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COP 26: A glass half full

'Conference of the Parties (COP)' of the United Nations Framework Convention on Climate Change (UNFCCC) in an annual conference of the United Nations with the high–level participation of party countries, observers, regional organizations and non–governmental actors.

The COP organized in France in 2015 (COP21) gave birth to the Paris Agreement on climate change. The Agreement´s goal is to limit global warming to well below 2 degrees Celsius, pursuing the efforts to limit it to 1.5 degrees Celsius, compared to pre–industrial levels.

The 26th COP was organized as COP26 in Glasgow, Scotland from 31st October, and concluded on the second week of November with the declaration of 'Glasgow Climate Pact'. Raising ambition on climate change mitigation, adaptation and finalization of the 'Rulebook for Paris Agreement' were some of the major objectives of the Conference. Keeping alive the 1.5 ^{o}C temperature target was one of the major objectives of the COP26. Finalization of enhanced transparency framework and market and non–market mechanism for carbon trading (Article 6 of the Paris Agreement) were also included in the Conference.

From the ambition point of view, the COP26 has delivered only a little despite the strong mitigation need of greenhouse gas emission presented by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report which clearly mentioned that global greenhouse gas (GHG) emission should be reduced by 45 percent to the 2010 level by 2030 to keep the 1.5^{o}C temperature goal alive. However, the latest synthesis report of Nationally Determined Contribution (NDC) indicates that the global emission is still going up by 13 percent as compared to the 2010–level even if the countries mitigation pledges will be fully implemented. However, the COP26 decided to present more ambitious emission mitigation plans that are in line with the IPCC's recommendation of 1.5 ^{o}C pathways by 2022. Historically, the COP26 decision has included the language of reducing the use of fossil–fuel that is contributing significantly to the global emission of GHGs. The Glasgow Climate Pact, which was the outcome of the intense negotiation among the country parties, has delivered some of the objectives set forth before the conference. It has included the provision of phasing down the unabated coal power and phasing out the inefficient fossil–fuel subsidies which are the bright side from the GHG mitigation point of view. However, those outcomes are not enough for anyone to feel confident about the fulfillment of the objectives of the COP26.

The COP26 has been successful to achieve some adaptation finance required for adaptation actions of the countries like Nepal.

It has been successful to generate an unprecedented space for the loss and damage due to climate change negotiation. Developing countries had demanded to establish a finance facility to address the loss and damage due to the climate change, which has not been fulfilled so far; however, the parties have agreed to keep the finance discussion going. The conference also approved the functions of the Santiago Network for Loss and Damage to technically assist the developing countries' work on averting, minimizing and addressing the loss and damage due to climate change. 'Glasgow Dialogue' between Parties, relevant organizations and stakeholders to discuss the arrangements for the funding of activities to avert, minimize and address loss and damage associated with the adverse impacts of climate change has also been established.

On the climate finance side, developed countries (Annex I countries) are still falling short of their climate finance commitments. The 100–billion–dollar annual finance commitments made back in 2009 which should have been fulfilled by 2020 has been further pushed back to 2023. However, COP26 decided to meet those promises as soon as possible and continue to the year 2025 when the new collective finance goal will be set from the floor of 100 billion dollar. Furthermore, the cooperative and market mechanism agreed for carbon trading might also assist generating some climate finance for developing countries that are able to produce significant mitigation outcomes.

From Nepal's point of view, the COP26 hasn't delivered enough towards emission mitigation ambition, addressing loss and damage and climate finance ambitions; however, it is not a complete failure either. The COP26 has kept the 1.5^{o}C temperature target alive even with a very weak pulse. The parties should do more to inline their GHG emission reduction in a pathway that is recommended by the IPCC. Outcomes on the loss and damage issue could be carried further to access the technical as well as financial facilities. Doubling the adaptation finance could really assist the countries to minimize the impact of changing climate. Importantly, COP26 has been successful to agree on the Paris Rulebook on transparency and Article 6 of the Paris Agreement which effectively implement the Agreement. As always, the success of the COP26 will be measured in future with the implementation of the outcomes both by the developed and developing countries in years to come.

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Exploring agroforestry systems and practices in the Terai and hill regions of Nepal

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This paper explores the status of agroforestry systems and practices in the Terai and hill regions of Nepal. Field survey, semi-structured interview and focus group discussions with the local farmers and stakeholders were conducted to explore the status of the agroforestry system and practices. The study covers forty-three districts, and represents agroforestry systems and practices in the Terai and hill regions of Nepal. Altogether, twelve agroforestry systems and forty-three agroforestry practices were documented in the Terai and hills of Nepal- ten systems in the Terai and seven systems in the hills. Agrisilviculture, agrisilvihorticulture, agrosilvopastoral, agrohortosilvopastoral, homegarden, hortiagriculture, silvofishery, agrosilvifishery, hortisilviculture and apiculture were the major agroforestry systems adopted in the Terai whereas those adopted in the hills included hortiagriculture, agrisilviculture, agrisilvihorticulture, agrosilvopastoral, homegarden, hortosilvipastoral and silvopastoral. The study revealed a gradual emerging scenario of commercial agroforestry systems in these regions although the continuation of traditional agroforestry systems was observed in most of the Terai and hill regions. Insufficient labour availability, fragmentation of land, market price fluctuation, lack of technical knowledge, and wild animal disturbances were some of the major challenges observed in the Terai and hills of Nepal.

Keywords: Agroforestry, agroforestry species, commercial, fragmentation.

The economy of Nepal is dominated by agriculture and forestry. Subsistence agriculture having linkage with forestry is the major source of livelihoods in the rural areas (MoFSC, 2014). Forest, agriculture, and human have complex and inseparable relationships. Agricultural systems are mostly traditional and subsistence. The farming systems in Nepal rely on forests and trees for their sustainability. Agroforestry trees are the most important source of fodder for livestock (Avis, 2018)

The increasing human population has put significant pressure on the forest and is further exaggerated by the fragile nature of geology and traditional farming system resulting in landslides, floods, and downstream sedimentation in Nepal (Amatya, 1996). Farmers in the hills have responded to forest degradation and deforestation by increasing the number of agroforestry trees on their farmland to meet their immediate demand for fodder, fuelwood, and small-sized timber products. Earlier, the agroforestry products were used by the rural people for their subsistence living. With the initiation of land allocation for the poor in the community forests, leasehold forests, and varieties of subsidies by the government, the rural farmers have started to commercialize agroforestry products, such as cardamom. Generally, agroforestry is practiced on private land and on communal land. Agroforestry on communal land and private land are becoming promising land-use options for maximizing diverse products to meet the diverse demands of

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rural people and to protect the remnant forest area from further destruction (NPC, 2019). Fourteen agroforestry systems have been identified in Nepal where five systems are the most popular and relevant to agroforestry research (Sinclair, 1999). Major government policies such as Forest Policy 2019 and Agricultural Development Strategy 2015 have emphasized agroforestry for fodder, small timber, and firewood production for livelihood improvement of the poor.

Agroforestry is a land-use system where agriculture and forestry components are integrated in order to provide multiple benefits such as food, timber, fodder, fuelwood, leaf litter, medicine related to agriculture, and forestry in a specific space and period. The International Centre for Research on Agroforestry (ICRAF) has defined Agroforestry as "a land-use system that integrates trees with agricultural crops and/or animals, simultaneously or sequentially, to get higher productivity, more economic returns, and better social and ecological benefits on a sustained yield basis, than is obtainable from monoculture on the same unit of land, especially under conditions of low levels of technological inputs and on marginal sites" (ICRAF, 1987).

Taungya system was the first agroforestry system practiced at Tamagadhi, Bara in the early 1970s by the then Department of Forest in coopeation with the Sagarnath Forestry Development Project to protect the remaining *Shorea robusta* Forest and its associate trees in central Nepal by involving poor and landless villagers as Taungya planters. They cultivated crops under the residual trees and in between the new plantations for the period of three to four years. The Department of Forest had planted tree species like *Eucalyptus camaldulensis*, *Dalbergia sissoo*, and *Tectona grandis.* Species like *Zea mays*, *Brassica juncea*, and other seasonal vegetables were planted in between the areas where agricultural crops were harvested twice a year. However, this practice doesn't exist now due to the determination of the farmers to settle in such areas permanently rather than practicing intercropping and the weakness of the government in providing new areas to the Taungya settlers (Amatya & Cedamon, 2018).

Agroforestry systems can be divided into two broad categories i.e. farm-based agroforestry system and forest-based agroforestry system. Farm-based agroforestry system includes home gardens, trees in agricultural fields, alley cropping, commercial crops under tree shade, intercropping with horticulture trees, cultivation of annual crops with bamboo, trees around agricultural fields, woodlot. Similarly, the forest-based agroforestry systems include Taungya, production of non-wood forest products, silvopastoral systems within the forested areas (Amatya, 1999). In Nepal, forest plantations on public lands have been raised for over 35 years for fuel, fodder, timber, leaf litter, and other products. Research on financial analysis of Nepalese agroforestry models shows that the internal rate of return (IRR) per hectare is 8.5% in the case of the area with less than 20 ha. Thus, twenty-hectare plantation size would be ideal for both economic and ecological considerations (Amatya *et al*., 1996).

This paper explores the current agroforestry systems practiced in the Terai and hills of Nepal in order to alert the policymakers and those who are involved in agroforestry to plan for the development, design and diagnosis of agroforestry systems in Nepal.

Materials and methods

Study areas

The study was conducted almost throughout the Terai (except Saptari, Siraha, Dhanusha and Mahottari districts) and the hilly regions (Siwalik or Churia, Mid-hills, and High Mountains) of Nepal (Figure 1). Out of the five distinct physiographic regions of Nepal, Terai is the southernmost region, stretching from east to west all along the Indian Boarder, just beneath the foothills of Siwalik range. It comprises a narrow (20–50 km wide) belt of flat and fertile land which constitutes 14% of the total land area of Nepal (LRMP, 1986; Amatya *et al*., 2016). It exhibits subtropical type of climate. Scattered patches of tropical semi-evergreen and deciduous forests with various species such as *S. robusta*, *Terminalia alata*, *T. bellirica*, *T. chebula*, *Adina cordifolia*, *D. sissoo*, *A. catechu*, *Lannea*

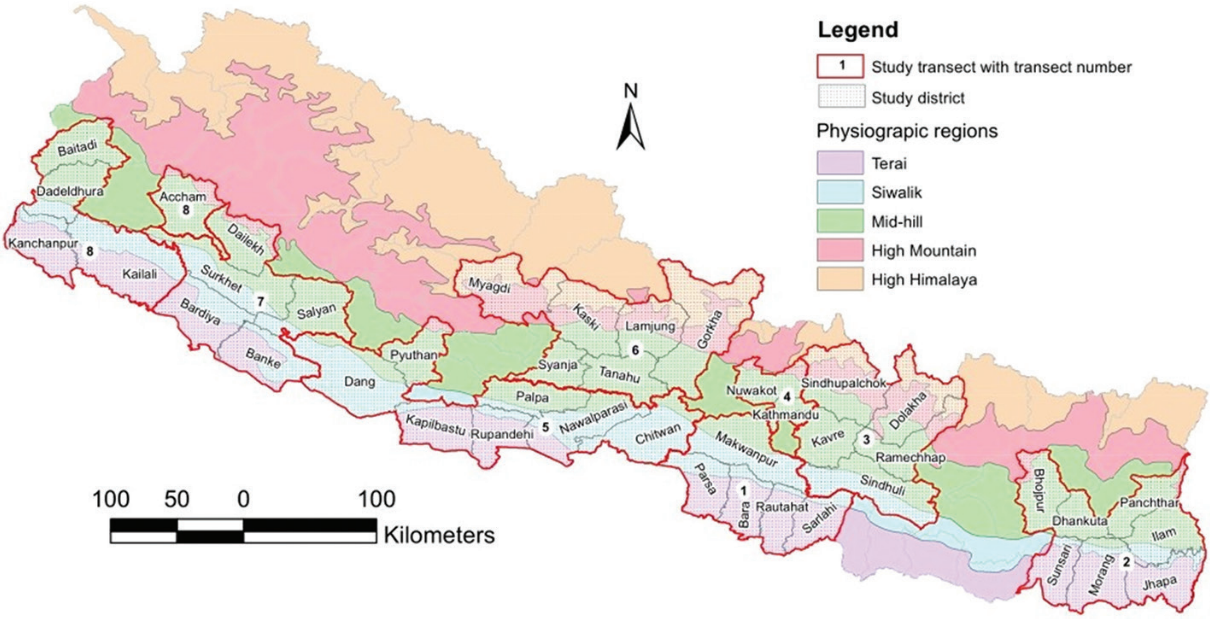

Figure 1: Map showing the study locations along with the physiographic regions of Nepal

coromandelica, *Albizzia* spp., *Tectona grandis*, *Anogeissus latifolia*, *Laerstroemia parviflora*, *Elaeocarpus ganitrus*, etc. and riverine forests dominated by *D. sissoo* and *A. catechu* are the major vegetation of the region (Jackson, 1994).

On the other hand, hilly regions stretch from east to west in between the Terai in the south and High Himalayas in the north, and are characterized by a great variety of terrain types and intensive farming on hillside terraces. The hilly regions for this study included Siwalik, Mid–hills, and High Mountains. Siwalik, Mid–hills, and High Mountains cover 15%, 29% and 19% land area of the country, respectively. The hilly regions have diverse climatic condition and vegetation types (Jackson, 1994). The hilly regions, in general, consists of tree species such as *S. robusta*, *T. alata*, *T. bellirica*, *Emblica officinalis*, *Elaeocarpus ganitrus*, *Eucalyptus* spp., *Castanopsis indica*, *Schima wallichii*, *Toona ciliata*, *Ziziphus spp.* at the lower altitudes while *Pinus roxburghii*, *Michelia champaca*, *Alnus nepalensis*, *Autocarpus lakoocha*, *Elaeocarpus ganitrus*, etc. are found in the middle mountains. Species like *Garuga piñata*, *Prunus* spp., *Swertia chiraita*, *Merica esculenta*, *P. wallichiana*, *Melia azedarach*, *Populus* spp., *Juglans regia*, *Ficus* spp., *Quercus* spp., *Acer oblongum*, *Rhododendron* spp., *Juniperus* spp., *Taxus* spp., *Picea smithiana*, *Abis spectbilis*, *Cedrus deodara*, *Betula utilis*, etc. occur in the higher mountain region (Jackson, 1994; Amatya *et al*., 2016).

Methodology

The study was designed to explore the existing agroforestry systems, practices, knowledge, challenges, and possibilities in the Terai and hills of Nepal. A qualitative data collection method was used, which included desk review; semi–structured interviews; focus group discussions; phone interviews; photographs & video captures; consultations with the provincial ministries of Industry, Tourism, Forest & Environment; Division Forest Offices; and Agriculture Knowledge Centres. Fieldworks were conducted from November, 2018 to May, 2019.

Primary data was collected through field surveys of agroforestry farms, interviews with farm owners and workers, and focus group discussions were conducted at the required sites (where most of the villagers were involved in some kinds of agroforestry practices). The Snowball sampling technique was adopted where the certain agroforestry system was identified through different sources during the fieldwork. Similarly, key informants' interviews were accomplished at the concerned Division Forest Offices and other relevant organizations.

Table 1: Identified transects and districts

Transects	Districts
1.	Makwanpur–Parsa–Bara–Rautahat–Sarlahi
2.	Panchthar–Ilam–Jhapa–Morang–Sunsari–Dhankuta–Bhojpur
3.	Kavre–Sindhupalchok–Dolakha–Ramechhap–Sindhuli
4.	Kathmandu–Bhaktapur– Nuwakot
5.	Chitwan–Nawalparasi–Kapilbastu–Rupandehi–Palpa–Dang–Pyuthan
6.	Tanahu–Gorkha–Lamjung–Kaski–Syanja–Myagdi
7.	Banke–Bardiya–Surkhet–Dailekh–Salyan
8.	Kailali–Kanchanpur–Dadeldhura–Baitadi– Accham

Eight transects were laid covering forty–three districts of seven provinces and four physiographic regions (Table 1; Figure 1). The agroforestry farms along the transects were selected based on the pre–set criteria. The identified transects followed the major highways. Altogether, one hundred and forty agroforestry farms were surveyed. The data were analysed with the help of Microsoft Excel Software.

Results

Altogether, 12 agroforestry systems and 43 agroforestry practices were explored within the Terai and hill regions. Ten agroforestry systems and twenty–one agroforestry practices were identified in the Terai region while seven agroforestry systems and twenty–two agroforestry practices were identified in the hill region (Tables 2 and 3). Thus, the number of agroforestry systems was found to be higher in the Terai region as compared to the one in the hills, but a higher number of agroforestry practices were identified in the hills as compared to the ones in the Terai region. Increasing trend of commercialization and abandonment of agricultural lands has diversified the agroforestry practices in Nepal.

Table 2: Agroforestry systems and practices adopted in the Terai region

S.N.	Agroforestry systems	Agroforestry practices
1.	Agrisilviculture	Tea (*Camelia sinensis*) under *Albizia procera* and *Dalbergia sissoo.*
		Turmeric and ginger under *Eucalyptus camaldulensis.*
		Seasonal agricultural crops under *Tectona grandis.*
		Seasonal agricultural crops along with mixed tree species.
2.	Agrisilvihorticulture	Agricultural crops along with banana and tree species.
		Fruit–trees and agricultural crops along with *T. grandis*, *Shorea borneensis*, and *D. sissoo.*
		Fruit–trees, agricultural crops and seasonal vegetables along with *E. camaldulensis*.
		Mangifera indica and agricultural crops along with *E. camaldulensis*, *T. grandis, Poplus* species, and *Melia azedarach.*
3.	Agrosilvopastoral	Agricultural crops along with *Acacia catechu* and *Elaeocarpus ganitrus,* and pig farming.
		Agricultural crops, tree species along with grasses and livestock.
4.	Agrohortosilvopastoral	Agricultural crops and *Areca catechu* along with *T. grandis*, *E. camaldulensis*, *E. ganitrus*, *S. borneensis*, and *A. catechu*, and livestock.
5.	Hortiagriculture	Fruit–trees along with seasonal agricultural crops.

S.N.	Agroforestry systems	Agroforestry practices
6.	Silvofishery	Fish farming in conjunction with *E. camaldulensis*, *T. grandis, D. sissoo* and mango trees (*Mangifera indica*).
		Fish farming along *Tectona grandis*, *Paulownia tomentosa*, *and S. borneensis.*
7.	Homegarden	Cultivation of cereals, vegetable spices with firewood, fodder and animals.
8.	Agrosilvifishery	Fish along with *E. camaldulensis*, *T. grandis*, and seasonal crops.
9.	Hortisilviculture	Banana plants along with *E. camaldulensis* and *T. grandis.*
		M. indica along with *E. camaldulensis* and *T. grandis*
		Avocado and pomegranate trees along with *T. grandis* and *E. camaldulensis*
		E. camaldulensis and *M. indica* along with asparagus, citronella, palmarosa, and mentha.
10.	Apiculture	Bee farming in conjunction with *T. grandis* and *P. tomentosa*.

