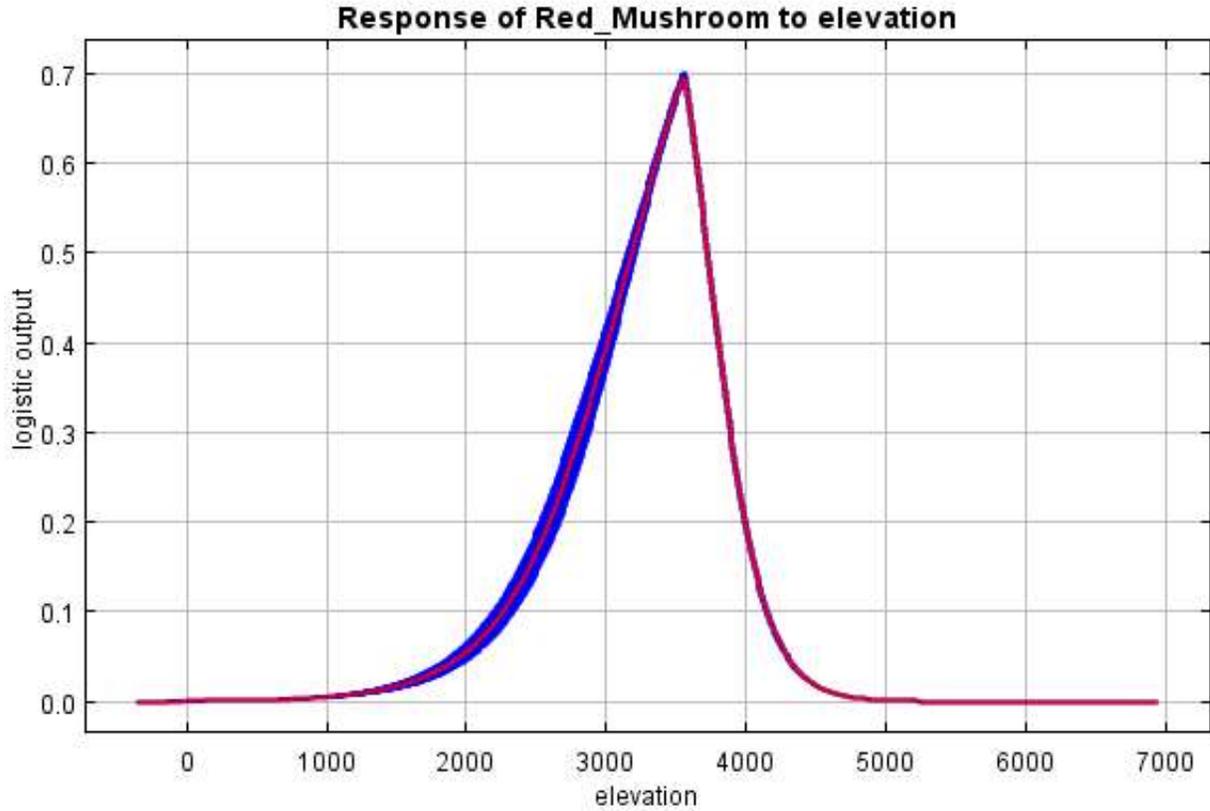
**Figure 10: Response of distribution of red mushroom to annual mean precipitation**

Another influencing factor to distribution of the red mushroom in the Karnali Province is annual mean temperature. Eight degree centigrade annual mean temperature is ideal required temperature for the suitable habitat of the red mushroom (**Figure 11**). Temperature less than 1 degree centigrade and more than 16 degree is not suitable for the distribution of red mushroom in the study area.



**Figure 11: Response of distribution of red mushroom to annual mean temperature**

Elevation is also influencing the distribution of red mushroom. 2, 600 m elevation is ideal for the best habitat of the red mushroom. Habitat having below 2,000 m and above 4,000 m elevation is not suitable for the distribution of this species in study area (**Figure 12**).



