Tusa Cultivation and Promotion in Machhapuchchhre Rural Municipality, Kaski district, Gandaki Province, Nepal

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Thank You.

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Abbreviations

ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
AIC	Akaike Information Criterion
CAMC	Conservation Area Management Committee
GPS	Global Positioning System
NTFP	Non-Timber Forest Product
MRM	Machhapuchchhre Rural Municipality
UCO	Unit Conservation Office

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Executive Summary

The global human population is benefited from the forests and forest products to sustain their livelihood. The people who live near to forest mostly depends on the forest resources and forest products. Therefore, the dependency on the forest and forest products is determined by proximity to the forest. The forest products extracted from the forest especially Non-Timber Forest Products can be used for nutritional and health needs. Bamboos are one of the major non-timber forest products and is widely distributed in Nepal from lowland to high mountain regions. The diversity and distribution of bamboo species varied according to altitude and other climatic and physiographic factors. Due to its contribution to a sustainable livelihood, and one of the major income-generating resources in the mountain region, the Government of Nepal has initiated programs to promote its production with people's active participation. However, the baseline data for site-and species specific is little known. Therefore, this study aims to provide baseline data on the possibility of *Tusa* cultivation and people's attitude towards its production and collection in Machhapuchchhre Rural Municipality of Kaski district. The data of this project was generated through field study, and questionnaire survey, key informant interview and group discussion. All together four species of *Nigalo* including *Tite* (*Drepanostachyum intermedium*), *Malingo* (*Himalayacalamus cupreus*), *Ghode* (*Himalayacalamus asper*), and *Jarbute* (*Thalmocalamus spathiflorus*) are recorded from the study area. Among these species, the *Malingo* is widely distributed and highlyabundantly available species, followed by *Tite* and *Ghode Nigalo* in the study area. The distribution of these *Nigalo* is mainly within the average elevation of 2451 m (range: 1496-2952 m) above the sea level within the average slope of 29° (range: 5°-60°). In addition, the regeneration of the *Tusa* in Machhapuchchhre Rural Municipality is influenced by the combination of best supportive variables such as elevation, the height of *Tusa*, number of *Nigalo* in the clump, slope of the area, soil type, land type, and anthropogenic threats. Furthermore, people in the area are supportive and has involved in *Tusa* cultivation and collection. All people including male and female, educated and uneducated, having any extra occupation with agriculture, low income and high-income sources families are involving and knew about *Tusa* cultivation. Therefore, based on these findings the Sardikhola and Ghalel of Machhapuchchhre Rural Municipality of Kaski district can be designed an ideal location for *Tusa* cultivation and promotion for sustainable livelihood.

1. Introduction

Background of the study

Globally, 1.6 billion people i.e., 25% of global human population directly get benefits from the forests and forest products including Non-Timber Forest Products (NTFPs), timber, wood, fodders, etc. for their livelihood and uplifting the income sources (FAO 2018). However, the dependency on the forest and forest products is determined by the proximity of forest to the human settlement. Approximately, 1.93 billion rural people had lived within 10 km from the forest in 2012 and followed by 1.60 billion, and 0.78 billion people within 5 km, and 1 km near to the forest, respectively (Newton et al. 2020). Not only the usefulness of forests to the livelihood is recognized, but also it contributes on carbon storage, carbon sequestration, biodiversity conservation, providing shelter for many faunal species and ecosystem services (Wan et al. 2018; Sullivan et al. 2017). In addition, the forests slow climate change and increase the resilience (Johnstone et al. 2010; Pawson et al. 2013). In developing countries more than 80% people rely on these forest resources for nutritional and health needs, and around 25% of medicinal drugs used in developed countries and 80% medicinal drugs are NTFPs related (UNFFS 2021). Not only for the uses of nutritional and health needs in rural areas, these NTFPs also contribute more income generating sources. People in the rural areas collect or cultivate these resources from the public and private land and forest (UNFFS 2021). Therefore, the NTFP is one of the important resources for sustainable livelihood especially at the rural communities.

Bamboo is one of the more important NTFPs in Nepal to improve livelihood and income generating sources. Varied species of bamboos are recorded in Nepal, and are widely distributed from lowland to high mountain regions. More than 50 bamboo species are recorded from Nepal (Das 1988; Stapleton 1994). The number of species in Nepal is around 0.33% of global species (*see* 1500 species worldwide: Ohrnberger 1999). The diversity and distribution of bamboo species varied (*see* bamboo on low land and mountain and small bamboos called *Nigalos* in the mountain and High Mountains; Das and Thapa 2011). In the mountain and highlands, the *Nigalo* distribution is noticed in dense understory bamboo forests. It has many useful characteristics, and has more contributions to sustainable ecosystem services by preventing landslides, water conservation, land rehabilitation, carbon sequestration, and soil erosion (Ben-Zhi et al. 2005). In addition, the *Nigalo* species are commonly used for constructing a house, fencing, thatching and

roofing, making bhakari (grain storage), scaffolding, walking sticks, baskets, furniture, handles for agricultural implements, and tool handles (Seeland 1980; Das 2002). Furthermore, these are also used for making pots and pipes for *tongwa* (uses for homemade beer), fishing rods and traps, handicrafts, packing cases for tea and fruits, poultry cage, pipes for water supply and irrigation, cradles, cart yokes, bullock carts, ladders, winnow, and sieves for cleaning grains. Leaves and shoots are used as fodder food for livestock, wildlife, and human (Williams 2004; Sharma et al. 2014; Panthi et al. 2019). In the urban areas, these are also used for ornamental plants (Seeland 1980; Das 2002). Furthermore, the *Nigalo* shoot has medicinal values, and human uses it for vegetables and pickles (Choudhary et al. 2010). It is highly demanded NTFPs for daily consumption, trade in local market. Not only to the local market, but also the product can be exported to the foreign country because it is a highly demanded vegetable (Das 2002), which can also help to add more revenue to the national economy. Therefore, the *Nigalo* bans is one of the well-known NTFPs with multipurpose uses.

The new sprout shoot of bamboo or *nigalo* is called *Tusa* which are developed from the culms of mature plants (Singhal et al. 2013), and mostly grow during pre-monsoon and monsoon seasons. Their consumption is also high and more demanded vegetables during this time for fresh shoot consumption. However, their availability is limited due to the knowledge gap on cultivation, harvesting time, preservation, etc.

In recent days, the majority of people are migrating from mountain regions to urban and low lands. Consequently, more agricultural land becomes unproductive. It can be used for bamboo shoots production. For that, the feasibility study on the potentiality of bamboo production and their growth and suitability, and people's knowledge of the bamboo cultivation, collection, and attitude toward working on the species is prerequisite for developing a management plan.