Table 3: Agroforestry systems and practices adopted in the hills

S.N.	Agroforestry systems	Agroforestry practices
1.	Hortiagriculture	Mango and banana plants along with maize.
		Pear trees along with maize and seasonal vegetables.
		Seasonal crops and vegetables under orange and sweet orange trees.
		Coffee under orange, banana, walnut and jackfruit trees.
		Zanthoxylum armatum (shrub) along with orange trees and agricultural crops.
2.	Agrisilviculture	Tea under *Alnus nepalensis.*
		Cardamom under *A. nepalensis.*
		Cardamom along with Broom Grass (*Thysanolaena maxima*)*, Elaeocarpus ganitrus, A. nepalensis*, *Schima wallichii*, and fodder tree species.
		Cardamom and Coffee plants under *A. nepalensis.*
		Coffee plants under multipurpose tree species.
		Coffee plants, maize, and seasonal vegetables under *E. ganitrus.*
		Cinnamomum tamala along with agricultural crops.
		T. maxima along with *C. tamala.*
		Kiwi, Cardamom and Chirato along with *Taxus wallichiana, E. ganitrus*, and *Michelia champaca.*
		NTFPs along with agricultural crops and tree species.
3.	Agrisilvihorticulture	NTFPs along with fodder and fruit–trees.
4.	Agrosilvopastoral	*T. maxima* along with fodder trees and livestock.
		Cardamom and *C. tamala* along with *E. ganitrus* and banana plants.
5.	Homegarden	Seasonal vegetables, fruit–trees along with multipurpose trees.
6.	Hortosilvipastoral	*Swertia chiraita* and *Z. armatum* along with fodder and fruit–trees.
		Multipurpose trees, fodder trees, fruit–trees, and grasses along with livestock.
7.	Silvopastoral	*Ziziphus budhensis*, *S. wallichii*, *Litsea monopetala*, *F. semicordata*, and grasses along with goat farming.

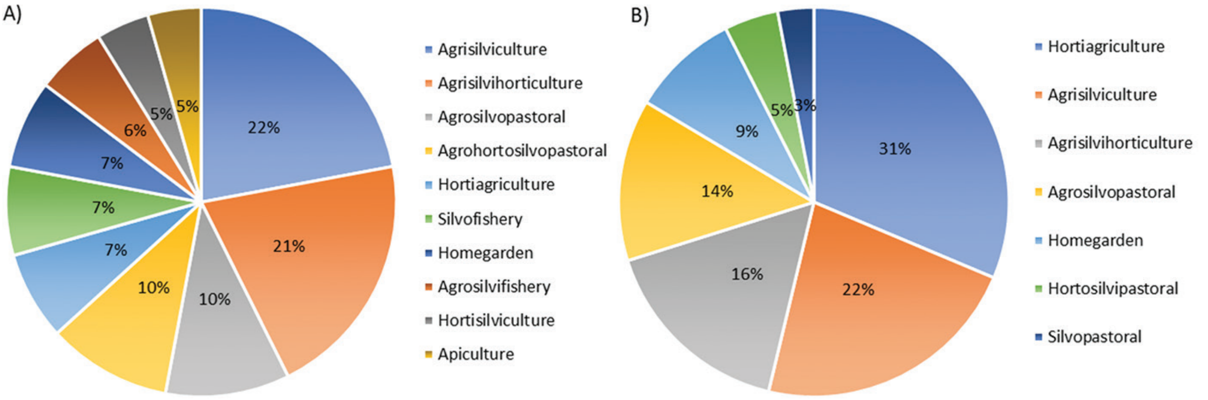

Figure 2: Agroforestry systems adopted in the A) Terai and B) hills of Nepal

We had surveyed one hundred and forty farms in the Terai and hills. In the Terai, 22% of the farms had adopted agrisilviculture system followed by agrisilvihorticulture (21%), agrosilvopastoral (10%) and agrohortosilvopastoral (10%, Figure 2A). Other adopted agroforestry systems in Terai were hortiagriculture, silvofishery, homegarden and agrosilvofishery with 7%, 7%, 7%, and 6% representations respectively. The least adopted agroforestry systems in Terai were hortisilviculture and apiculture both representing about 5%.

The major agroforestry systems adopted in hills included hortiagriculture (31%) followed by agrisilvicultire (22%) and agrisilvihorticulture (16%) (Figure 2B). Other adopted agroforestry systems in hills included agrosilvopastoral (14%) and homegarden (9%). Hortosilvipastoral and silvopastoral were found to have lowest adoption in hills representing 5% and 3% respectively.

The highest diversification of adopted agroforestry practices was observed in Agrisilviculture system the Terai and hill regions of Nepal (Figure 3), suggesting agrisilviculture as the most preferred and diversified system practiced in the Terai and hills of Nepal followed by hortiagriculture, agrisilvihorticulture, hortisilviculture, agrosilvipastoral, hortosilvipastoral, silvofishery, homegarden, silvopastoral, agrihortosilvopastoral, agrosilvifishery and apiculture respectively.

The major tree species planted in agroforestry

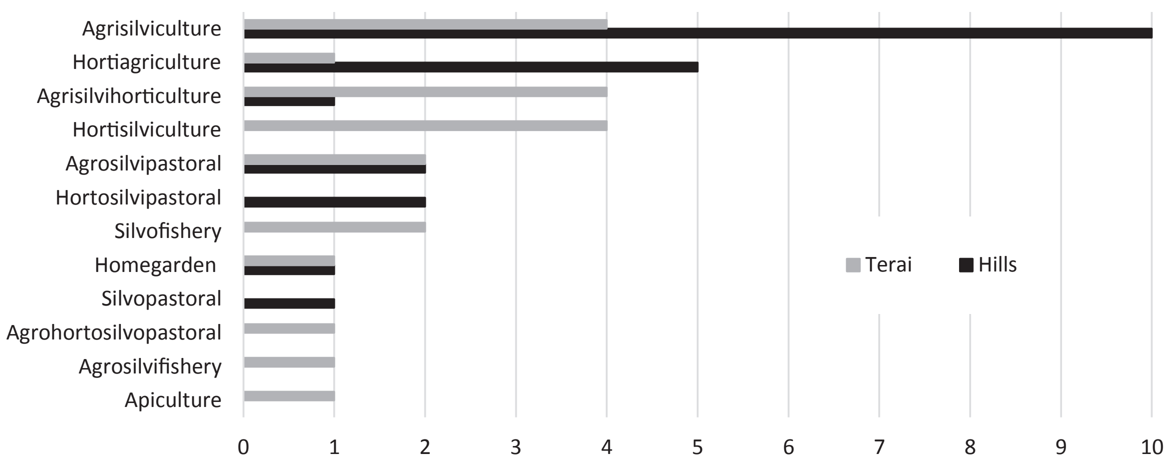

Figure 3: Diversity of agroforestry practices within the systems

practices in the Terai and hills of Nepal are listed in Tables 4 and 5 below:

Table 4: Major trees species preferred in agroforestry in the Terai region

S. N.	Scientific name	Local Name	Family
1.	*Albizzia* spp.	Siris	Fabaceae
2.	*Dalbergia sissoo*	Sissoo	Fabaceae
3.	*Eucalyptus camaldulensis*	Masala	Myrtaceae
4.	*Tectona grandis*	Teak/Sagwan	Lamiaceae
5.	*Areca catechu*	Betel–nut	Arecaceae
6.	*Shorea borneensis*	Malaysian Sal	Dipterocarpaceae
7.	*Acacia catechu*	Khair	Fabaceae
8.	*Elaeocarpus ganitrus*	Rudrakshya	Elaeocarpaceae
9.	*Paulownia tomentosa*	Paulownia	Paulowniaceae

Table 5: Major trees species preferred in agroforestry in the hills

S. N.	Scientific name	Local Name	Family
1.	*Alnus nepalensis*	Uttis	Betulaceae
2.	*Elaeocarpus ganitrus*	Rudrakshya	Elaeocarpaceae
3.	*Michelia champaca*	Champ	Magnoliaceae
4.	*Toona ciliata*	Tooni	Meliaceae
5.	*Melia azedarach*	Neem	Meliaceae
6.	*Castanopsis indica*	Katus	Fagaceae
7.	*Ficus semicordata*	Khanyu	Moraceae
8.	*Myrica esculenta*	Kafal	Myricaceae
9.	*Cinnamomum tamala*	Tejpat	Lauraceae
10.	*Juglans regia*	Walnut	Julgandaceae
11.	*Schima wallichii*	Chilaune	Theaceae
12.	*Artocarpus lakoocha*	Badahar	Moraceae
13.	*Garuga piñata*	Dabdabe	Burseraceae
14.	*Litsea monopetala*	Kutmero	Lauraceae
15.	*Ziziphus budhensis*	Bodhichitta	Rhamnaceae

Challenges of agroforestry development in the Terai and hills

Agroforestry has a high possibility to add in to social, financial, and natural capitals; and hence in local, regional and national prosperity. Most of the farmers face acute shortage of farm–workers because of the movement of villagers to urban areas and foreign countries for better life and services. In most of the surveyed households, the aged and children were the majority family members, and were unable to continue the agroforestry that had been practiced for many generations. In most of the Terai region, farmers are inclined towards the plantation of trees only rather than agroforestry practices. Growing agriculture and forest crops requires the understanding of silviculture and management aspects of the trees and crops. The farmers were exultant to plant forest crops and let them grow without caring for water, cleaning, etc.

The technical knowledge of the farmers to manage the agroforestry crops simultaneously and sequentially in the same piece of land is limited. For example, in the Surkhet, Banke and Bardia districts of western Terai, most of the farmers import seedlings of *Eucalyptus*, *Tectona* and other horticultural crop seedlings from Indian nurseries; and to sell more seedlings, the Indian vendor suggests the farmers to plant seedlings in closer spacing, resulting in less return both from forest and agriculture crops. In addition, most of the farmers have fear of casting shade by the agroforestry trees and hampering the growth of the agricultural crops where agricultural crops are the first priority. High–quality quality and vigor seedlings of forest and horticultural crops are not easily available; even if they are available, it is difficult to assure their quality. Most of the farmers concerned about the easy availability and certified seedlings of their interest.

Agriculture crops and tree species combination plays an important role to enhance the productive and protective function of the agroforestry systems. Most of the agroforestry farms overlooked the suitable species specific combinations. Most of the farmers had planted the tree species which were easily available or freely distributed by governmental or non–governmental organizations without considering the need of the farmers and species suitability of the particular locality. Similarly, proper species combination, e.g., the species that shade leaves during the crop cultivation period and flourish green leaves during the fodder deficit season in winter when farmers are in need of fodder to feed livestock was not observed.

Many agroforestry practices, especially with commercial crops like tea and cardamom are shifting from subsistence to commercial in the western and eastern regions. Furthermore, farmers were concerned about the marketing of agroforestry products. The lack of two–way market linkages and buyback guarantee of the agroforestry products have discouraged the farmers to continue the practices in the long run. In addition, the tedious and long bureaucratic hassles to get the release permits discouraged the farmers to continue agroforestry on their farmlands.

Return on investment from planting trees takes many years, and it is a long–term investment with the risk of failure from environmental, social, and technical reasons, e.g., insect and pest infestation may destroy the seedlings, poles or trees. The farmers were concerned about the insurance of the agroforestry crops that encouraged them to adopt the system with full confidence. Most of the farmers, especially in the hills where subsistence farming is considered beneficial, have very small landholding sizes which limit the adoption of agroforestry practices.

Discussion

There is no definite agroforestry classification system that has incorporated all the agroforestry practices in all ecological regions (Nair, 1994). This study categorised the agroforestry practices based on the component and predominant usages of land, and identified 12 agroforestry systems and 43 agroforestry practices in the Terai and hills of the country. Sinclair (1999) classified the major agroforestry practice on the basis of components involved and the principal usage of land, and identified fourteen agroforestry systems in Nepal. Similarly, Amatya *et al*. (2018) have explored seven agroforestry systems and thirty–five agroforestry practices in the eastern, central, and far–western regions of Nepal. Farmers with less availability of land and less access to financial resources are practicing traditional agroforestry practices with their own traditional knowledge. Many years of experiences of farmers with many trials have developed local practices maintaining interaction of crop, tree and animal (Thapa *et al*., 1997; Thapa *et al*., 1995).

Agroforestry practices in Nepal suffer from scarcity of quality planting material and improved seed varieties and also lack of simple to complex machineries and proper treatment practices of diseases in tree species (Subedi *et al*., 2014). In western Terai, most of the farmers bought seedlings of fast–growing timber species such as *Eucalyptus* and *Tectona* from a border–side Indian vendor with no assurance of quality. Generally, small landholder farmers plant the tree species which are easily available or freely distributed by different organizations without the certainty of quality seeds and seedlings.

There are possibilities of generating additional income by identifying and promoting fast–growing and high–value crops and tree species. In the agroforestry system of Nepal, the multipurpose high–value tree species planted are *D. sissoo*, *Ficus* species, *Bauhinia* species, *A. catechu*, *A. lakoocha*, *C. siamea* and *A. lebbeck* in the Terai region and *Bauhinia* species, *A. procera*, and *A. nepalensis* in the hills (Atreya *et al*., 2021). Additionally, *E. camaldulensis*, *T. grandis*, *A. catechu*, and *P. tomentosa* are some of the prominent agroforestry species in the Terai while *M. champaca*, *M. azedarach, C. indica*, *F. semicordata*, etc. are noticeable species in the hills; however, the choice of species largely depends upon the production fuelwood, fodder or timber.

Conclusion

Different agroforestry practices are adopted in Nepal to meet the immediate need for fodder, fuelwood, and small–sized timber. Agroforestry provides a sound ecological basis for increased crop and animal productivity, more economic return, greater biodiversity, and increased social benefits on a sustainable basis.

Traditional agrisilviculture is one of the commonly adopted agroforestry practices in most parts of the Terai and hills of Nepal. However, agroforestry practices are gradually shifting towards the commercialization of products. Agroforestry practices based on timber and cash crops in the Terai and fruit–based agroforestry practices in the hills are inclined towards commercialization, indicating the paradigm shift in the traditional agroforestry in Nepal. In this study, the tree–based agroforestry systems were found to be common in the Terai whereas agricultural and horticulture–based agroforestry systems were dominant in the hills. Interestingly, it was observed that commercial agroforestry had been mostly adopted by the retired professionals having interest in agroforestry, and the youth entrepreneurs having abroad knowledge and experiences were found to be investing in commercial agroforestry practices in the Terai. Farmers with less availability of land and less access to financial capital were found to be practicing traditional agroforestry practices with their own traditional knowledge. Most of the farmers were found to be lacking with sufficient ideas about suitable agroforestry species and land management techniques. Similarly, drought, labour scarcity, and labour–based agroforestry practices were reported as the major challenges for the farmers. In addition, undefined administrative boundaries are one of the major hindrances to the development of agroforestry system in Nepal. This study explores the existing status of agroforestry systems and practices in the Terai and hills of Nepal; however, more research on socially acceptable, ecologically sound, and economically beneficial agroforestry systems and practices are the need of farmers to maximize the products and benefits from the limited available arable land.

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Processing and marketing of rattan canes in Nepal

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This study highlights the processing and marketing of rattan canes with reference to small and medium enterprises (SMEs). The study was designed based on the exploratory research, and was carried out in all the districts of Nepal with rattan enterprises. The main objective was to assess the processing status, supply and demand including constraints and potentialities of rattan–canes as well as their marketing practices. Systematic random sampling method was followed to take the sampling of rattan processing enterprises of CFUGs. The questionnaire survey was conducted among 35 rattan entrepreneurs cum rattan traders and ten executive committee members of CFUGs. The quantitative data was analyzed using Frequency. The study found that hanger, cradle, stools, chairs, and tables were largely manufactured items among all the rattan–cane products. The annual consumption of imported rattan from India and other countries ranged from 850 MT to 1094 MT. Nepalese rattan fulfills 30% of the total demand. The average marketing margin of rattan products was found to be 37−64%. Nepalese rattan is potential to fulfill 70−80% of the total domestic demand of smaller size strands of rattan.

Key words: Competitiveness, Rattan enterprises, small and medium enterprises, supply and demand, traders

Rattan is one of the economically high potential non–wood forest products (NWFPs) (Bystriakova *et a*l., 2000; Belcher, 1995)contributing to biodiversity as well as local economy (Weinstock, 1983) in Nepal contributing 20−30% demand of the Nepalese rattan industries (MDBRPP/DFRS, 2010; Chowdhary & Paudel, 2008). Overexploitation, poor forest management (Bystriakova *et al*., 2000)and loss of forest habitats were found to have threatened the existence of rattan in Nepal (Chowdhary, 1994; 1995; Paudel & Chowdhary, 1996; 2005).

Most of the forest enterprises in developing countries fall under Small and Medium Enterprises (SMEs) (Elson, 2009). Community–owned forest–based enterprises are effective tool to address poverty issues by creating employment, generating income, and increasing rural livelihood options (Koirala *et al.,* 2013). SMEs contribute in building local wealth, encouraging local entrepreneurship, enhancing social networks, promoting local stewardship of natural resources through increased cultural, social, financial and environmental accountability, and keeping indigenous knowledge, cultural values and traditions intact. Adding value to raw rattan through improved pro–poor value chain development and cleaner processing technologies could lift several millions more out of poverty, while maintaining a healthy natural resource base (INBAR, 2015).

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Rattan is marketed and used for multiple purposes including furniture frame, basketry, ropes, mats and bird cage (Sunderl and, 1999). In Nepal, major rattan products are indoor handicrafts such as chair, table, sofa set, hanger, stool, baskets and decorative items. Although rattan processing industries were confined to major cities in the past, they are now open both in the rural areas and urban peripheries. The total number of rattan processing industries were found to have reached 66 in 2005 from 42 in 1996. Presently, there are 57 processing enterprises running in Nepal (Chowdhary, 2017; Chowdhary & Dutta, 2021); out of them, 70% are operated using raw rattan cane of Indian and other countries, and they are located in urban and semi–urban areas; rest of 30% SMEs rely on domestic rattan (Chowdhary, 2017). The main constraints of the rattan processing industries are supply of raw materials, diversification of products, and market linkages. An established rattan furniture unit creates employment and income generating opportunities for a wide range of people, and helps improve the economies of the rural communities (Benton *et al.,* 2011). Community based rattan resource management approaches can be cost effective and reliable (Campbell & Knowles, 2011). Rattan–based enterprises in Nepal are involved mainly in manufacture of furniture and other household items. The industry accounts for the production of more than NRs. 17 million worth of various rattan products, and has substantial market potential in urban areas of Nepal (Sharma, 2007).

Approximately 66% of the total consumption of rattan in Nepal are imported from North–East India, because the large–diameter rattans are not available in Nepal at commercial–scale. Most of the rattan firms are located in the urban cities, and have low market in the rural area (MDBRPP/DFRS, 2010). Although the importance of bamboo and rattan as valuable resource is widely acknowledged, the exact scale of their trade is barely known. Tackling the international trade is difficult because of the lack of custom codes for bamboo and rattan. The international trade of all available products is recorded through Common Format for Transient Data Exchange (COMTRADE) which uses internationally agreed standard definitions and product coding. In recognition of this potential, 14 new 6–digit individual codes for bamboo and rattan were introduced under the Harmonized Commodity Description and Coding System (HS) for global trade in 2007, an increase from only two species for bamboo and rattan (Benton *et a*l., 2011). The position of rattan in the world market is expanding due to increasing demand for environment–friendly products in Europe and the United States of America (USA). The world's rattan sector is estimated to generate global revenue of USD 10 billion annually (INBAR, 2015).