**Figure 12: Response of distribution of red mushroom to elevation**

Forest cover is also influencing environmental factor to distribution of the red mushroom. In figure 13, the denseness of forest cover is categorized from 1 to 100 values. Value 1 denotes no forest and value 100 denotes very dense forest. Denser the forest, higher the suitability for the habitat of red mushroom (**Figure 13**).

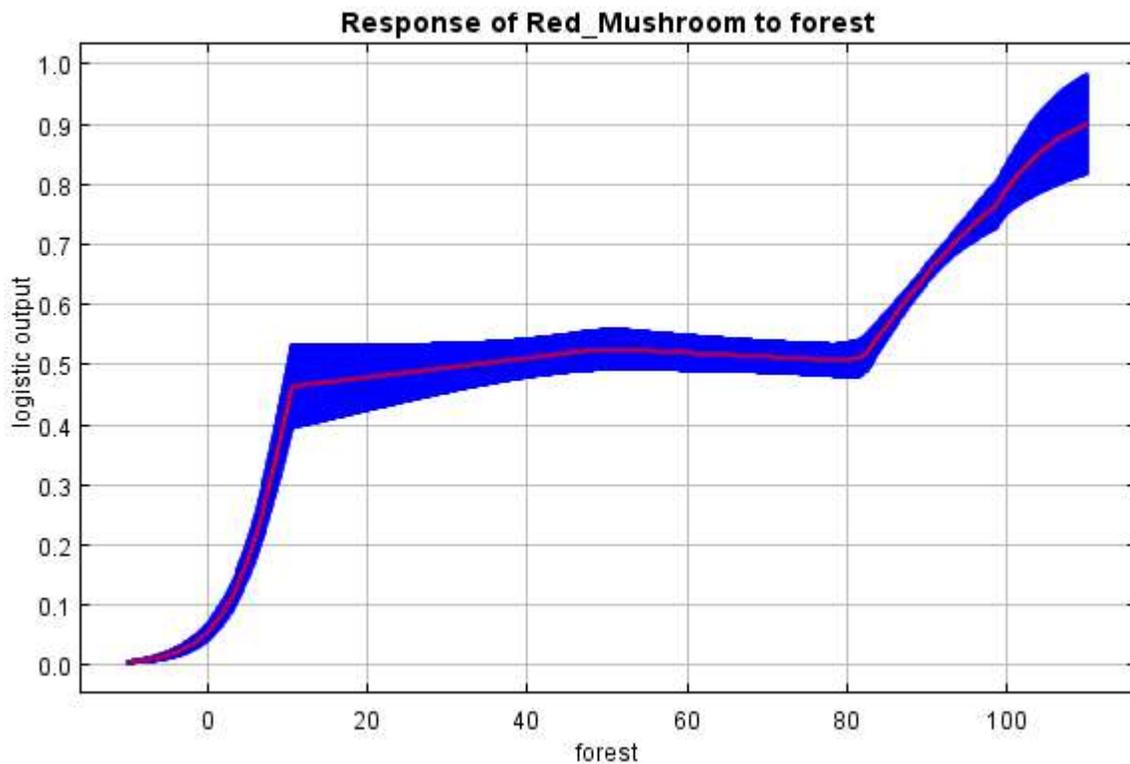


Figure 13: Response of distribution of red mushroom to forest cover

### 3.6 Current marketing channels and strategies employed for red mushroom products

In Karnali Province, here is semi developed marketing channel of red mushroom. Local people collect the red mushroom from forest during Shrawan to Kartik months every year. Mainly adult men are being involved to collect the red mushroom but in some cases, women and children are also collecting the red mushroom. One person can collect 10 to 15 kg red mushroom per season. Then they sell it to local traders (trades based on the district headquarters) in NRs 3,500 to 6,000 per kg. Local traders collect some amount of red mushroom and transport

to Kathmandu. The price of this mushroom in Kathmandu is 10,000-15,000 per kg. Sometimes local traders transport red mushroom to Nepaljung to sell to another traders. Traders of Kathmandu export red mushroom to China.

