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*

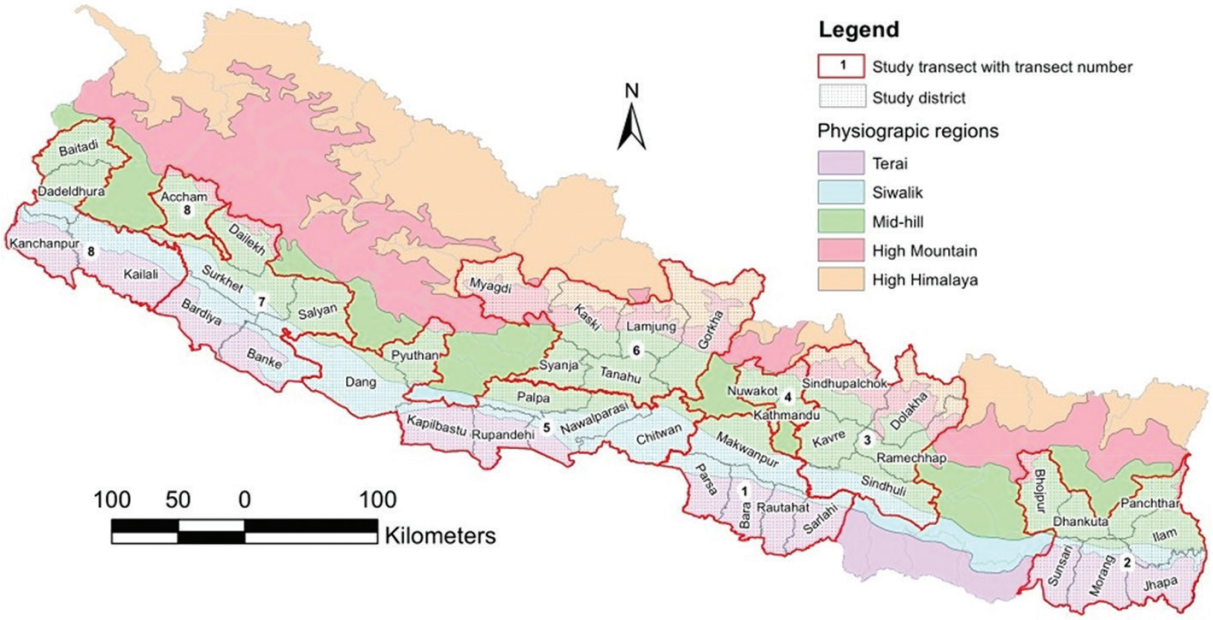

Figure 1: Map showing the study locations along with the physiographic regions of Nepal

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.

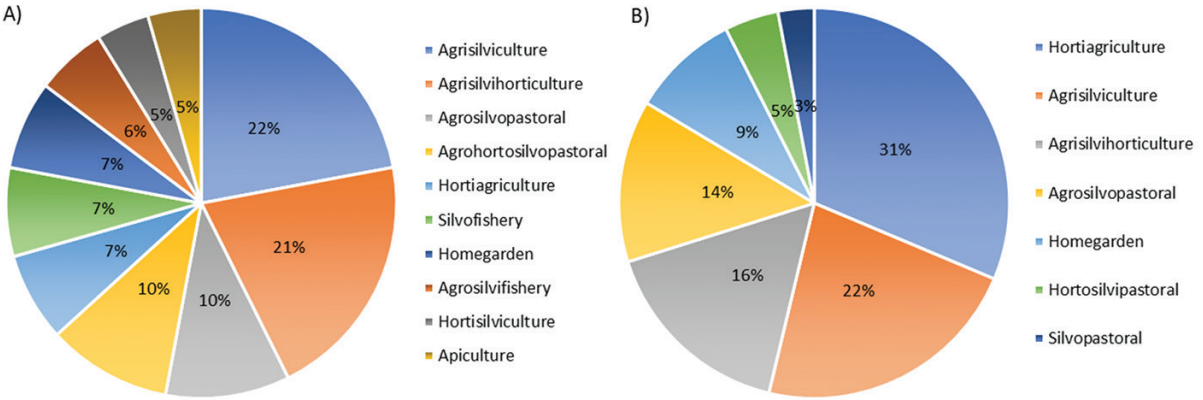

Figure 2: Agroforestry systems adopted in the A) Terai and B) hills of Nepal

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

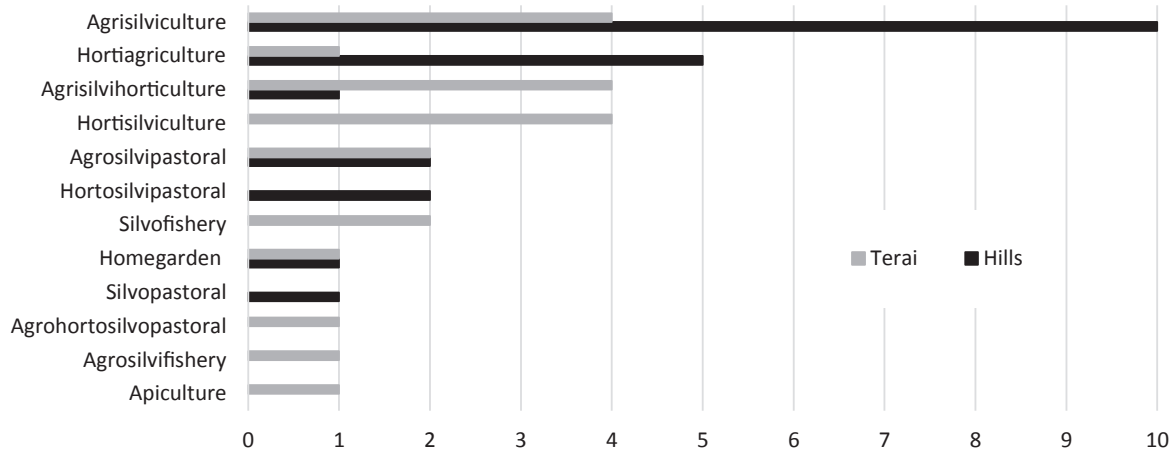

Figure 3: Diversity of agroforestry practices within the systems

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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