There are limited number of studies that examine their management strategies together, particularly in the context of SMEs (Mokhtar *et al*., 2014). Despite the initiation of rattan SMEs in the urban areas of Nepal in 1976, their status, marketing behavior, consumption of raw material, market growth, contribution in economy, constraints and opportunities are yet to be explored.

This paper identifies the market orientation of rattan SMEs, supply and demand situation of raw material, major market centers, marketing channel, and marketing margin. However, this paper does not cover technical aspects of rattan SMEs.

Study areas

The study was carried out in Kathmandu, Lalitpur, and Bhaktapur of the Valley together with the major cities viz. Mahendranagar of Kanchanur district, Tikapurand Sati Bazar of Kailali district, Gulariya and Rajapur of Bardiya district, Nepalganj and Kohalpur of Banke district,Pokhara of Kaski district, Bharatpur and Narayangarh of Chitwan district, Dharan of Sunsari district, and Kakkarvitta of Jhapa district where Rattan SMEs were located with potential market centers. Some of them were even located in the CFUGs' areas of Kailali and Bardiya districts. The study was conducted in the Fiscal Year (F. Y.) 2017/018.

Methods and material

This study was designed based on the exploratory research. The research has explored research framework which includes the combination of marketing, enterprises and socio–economic status of the people. For this, simple random sampling method was followed to take the sampling of rattan SMEs and CFUGs. Sampling size was selected using the Equation developed by Yamane (1967) at 95% confidence level. Sampling was determined from the total availability of rattan processing enterprises available in the areas. The researcher collected data through face to face and self–administered questionnaire techniques from the marketing managers or owners of rattan processing SMEs. Out of the 57 SMEs operating in Nepal, 25 (44%)were found to be running in the Kathmandu Valley alone (11 in Kathmandu, 12 in Lalitpur and 2 in Bhaktapur districts) while the other SMEs were located in the major cities like Pokhara, Narayangarh, Bharatpur, Kakkarvitta, Nepalganj, Kohalpur, Rajapur and Tikapur. The survey was conducted within 35 SMEs (61. 4%) using proportionate random sampling. The respondents were either marketing managers or owners of the SMEs, with 7 women and 28 men.

The survey included 35 rattan processing and manufacturing SMEs, 526 households (HHs), 10 executive members of the CFUGs, and 3 Key Informant Interviewees (KIs). Two types of SMEs were selected – (i) the private rattan processing SMEs and (ii) the community–managed rattan forests representing all the geographical locations. Of the 35 SMEs selected, 16 were selected from the Kathmandu Valley, 4 from Kailali, 3 from Chitwan, 3 from Bardiya, 1 from Sunsari and 3 from Jhapa districts, 2 from Banke and 2 from Kaski districts, and one each from Dang and Sunsari districts. The HHs selected were from the users of the CFUGs managing rattan in their community forests. Similarly, 10 executive members of the CFUGs 3 officials from the governmental and non–governmental organizations were interviewed.

Data analysis

The qualitative data were obtained from personal observations and voice records. They were first coded into themes, and then analyzed for connections between data, concepts and theories. The quantitative data were analyzed using frequency of the SPSS 20 Software

Results

Types of rattan processing industries/ enterprises

Rattan processing enterprises are categorized into processing enterprises, selling enterprises and both manufacturing as well as selling enterprises. The processing enterprises manufacture varieties of handicrafts, and sell those only to the wholesalers while the selling enterprises only sell the products after collecting finished products from various processors. On the other hand, manufacturing and selling enterprises do both manufacturing and selling of rattan products by themselves. Altogether, there were3 (9%) manufacturing rattan enterprises, 7 (20%) selling enterprises, and 25 (71%)both manufacturing and selling enterprises (Figure 1). Thus, majority of the rattan enterprises/entrepreneurs were found to be involved in manufacturing and selling the rattan products by themselves.

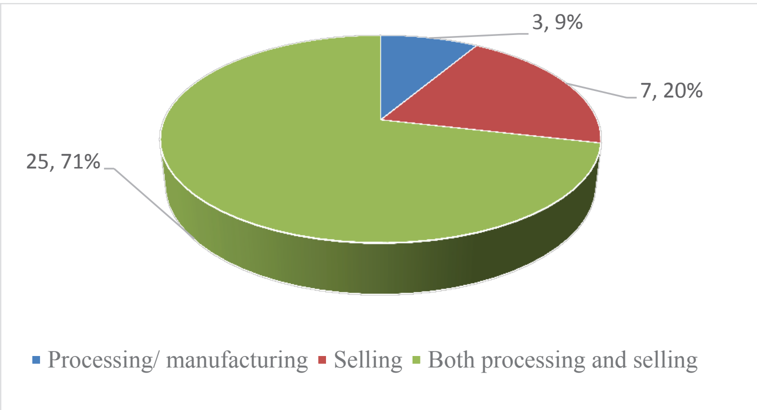

Figure. 1: Types of rattan processing industries/ enterprises

In 2016, the number of rattan processing industries were reported to have decreased to 57from 66 in 2005, i. e. 17%decrease in the total number (Figure 2). More or less, 17 % of the rattan SMEs were reported to have closed their business as they faced adequate shortage of raw material, poor market and administrative hurdle.

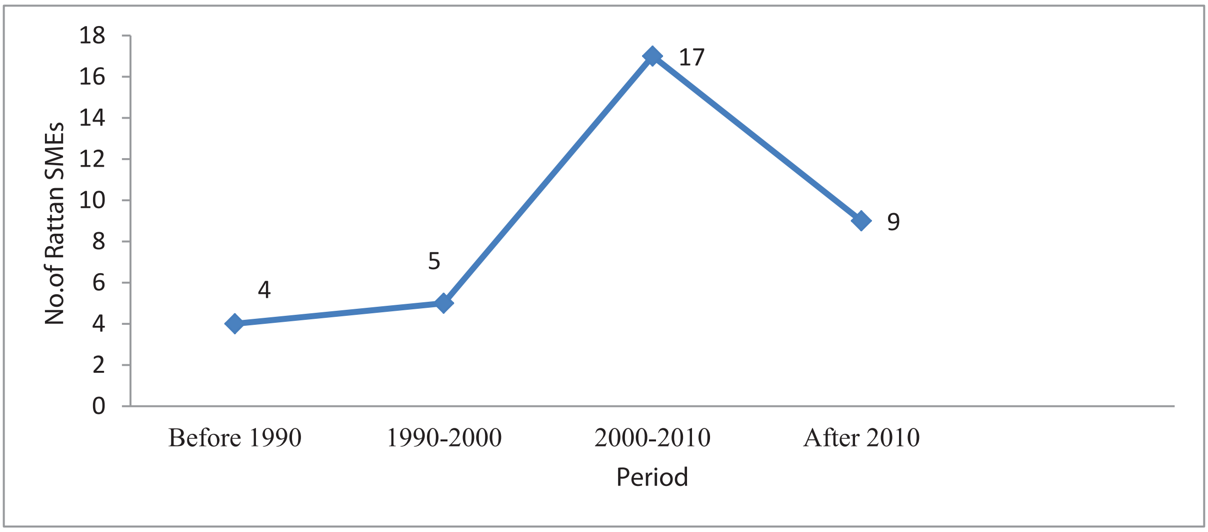

Figure 2: Establishment of Rattan SMEs (n=35) during different time–periods

Out of the total 57 rattan processing industries, 25 processing industries were located in the Kathmandu Valley alone while the other processing industries were located in the major cities like Pokhara, Narayangarh, Bharatpur, Kakkarvitta, Nepalganj, Kohalpur, Rajapur and Tikapur.

The processing industries located at Birgunj, Janakpur, Rajbiraj, Itahari, and Hetauda were reported to be completely closed whereas those located in Pokhara, Nepalgunj, Kohalpur, Biratnagar, Dharan, Bhairahawa and Butwal were reported to be partially closed (by more than 50%, Figure 3). The study found that about one third (30 %) of the total demand (2,835 MT) of unprocessed rattan cane per annum were fulfilled from its national production.

The study also found that all the 18 processing industries located in the Kathmandu Valley also used 'nigalo' (*Drepanostachyum khasianum*), a small–size bamboo, as an alternative raw material while producing various products. On an average,

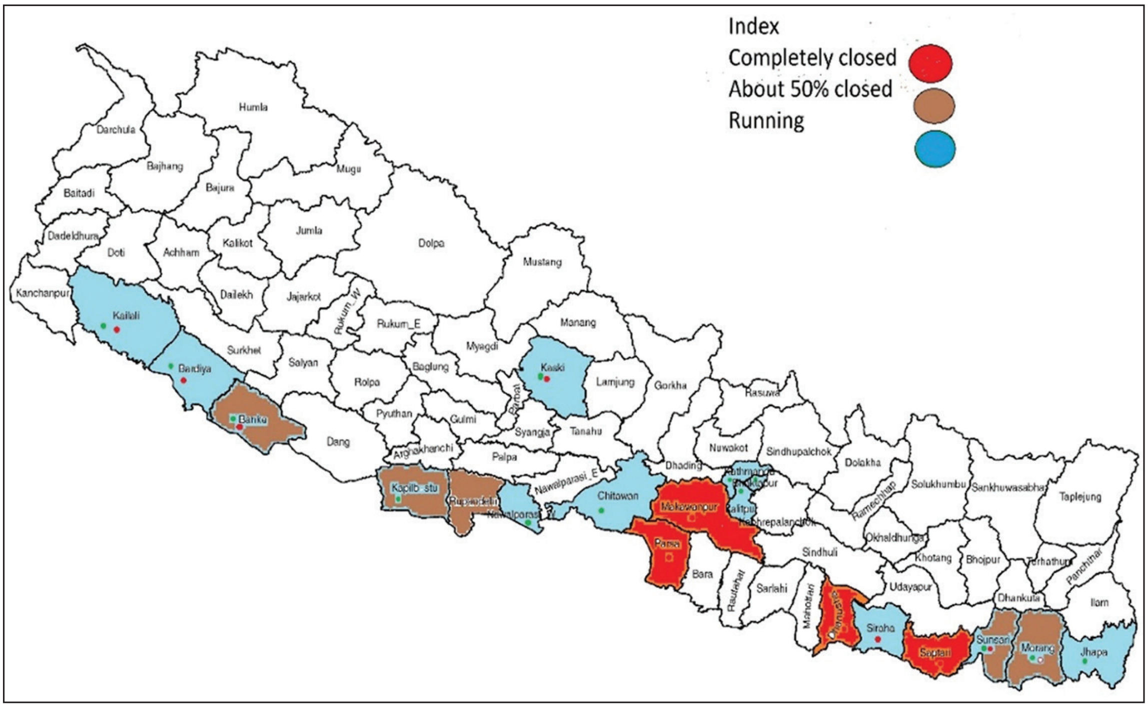

Figure 3: Distribution of Rattan SMEs showing the running, partially closed, and fully closed ones

a processing enterprise consumed a slightly over 24,500 nigalo culms per annum (Table 1).

Table 1: Consumption of nigalo by rattan processing industries

Use of nigalo	Quantity	Value (NRs.)	Remarks
Annual use of nigalo	3,600−4,800 bundles, i. e. 4,000−6,000 culms	NRs. 5−15 per culm (small–size NRs. 5/culm; large–size NRs. 15/culm)	20 culms per bundle
Total consumption	102,000−340,000 culms	NRs. 510,000−5,100,000	
Average consumption	24,555 culms		17 SMEs mixed nigalo with rattan

Source: Field Survey, F. Y. 2017/018.

The production of rattan handicrafts initiated by the CFUGs is expected to give a big boost to the industry. Currently, Nepalese artisans experimented the Nepalese rattan, *Calamus tenuis*, as a reliable raw material for the production of various products. There are eight rattan enterprises in Kailali and Bardiya districts using solely *C. tenuis* acquired from the local community forests. They were reported to be running within Tikapur of Kailali and Rajapur of Bardiya districts.

Major rattan products

The major rattan products were indoor handicrafts such as chairs, tables, sofa–sets, hangers, stools, baskets, cradles, stools, chairs, tables, lamp–covers, and decorative items. Among them, hangers, cradles, stools, chairs and tables were found to be the largely manufactured products whereas lamp–covers were the least–manufactured and marketed items in the processing industries. Figure 4 below presents the number and percentage of the manufacturing of rattan products of the 35 rattan processing enterprises. The rattan products,comparatively with cheaper prices and commonly used for household purpose, were the priority products of most of the processing industries. Their next priority products were the items preferred by hotels and restaurants, which indicated that the processing industries had targeted the market demand.

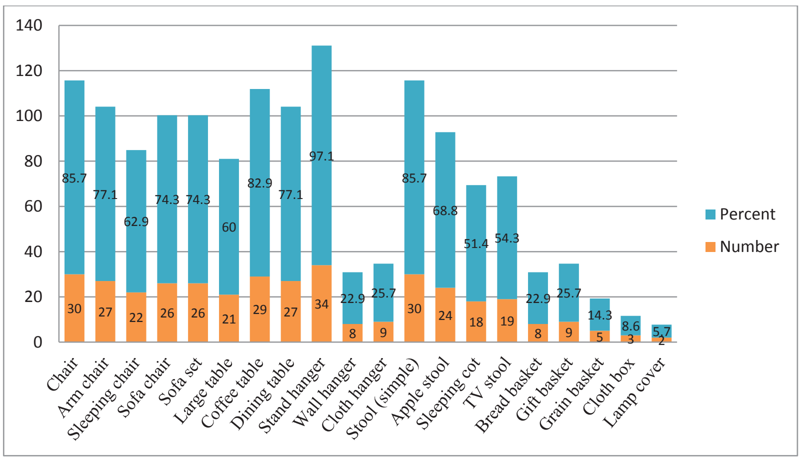

Figure 4: Processing priorities of rattan products by SMEs

Consumption of rattan

The major raw materials for rattan handicrafts were solid rattan cane, Nigalo (bamboo species with small–diameter), and weaving rattan (split–one). The major rattan species consumed in the enterprises were Panibet (*C. tenuis*), Fekribet (*C. latifolius*), Gouribet (*C. acanthospathus*), Putalibet (*C. inermis*), Murgibet (*C. guruba*), Dudhiyabet (*Daemonorops jenkinsianus*),and Rotangbet/ Radanbet (*C. rotang*). Both the large–size and small–size rattan were mostly imported from India;however, some processing industries also imported rattan from Indonesia, Thailand, Malaysia and Singapore. Our study found that the annual consumption of the imported rattan from India and other countries ranged from 850 MT to 1,094 MT with the value of NRs. 60−98 million in the F. Y. 2017/018; the import of Indian rattan

Table 2: Summary of the quantities and cost of raw materials in the F. Y. 2017/018

Raw material	Quantity (MT, on an average)	%	Value (NRs. million)
Indian rattan	980. 00	66. 00	60. 00–90. 00
Malaysian, Thai, Indonesian, etc. rattan	56. 70	4. 00	
Weaving (split–rattan)	5. 75		4. 12−4. 50
Nepali rattan	445. 50	30. 00	4. 37−5. 25
Sub–total	1,487. 95	**100. 00**	**68. 49−99. 75**
Nepali rattan exported to India	1,012. 50		44. 55−156. 70
Sub–total	***2,500. 45***	***100. 00***	***113. 04−256. 45***
Nigalo	567		3. 92−4. 90
Total			**116. 96−261. 35**

Source: Field Survey,F. Y. 2017/018.

alone shared about 66% of its total consumption in Nepal (Table 2).

The cost of the imported rattan canes varied depending on their diameter–size. Smaller the diameter, cheaper the price and vice versa; the cost of the imported rattan cane with small–size diameter varied from NRs. 15 to NRs. 20 per culm and with large–size diameter ranged from NRs. 400 to NRs. 500 as compared to the domestic one costing NRs. 55 to NRs. 65 per kg. However, the processing industries located in Kailali and Bardiya districts were reported to be fully dependent on domestic rattan. In the F. Y. 2017/018, a slightly over 1,487. 95 MT rattan canes,costing NRs. 68. 49−99. 75million were consumed by the total 57 rattan processing enterprises in Nepal (Table 2).

The Nepali rattans were extensively used in the past by the domestic rattan processing enterprises. Out of the nine rattan species recorded in Nepal, *C. tenuis* is mainly commercially available. However,the purchase of Nepali rattan was dramatically reduced due to administrative cumbersome from Division Forest Office (DFO), national parks and police check posts. The Indian contractors purchased Nepali rattan mainly from the CFUGs. Our survey showed that the value of Nepali rattan consumed (445. 5 MT) in the domestic market ranged from NRs. 4. 37 million to NRs. 5. 25 million whereas that of the exported one (to India) ranged from NRs. 44. 55 million to NRs. 156. 7 million.

The split–rattan is mainly used for binding purposes. The split–rattans were imported from India, Indonesia, Malaysia, and China (via Singapore). The Indian split–rattans were brought from Calcutta, Siliguri and Susta. The consumption of split–rattan was about 15 bundles (150 kg) per SME per annum. Our survey estimated that annually around 5,500−6,000 kg split–rattan costing around NRs 4.1 to 4.5 million were consumed by the rattan processing industries of Nepal in the F.Y. 2017/018 (Table 2)

Supply of rattan from the Community Forests

A Division Forest Office approves the request for harvesting various quantities of rattan from the community forests (CFs) within its territories. During the last 12 years (2005−2016), 129.96 MT with the value of NRs 12.83 million rattan were sold from the community forests of Kailali and Bardiya districts (Figure 5). After imposing Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) in 2007, the harvesting of rattan from community forests was considerably reduced. In Bardiya district, more than 15 CFUGs had neither renewed their Forest Operational Plans (FOPs) nor carried out IEE. The concerned district forest offices approve the request for harvesting various quantities of rattan from their community forests. As a result, the local entrepreneurs did not get adequate raw material to sustain their enterprises. The entrepreneurs of Rajapur area revealed that they got 25−50% of raw rattan supply from their community forests.