The identified market channel of red mushroom is Karnali – Kathmadu – China. This species is not consumed by the local people. Like other goods rate of this mushroom depends on demand and supply of this species. The ultimate market destination of the red mushroom is China. Therefore, demand and price are depend upon the Chinese market.

### **3.7 Economic impact of red mushroom on local communities**

The red mushroom, specifically *Ganoderma lucidum* has significantly impacted the local communities in Karnali Province, Nepal, economically. As one of the most valuable natural resources in the region, it provides a crucial source of income for many families, especially during its harvesting season from August to October. The mushroom's high market value, driven by its demand in traditional medicine, has transformed the local economy. Harvesters often travel to high-altitude pastures, facing harsh conditions, but the financial rewards are substantial, contributing to better living standards, educational opportunities, and improved infrastructure. Nevertheless, the red mushroom's economic benefits have been

instrumental in uplifting many households from poverty and fostering economic resilience in this remote, mountainous region.

One person can collect 10-15 kilograms per season and cost of this mushroom is NRs 3,500 to NRs 6,000. If capable person collect 15 kg (estimate dry weight is 5 kg) mushroom and sell it with NRs 6,000, that person can earn 30,000 (5kg X NRs 6,000) per season. Although it is an ideal condition, it can be imagined that, red mushroom is providing lots of opportunities for local people such as collectors, traders, general public. If money enter into the village, then farmers, local shopkeepers, drivers, small businessmen and overall villagers will be benefited by money circulation.

### **3.8 Problems related to red mushroom conservation, harvesting and marketing**

The red mushroom known for its medicinal properties, faces several challenges in terms of conservation, harvesting, and marketing in Karnali Province, Nepal. Conservation efforts are hampered by overharvesting due to high demand and lucrative market prices, leading to the depletion of natural stocks and habitat degradation. The lack of sustainable harvesting practices and limited knowledge

about the mushroom's ecology exacerbates the risk of depletion. Furthermore, the absence of proper regulations and enforcement allows illegal harvesting, causing further strain on the species. Marketing of the red mushroom also presents issues; while there is significant demand in international markets, local harvesters face barriers such as poor infrastructure, lack of market access, and limited knowledge of quality standards, which diminish their bargaining power and potential profits.

Additionally, the lack of proper storage facilities and processing knowledge often leads to post-harvest losses. These challenges underscore the need for coordinated efforts involving sustainable harvesting practices, improved market access, and better regulatory frameworks to ensure the long-term viability of *Ganodermalucidum* in Karnali Province. Key business obstacles related to medicinal plants were export barriers, low access to technology, infrastructure and service barriers, labor challenges, socio-economic and political instability, and the inefficient bureaucracy (Caporale et al., 2020).

Forest fire was identified as major problem during the field survey. Due to forest fire, dead trees, a best for red mushroom grow, are being destroyed. In some cases, the collectors are encountering with wildlife such as Himalayan black bear and common leopard. Some collector visit the forest but they can't collect any amount of red mushroom. Sometimes collectors couldn't find the traders to sell the collected amount. In Karnali Province, here are not any proper storage to store red

mushroom for long time. Therefore, it can't be stored properly. Furthermore, due to lack of processing plant and techniques, it is being sold in raw form and at low price.