Objective

The general objective of the study was to identify the suitability of *Tusa* cultivation and promotion in Machhapuchchhre Rural Municipality, Kaski district, Gandaki Province, Nepal.

Specific objectives

The specific objectives of the study were as follows:

- To identify the factors affecting the *Tusa* production (regeneration from the clump) in the study area.
- To assess the people's attitude and activities towards *Tusa* collection and promotion in the study area.

Rationale

Tusa, the newly sprouted shoot of bamboo/*Nigalo*, is one of the valuable vegetables which has nutritious contents and is more delicious. It is mostly used for dishes and broths in Asian countries. Its production is directly linked to the people's livelihood as a source of income-generating sources, especially in the rural area of Nepal. However, the naturel resources in the rural areas are threatening from increase human population unplanned natural resource utilization, increasing agricultural land and infrastructure development through forest encroachment (UNEP 2001; CBS 2011). Major loss of natural resources including forest in the mountain region is started since 1980 (DFRS 2014). Therefore, the Government of Nepal every year develops strategies for providing incentives to the people or society to increase their income sources to prevent the potential loss of natural resources from their exploitation. In this connection, the promotion of *Tusa* production with sustainable management of forest resources is also one of the Nepal government's strategies. In addition, the government is also concerned with the conservation of natural resources and people's active participation in these activities. To initiate the *Tusa* production and promotion, a basic knowledge on a site-specific study is a prerequisite for identifying the potential suitable habitat and people willingness for the *Tusa* production. The data generated from this project can be used for developing a site- and species-specific management plan for *Tusa* production and promotion activities in Machhapuchchhre Rural Municipality, Kaski, and also can replicate to other parts of Nepal.

2. Study area

The study was carried out at Machhapuchchhre Rural Municipality (MRM: 83.71667 Longitude to 84.53333 Longitude and 28.3 Latitude to N28.65' Latitude) of Kaski district, Gandaki Province, Nepal (Figure 1). The municipality is bordered by Madi Rural Municipality in the east, Annapurna Rural Municipality in the west and south and Pokhara Metropolitan in the south, and Manang district in the north. The MRM lies in Annapurna Conservation Area (ACA) which is the largest protected area of Nepal and comprises 7629 km^2. It ranges from sub-tropical to alpine

climatic zones representing different eco-regions including broadleaf forests, pine forests, conifer forests and alpine meadows. Various people with mixed ethnicities such as Brahmin, Chhetri, Tamang, Gurung, Dalits, etc. inhabit in the ACA. The major economic source of people living in ACA are agriculture, animal husbandry, service, trade, etc. (CBS 2011).

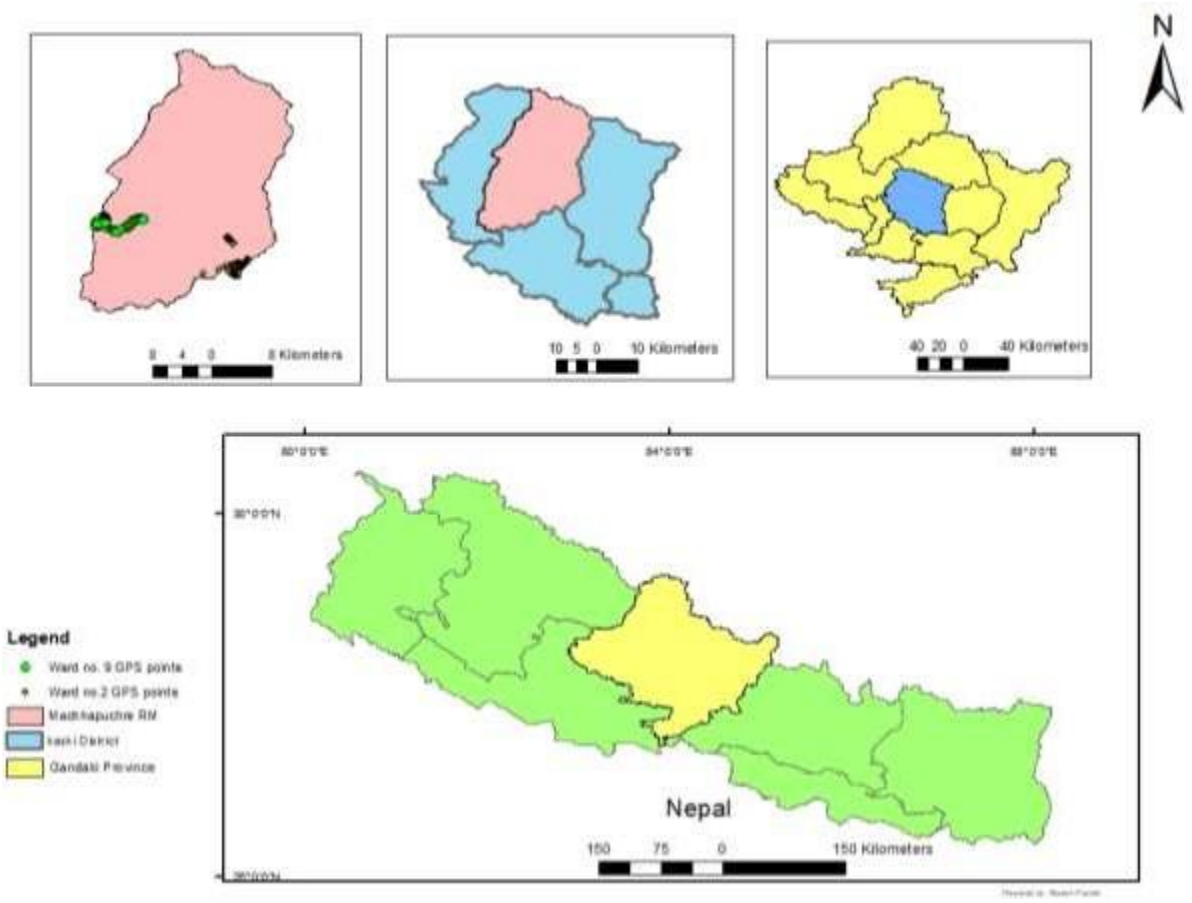

Figure 1. Machhapuchchhre Rural Municipality for Tusa production and promotion research area in 2022.