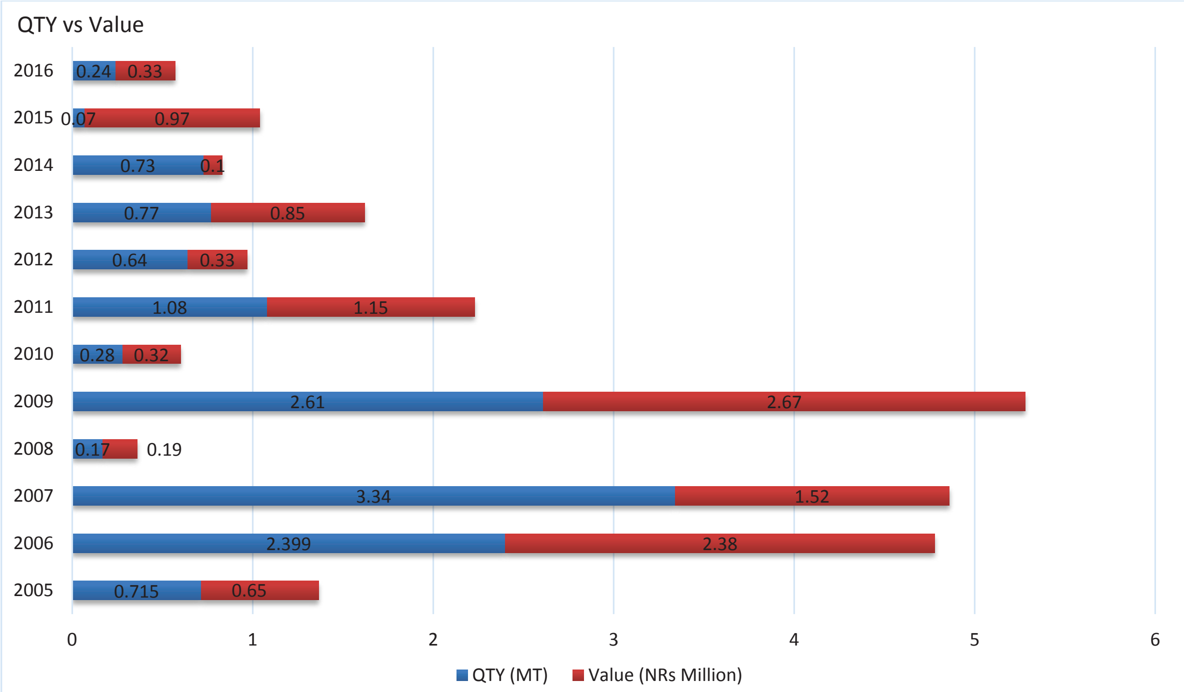

Figure 5: Qty. vs. Value (NRs. million) of rattan (in quintal) from the CFs of Kailali and Bardiya districts during 2005−2016 (Source: Field Survey, F. Y. 2017/018)

Demand and supply of rattan

According to the rattan entrepreneurs of Nepal, the total annual supply of rattan canes (both from the CFs as well as imported from the foreign countries) in the nation was estimated to be a slightly over 1,487.95 MT (see Table2). The total demand of rattan cane in Nepal, as per their version, was around 2,835 MT which indicated that the deficit of rattan cane supply was approximately 1,470.5 MT (Table 3).

The total production capacity of rattan of different community forests was about 1,418 MT per annum. However in the recent years, the potentiality of harvesting of Nepalese rattan was only 30%. It indicates that 70% rattan was not harvested due to the expiry of the forest operational plans (FOPs) and administrative hurdles. Rattan forests were increased tremendously in the community forests of Nepal over the last two decades. It is estimated that the total production could increase up to4,455 MT per year if proper harvesting techniques are adopted. It could fulfill the demand of 70 to 80%rattan except the demand of large–size rattan. Large–size rattan such as *C. latifolius*, *C. acanthospathus,* and *C. leptospadix* are also found in many places of hilly areas. There are some 10−15 forest areas of such large–size rattan cane throughout Nepal (Chowdhary & Paudel,

Table 3: Demand and supply of rattan

Raw material	Quantity (MT)	Average (MT)
Total demand of rattan	2,430−3,240	2,835. 0
Deficit of rattan	1,215−1,620	1,470. 5
Total capacity of production of domestic rattan (small–size diameter rattan, e. g., *C. tenuis*), if fully regulated	4,050−4,860	4,455. 0
Total capacity of production of domestic rattan (large–size diameter rattan, such as *C. inermis, C. laptospadix,* and *C. acanthospathus*	41−81	61. 0

Source: Field Survey, F. Y. 2017/018.

2008). If they are properly managed, some 41−81 MT rattan could be harvested per annum after 5 years (Table 3).

Market of local rattan products

There are five major market centers of rattan cane products in Nepal, viz. Kathmandu, Pokhara, Chitwan, Kakkarvitta and Midwest Nepal. Kathmandu is the largest market center followed by Chitwan and Pokhara. From Kathmandu, Pokhara and Chitwan market centers, rattan cane products are sold to the local people for their household purposes and also to the hotels and restaurants. There are four types of consumers of rattan cane products in Nepal, viz. i) domestic users, ii) hotels and restaurants, iii) offices, and iv) foreigners. The field survey revealed that out of the total consumption of rattan products, approximately 34.5% cane furniture were consumed by household users, 58. 0% furniture consumed by hotels, restaurants, and offices, and 7.5% furniture were consumed by foreigners living in Nepal. On the other hand, high quality Nepalese furniture were also exported to Germany, America and Japan. About 50% rattan cane products were sold in the market places of Pokhara and 30% in the market places of Chitwan. Similarly, various rattan products of different places of eastern Nepal such as Kakkarvitta sold about 60% cane products in the market places of the Kathmandu Valley and 40%in the neighboring cities.

In the Far– and Mid–West Nepal, *C. tenuis* is used for furniture making. The local entrepreneurs prefer *C. tenu is* for the production of all types of furniture items such as chairs, stools, hangers, cradles, and sofasets. Hangers, stools and cradles are highly consumed by the local users. There are, altogether, 9 major market centers located in the cities of the mid–western and far–western Terai regions of Nepal, viz. Nepalgunj, Kohalpur, Surkhet, Ghorahi, Tulsipur, Tikapur, Attariya, Mahendranagar, and Dadeldhura. According to the entrepreneurs of the mid–western and far–western Terai regions of Nepal, 30% of the total rattan products were sold in the local markets for domestic use 20% finished products were sold in the market places of the Kathmandu Valley, 10% each in the market places of Dadeldhura, Nepalganj and Dang, and the rest 20% in the market places of Mahendranagar.

Marketing channel

Marketing channel of rattan cane highlights people, organizations and activities necessary to transfer the ownership of both Nepalese and Indian rattan from point of production to point of consumption. Indian rattan is mainly imported from Arunachal, Silapathar (Assam), Siliguri (West Bengal), Nagaland, UP and Susta (Bihar). Both small–size and large–size rattan used to be imported from these places. However, some high–quality and large–size rattan were also imported from Indonesia, Malaysia, Thailand and Bhutan too. Such high–quality rattans were utilized by only a limited processing industries of the Kathmandu Valley. The community forests of Kailali, Bardiya, Dang,and Chitwan districts were reported to have produced *C. tenuis* at commercial scale. About 233. 4 MT rattan were produced in Kailali, 32. 1 MT in Bardiya, 1 MT in Dang, and 0. 5 MT in Chitwan districts.

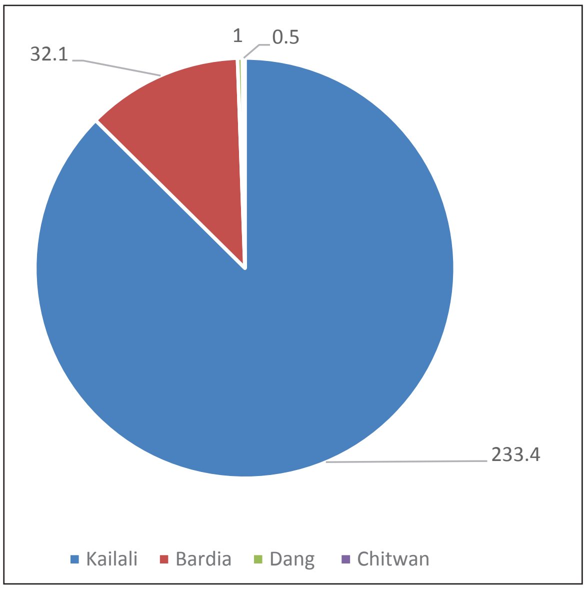

Figure 6: Quantities of rattan harvested in various districts

Although some community forests of Nawalparasi and Kapilvastu districts were also reported to have produced *C. tenuis*, their supplies were not regular and also the quantities were unknown. A few years ago, Nepalese rattan was highly

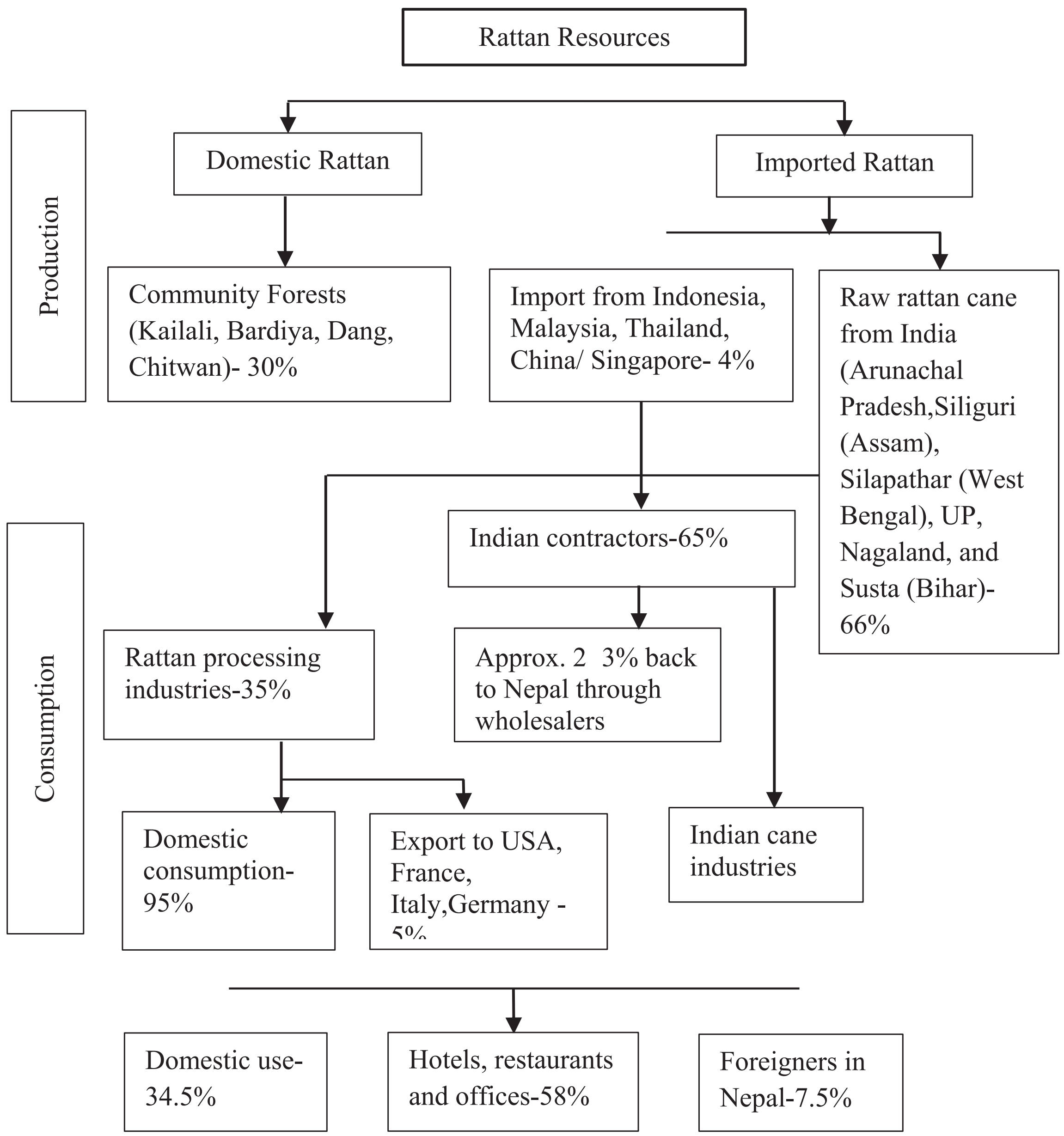

Figure 6: Marketing channel of rattan in Nepal

preferred by the processing industries of the Kathmandu Valley due to their high quality cane. It was estimated that 2–3% Nepalese rattan mixed with Indian rattan were again brought back to Nepal from India. Split rattan was mainly imported from Indonesia, Malaysia and China through Singapore.

Of the total production of rattan cane items, 95%were consumed in Nepal and only 5%were exported to foreign countries such as USA, Germany, Italy and France (Figure 6). Previously, rattan items was also exported to Canada and Australia.

Cost of production, average selling price and marketing margin

The cost of production of raw rattan was estimated to be NRs 28–30 per kg in the community forest. This cost includes harvesting and transportation up to nearest seasoning place. However, due to shortage of rattan in the market, contractors paid higher price of raw rattan. For example, In the

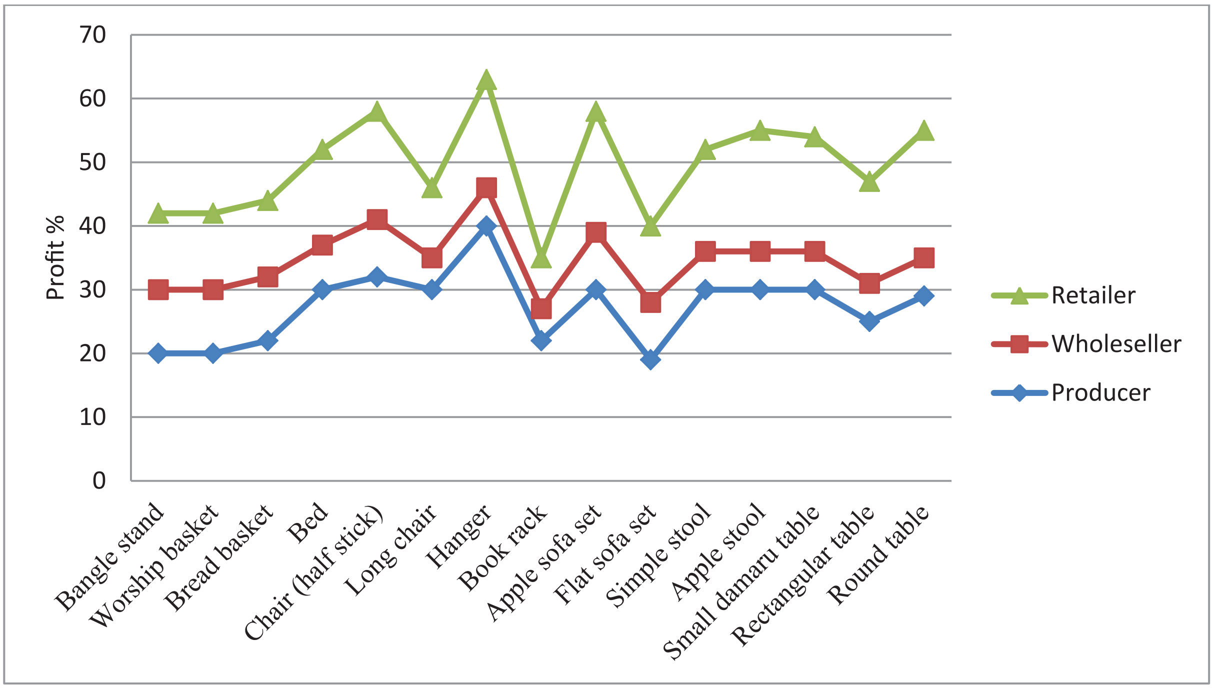

Figure 8: Marketing margin of rattan products

Kailali district, stocked rattan was sold at the rate of NRs 57 per kg in 2016.

In the case of finished products manufactured using imported rattan, the selling price might be up to 50 % more than the cost price due to distance from the market centers, availability of raw material, storage capacity, and market condition. According to the entrepreneurs, if the products were immediately sold after finishing, there was likely to be 90% profit, and if stored for a longer time, there might be a chance of loss. On the other hand, nigalo–mixed items were comparatively of low cost. It was found that some of the entrepreneurs store goods in the warehouse for more than eight years since rattan products did not deteriorate even after eight years in the warehouse. Longer the period of storage of finished goods means financial flow is locked, and profit margin is less.

The marketing margin is the cost of difference between selling cost and production cost. The study found that the average marketing margin of rattan products ranged from 37 to 64%. However, the normal margin was about 50%. Figure7 presents the marketing margin based on the calculation of the cost of production and average selling price. The benefits shared by producers, wholesalers and retailers were 18−41%, 5−10%,and 8−20%, respectively.

Discussion

Nepalese rattan processing SMEs are scattered, unorganized and less competitive in marketing. However, SMEs contribute in building local wealth, encouraging local entrepreneurship, enhancing social networks, promoting local stewardship of natural resources through increased cultural, social, financial and environmental accountability, and keeping indigenous knowledge, cultural values and traditions intact (Koirala *et al.,* 2013). Despite the multiple–use potentialities of rattan, indoor handicrafts such as chairs, tables, sofa sets, hangers, stools, baskets, cradles, and decorative items are major rattan products in Nepal. Among them, hangers, cradles, stools, chairs and tables are largely manufactured items in the processing industries. Sunderland (1999) also argued that rattan is marketed and used for multiple purposes including making furniture frames, basketry, ropes, mats, and birdcages. According to Benton *et al.* (2011), producing goods from rattan creates community–based jobs, many of which are for semi–skilled labor in processing and finishing, which require training to increase individual's skills, and thus help empower them. Our study revealed that over the last four decades, 17% rattan processing SMEs had been closed due to irregular supply of raw material. Thapa *et al.* (2000) also argued in favor of this statement that the irregular supply of raw cane had caused to close 30−40% enterprises. The present study also found out that the Nepalese rattan supply fulfilled 30% of the total demand. According to Sumarno *et al.* (2019),the productivity of rattan furniture industry and the efforts to increase the competitiveness level of rattan products has not yet developed in Nepal although rattan industry accounts for over NRs. 17 million and there is substantial market potential in urban areas of Nepal (Sharma, 2007).

Currently, Nepalese artisans have been using *C. tenuis* as a raw material for various furniture in the local rattan processing enterprises. Currently, there are eight rattan processing enterprises in Kailali and Bardiya districts solely using *C. tenuis* from the local community forests. However, scarcity of raw material posed them at a risk to sustain. The initial environment examination (IEE) and environment impact assessment (EIA) processes imposed by the Government of Nepal has affected harvesting of rattan in the community forests. Before amendment of the Environmental Protection Act 2076 and the Environmental Protection Regulation 2077, the CFUGs required to conduct IEE and get approval from their respective DFOs to harvest more than 5,000 kg. It has seriously impacted upon the harvesting of rattan (Karki & Chowdhary, 2019). According to Sharma (2016), more than 15 CFUGs of Bardiya district had neither renewed their FOPs nor had conducted IEE. As per the amended Environmental Protection Act 2076 B. S., the CFUGs require to conduct IEE and get approval from their respective Provincial Ministries of Forest, Environment and Soil Conservation to harvest more than 150 MT of rattan or forest products at a time (MoFE, 2021).

Importing rattan cane from India and other countries is a risky job in Nepal since export is banned by the Government of India. There are many formalities to address in the route such as check posts, local taxes, etc. during transportation. Pradhan (2015) insisted that the price of cane had been increased continuously by 10−15% per year. There are no securities and incentives to rattan processing industries from the Government of Nepal. Thapa *et al.* (2000) also favored the statement and argued that the price of raw cane sometimes increased 4−5 times the farm gate price. According to INBAR (2000) and Bajaj (1994), there are relatively few policies in place in most countries on bamboo and rattan, and several Asian countries have imposed bans on the export of unprocessed rattan.

Conclusion and recommendation

Rattan processing SMEs are categorized into processing enterprise, rattan selling enterprise and both manufacturing and selling enterprises. The main constraints regarding the trade of rattan are supply of raw materials, diversification of products, and market linkages. Nepal has limited supply of commercial rattan canes mainly produced in community forests. Large amount of rattan are imported from India and other foreign countries. Rattan–based enterprises in Nepal are involved mainly in manufacture of furniture and other household items. Major rattan products are indoor handicrafts such as chairs tables, sofa sets, hangers, stools, baskets and decorative items. The weak supply chain of rattan from production to processing stage, and the lack of improved skills in the processors are the major problems in most of the rattan enterprises of Nepal. Nepalese youths have proved that various types of competitive rattan cane items could be manufactured using *C. tenuis* alone. Therefore, effective processing technologies are required to transform the youths to design rattan products using domestic rattan. Despite *C. tenuis* including other large–size rattan have potential to scale up to meet the demand of rattan processing SMEs, the government's restriction on the harvesting, transportation and uses seems to be the main obstacle for the smooth operation of these enterprises, and so the prevailing restrictions need to be removed urgently so as to sustain them.