## 4. Conclusion

This study was conducted in Karnali Province to explore current status, distribution and marketing of RatoChyau (red mushroom; *Ganoderma lucidum*). Intensive field survey was conducted in Jumla and Kalikot Districts of the Karnali Province. Maximum Entropy (MaxEnt) software was used to model the distribution/suitable habitat of this species. This study identified 1773.15 km<sup>2</sup> area as distribution area/suitable habitat of this species in Karnali Province. Jumla, Mugu, Dolpa, Humla, Rukum West, Jajarkot and Kalikot Districts are good habitats and Dailekh, Surkhet and Salyan Districts are not habitat of this mushroom species. Dead tree of ThingreSalla (*Abies pindrow*), Kharsu (*Quercus semecarpifolia*) and Bhanjh (*Q. incana*) are best to grow this species. Land use land cover, annual mean precipitation, annual mean temperature, elevation and forest are influencing the distribution of red mushroom in study area. Distribution is best at the dense needle leaved forest, 600 mm annual mean precipitation, eight degree centigrade annual mean temperature, and 2600 m elevation. Threshold 0.184 was used to convert the continuous MaxEnt out into the suitable/unsuitable binary map. The model has good accuracies (TSS=0.900, AUC=0.963). Red mushroom is contributing the local economy. One person can collect 10 to 15 kg red mushroom per season. Then they sell it to local traders (trades based on the district headquarters) in NRs

3500 to 6000 per kg. Local traders collect some amount of red mushroom and transport to Kathmandu. The price of this mushroom in Kathmandu is 10,000-15,000 per kg. The ultimate market destination of the red mushroom is China. Therefore, demand and price are depend upon the Chinese market.

## 5. Recommendation

Forest fire was identify as major problem of habitat of red mushroom in Karnali Province. Due to forest fire, dead trees are being destroyed. It is recommended to control the forest fire for the conservation of this species in its natural habitat. In some cases, collectors are encountering with wildlife such as Himalayan black bear and common leopard. Therefore, this study strongly recommend to prohibit the children to enter the core forest area to collect the red mushroom.

Key business obstacles related to medicinal plants were export barriers, low access to technology, infrastructure and service barriers, labor challenges, socio-economic and political instability, and the inefficient bureaucracy (Caporale et al., 2020). Similar problems such as lack of effective storage facilities and no market guarantee are associated with red mushroom in Karnali Province, Nepal. Therefore, this study recommends to ensure the effective storage facilities and market guarantee for effectively management of market of the red mushroom in Karnali Province. The most feasible areas for mushroom farming are valley and other areas near urban centers (Poudel & Bajracharya, 2018). Production of mushroom (domesticated species) in urban areas are also recommended for fulfillment of the market need. This action can help to promote the sustainable harvesting of wild mushroom.

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## Appendix

### GPS points collected for modelling

S.N.	Species	X Coordinate	Y Coordinate
1	Red Mushroom	82.15257	29.34274
2	Red Mushroom	82.1196	29.3446
3	Red Mushroom	82.10354	29.31493
4	Red Mushroom	82.09437	29.3232
5	Red Mushroom	82.08341	29.31843
6	Red Mushroom	82.19583	29.24878
7	Red Mushroom	82.18241	29.24651
8	Red Mushroom	82.1802	29.25627
9	Red Mushroom	82.16814	29.2459
10	Red Mushroom	82.19031	29.23616
11	Red Mushroom	82.40352	29.32392
12	Red Mushroom	82.43676	29.21966
13	Red Mushroom	82.39297	29.22412
14	Red Mushroom	82.23108	29.33967
15	Red Mushroom	82.22536	29.33424
16	Red Mushroom	82.11519	29.32411
17	Red Mushroom	82.11092	29.3171
18	Red Mushroom	82.16608	29.34749
19	Red Mushroom	82.19463	29.36575
20	Red Mushroom	81.94508	29.34258
21	Red Mushroom	81.95736	29.34467
22	Red Mushroom	81.90983	29.35974