Within the MRM, the study was carried out at Sardikhola (Ward No. 2, 83.93333 Longitude to 84.05 Longitude and 28.31667 Latitude to N28.4 Latitude) and Ghalel (Ward No. 9, 83.9003022 Longitude and 28.4317159 Latitude) (Figure 1). The Sardikhola is located at north,15 km far from Pokhara Valley. It covers an area of 51.07 km^2 and situated at the elevational range of 1100 m to 4400 m of elevation from the sea level. Agriculture and livestock farming are the major traditional economic activities to sustain lives. In addition, labor work and remittance from overseas are other major income source to the people. Low income people also depends on the

natural resources to sustain livelihood. A total of 3285 people inhabit in Sardikhpla (MRM 2020).

The Ghalel village is located at north-west to Pokhra Valley and 30-40 km far from the Valley. It covers an area of 140.99 km^2 and the average elevation of the area is 3018 m above the sea level. Agriculture and livestock farming are also the major traditional economic activities to sustain lives. In addition, labor work and remittance from overseas are other major income source to the people. Low-income people also depend on the natural resources to sustain livelihood. A total of 1480 people inhabit in Ghalel (MRM 2020).

These study areas are rich in biodiversity with many floral and faunal species. The flora of the area includes Firfire (*Albizzia* sp.), Lwangkesari (*Mahonia acanthifolia),* Nimaro (*Ficus roxburghii),* Champ (*Magnolia champaca*), Uttis (*Alnus nepalensis*), Faledo (*Erythrina strica),* Khanyu (*Ficus semicordata),* and different species of rhododendron. The major fauna in the area includes leopard (*Panthera pardus*), Himalayan black bear (*Ursus thibetanus*), Barking deer (*Muntiacus vagianalis*), Golden jackal (*Canus aureus*), Leopard cat (*Prionailuru sbengalensis*), jungle cat (*Felis chaus),* etc. (Jnawali et al. 2011). The birds such as Himalayan Griffon (*Gyps himalayensis*), Egyptian Vulture (*Neophron percnopterus*), Black Kite (*Milvus migrans*), etc. are also noticed in the study area.

3. Methods

Data collection

Both primary and secondary data were collected during this study period. Primary data such as *Tusa* number, production, and factors acting on the *Tusa* production were collected from the field survey. In addition, the demographic data and people's attitudes and activities on the *Tusa* cultivation and collection were also collected during the questionnaire survey. The secondary data such as household numbers of the municipality were collected from the municipality office.

Field Data Collection

A preliminary field visit was carried out in August 2021 (Bhadra 2078). During the period, the consultations with ACAP Lwang officials, local people was performed to identify the types of Nigalo shoots consumed/used by local people, their distribution range, probable area of *Tusa* availability and abundance, people involvement in *Tusa* collection and probable area of *Tusa*

production. The consultation was mainly performed in Ward No. 1, 2, 8, and 9 of Machhapuchchhre Rural Municipality due to logistic constraints. With rigorous interactions with key informants and group discussion, only Sardikhola (Ward No. 2) and Ghalel (Ward No. 9) were selected for this study.

Figure 2. Interactions with key informants, group discussion, local people (Top: from left to right), field visits and *Tusa* market in Pokhara for sale (Down: right to left).

Sampling

After identifying the highly abundant *Tusa* production probable area, 1 m X 1 m sampling plots were established in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality in October 2021. Altogether 1,92,000 plots were designed within the study area. Among the established plots, a total of 269 plots were used for sampling, which were randomly chosen under the 6% margin of error at a 95% confidence level (Krebs 2014). In each plot, the latitude and longitude, elevation, slope, aspect, types of *Nigalo,* number of mature *Nigalo* individuals, number of newly sprouts *Tusa,* number of regenerated Tusa, the circumference of the clump, and height of *Tusa* in the clump were recorded. The latitude and longitude and elevation of the plot were recorded using Global Positioning System (GPS Etrex 10). The slope and aspect of the plot were recorded using a clinometer. In addition, the land type (public and private) and soil type (humus and non-humus), and human disturbances were also recorded from the plot. The black-brown color of soil

with a large amount of organic matter was categorized as humus soil (assume it has a large amount of humus) whereas red soil and soil with a large amount of sand were categorized as non-humus soil during this study. The *Tusa* damage and removal of *Nigalo* from the clump were categorized as human disturbances. The presence and absence of human disturbances were also recorded from each sampling plot.

Questionnaire survey

For identifying peoples' attitudes and activities on the *Tusa* collection and cultivation for sustainable livelihood in and around the study area, a semi-structured questionnaire was developed (Appendix 1), and the interviewee was conducted on the inhabitants of Sardikhola (Ward no. 2) and Ghalel (Ward no. 9) of Machhapuchchhre Rural Municipality. A total of 88 respondents participated in the questionnaire survey (Appendix 2). Among the 1249 households of the study area, a total of 88 respondents were selected randomly for the questionnaire survey with a 10% margin of error at 95% confidence level (Kreb 2014).

The survey included only those people who were older than 18 years. Only one respondent was chosen for the questionnaire survey from a household. There was no discrimination against the interviewee based on education level, gender, ethnicity, or religion. During the interview, demographic data such as age, gender, education (educated: people who attended school; non-educated: people who did not go to school), family size, and the occupation of respondents were collected. People were asked whether they experienced *Tusa* cultivation and collection in and around the public and private forests. In addition, the respondents were asked about the availability of *Tusa* in the last few decades. How many times do they collect *Tusa* from the forest and how far is the *Tusa* available area from the road. In addition, they were asked about factors affecting the availability of *Tusa* in the forest and their private land.

Key Informant Interview

The information on the *Tusa* availability in the area, their current harvesting practices, number of shoot collection, trend of resource consumption and condition, problem associated with Nigalo shoot collection was collected after the formal and informal interview with different stakeholders mainly with ACAP' Unit Conservation Office (UCO) staff, member of CAMC, bamboo shoot entrepreneurs, and bamboo shoots collectors.

Group Discussion

Group discussion was carried out with a group of local people who collects bamboo shoot regularly. Participatory resource mapping was carried out to allocate the area where *Tusa* availability is highly abundant. Similarly, the information about the types of *Tusa*, their local names, range of distribution, their usages, and most preferred *Tusa* for vegetables, best season of harvesting, techniques of harvesting, trend of *Tusa* availability in the studied villages of Machhapuchchhre Rural Municipality was collected.