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Regeneration status and species diversity of major tree species under scientific forest management in Kapilbastu district, Nepal

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In Nepal, scientific forest management has been practiced as an effective forest management technique to utilize forest resources sustainable. However, the program has faced many controversies such as intentional logging of only high–valued timber species like *Shorea robusta.* In addition, few believe this program is severely affecting the regeneration productivity and species diversity in the natural forests. In order to address these issues, we examined the regeneration condition and plant species diversity in the stands where scientific forest management operations were carried out. The data related to regeneration status and species diversity were collected using a systematic random sampling of the selected stands. Our results showed good regeneration conditions (Seedling >5000, Sapling>2000) in all the studied stands. The tree species community was dominated by *S. robusta* (Sal) followed by *Schleichera oleosa* (Kusum) and *Casia fistula* (Rajbriksha). The value of diversity indices of different species varied significantly between felling series. The highest diversity was found in the second year felling series with the Simpsons Index of dominance value 0. 6934 and the lowest species diversity was in the first year felling series with a value of 0. 8448. It can be recommended that the regeneration felling practice has helped in promoting the regeneration condition and growth.

Keywords: Regeneration, scientific forest management, *Shorea robusta*, silvicultural treatment.

Nepal consists of a total of 5. 96 million ha i. e. 40. 36% forest area (DFRS, 2015). There was no robust management of productive forests in the past due to the centralized institution structure of forest management in Nepal (Paudyal, 2007). The management was based on the annual allowable cut principle in which a single selection silvicultural system was applied for harvesting. Recently, the government of Nepal has started promoting Scientific Forest Management (SciFM) describing "an application of a appropriate silvicultural system and forest management principles through design of systematic compartments of fixed rotation age". This highlights the use of shelterwood silviculture system with very high intensity logging, leaving only 15−30 mature mother trees per ha to address inactive forest management, suboptimal forest production, and forest health degradation (Bhattarai *et al.,* 2018; Poudel, 2018). At present, it has been implemented by 285 Community Forest User Groups (CFUGs) across Nepal (Baral & Dhakal, 2018). Since its pilot implementation in Tilourakot Collaborative Forest, SciFM now has been expanded to 30 collaborative forests, 285 community forests and seven government block forests (Baral & Dhakal, 2018). As of 2020, around 121,852 ha of forests are currently being managed scientifically using SciFM principles both within collaborative forests and community forests in 52 districts of the nation (Bhandari & Lamichhane, 2020). The regeneration and

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community–level species richness of both seedlings and saplings increases under active forest management (Subedi *et al.,* 2018). The forest management activities benefit the forest with improved regeneration (Malik & Bhatt, 2015), greater species diversity and richness (Poudyal *et al.,* 2020), and ultimately leading to sustainability (Pokharel *et al.,* 2015) if followed in prescribed way. In forest management, regeneration study not only depicts the current status but also hints about the possible changes in forest composition in the future (Malik & Bhatt, 2016). Also, species is one of the major analytical characteristics of the plant community (Malik et a*l.,* 2014). Knowledge of species composition and diversity of tree species is of utmost importance not only to understand the structure of a forest community but also for planning and implementation of conservation strategy of the community (Malik & Bhatt, 2015). Assessment of forest community composition and structure is very helpful in understanding the status of tree populations, regeneration, and diversity for conservation purposes (Mishra *et al.,* 2013). The species richness and diversity of trees are fundamental to total forest biodiversity because trees provide resources and habitat for almost all other forest species (Malik, 2014).

The forests of lowland Nepal are prone to many calamities like fire, grazing, and flood. The most affected plant communities by these calamities are regenerations and young trees. Enough knowledge and study in forest characteristics of different tree species is essential to guarantee forest's natural regeneration (Mousavi *et al.,* 2011). Several researchers (Hull *et al.,* 2010; Sunam *et al.,* 2013; Baral *et al.,* 2018; Basnyat *et al.,* 2018a; Basnyat *et al.,* 2018b) define SciFM as a tool having complex mechanism which promotes centralization of forest disfavoring forest users in Nepal. It is also explained as the name of active utilization implemented without considering institutional aspects (Paudel *et al.,* 2018). The government has announced to discontinue SciFM practice in June 2019 stating the excessive logging of only high–valued tree species like *Shorea robusta* which results in lowering and decling the plant diversity and regeneration status, respectively. The long–term effects of SciFM on plant species and regeneration conditions are not studied well. Most of the studies are concerned with livelihood impact on SciFM. There has been significant increment in the regeneration per hectares after implementing the SciFM program in this study area that makes it as an ideal location to assess the success or failure of SciFM program. Therefore, this study was carried out to assess the regeneration status and plant species diversity of major tree species after felling of the stands in SciFM.

Materials and methods

Study area

The study was carried out in the Shringigh at Community Forest (CF) which is located in Badganga Municipality of Kapilbastu district in the western Terai region of Nepal in 2019 (Figure 1). The Shringigh at CF covers an area of 499. 26 ha, and is located between 27°44'13. 2"–27°45'14. 1"N latitudes and 83°11'27. 8"–83°11'57. 5" E longitudes. The elevation of the study area ranges from 190 m to 200 m above the mean sea level. This forest is dominated by Sal (*S. robusta*)

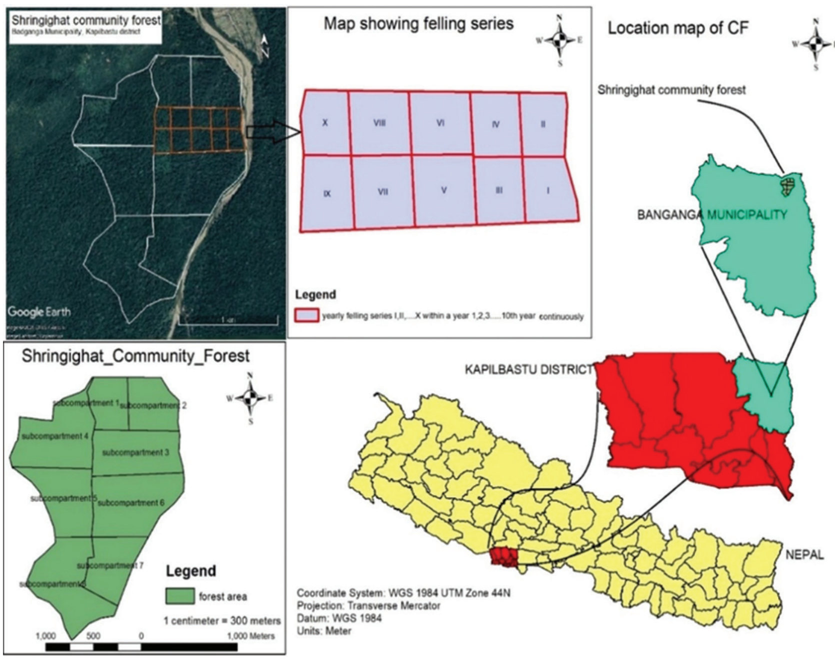

Figure 1: Map showing the location of the study area

associated with Asna (*Terminalia alata*), Karma (*Adina cordifolia*), Kusum (*Schleichera oleosa*), Satisal (*Dalbergia latifolia*), Rohini (*Mallotus philippensis*), Kutmero (*Litsea polyantha*), Bel (*Aegle marmelos*), etc. The major soil types found here are clayey loam, alluvium, and rocky types of soil. The forest is managed under an Irregular Shelterwood Silvicultural System. Altogether, 2,480 households are benefited from this Community Forest.

Data Collection

The data was collected using a systematic random sampling method. The vegetation sampling data were collected from a total of40 concentric circular sample plots (CCSPs) of 10 m radius spaced at 50 m (Figure 2, Aryal *et al.,* 2017). Further, the data on the plant species diversity were also collected from each of sample plot. The sample plots were overlaid on the map using the fishnet tool in ArcGIS 10. 4. 1, and the GPS coordinates of the plots were extracted. Each plot was located in the field with the help of Garmin GPS device. The total number of sample plots was determined in accordance with the total felling area, and resource inventory was carried out with a sampling intensity of 1% as per the Community Forest Inventory Guidelines 2061 (DOF, 2004).

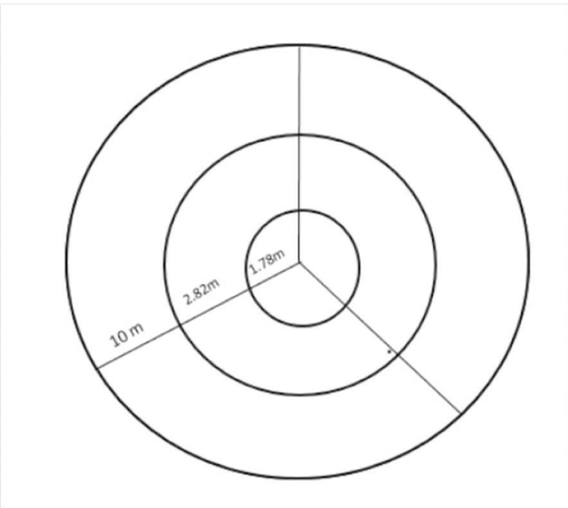

Figure 2: A concentric circular sample plot

The number of tree species (≥10 cm DBH) were counted in the main plot of 10 m radius. To gather data on regeneration, individual plants were categorized into seedlings (height< 1. 3m), and saplings (height > 1. 3 m and < 10 cm DBH). The study was conducted in those periodic blocks where regeneration felling operation was carried out, and the areas were mapped out using ArcGIS 10. 4. 1. The seedlings and saplings within 1. 78m and 2. 82m radii in each CCSP (Subedi *et al.,* 2010) were counted and noted. The density per hectare of each species was calculated to determine their regeneration status in the managed coup. Table 1 shows the area and the total number of sample plots in different felling series.

Table 1: No. of sample plots vs. Area of different felling series

Felling Series	Area (ha)	No. of sample plots
First–year	3. 43	15
Second–year	3. 82	15
Third–year	2. 86	14
Fourth–year	3. 76	16
Total	**13. 87**	**60**

Data analysis

ArcGIS10. 4. 1Software was used for the proximity of establishing sample plots and map preparation. The data were processed and analyzed using MS Excel. The number of seedlings and saplings of *S. robusta* and other species per hectare were calculated, and their status and forest condition were analyzed as per the CF Inventory Guidelines 2061 (DOF, 2004). The density of each species per hectare was calculated using the formula:

$$\text{Species density per hectare} = \frac{\text{Total no. of seedlings and saplings}}{\text{Area of sample plot}} \times 10000$$

The condition of different felling series were assessed on the basis of the total number of seedlings and saplings of different tree species per hectare found in the respective felling series. As per the CF Inventory Guidelines 2061 (DOF, 2004), the condition of the forest is 'good' if the numbers of seedlings and saplings exceed 5,000 and 2,000 per hectare. Similarly, the condition of the forest is 'medium' if the numbers of seedlings and saplings occur between 2,000−5,000 and 800−2,000 per hectare;and 'poor' if the numbers of seedlings and saplings occur below 2,000 and 800 per hectare, respectively (Table 2).

Table 2: Condition of forest based on regeneration status

Plant Type	No. per hectare		
Seedling	>5,000	2,000–5,000	<2,000
Sapling	>2,000	800–2,000	<800
Condition of Forest	Good	Medium	Poor

Source: CF Inventory Guidelines, 2061 (DOF, 2004).

Plant diversity

Species diversity refers to the frequency and variety of species within a geographical area (Malik *et al*., 2014). It is the combination of species richness and species evenness. Species richness is the total number of species per sampling unit, and this makes no use of relative abundances. Species evenness is the distribution of individuals among the species. Species diversity can be expressed in a single number which can be used to assess the diversity of any population in which each member belongs to unique species. The plant diversity was measured using the following diversity indices:

a) The concentration of dominance was measured using the Simpson's Index which is mathematically expressed as–

Simpson's Index of Dominance (D) $= \sum_{i=1}^{S}(pi)^2$ ………. (i)

Where 'S' is the total number of species, 'pi' is the proportion of all individuals that belong to species 'i' in the sample. The value of 'D' ranges between 0 and 1. The value near zero corresponds to higher diversity or heterogeneous community while the value near one relates to a more homogeneous community.

b) The Simpson Index of Diversity is calculated by subtracting Simpson's Index of Dominance from 1, i. e.

Simpson Index of Diversity =1–D ………… (ii)

where,'D' is the Simpson Index of Dominance the value of which also rages between0 and 1; the greater the value, the more the sample diversity.

c) Shannon–Wiener Diversity Index (Shannon, 1948) was used for the calculation of species diversity. Mathematically, it is expressed as:

Shannon-Wiener Diversity Index (H) $= -\sum_{i-1}^{S}(Pi)\,(lnPi)$ ………. (iii)

where,'S' is the total number of species in the sample, 'Pi' is the proportion of all individuals that are of species 'i'. The Shannon Index increases as both the richness and the evenness of the community increase.

d) Species richness index (d) indicates the mean number of species per sample (Margalef, 1958), and is expressed as:

$d = \frac{s-1}{lnN}$ ……….. (iv)

where 'd' is the species richness index, S is the number of species and N is the number of individuals of all species.

e) Equitability or evenness index (e) refers to the degree of the relative dominance of each species in that area. Mathematically, it is expressed as:

$e = \frac{H}{lnS}$ ……… (v)

where 'e' is the evenness, 'H' is the Shannon–Wiener's Diversity Index and 'S' is the number of species. The value of e ranges from 0 (not even) to 1 (completely even).

Results

Regeneration status

The quantitative structures of regeneration of different tree species in the different felling series were studied based on the count of their seedlings and saplings in the sample plots. Table 1depicts the area and the total number of sample plots in different felling series while Table 3 shows the number of seedlings and saplings of different species in the sample plots of different felling

Table 3: Total count of regenerations of different species in the sample plots

Species	Felling Series							
	1st yr. Felling Series		2nd yr. Felling Series		3rd yr. Felling Series		4th yr. Felling Series	
	No. of Seedlings	No. of Saplings	No. of Seedlings	No. of Saplings	No. of Seedlings	No. of Saplings	No. of Seedlings	No. of Saplings
S. robusta	150	230	239	289	185	260	381	275
S. oleosa	10	0	9	0	11	0	5	1
C. fistula	5	0	0	0	7	0	2	2
D. latifolia	0	3	8	0	2	0	0	0
T. alata	0	0	8	10	0	0	0	3
A. cordifolia	0	0	6	0	23	0	1	0
Others	16	0	70	11	16	6	62	0
Total	**181**	**233**	**332**	**310**	**244**	**266**	**451**	**281**

Source: Field Inventory, 2019.

series counted during the inventory process. The regeneration count of S. *robusta* was found to be the highest among all the other species present in all the felling series.

The numbers of seedlings and saplings of different species per hectare were determined based on their regeneration counting in the sample plots. *S. robusta* had the highest number of seedlings and saplings per ha in all the felling series as compared to those of all the other tree species. The regeneration status of different species are highlighted in Figures 3−6with respect to their felling series.

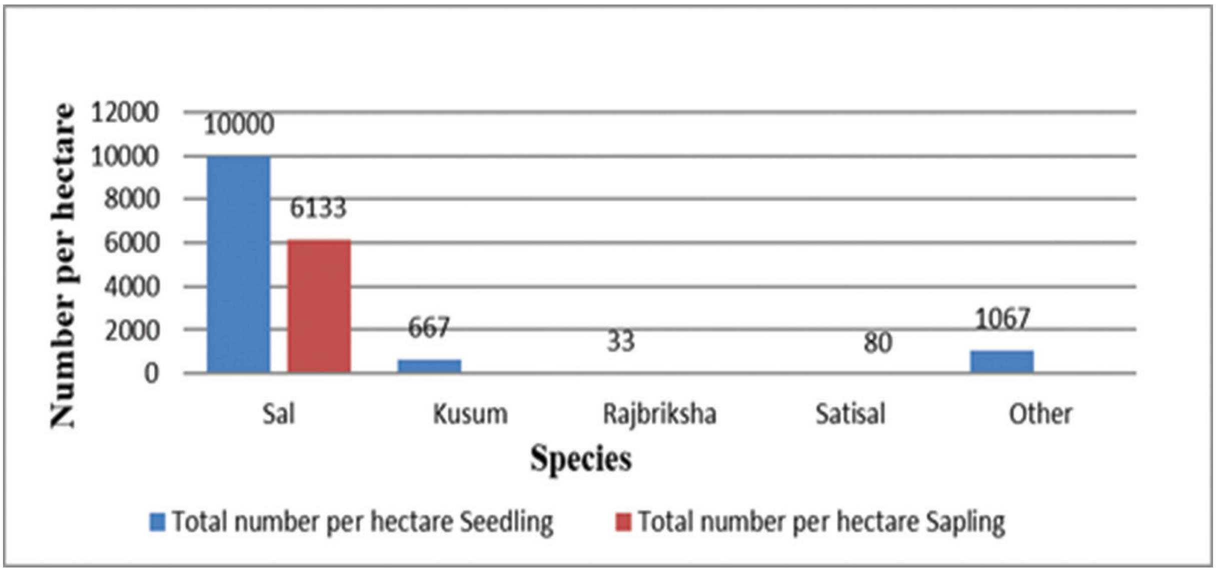

Figure 3: Regeneration status of seedlings and saplings of different. spp. in the 1st Yr. Felling Series

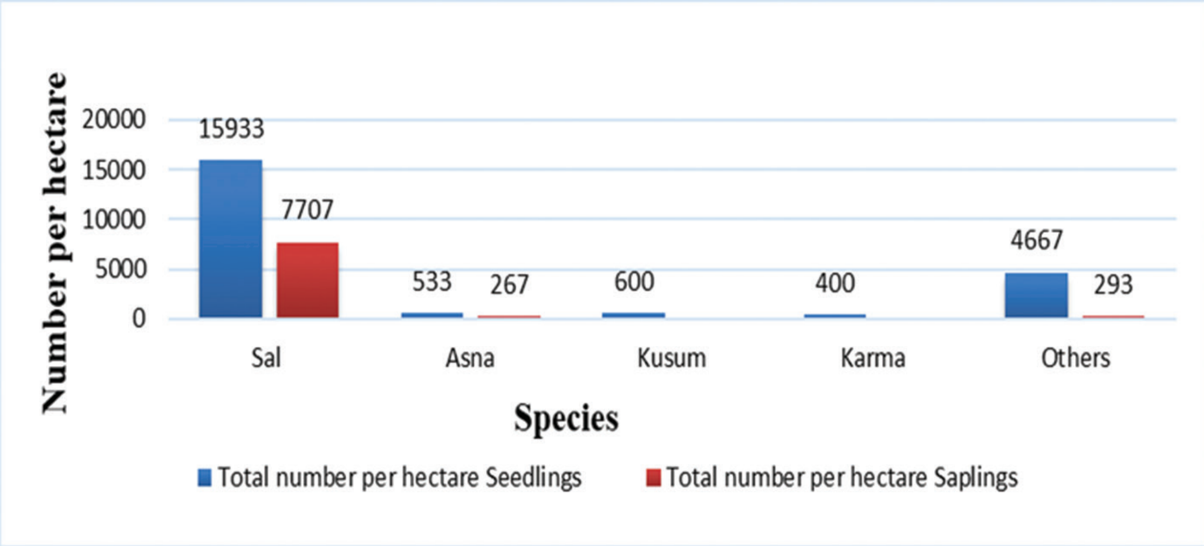

Figure. 4: Regeneration status of seedlings and saplings of different spp. in 2nd Yr. Felling Series