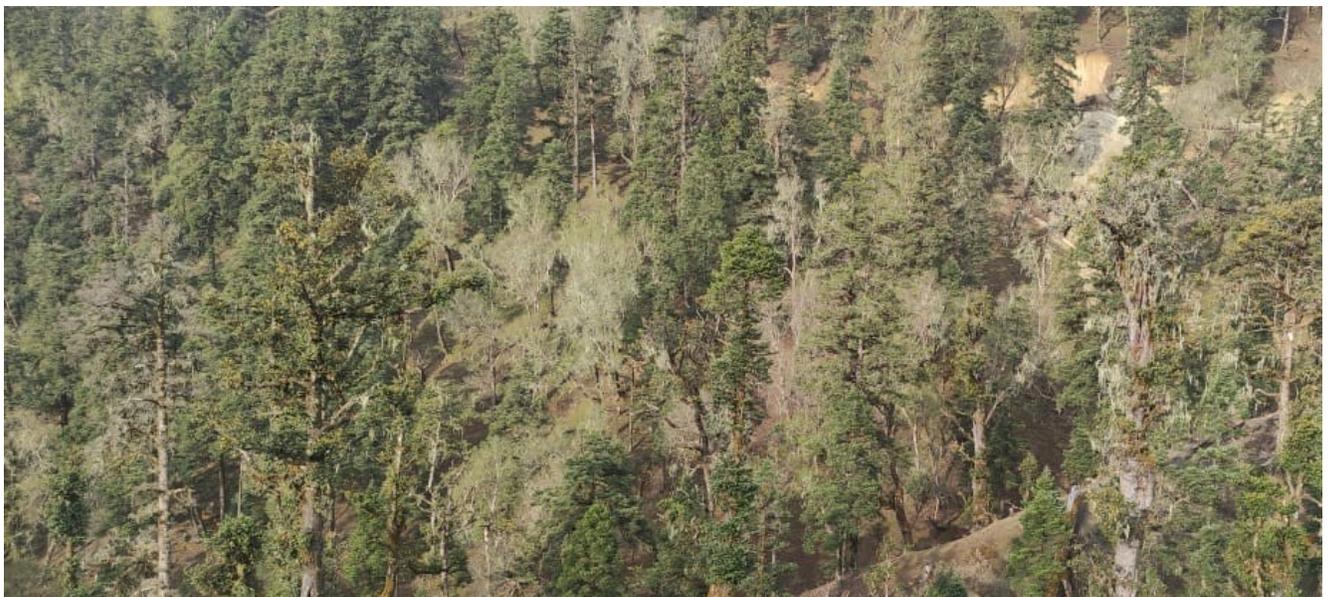
23	Red Mushroom	82.10836	29.35153
24	Red Mushroom	82.1125	29.33394
25	Red Mushroom	82.1277	29.33526
26	Red Mushroom	82.40318	29.28319
27	Red Mushroom	82.39131	29.28784
28	Red Mushroom	82.41404	29.2857
29	Red Mushroom	82.39473	29.22217
30	Red Mushroom	82.15019	29.3805
31	Red Mushroom	82.35821	29.23384
32	Red Mushroom	82.41514	29.25105
33	Red Mushroom	82.38318	29.23375
34	Red Mushroom	82.38928	29.23636
35	Red Mushroom	82.24798	29.34397
36	Red Mushroom	82.25585	29.3452
37	Red Mushroom	82.24798	29.34069
38	Red Mushroom	82.17723	29.19211
39	Red Mushroom	82.17337	29.18995
40	Red Mushroom	82.18418	29.19874
41	Red Mushroom	82.19539	29.19721
42	Red Mushroom	82.15309	29.22168
43	Red Mushroom	82.14911	29.22051
44	Red Mushroom	82.15091	29.21642
45	Red Mushroom	82.14418	29.20064
46	Red Mushroom	82.12538	29.22333
47	Red Mushroom	82.12029	29.22182
48	Red Mushroom	82.35614	29.23507

49	Red Mushroom	82.43283	29.24525
50	Red Mushroom	82.40361	29.20566
51	Red Mushroom	82.43256	29.22436
52	Red Mushroom	82.41893	29.28494
53	Red Mushroom	82.43619	29.24723
54	Red Mushroom	82.38405	29.29131
55	Red Mushroom	82.39228	29.29082

Snap during data collection



PhotoPlate: Identification of potential habitat of red mushroom



PhotoPlate: Habitat of red mushroom