3.2. Data analysis

A Chi-square test was performed for binary data to identify the association between them. A generalized linear model was performed to identify factors influencing *Tusa* regeneration in the study area. Factors included elevation, slope, and number of *Nigalos* in the clump, the height of *Tusa* in the clump, the circumference of the clump, soil type, land type, and human disturbances. Models were ranked using Akaike Information Criterion (AIC) adjusted for small samples (Burnham and Anderson 2002) and the relative strength of evidence for each model was estimated using Akaike model weights. Models with "AICc scores of 4" were considered the most parsimonious model to support the model (Burnham and Anderson 2002). The model averaging was calculated using models within 4 AICc of the top model to estimate 95% confidence intervals for each variable and accepted statistical significance at $\alpha = 0.05$. All analyses were performed in the R program (R Core Team 2022).

4 Results

***Tusa* distribution and production**

All together four species of small sized bamboos (*Nigalo* bans) including *Tite* (*Drepanostachyum intermedium*), *Malingo* (*Himalayacalamus cupreus*), *Ghode* (*Himalayacalamus asper*), and *Jarbute* (*Thalmocalamus spathiflorus*) were recorded from the study area. Among these *Nigalo* species, the *Malingo* was found with higher distribution i.e., 57% of studied plots were occupied by *Malingo*, and followed by *Tite* (21%), *Ghode* (19%), and less than 4% by *Jarbute*. These *Nigalo* species were distributed at the average elevation of 2451 m (range: 1496-2952 m) above the sea level within the average slope of 29° (range: 5°-60°; Figure 3). Among the *Nigalo* species, the *Tite* was recorded at the lower elevation of 1496 m whereas Jarbute in a higher elevation at 2952 m (Table 1). The *Malingo* species grow at varied slope ranges i.e. from 5°-60°

to other species (Table 1). Majority of the *Nigalo* bans (52%) was distributed in North-west face (Figure 4). Among the *Nigalo* bans, 72% of *Ghode*, 63% *Tite* and 40% *Malingo* Nigalo distribution was recorded in North-west face (Figure 4).

Table 1. A variation in the occurrence of *Nigalo* species in different elevation and slopes. The average number of newly sprouted shoot, germinated shoot, matured *Nigalo* in the clump and their height in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality. The values in parenthesis is range.

Species	**Elevation (m)**	**Slope (°)**	**Shoot in clump (number)**	**Shoot height (cm)**	**Regermin ated shoot (number)**	***Nigalo* (number)**
Tite	2180 (1496-2725)	24 (12-36)	32 (17-45)	2 (1-4)	51 (14-87)	78 (41-107)
Malingo	2633 (2004-2919)	32 (5-60)	28 (8-60)	3 (1-10)	45 (3-89)	73 (16-130)
Ghode	2104(1559-2868)	27(16-45)	32(10-120)	3(1-9)	39(5-89)	81(20-250)
Jarbute	2833 (2601-2952)	28 (13-44)	29 (19-41)	3 (2-4)	52 (22-89)	89 (50-117)

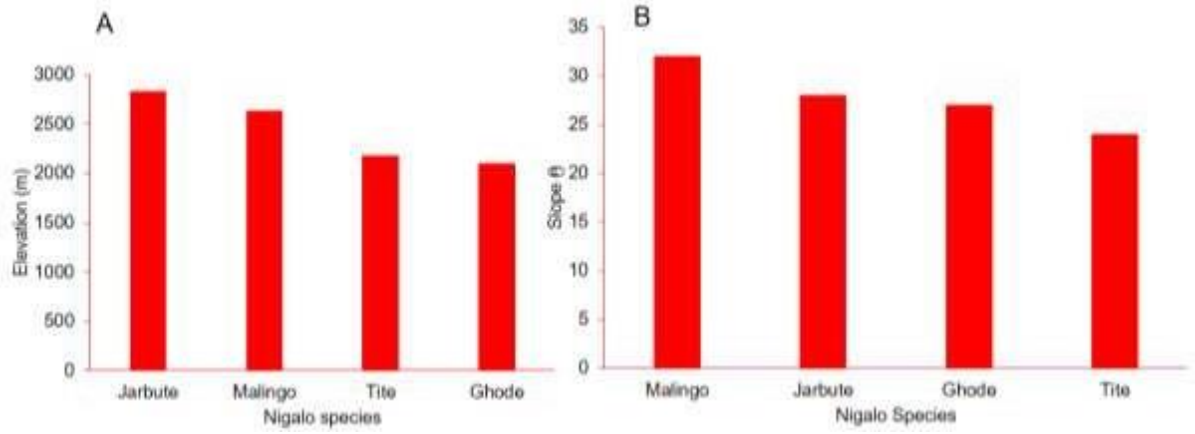

Figure 3. Distribution of *Nigalo* species at different elevation (A) and slope (B) in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality.

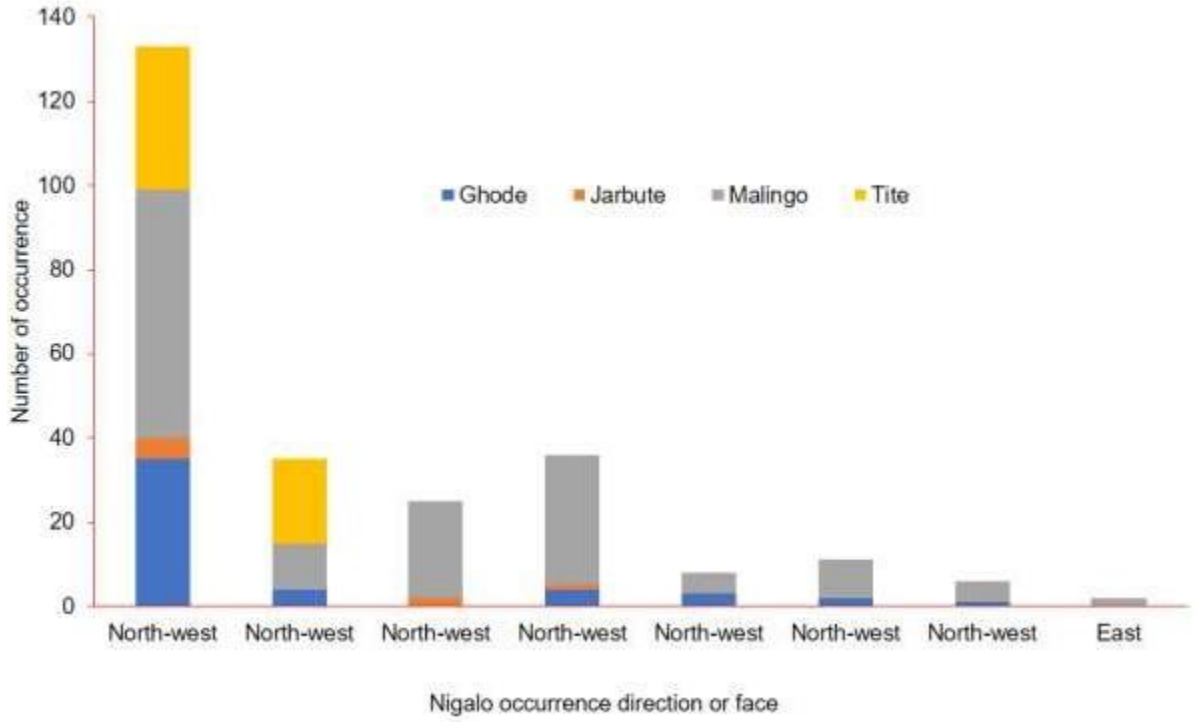

Figure 4. Distribution of *Nigalo* species at different facing slopes in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality.