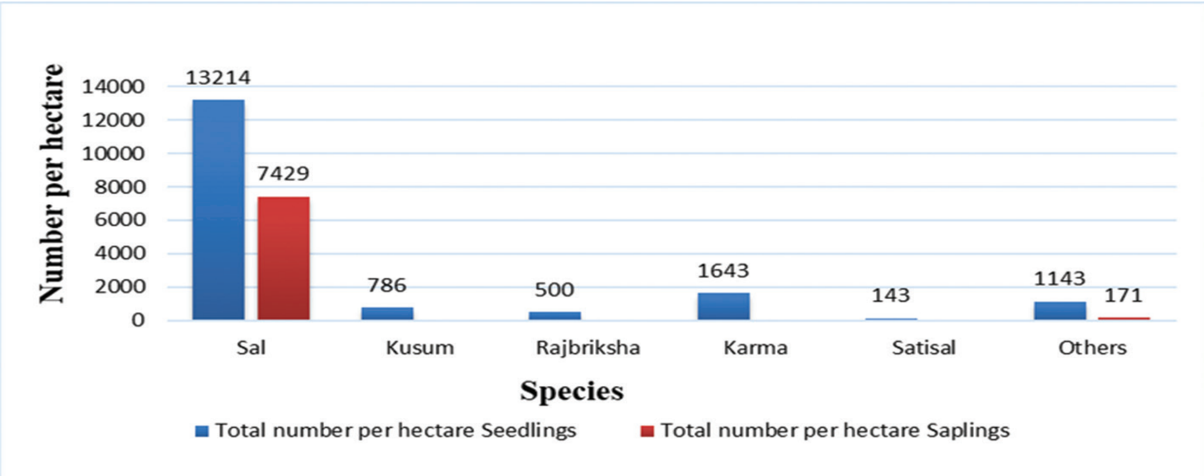

Figure 5: Regeneration status of seedlings and saplings of different spp. in the 3rd Yr. Felling Series

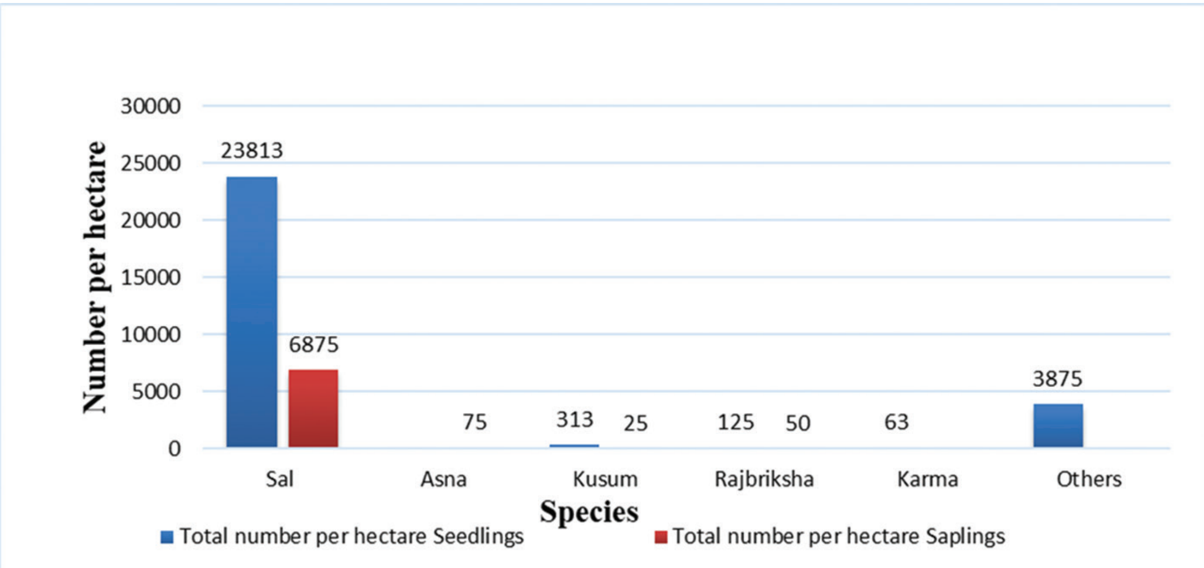

Figure 6: Regeneration status of seedlings and saplings of different spp. in the 4th Yr. Felling Series

Regeneration status of different felling series

Table 6 below depicts the regeneration status of different felling series.

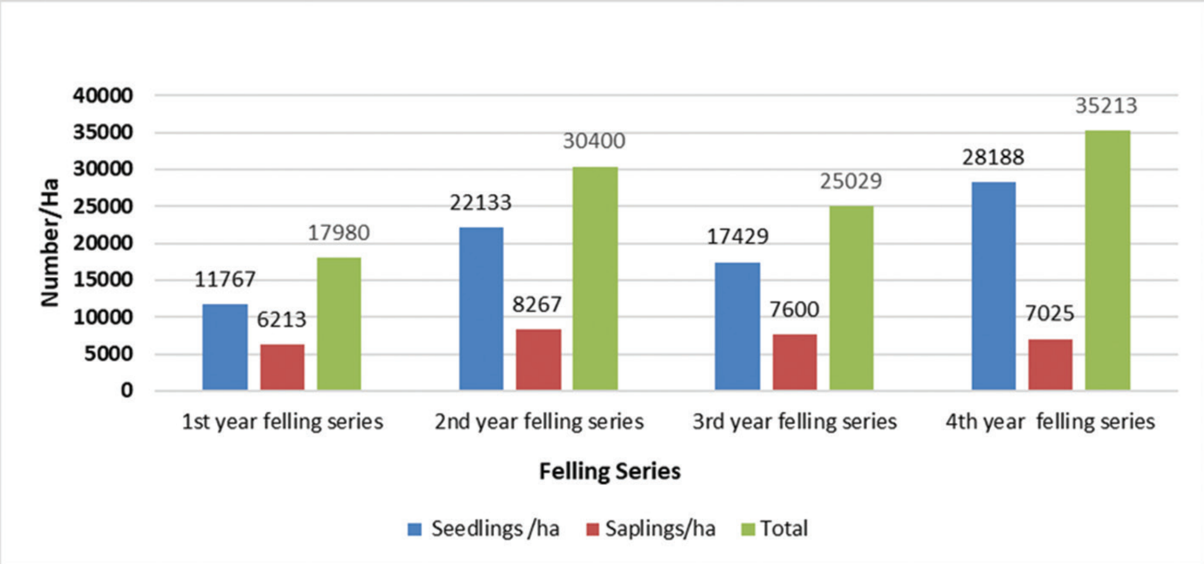

Figure 7: Regeneration status of different felling series

The total number of seedlings (28,188/ha) and saplings (7,025/ha) combined per ha was found to be the highest (35,213) in the 4thYear Felling Series. In this Felling Series, *S. robusta* possessed the highest number of seedlings (15,933) and saplings (6,875) per ha while *A. cordifolia* had the least (only 63 seedlings per ha, Figure 6).

The 2nd Year Felling Series had the second highest number of seedlings (22,133/ha) and saplings (8,267/ha) combined (30,400) per ha. In this Felling Series, the highest number of seedlings (23,813) and saplings (7,707) per ha were belonged to *S. robusta* while *A. cordifolia* consisted of the least (just 400 seedlings per ha, Figure 4).

Similarly, the third highest number of seedlings (17,429/ha) and saplings (7,600/ha) combined (25,029) per ha was noticed in the 3rd Year Felling Series. This Felling Series also possessed *S. roubsta* as the dominant species with 13,214 seedlings per ha and 7,429 saplings per ha; *D. latifolia* consisted of merely 143 seedlings per ha (Figure 5).

The 1stYear Felling Series consisted of the least number of seedlings (11,767/ha) and saplings 6,213/ha) combined (17,980/ha) per ha. *S. roubsta* possessed the highest number of seedlings (10,000/ha) and saplings (6,113/ha) whereas *C. fistula* occupied the least (just 33 seedlings per ha, Figure 3).

Figure 7 shows the summary of regeneration status in different felling series.

As per the CF Inventory Guidelines 2061, the regeneration status of all the felling series were found to be in good condition with the number of seedlings and saplings exceeding 5,000 and 2,000 per ha, respectively.

Diversity of plant species

Table 4 shows a different scenario of the plant diversity indices. Comparing the diversity indices among the four felling series, the value of the Simpson's Index (0. 6934) in the 2nd Year Felling Series was more near to '0'which indicated that it was more diverse as compared to the other felling series. Also, the value of the Shanon Weiner Index (0. 6255) was higher in the 2nd Year Felling Series in comparison with those of the other felling series which also supported the result of the Simpson Index. In the case of the species evenness, the value was found to be greater (0.3869) in the 2nd Year Felling Series which depicted that the species were more evenly distributed in this series as compared to the other felling series.

Table 4: Plant diversity indices in different felling series

Felling Series	No. of species	Simpson's Index of Dominace (D)	Shannon Wiener Index (H)	Simpson's Index of Diversity (1–D)	Species Richness Index (d)	Evenness Index (e)
1stYear	6	0. 8448	0. 3833	0. 1552	0. 8298	0. 2139
2nd Year	6	0. 6934	0. 6255	0. 3066	0. 7734	0. 3869
3rd Year	7	0. 7663	0. 5072	0. 2337	0. 9624	0. 2606
4th Year	7	0. 8104	0. 4071	0. 1896	0. 9097	0. 2092

Source: Field Inventory, 2019.

Similarly, the species richness index was greater (0. 9624) in the 3rdYear Felling Series which possessed total of seven species. The 4th Year Felling Series also consisted of seven species, but hada comparatively lower value of the species richness index (0. 9097) which could be due to the difference in the abundance of the species in those two felling series. However, if the values of all the plant diversity indices were analysed independently without comparing one felling series with another, then we could relate that there was no suitable plant diversity maintained in all the felling series as the dominance of a single species (*S. robusta*) was found to be more in all felling areas. It can be noticed from Figures 3, 4,5& 6 and Table 3that there is a homogeneous type of regeneration in all the felling series.

Discussion

Natural regeneration of plant species is crucial to the sustainable management of tropical forests (Medjibe *et al.,* 2014). Therefore, knowledge about the plant regeneration procedure and dynamics is essential to plan and implement the management activities in the forest (Mwavu & Witkowski, 2009; Puhlick *et al.,* 2012; Yang *et al.,* 2014). This study revealed the number of regenerating species and plant diversity in the Shringighat CF. The study found that executing SciFMin community forests safeguards the promising forest health in terms of substantial regeneration of demanded species, *S. robusta* in the lowland region of Nepal. In all the felling series, *S. robusta* was found to be the dominant species, which is similar to the findings of the Terai forest inventory during 2010−2012 (DFRS, 2015). The same results was reported by Giri *et al.* (1999); Paudyal (2013); Acharya *et al.* (2009); Sapkota *et al.* (2009). After *S. robusta*, the dominance of other species was found to be different in the different felling series (see Figure 3, 4, 5 & 6).

The study found higher seedlings and saplings number in this CF;it could be the result of regeneration felling in the Shringighat Community Forest. The numbers of seedlings were found to be 11,767/ha in the 1st Year Felling Series, 22,133/ha in the 2nd Year Felling Series, 17,429/ha in the 3rd Year Felling Series, and 28,188/ha in the 4th Year Felling Series. On an average, there were19,879 seedlings per ha in all the felling series which corresponds to the results of Awasthi *et al.* (2015) who found 16,555−21,000 seedlings per ha after regeneration felling of *S. robusta* forest under irregular shelterwood system in a similar site of Rupandehi district. Similarly, there were 6,213 saplings per ha in the 1st Year Felling Series, 8,267 per ha in the 2nd Year Felling Series, 7,600 per ha in the 3rd Year Felling Series, and 7,025 per ha in the 4th Year Felling Series with *S. robusta* as the dominant species. As per the Community Forest Inventory Guidelines 2061, the status of regeneration (good, satisfactory, poor), the densities of the seedlings and saplings were found to be 'good' in all the four felling series. The difference in regeneration status in the different felling series may be due to the differences in the intensity of grazing, logging, cleaning operations, and the growth of invasive species in the different felling areas. A number of researchers such as Gautam *et al.* (2002); Sakurai *et al.* (2004); Yadav *et al.* (2003) have stated that the prohibition of controlled grazing inside CFs in Nepal is to contribute positive ecological impacts of the CF program, which ultimately increases forest cover, stem density, and natural regeneration. A study carried out by Buffum *et al.* (2009) also sorted the overall increase in seedling and sapling density to the reduced grazing intensity in a late successional broadleaved community forest in Bhutan. Similarly, the impact of logging on tree regeneration varied with size and disturbance intensity. When the disturbances were immediate in intensity, the diversity of natural regeneration was highest whereas, pioneer tree species proliferated in the more heavily disturbed areas (de Carvalho *et al.,* 2017). A study conducted by Baniya *et al.* (2019) in Pine forest has also recommended that, the regeneration status and normal growing stock can be enhanced if the thinning and felling is carried out annually in different compartments in different CFs. Invasive Tree Species (ITS) might influence natural regeneration by directly limiting the saplings of native species (Hejda *et al.,* 2017). The ITS shed large numbers of seeds below their canopies, and there exists competition for light and soil resources (Kawaletz et a*l.,* 2014). Hence, it affects regeneration too.

From long ago, species richness, various diversity indices, stem density and species importance value index has been used to evaluate population dynamics and their diversity in the forest (Gimaret–Carpentier *et al.,* 1998). Different types of forest management practices significantly affect the structure of plant species diversity in forests (de Avila *et al.,* 2015). However, the script of the management objectives also plays a crucial part in determining plant diversity and species richness in the long–term (Cedamon *et al.,* 2017). Species diversity refers to the frequency and variety of species within a geographical area (HMGN/MFSC, 2002). It refers to the species richness and evenness within an area which describes the structure of the plant community. Plant species are directly affected by the harvesting or management practices operated in a stand. This study showed the dominance of single species was higher,i. e. 0. 69 to 0. 84. Subsequently, the diversity index was low in all the four felling series. The Simpson Species Diversity Index was found to be less in all the four felling seriesi. e. between 0. 15 to 0. 30. Awasthi *et al.* (2020) also concluded that the silvicultural practices under SciFM decreases plant diversity as the species diversity index was found to have decreased in all the managed blocks than in the unmanaged ones. The Shannon–Wiener Index was found to be between 0. 38 to 0. 62. As these four felling series can be considered as managed forests, the present values are closely comparable to those reported by Uniyal *et al.* (2010) from Garhwal Himalaya, where it was 0. 7 for the managed forests and 1. 4 for the unmanaged ones. Also, the species richness and species evenness were found to be comparatively low in this study; the species richness was found to be between 0. 77 to 0. 96 while the species evenness was found to be within the range of 0. 20 − 0. 36 which could be due to the harvesting and logging practices in the felling series. Harvesting operations and logging intensity are accounted to be decidedly effectual in shaping species diversity and composition (González–Alday *et al.,* 2008). For example, the higher the harvesting quantity, the lesser the species diversity in SciFM practices (Shima *et al.,* 2018). The cause of lowering species diversity, evenness, and richness in managed blocks is also accounted for the proportionately higher logging intensity in SciFM, where just 15−30 mother trees per hectare are kept during regeneration felling in the forest (Poudyal *et al.,* 2019). The species richness indices in the 1st, 2nd, 3rd and 4th Year Felling Series in this study were found to be 0. 8298, 0. 7734, 0. 9624, and 0. 9097, respectively, indicating less species richness in our study site. A study conducted by Halpern & Spies (1995) and Smith *et al.* (2005) reveled the declining of species richness due to high logging intensity in the sub–tropical forests of Australia. Our findings also indicated positive impacts towards regeneration status in different felling series but with less species diversity. Several researchers such as Carreño–Rocabado *et al.,* 2012; Smith *et al.,* 2005; and Roberts & Gilliam, 1995) have argued that there is less species diversity in intensively managed production forestry than natural forest. The study performed by Sapkota *et al.* (2010) also found the significant decline in the species diversity along the disturbance gradient in *S. robutsa* forest in Nepal. The additional management activities like fertilization, grazing, and herbicide application could also affect the species composition and diversity of vegetation in addition to the initial effect of logging and preparation of site. Shima *et al.* (2018) concluded that species diversity increased with the decreasing logging intensity in Malaysia suggesting that the active management activities and logging practices in forests would change the species composition with due regards of changes in species mortality and recruitment.

Conclusion

This study conducted a comparative analysis about the regeneration status and species diversity in different felling series of the Shringigh at CF where SciFM was practiced. We found that SciFM resulted in homogeneity of the tree species and increased the number of regeneration of the seedlings and saplings whereas it eventually decreased the species diversity within the felling series. We found that SciFM practices increased the dominance of the intended/high–value species. The silvicultural operations like regeneration felling followed by the post–harvesting operations showed excessive growth in the seedlings and saplings density. Similarly, the regeneration promotion activities like cleaning, weeding, thinning were found suitable for establishing the regeneration of the intended species. Taking this into consideration, the CFUGs, management planners and practitioners should focus on maintaining the species diversity avoiding the excessive dominance of any single species. Hence, this study recommends the concerned authorities to adopt various measures for establishing a heterogeneous plant community under SciFM and control the risk factors that may affect regenerations. However, the reason behind the homogeneity of the species and essential measures to maintain plant species diversity should be further studied.

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Climate change adaptation governance in Nepal: a framework for sustainable generationof adaptation services

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Poverty and high dependency of rural and mountainous households on the natural resources of Nepal have made the country more vulnerable to climate change. On the other hand,there is inadequacy of adaptation services provided to the vulnerable households and ecosystems. Responding to climate change necessitates a more consolidated effort and effective implementation interventions from both the government and non–government actors. To help achieve this very essence, this study has aimed to– (i) review the existing climate change adaptation (CCA)practices, processes and patterns of sustainable resource mobilization and benefit sharing, and (ii) develop a framework that ensures sustainability of resources and equitable sharing of services and benefits accrued from CCA. Consultations with the communities, key state and non–state stakeholders both at federal and provincial levels, reviews of national policies, strategies, periodic plans and programs and field visits were carried out to synthesize the information, document the knowledge, and highlight the gaps pertaining to CCA. Qualitative Content Analysis (QCA) was executed for analyzing qualitative information. Recently, the Government of Nepal has developed a priority framework on sustainable resource management and delivery of adaptation services. In line with the eight themes identified by the National Climate Change Policy (NCCP, 2019), the proposed framework has paid central attention on medium and long–term adaptation planning adhered with Ecosystem–based Adaptation (EbA) and Community–based Adaptation (CbA). Building resilience, reducing vulnerability, increasing capacities, enabling environment, and integrating CCA in development planning have been the focus of the framework. It is found that the delivery of adaptation services to the climate vulnerable groups and poor communities is well reached out through CbA and EbA approaches. It is therefore, crucial in strengthening community– and locally–based mechanisms (such as forest–user groups, farmers groups, agricultural and fisheries cooperatives, and community networks) for sustainable management and delivery of services to facilitate effective adaptation.