The average number of newly sprouted *Nigalo* shoot (*Tusa*) and their average height in the clump of the study area was 30 (Range: 8-120) and 3 cm (range: 1-10 cm), respectively (Table 1). The average number of a newly sprouted shoot in the clump was 44 (range: 10-120) found for Ghode than other species (Table 1; Figure 5). In addition, the average number of *Nigalo* in the clump was 76 (range: 16-250; Figure 5), and among the species, the highest average number 101 (20-250) was recorded *Ghode* while the lowest average number was 73 for *Malingo* with a minimum number in the clump than other species (Table 1). The average number of regerminated *Tusa* in the clump was 46 (range: 3-89; Figure 5).

The regeneration of the *Tusa* in Sardikhola and Ghalel area is influenced by the combination of best supportive variables such as elevation, the height of *Tusa*, number of *Nigalo* in the clump, and slope of the area, soil type, public land, and anthropogenic threats (Table 2).

Table 2. Logistic regression models describing the regeneration of *Nigalo* shoot *Tusa* in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality in 2022, ranked according to the

Akaike Information Criterion adjusted for small sample size (AICc). Regeneration of *Nigalo* shoot (number), matured *Nigalo* (number), elevation (m), slope (°), the height of shoot (cm), land (private and public), soil type (humus or nun-humus), and human disturbances (presence or absence). K is the number of parameters, ΔAICc is the difference between the AICc value of the best-supported model and successive models, and wi is the Akaike model weight. Only the models within 4 ΔAICc of the top model were included.

Variables	K	AIC	ΔAICc	Wi
Elevation + Height + *Nigalo*+ Slope + Humus + Threats + Public land	8	2698.8	0	0.44
Height + *Nigalo*+ Slope + Humus + Threats + Public land	7	2701.1	2.31	0.14
Elevation + Height + *Nigalo*+ Slope + Threats + Public land	7	2701.3	2.56	0.12
Elevation + Height + *Nigalo*+ Slope + Threats	6	2701.3	2.57	0.12
Height + *Nigalo* + Slope + Threats	5	2702.9	4.15	0.05
Null	2	4148.9	1450.1	0

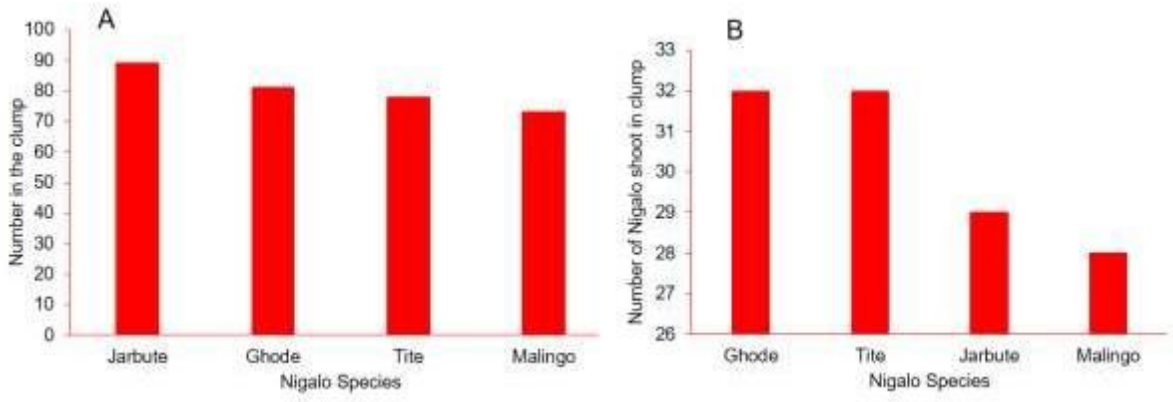

Figure 5. Number of matured *Nigalo* (A) and *Nigalo* shoot (B) in the clump of different *Nigalo* species in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality.

The newly sprouted *Nigalo* shoot germinates from the clump, and the number of new sprouts is determined by different factors. The number of *Tusa* in the clump was significantly increased with increasing the matured *Nigalo*. The number of *Tusa* in the clump was also increased with increasing elevation, however, decreased with increasing slope (Table 3). In addition, more *Tusa* were found in humus-containing soil in human disturbance areas. However, a decreased number of *Tusa* was found on public land (Table 3). There are no significant effects of the circumference of the clump on the number of shoot germination, but the number of germinations was increased with increasing the size of the clump.

Table 3. Model average parameter estimates and 95% Confidence Limits describe the regeneration of Nigalo shoot (*Tusa*) in August 2022. Model parameters include regeneration of *Nigalo* shoot (number), matured *Nigalo* (number), elevation (m), slope (°), the height of *Tusa* (cm), Circumference of culm (cm), land (private and public), soil type (humus or nun-humus) and human disturbances (presence or absence). Bold values are with significant effects.

Variables	**Estimate**	**SE**	**Z**	**P**
Intercept	2.40100	0.09907	24.236	**0.001**
Matured Nigalo	0.01301	0.00044	29.335	**0.001**
Elevation	0.00005	0.00002	2.15	**0.032**
Slope	-0.00987	0.00107	-9.237	**0.001**
Height of the *Tusa*	-0.04600	0.00774	-5.939	**0.001**
Circumference of culm	0.01142	0.00911	1.253	0.210
Public land	-0.20980	0.07990	-2.625	**0.008**
Humus soil	0.12590	0.06132	2.054	**0.039**
Human disturbances	0.71420	0.04871	14.663	**0.001**

Peoples' attitude on *Tusa* cultivation and collection

Altogether 88 respondents were participated in the questionnaire survey. The respondents were between the age of 22 to 72 years old (median age of 39 years). Among them, 72% of respondents were male. The average family size of the respondents was 5 (Range: 2-9). Among the respondents, 76% of respondents had collected *Tusa* from the forest, and 45% of respondents mentioned that the availability of newly sprout *Tusa* in the forest is decreasing while 44% said that the availability is normal in the past few years and now (Figure 5). The average distance of the *Tusa* availability area from the walking road was 95 m (range: 4 – 500 m).

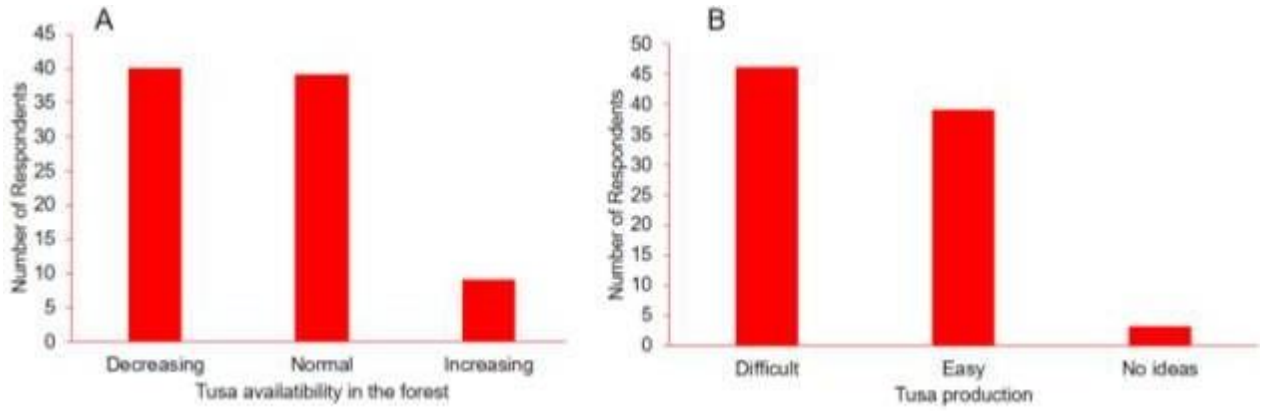

Figure 6. Respondents' perception of the *Tusa* availability in the forest (A) and practices for *Tusa* production (B) in Sardikhola and Ghalel of Machhapuchchhre Municipality.

Fifty-two percent of respondents had cultivated *Nigalo* by themselves, and the majority of them mentioned that it is difficult to cultivate *Nigalo* (Figure 6). They mentioned that the difficulties in *Nigalo* cultivation were due to livestock grazing, forest fire, unsuitable land, and unsuitable land due to climate (Figure 7).

Both educated (44%) and uneducated (9%) respondents cultivated *Nigalos*, but there were no differences on the *Nigalo* cultivation between educated and uneducated respondents ($\chi^2 = 1.0203$, df = 1, p = 0.3125). Both male and female respondents cultivated *Nigalo* (male: 32%; female: 16%), and there was no variation between them for *Nigalo* cultivation ($\chi^2 = 0.04176$, df = 1, p = 0.8381). Respondents with high income (>30000 NRs) and low income sources (<30000 NRs) cultivated *Nigalo* and there were no differences for *Nigalo* cultivation between them (χ^2 =

1.1387, df = 1, p = 0.2859). More Buddhist respondents (63%) cultivated *Nigalo* than Hindu (χ^2 = 4.7296, df = 1, p = 0.02965) but there was no differences on *Tusa* collection between them (χ^2 = 1.3107, df = 1, p = 0.2523). There was no variation on the *Nigalo* cultivation (χ^2 = 1.8518, df = 1, p = 0.1736) between the respondents having only agriculture occupation (28%) and other occupations including agriculture (72%).

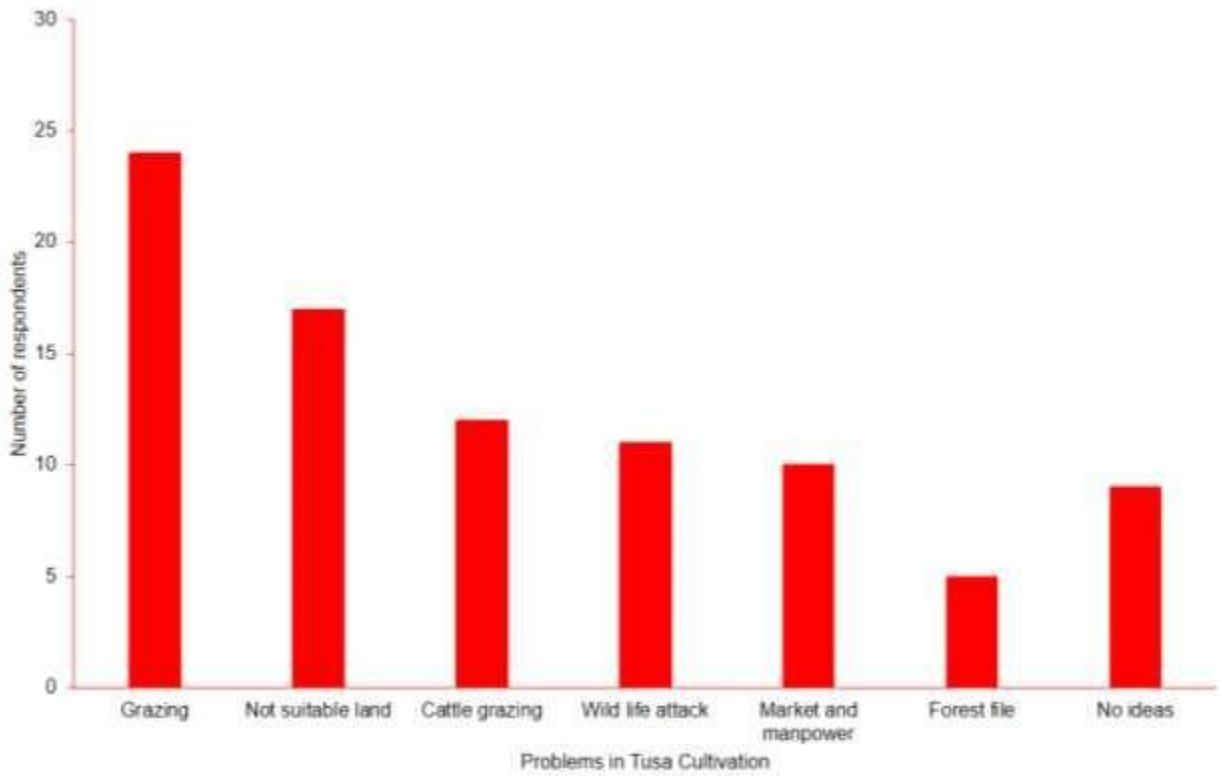

Figure 7. People's responses to the *Tusa* cultivation in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality

Among the respondents, 43% respondents had collected the *Tusa* occasionally from the forest (Figure 8). Only 39% of low-income families and 38% of the high-income family had collected *Tusa* from the forest.