Keywords: Adaptation service, benefit sharing, climate change, EbA, sustainable resources.

Nepal began systematic climate change adaptation (CCA) planning after the initiative of the United Nations Framework Convention on Climate Change (UNFCCC) in 2001 as the COP7 (decision 1/CP. 7) decided to formulate and implement National Adaptation Program of Action (NAPA) in the Least Developed Countries (LDCs), and established the Least Developed Countries (LDC) fund, Special Climate Change Fund (SCCF), and Adaptation

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Fund (AF). The Millennium Development Goals (2001), 10th Periodic Development Plan (2002−2006), Sustainable Development Agenda (2003), and Poverty Reduction Strategy Paper (2003) are the entry–level protocols for addressing climate change issues in Nepal. Since 2002, the Government of Nepal recognized climate change as an emerging issue when the 10th Plan (2002−2007) aimed at working the influence of weather on national economy (Agrawal *et al.,* 2003). The plan accompanied by Medium–Term Expenditure Framework (MTEF) paper for the agriculture sector paid attention to curb climate–related risks. The First National Communication (NATCOM–1) Report to the UNFCCC (2004) provided an overview of the national circumstances that reflects Nepal's capacity to respond to climate issues. The National Capacity Need Self–Assessment (NCSA) (2008) accounted a report to jointly implement multilateral environmental agreements (MoEST, 2008), and came up with the challenges of climate change. These initiatives may advocate changes in practices and technologies, diversification of livelihood systems, and reconfiguring resource allocation and collective actions to access services, resources or markets as climate change actions (NCVST, 2009).

Adaptation to climate change has gained a prominent place on global, national, and local policy agendas only after 2010 (Swart *et a*l., 2014). Nepal prepared National Adaptation Program of Action (NAPA) in September 2010 with documentation of national climate change vulnerability and measures to identify the immediate and urgent CCA needs and priorities. The REDD Readiness Preparation Proposal (2010), National Framework on LAPA (2011), and Climate Change Policy (2011) were some other key strategic moves towards advancement of CCA(Regmi & Karki, 2010). While proceeding, the Nepal National Adaptation Plan (NAP) process started in 2015 complements the mission that enables achieving sustainable development goals (SDG 2030) and CCA together (Karki *et a*l., 2017). The Government of Nepal has endorsed the National Climate Change Policy (NCCP) (2019) that aims to contribute to the nation's socio–economic prosperity by building a climate–resilient society. Sustainability of resources and equitability in sharing the benefits and services are envisioned in the NCCP.

Significance of the study

Translating policies and protocols into actions requires enhancing the knowledge through scientific investigation, understanding the task, implementing the efficient and acceptable measures, generating the resources, fair sharing the benefits and building ownership through development programs. However, the mechanism for CCA resource management and benefit sharing in Nepal is hitherto unknown. The research on climate change and adaptation rendering implications to the national–level strategic way forwards for sustainable development and building resilience and adaptive capacity in Nepal are limited (Gentle *et a*l., 2018). The current climate change research agendas are consequence focused, not the cause, drivers and options based (Kunwar, 2020). It should also be equally relevant to address the "uncertainties" and "surprises" (Karki *et a*l., 2020) that arise from future climate change and its impacts, and pave the way forward that balances the adaptation services and benefits (Schneider & Kuntz–Duriseti, 2002). In this regard, this study, through the review, consultation and assessment of available adaptation services and needs, aims at developing a framework on 'how and where the adaptation services are generated, and what could be the best vehicle to distribute those adaptation services to the most vulnerable systems and households while giving due focus on sustainability of resources and equability of benefits and services.

Materials and methods

Study sites

The fieldwork for this study was conducted in Aabukhaireni (27° 54'– 27° 57' E latitudes and 84° 24'– 84° 32'N longitudes) of Tanahun district and Panchase (28° 15' – 28° 23' E latitudes and 83° 48' – 83° 51' N longitudes) of Kaski district, both situated in the mid–hills of central Nepal (Figure 1). As mid–hills are highly populated and curtailed by climate change, we selected Aabukhaireni from Tanahun district and Panchase from Kaski district as our study sites. The fieldwork was carried out in December2020, and was facilitated by two local assistants.

Methods

Climate–change–related programs, technical reports and other published documents were reviewed for the purpose of the study. The review was complemented by consultative process where the national, provincial, community and local stakeholders were interviewed. The data collection method was complemented by fieldworks. A 15–day–long fieldwork was carried out to obtain information regarding where and how the CCA resources, services and benefits had developed and shared. Field observation and discussion at Aabukhaireni helped collate information on climate change impact, vulnerabilities, and adaptation services at community–managed sites while that at Panchase helped record the account of the same from the temperate and protected forests. The field visit at Panchase also helped observe and assess the impacts of the intervention of EbA. Twenty–six respondents from both sites representing community forest user group (CFUG) members, farmers, and village–elders were interviewed for acquiring the needed data and information. The major climate change adaptation services that tightly intrigued with climate stress, shocks, vulnerabilities & risks, and that helped promote lessening those constraints were sought while carrying out the fieldwork.

Data analysis

In course of data analysis, a qualitative method with quantitative steps was followed since the qualitative information were quantified and measured for Qualitative Content Analysis (QCA) (Mayring, 2014). With due focus on sustainable management, generation and delivery of CCA services and adherence with the eight major thematic areas identified by NCCP (2019), a framework on sustainable generation and delivery of adaptation services to the most vulnerable systems and communities

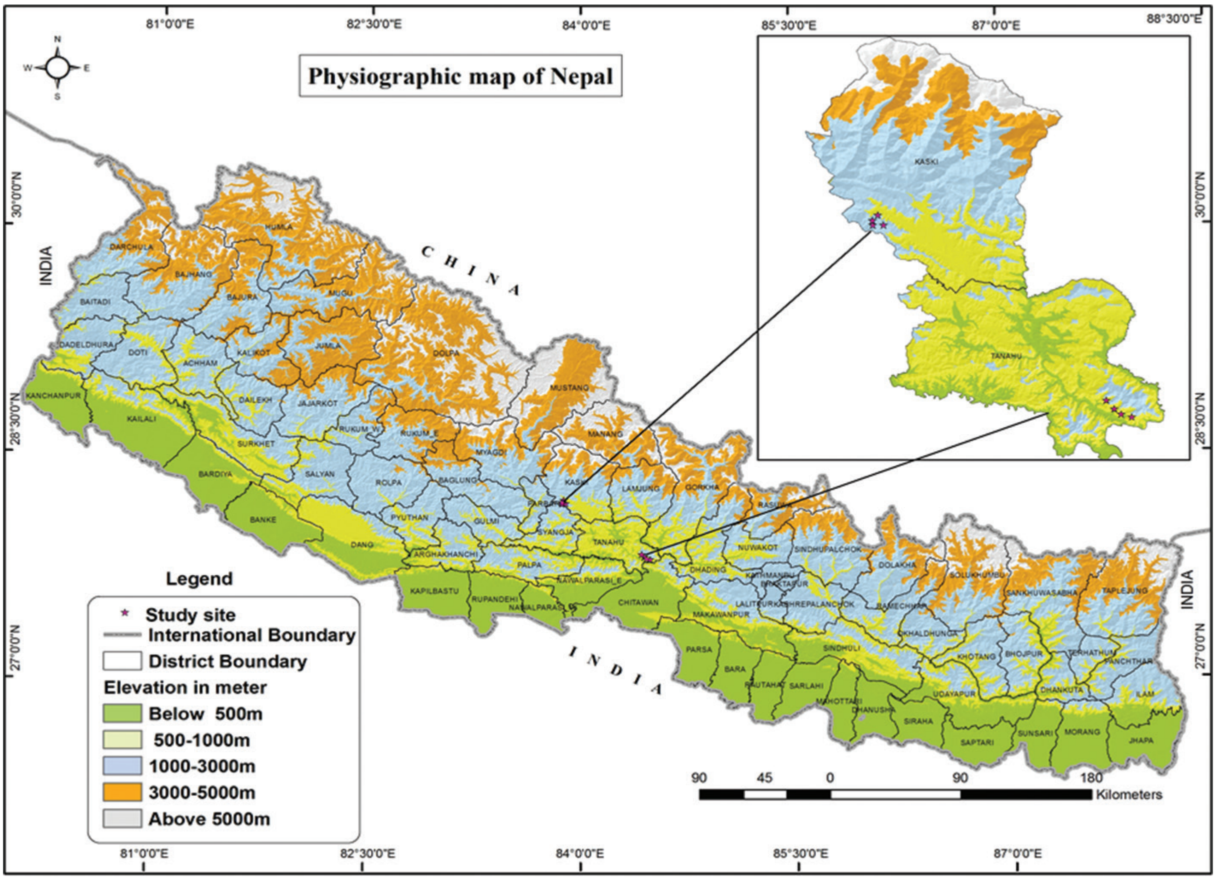

Figure 1:Map showing the location of the study–sites

was proposed. Additional focus was given on keeping on reducing vulnerability, strengthening institutions, enabling environment and integrating CCA in development planning for strengthening adaptive capacity and building more resilient system of CCA.

Results

Understanding climate change vulnerability and adaptation services

Climate change vulnerabilities and impacts on rural livelihood–base such as reduction in crop yields, destruction of homes and increase in food prices and food in security were common in the studied districts. The local residents also responded that the climate–induced erratic rainfall triggered landslides that caused in land degradation and crop loss in and around the study area. Here,the erratic rainfall was primary, landslide was secondary and land degradation and crop loss were tertiary impacts caused by climate change (Figure 2).

The climate change effects and their adaptation measures were observed to be different, locally developed in the study sites, as assumed;the warming effects were locally adapted and local counter measures were developed in Panchase area of Kaski district,which could be due to more community–centric and ecosystem–based adaptation–led works where forest–products–based local livelihood might have helped the communities resilient to climate change. The local communities in the mountains have long been using their indigenous knowledge for CCA. The common adaptation practices adopted by the local people of Kaski and Tanahun districts included seasonal and/or permanent outmigration, redesigning their houses, diversifying livelihood portfolios, raising perennial vegetation around the settlements by planting bamboos in their homesteads for controlling soil erosion, forest–product collection and their storage, and ecotourism.

Climate adaptation services and priority activities

Panchase area demonstrated that the climate adaptation services rendered from the available ecosystem services were also due to the social coherence, which was also reflected in Lavorel *et a*l. (2015), supported the local residents to be resilient to climate change and variability. Adaptation services complement the ecosystem services approach, and helps people develop choices for adaptation to climate change (Figure 3). It is, therefore, imperative to carry out to offer CCA options and services at local–levels. We observed that the climate services fostered the provision of more and better climate information/data (forecasts, modeling) that allowed farmers to fine–tune their planting, harvesting and marketing strategies based on climate forecasts (Goosen *et a*l., 2013; WMO, 2015; Webber, 2017).

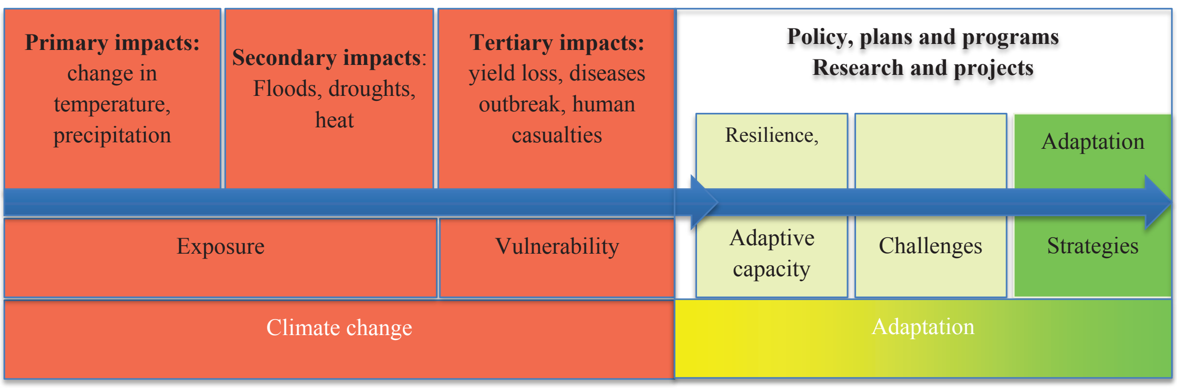

Figure 2: Climate change adaptation service approach (adapted from Goosen *et al.*, 2013)

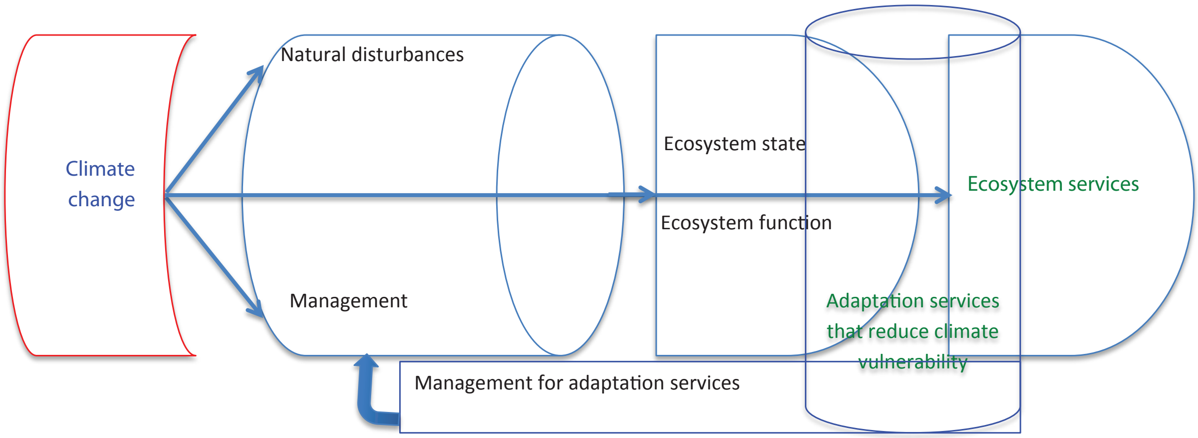

Figure3: Adaptation service framework (adapted from Lavorel *et al.*, 2015)

Our study found the following adaptation services from the reflection of community experiential learning, desk mining and field observation, which could be grouped under six thematic areas (Table 1); out of the 55 adaptation services catalogued, 14 were being practiced in Kaski and Tanahun districts.

Table 1: Thematic areas and potential sectors where additional CCA services can be generated

Thematic areas	Potential areas/ sectors	Potential CC adaptation services and generation traits
Forest, Biodiversity, and Watershed management	Community Forests (CFs), Leasehold Forests (LFs), Buffer Zone Community Forests (BZCFs), Collaborative Forests (CoFs), Private Forests (PvtFs), Protected Forests (PFs), NTFPs/MAPs	• Timber & non–timber–based enterprise/value addition activities in all types of forest management (e. g. saw–mills, furniture, essential oils, handmade paper, resin tapping); • Promotion of agroforestry model in Terai and mid–hills in PFs, LFs and other fallow lands; • Utilization of underutilized forest plant species such as Dhatelo (*Prinsepiautilis royle*), Chiuri (*Diploknema butyracea*), and Amriso (*Thysanolaena maxima*); • Cultivation of high–value MAPs such as Satuwa (*Paris polyphylla*), Valerian plants (Valeriana *officinalis*), Atis (*Aconitum heterophyllum*), Ban Lasun (*Allium wallichii*), Kurilo (*Asparagus officinalis*), etc. with value addition at local–level; • Forest–fire management; • Sustainable forest management; • Fruit tree planting.
	Watershed management	• Promotion of vegetation covers in Chure, Mahabharat and high–mountain areas; • Soil conservation practices (Hedge rows plantation, zero tillage cultivation, agroforestry practices); • Development of drought hardy forest species; • Creation of conservation pond especially in Chure foothills; • Degraded land rehabilitation.

Thematic areas	Potential areas/ sectors	Potential CC adaptation services and generation traits
Agriculture and Food security	Agriculture	• Crop calendar; • High–value agriculture; • Off–season vegetables (e. g. cucumber in tunnel farming). • Climate–resilient seed varieties development, community seed banks; • Smart agriculture practices, climate–friendly agriculture practices (terrace farming, conservation tillage, SALT technology); • Cover crop, rotational, multiple cropping; • Agro–processing enterprises (jam, jelly); • Development of drought–hardy, low–moisture–requiring cereal and vegetables, integrated pest management; • Use fallow and unused land such as garlic cultivation after rice harvesting, watermelon in sandy land.
	Horticulture and livestock	• High–value horticulture (orange, mango, avocado, kiwi, dragon fruit); • Native/indigenous horticulture crops such as Sankhotra (*Citrus decumana*), Khurpani (*Prunus corbneta*), Lapsi (*Choerospondias axillaris*), Okhar (*Juglans regia*), etc. ; • Development of drought–hardy, water–resistant horticultural crop species; • Improved shade for livestock; • Plantation of forage and fodder trees; • Value addition in dairy products (e. g. make Paneer from milk, hard cheese); • Dry meat products, caning fish.
Water and Energy	Irrigation	• River–bed farming; • Increase irrigation facility and water use efficiency through promotion of shallow tube–well, water collection/recycling and rainwater harvesting; • Promotion of low–cost irrigation technology including drip/ sprinkle irrigation, Thai–Jar and overhead water tank.
	Water (springs, streams, rivers and lakes)	• Conserve natural springs, streams, rivers, lakes and ponds; • Rainwater harvesting in water–scarce areas; • Watershed management, landscape management.
	Energy	• Replace the fossil fuel to green energy and hydro energy; • Utilize micro–hydro and biogas: integrating adaptation and mitigation; • Harness solar power; use improved cooking stoves; replace fuel wood to other types of energy; • Improve water mills.

Thematic areas	Potential areas/ sectors	Potential CC adaptation services and generation traits
Disaster risk reduction	Meteorological information, DHM	• Early warning system for extreme events; • Data for forecasting; • Flood defense: disaster risk reduction, ecological restoration; • Provide scope of IGA for poor and vulnerable communities; • Go beyond emergency planning: sustainable management of land, soil and vegetation; • Community–based seed bank/management; • Village–level emergency fund, crop and livestock insurance.
Water, Sanitation and Health	Health	• Forecasting diseases outbreak; • Investments in health infrastructure and facilities; • Mapping watersheds and water–bodies.
Tourism and Infrastructure development	Tourism	• Early warning system for extremes in major touristic areas; • Ecotourism development at local–level; • Nature–based tourism development in potential areas beyond protected areas; • Heritage tourism development (both natural and cultural); • Village tourism development in rural areas.
	Infrastructure development	• Climate–resilient roads, houses and other infrastructure designs and built–ups; • Piloting of gravity–rope ways.

Delivery of adaptation services

The National Framework on Local Adaptation Plans for Action (LAPA) developed in 2011 and updated in 2019, presents an approach for "delivery of adaptation services to the most climate–vulnerable areas and people". It has succeeded in mobilizing local institutions and community groups in adaptation planning and in recognizing their role in adaptation. With the advent of LAPA, there are several community–level initiatives in generation and delivery of climate adaptation services. Processes that are participatory and that acknowledge key government agencies and stakeholders such as local government or district–level institutions such as divisional forest office are more responsive to complement the local needs through more integrated approaches (Sharma, 2009). In this regard, the significance of community–based and community–led legally authorized organizations such as forest–user groups, farmer groups, cooperatives, and community networks was clearly emphasized for the generation of adaptation services and functional flow to the needful households.

Nepal's National Climate Change Policy (NCCP, 2011 and its Update, 2019) have proposed eight key climate vulnerable areas where adaptation services are to be focused and delivered through the coordinating leadership of the corresponding thematic lead ministries. These areas broadly include– i) climate adaptation and disaster risk reduction; ii) low carbon development and climate resilience; iii) access to financial resources and utilization; iv) capacity building, peoples' participation and empowerment; v) study and research; vi) technology development, transfer and utilization;and vii) climate–friendly natural resource management. Yet, creating an enabling environment, building capacities of all three levels (local, provincial, and federal) of governance and active linkage amongst research, policy and practice also needs to be considered as priority while advancing adaptation. Thus, service generation and delivery could sustain once direct and effective vertical and lateral communications are in place amongst central, provincial, and local governments and non–government stakeholders (Figure 4).

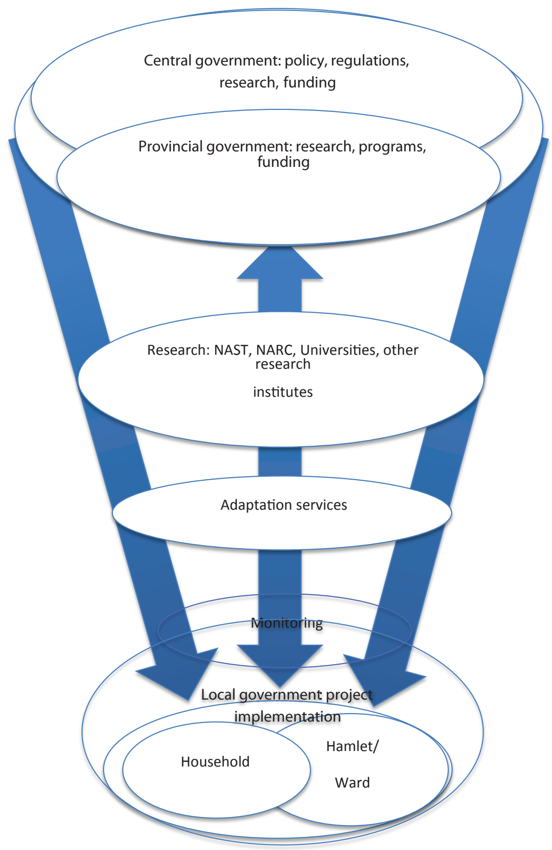

Figure 4: Climate change adaptation service delivery framework

Discussion

The study helped understand that climate–related hazards exacerbate other stressors, they often chain with negative outcomes for livelihoods, especially of the pro–poor people living in inaccessible areas. Thus, the poor and rural residents of hills and mountains,who are heavily dependent on forests and other natural resources for their livelihoods are more hard–hit (Mainali & Pricope, 2019) and challenged by the climatic disorders. Despite the local adaptation practices and application of indigenous traditional techniques, many households were already forced to abandon their dwellings, and migrated to the nearby cities/towns for the protection of their lives and earn livelihoods. Out–migration of the folk population leaving their properties un–attended could be noticed in many places of Panchase of Kaski district and in other districts, such as Manang, Mustang, Ramechhap and Nuwakot (Khatri, 2013). Land abandonment due to un–attendance is prevalent in Tanahun (Baral *et al.*, 2021).

Policy and CCA service generation

In spite of the promulgation of over a dozen of climate change protocols, their implementation is fairly effective,which could be attributed by the fact that they were not efficiently materialized, monitored and measured by virtue of limited capacity of the service providing and regulating bodies. In addition, the policy makers and decision makers are not well aware of the urgent call of embedded vulnerability of poor households for climate change adaptation interventions. Local and community–based adaptation interventions are, therefore, needed that can address climate vulnerabilities and help rural communities adapt in better ways sooner than later. In here enabling policy environments, capacities and partnerships are prerequisite for successful adaptation at all level.

NAPA (2010) and Climate Change Policy (2011 and 2019) both place significant emphasis on local adaptation plans, including implementing mandatory provisions to use at least 80% of their available budget for local adaptation activities (GoN, 2011). Moreover, the National Planning Commission (NPC) had developed a framework, for climate–resilient planning, that included a useful format for the appraisal of core plans, providing support, and developing institutional systems (NPC, 2011). Apart from the institutional approaches in service generation, there were some community–led initiatives in generating adaptation services despite the incentives are local and minimal. The locally–embedded initiatives like agroforestry system helps support agricultural production, checks air quality and soil health, maintains biodiversity, connects habitats and wildlife, sequesters carbon, and promotes regeneration of plants;the latter four being adaptation services underpin bundles of regulating services fostering the former two.

As the review manifested that the delivery of adaptation services to the climate vulnerable groups of hills and mountains is immediate and could be well reached out through community–based adaptation (CbA) and ecosystem–based adaptation (EbA), it is advised to ensure that the poor and vulnerable households and communities are prioritized, and the issue of inclusion and equity and integration of adaptation plans at CFUG or village–level is considered (MSFP, 2016; Karki *et al.,* 2021).

Collaboration between political leadership and resource users such as local governments and CFUGs seemed to be imperative for delivery of CCA services as purported by Regmi & Karki (2010); FAO (2011); Dhakal & Jamil (2015). Besides, considerable investment is also a matter of concern for the purpose of generating and delivering adaptation services, and also transparent and inclusive decision processes and competent human resources and political leadership having good understanding of climate foresight are needed to best deliver the adaptation services (Pettengel, 2010). A suite of services comprised of administrative, financial and institutional services is an imperative for the generation and supply of adaptation services to the climate–vulnerable households.

Conclusion

Translating policies, protocols and plans into practices requires enhanced knowledge through research, understanding the gaps, implementing the efficient and acceptable measures, managing available resources in coherence for optimum products in perpetuity, fair sharing of the benefits and building the ownership. Locally–governed institutions, for resource governance, are the best powerhouse for generating adaptation services through mobilization of natural and social capitals. For the delivery of climate change adaptation services, institutional mechanisms comprised of multi–stakeholders and having interconnectedness are required to deliver adequate supply of adaptation services. As climate change adaptation planning and implementation is a multi-stakeholder country–driven process, the best possible and available option for the mobilization of natural and bio–physical capital need to be explored and restrengthened. This study concludes that there are multiple opportunities of generating adaptation services where the opportunities of mobilizing natural and social capital are available. In the present context,local communities are well acquainted with the knowledge of community–based and ecosystem–based adaptation, which need to be capitalized with the embracing of circular economy and nature–based solutions to the adverse impacts of climate change. Local governments are constitutionally mandated to act on local development together with climate change adaptation and disaster risk management; therefore, their capacity of coordination and leveraging resources could play a crucial role. There is a need of capacity building of all level of governments for leveraging adaptation resources and develop multi–stakeholder partnership for synergy in actions.

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Short note

First generic record of aero–terrestrial algae: *Apatococcus lobatus* (Chodat) J. B. Petersen for algal flora of Nepal

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Aero–terrestrial green microalgae grow as epiphytic or as epilethic on natural surfaces such as tree bark, soil and rock (Ettl & Gärtner, 1995). This organism also causes developmental attachment, in cities, on artificial surfaces such as tiles, concrete, building facades and other artificial surfaces causing incrustations (Tomaselli *et al*., 2000). Aero–terrestrial habitats are characterized by a wide range of temperature and availability of solar radiation and water. Algae growth occurs with the availability of moisture from the deposition of dust between the erosion of metal and the passage of time by chemical erosion, and the presence is driven by rain and atmospheric moisture (Das & Gupta, 2015).

The genus *Apatococcus* F. Brand belongs to the phylum 'Chlorophyta' and Order 'Chlorellales' in the family 'Chlorellaceae'. It is cosmopolitan, and is composed of globular cells which, in most cases, divide into two or three planes, and form irregular, cubic packets, sometimes forming short uniseriate i.e. arranged in a single row, layer, or series of filaments. The cells are uninucleate, often lobed, parietal chloroplast without pyrenoids. The genus *Apatococcus* consists of 5 species viz. *A. constipates* Printz, *A. fuscideae* Beck & Zahradnikova, *A. lobatus* (Chodat) J.B.Petersen, *A. minor* Edlich, and *A. vulgaris* (Guiry & Guiry, 2021) including *A. lobatus* as holotype of the genus.

A. lobatus has been recorded in Austria, Great Britain, Czech Republic, France, Italy, Germany, Netherlands, Romania, Spain, and Ukraine of Europe, Japan (Asia), Queensland (Australia), New Zealand, and Pacific Islands (Guiry & Guiry, 2021). In India, it was found to have occurred in the iron pole in the AJC Bose Indian Botanic Garden, Howrah (Das & Gupta, 2015); they observed that the occurrence of *A. lobatus* was inversely proportional to the availability of the sun, possibly due to dependency on the atmospheric moisture.

In our study, *A. lobatus* was found to be growing on the painted iron poles (situated at the elevation of 1505 m between 27.5970° N–27.5971° N latitudes and 85.3074° E–85.3809° E longitudes in the Fern Garden within the National Botanical Garden of Godawari, Lalitpur, Nepal. The species has been neither included in the checklist of the algal flora of Nepal (Prasad, 2011) nor mentioned in the recent publication of Rai & Ghimire (2020). Likewise, Joshi (1977; 1979), Prasad & Prasad (2001), and (Dhakal *et al*. 2021), who have carried out the studies on the algal flora of the Godawari area of Lalitpur district, have also not mentioned the present genus. So, we confirmed this genus to be the new one in the list of algal flora of Nepal.

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Materials and methods

Study area

The study was conducted within the National Botanical Garden (NBG) of Godawari which is situated at the foothills of Phulchoki mountain of Lalitpur district of Nepal. Geographically, this garden is located between 27.5985°–27.5946° N latitudes and 85.3770°–85.3881° E longitudes at an altitude of 1,480–1,520 m above the mean sea level (Figure 1). The study sites exhibit subtropical type of climate. The average annual temperature as recorded in 2020 was 15.9 °C with the averages of 20.3 °C in June and 9.1 °C in January, respectively, and the average annual rainfall of 2,595 mm (Climate–data.org, 2020). The study was conducted in August, 2021.

Collection and identification of the algal samples

The samples were collected from the painted iron surfaces in the fern garden within the NBG. The algae were scrapped using toothbrush. The samples were brought to the Cryptogams Section of the National Herbarium and Plant Laboratories at Godawari (Lalitpur district) where they were preserved in 4% formalin. Their microscopic study was performed using a Huma Scope LED Microscope with 10 MP Camera Adaptor.

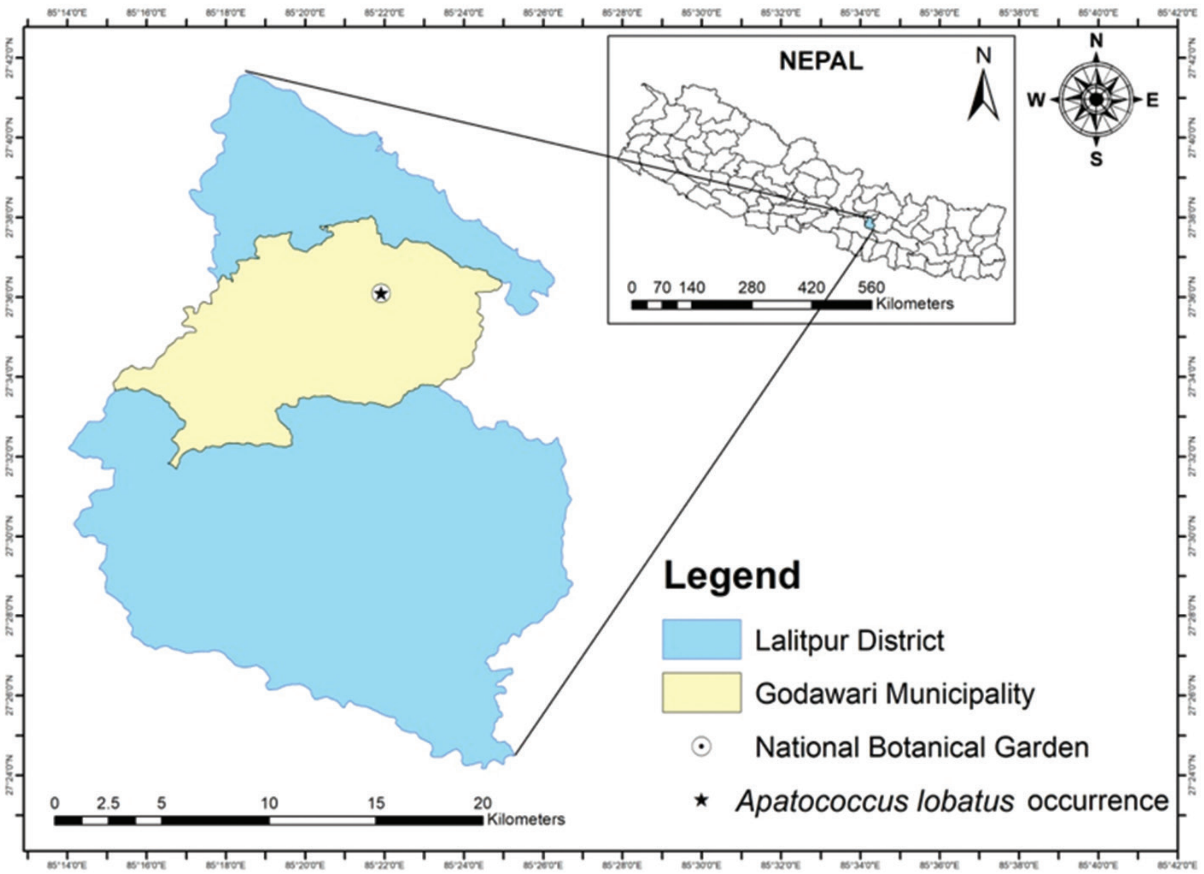

Figure 1: Map showing the occurrence of *A. lobatus* (Chodat) J. B. Petersen in the study area (NBG, Godawari)

Fig. 2 (A): Growth of *A. lobatus* on painted iron pole; and (B): Collection of algal sample in a bottle using a toothbrush

Results

Taxonomic treatment: The taxonomic treatment of Petersen (1928) was followed while confirming the samples of *A. lobatus* in the Laboratory.

Basionym: *Pleurococcus lobatus* Chodat (1902).

The cells of this species were found to be spherical to slightly irregular in shape; the mature ones being in the group of 2–4 in number divided in both horizontal and vertical directions; cell–diameter being 3.7–7.2 µm; chloroplast parietal, and pyrenoid inconspicuous (Figure 3).

Collectors of samples: The samples were collected by S. Dhakal and R. Tamang of the NBG.

Date of collection: 10th August, 2021.

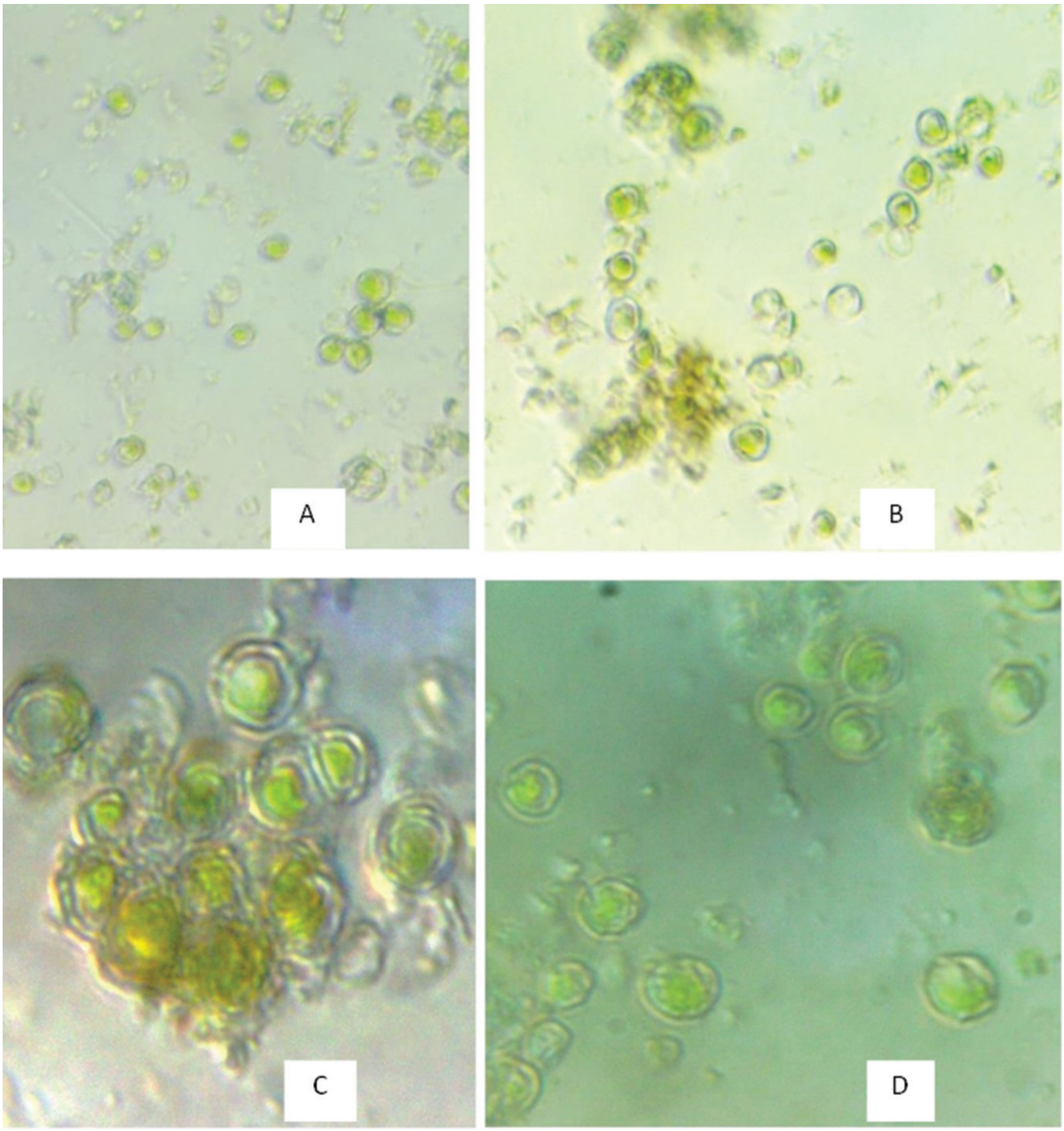

Figure 3 (A–C): Cell morphology and colony formation of *A. lobatus*; (D): Cells representing parietal chloroplast.

Discussion

The finding of the genus *Apatococcus* as new record in National Botanical Garden area; one of the most familiar and important scientific research centers of department of Plant Resources reveals that we need to do more exploration regarding the algal flora of Nepal and young researchers are needed to be a focus for future algal survey.

Conclusion

A. lobatus (Chodat) J. B. Petersen found in the NBG of Godawari (Lalitpur district) was detected as a new generic record for algal flora of Nepal.

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