Existing practices on *Tusa* collection and management in the study area

Information on existing practices on *Tusa* collection was collected from the group discussion and key informant's interview.

- The best season for *Tusa* harvest is rainy/monsoon season and the best month is Shrawan (July/August).
- *Tusa* can be harvested if the size or its diameter became 2-3 cm, and the approximate height for harvesting is 3-5 feet. The approximate height, and size of harvesting *Tusa* will be decided after the visual observation by harvester.
- Mostly *Nigalo* shoots are cut using sickle or will be broken by hand when it is taller than foot.
- Normally, one can collect 350 shoots from 8.00 am to 5.00 pm. The collectors generally make bundles/mutha of 5-8 pieces. The harvested shoots will be kept in wet places to make it fresh for longer time.
- *Tusa* of *Malingo* and *Ghode* are more preferred shoots than other species by local.
- Approximately, one household (with average family size 4) can earn 70 thousand to 1.5 lakhs Nepalese rupees in a season/month from *Tusa* collection.
- Not only to local use, but also the ACAP can provide export permission for *Nigalos* outside the Municipality.
- In addition, the CAMC can also provide permission to export 50,000 kg *Tusa* (1kg = 30-32 shoots) in one annual season/month i.e., approximately 2 lakhs shoots.
- EIA report is needed if anybody wants to collect *Tusa* more than 50,000 kg.

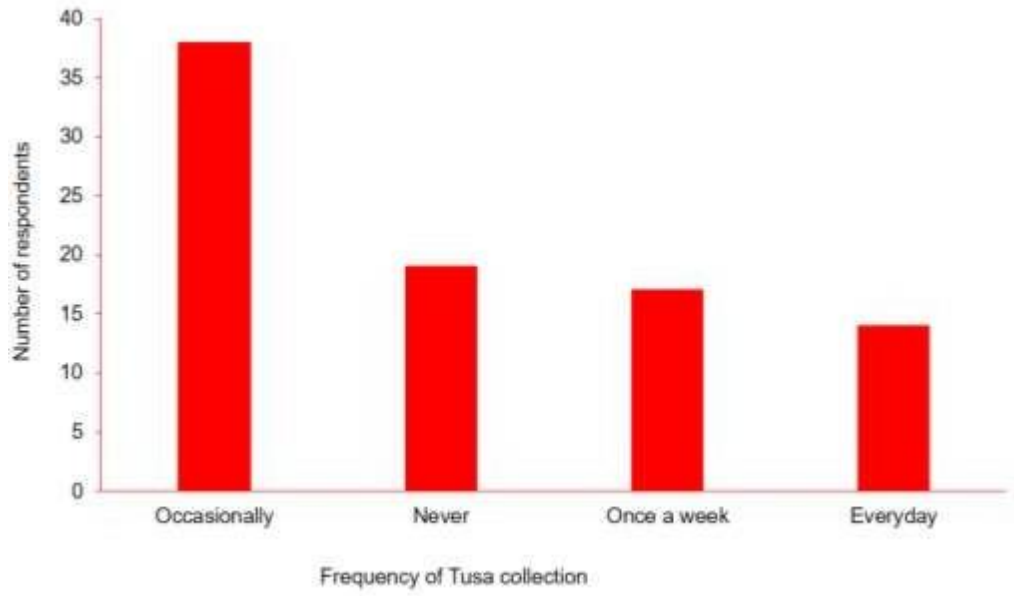

Figure 8. Frequency of Tusa collection by local people in Sardikhola and Ghalel of Machhapuchchhre Rural Municipality.

5. Discussion

Tusa distribution and production

During this study, the recorded Nigalo species *Tite, Malingo, Ghode*, and *Jarbute* can contribute to sustainable economic development and livelihood of local people in the mountain regions because people rely on these species for daily life (Malla et al. 1995). Their distribution within the mountain regions at higher slopes i.e., on average 29° indicates their occurrence mostly at steeper slopes even though the species-specific slope is varied. On this slope large body livestock such as cows, buffalo and horses hardly visit the clump, however, wildlife such as Himalayan black bear can consume it. The potential severe grazing effects on the *Nigalo* species can be assumed as low because wildlife outside the protected area is decreasing (Jnawali et al. 2011). So the growth of newly sprouted *Tusa* at a steeper slope will be more beneficial for human use and ecosystem services (Ben-Zhi et al. 2005; Zhu et al. 2022). However, with increasing the slope the number of germinations of *Tusa* decreased, it was probably due to low nutrients content in the higher steeper (Wang et al. 2019). In addition to local consumption, people also collect and sell it to the local market, which increases the income sources of people. Not only in Nepal but

also the bamboo species is used for income sources in other countries like Ethiopia, China, etc. (Hogarth and Belcher 2013; Mekonnen et al. 2014).

A large number of germinations of the newly sprout *Nigalo* shoot (*Tusa*) in the clump might be due to the presence of more mature *Nigalos* in the clump and their size because these are sources for new germination. The germination of the newly sprout *Tusa* might be supported by a healthy environment with nutrient-rich soil (Hong-Bo et al. 2012). A large number of germination is also favored at a higher elevation with humus soil containing forest, and human disturbances. The systematic regular cultivation of *Tusa* sometimes fosters production rather than disturbances. The germination of newly sprout *Tusa* is higher if the clump or *Tusa* is damaged/used by humans or animals but it must be at the early stages. Therefore, regular harvesting is important for increasing the *Nigalo* clump.

Peoples' attitude on *Tusa* cultivation and collection

There is no variation in the respondent's participation in *Tusa* cultivation and collection. The statistical data of this study showed that both males and females equally participated in *Tusa* cultivation and collection. Not only in the study area but this type of gender involvement can be found in other income-generating sources in Nepal (Gurung 2005). It might increase the devotion to sustainable farming. In addition, educated and uneducated, low-income to high-income families also cultivated and collected *Nigalos*. It indicates government can provide/invest financial support for *Tusa* cultivation in the area for increasing income sources. More Buddhist respondents cultivated *Nigalo* than Hindus because Buddhists prefer to eat vegetables than meat. Therefore, for more protein intake in the body, they cultivate *Tusa*. The majority of the people in the area mentioned that the *Tusa* production is decreasing these days. Not only the *Tusa* production, the biological diversity, and species distribution are affected by habitat loss and degradation, over-exploitation, biological invasion, climate change, and environmental pollution (IPBES 2019; Slingenberg et al. 2009).

Existing practices on *Tusa* collection and management in the study area

The Annapurna Conservation Area Project (ACAP) has developed Conservation Area Management Regulations 1996 and Conservation Area Management Directives 1999 for the conservation and sustainable management of the resources including *Tusa* in the ACAP regions.

The Conservation Area Management Committee (CAMC) and its sub-committees are authorized for the conservation, management, and utilization of Bamboo resource of their respective villages (formerly called Village Development Committee). The CAMC prepares separate working plan for bamboo resource management. Based on the plan, the committee members decide the place and duration for bamboo harvesting in the area, and one can harvest bamboo (*Nigalo*) shoots/*Tusa* during the permitted time. It is allowed only for local people (inhabiting in that locality) to collect the *Nigalo* shoots from 15 Shrawan to 14 Bhadra of the year. For *Tusa* collection, they need to take permission before *Tusa* collection. While taking permission, local people must pay charges (Rs 50 per head per time) for shoot collection during permission period. In addition, the collectors need to follow the rule and regulations of the CAMC and sub-committees. For example, while harvesting *Tusa* they must leave at least 40% of newly sprout shoots in the culm for their sustainable management. It is one of the most appropriate methods for sustainable management of resources. To avoid over exploitation, the CAMC also controls on *Tusa* harvesting. For example, CAMC permits for the collection of 2 lakhs shoots. However, the actual harvested number of *Tusa* is assumed to be more because no more quantified information is available on collected and sold *Tusa* in the local markets other than the month of Shrawan which indicates peoples are collecting more than the permitted quantity. The direct income from *Tusa*, accessible market, quick return, no financial investment besides collector own labor cost are contributing in the over harvesting of *Tusa.*

Local people were also aware on the potential impact of number of *Nigalo* on the number of Tusa regeneration in the culm. If *Tusa* are harvested in Shrawan (July/August), there will be less impact on regeneration of *Tusa* in the clump. But if there is early/late harvesting then there will be chances of not getting appropriate size of *Nigalo* in coming days and years. The number of *Tusa* harvested in one year can affect the quantity for next year. To avoid the potential impact of unmanaged harvesting, every harvester must follow the rule and guidelines of CAMC. Inspite of these rule and regulations, the *Tusa* production and collection in large number in the study area is affected by forest fire, wildlife attack, heavy grazing, illegal *Tusa* collection are some of the problems in *Tusa* conservation and management. For that local people should be made aware about the conservation and management of *Tusa*/*Nigalo*, illegal collection and impacts of early

and late harvesting of *Tusa*, local people should be encouraged to cultivate bamboos on the non-cultivated barren/abandoned/sloppy lands.

6. Conclusion and way to forward

In Sardikhola and Ghalel of Machhapuchchhre Rural Municipality a four species of *Nigalo* (*Drepanostachyum intermedium, Himalayacalamus cupreus, Himalayacalamu sasper, Thalmocalamus spathiflorus*) that are consumed as vegetable by local people can be promoted for cultivation. The production of *Tusa* for these species in these areas is supported by elevation, soil type, available public land, and more people's willingness to cultivate. The *Nigalo* suitable habitat in the study area is under the threats from forest fire, *Tusa* damages from wildlife, livestock, and wildlife grazing, illegal *Tusa* collection. Therefore, a strong management plan is pre-requisite for sustainable management of *Tusa* cultivation and production. The information on prescribed month and time for *Tusa* collection and cultivation need to be monitored and followed strictly. More research is needed to identify the probability of overexploitation on bamboos and other vegetation in the area at temporal and spatial scales. *Malingo*, *Tite* and *Ghode* species are more popular in the study area. Therefore, we also recommend to promote the cultivation and production of these species. All inhabitants enjoy *Tusa* cultivation i.e., people participation is more important for sustainable development. Therefore, based on this finding, we strongly recommend providing incentives in this area for *Tusa* production for increasing income sources and sustainable livelihood of local people. At that time, more training and awareness programs on *Tusa* cultivation and promotion, harvesting and their value chain mechanism are needed to local people and farmers.

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Appendix 1 Format of questionnaire survey which was applied for Sardikhola and Ghalel of Machhapuchchhre Rural Municipality in 2021.

Questionnaire survey format

S.N.:

Interviewer name:……. Date:……

Time:……. Duration:……

1. Name of respondent:…… 2. Age:……

3. R.M:…….……..Ward……..Tole:……..

4. Caste:……. Religion:……...

5. Family Size:……. Male: …….. Female:……

6. Name of Household Head:……..Sex:……..

7. Education: i) None ii) Primary iii) Secondary iv) > Secondary

8. Education status of the family: i) None ii) Primary iii) Secondary iv) > Secondary

9. Major and other occupation of your household

9. Livestock number owned with number:

10. land type:

11. Walking distance from your house to forest……..

12. Walking distance from your house to nearest road…….

13. Do you harvest/collect *Tusa*? i) Yes ii) No

14. If yes, how often during the season of harvesting?

i) Everyday ii) once/twice in a week iii) occasionally iv) never

15. If you harvest, how much quantity do you collect during the season and for what purpose?

S. N.	Species	Quantity collected at one visit	Quantity collected during season		Purpose of collection			Remarks
			Consumed	Traded	Food	Sale	Both	

16. Who mostly go for the collection from your household?.....

17. How much income did you get during a season/year from *Tusa* collection?.....

18. How much is the market price of the products?

On site?..... nearby markets?.....Pokhara/Kathmandu market?.....

19. Household share of income from Tusa collection (yearly)

From Agri	From livestock	From tusa collection	Service	Others	Saving	Expenditure

20. Total income from forest products (annual)

Timber (cft)	Fuelwood	Fodder	Others (beside *tusa*)	Total income generated

21. What is the relative availability of Tusa in this area in the last five years?

i) Highly Increasing ii) Increasing iii) Constant iv) Decreasing v) Highly Decreasing

22. What is the condition of the culm health?

i) Better ii) No change iii) Decreasing

23. Have you cultivated any varieties of Nigalo in your land?

i) Yes ii) No

If yes, then

Species	From when?	Where?	How much area?	Purpose of cultivation

24. What do you think of the possibility of cultivating Nigalo (Malingo tusa) in your nearby fields?

i) Difficult ii) Easy

25. What may be the problems for tusa cultivation in this area?

26. What would be the possible solutions for it?

27. Can you suggest any measures that can be taken for sustainable use and promotion of Tusa in this province.