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System units and constraints of existing agroforestry systems in North - Western Himalayas

Ranjeet Singh, KS Pant, Prabhat Tiwari and Rajeev Dhiman

Abstract
The study was carried out to identify the existing Agroforestry systems as well as system units and technological constraints present there in Agroforestry systems in North–Western Himalayas. The study area was divided into 5 altitudinal zones. In each altitudinal zone farmers were selected based on their land holding size and further grouped into 3 farmer's category *viz*., marginal, small and medium. The agroforestry systems identified among 3 farmer's categories in all the altitudinal zones were Agri-Silviculture (AS), Agri-Horticulture (AH), Horti-Agriculture (HA), Horti-Pastoral (HP), Pastoral-Silviculture (PS), Pastoral-Horti-Silviculture (PHS) and Silvi-Pastoral (SP).The most pre-dominant Agroforestry systems were Agri-Horticulture (AH), Horti-Agriculture (HA), Horti-Pastoral (HP) and Agri-Silviculture (AS). The study revealed that horticulture based agroforestry systems seem to a play vital role in socio-economic upliftment of farming communities in the study area. It is also evident from the study that lack of awareness regarding government sponsored schemes is a major constraint in the study area which needs to be solved with the best possible solutions.

Keywords: System units and constraints of existing agroforestry systems

Introduction
Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system (Lundgren, 1982) [6]. According to Nair (1979) [8], agroforestry is a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers.

North western Himalaya is basically an agro-ecosystem, where 90 percent of its total population lives in villages, whose economy is dependent on agriculture, horticulture and animal husbandry (Atul *et al.,* 1994) [2]. Various fodder, fuel wood and timber trees are deliberately retained on bunds of agriculture fields and species composition varies depending on land holdings and basic requirement of the farmers of the state (Toky *et al.,* 1989) [12]. Forest area is reducing and degrading at a faster pace and it has become difficult to fulfill the fuel, fodder, timber and other forest based requirements of a huge and ever increasing population from a lesser area of forest. To fulfill basic requirements of people is the need of hour, but at the same time fragile and sensitive environment is to be taken care of. In this context, the concept of agroforestry, which is a mutual adjustment of agricultural crops and forest tree species for the benefit of people and nature as a whole, seems to be the answer. Numerous agroforestry systems both natural as well as manmade have been developed in different agro-climatic regions of the country, which have been found highly productive and environmental/ecofriendly. In fact the agroforestry momentum is getting a good response in India. India launched National Agroforestry Policy in 2014 and became the first country in the world to have a National Agroforestry Policy (Anonymous 2014) [1]. The prosperity of the hill communities has traditionally been depended on forest, farming, and livestock (Yadav *et al.*, 2016) [13]. It has been shown that the socially and culturally valued species in agroforestry systems, right across the Himalayan region and elsewhere in the world where traditional agriculture is practiced, are invariable ecological keystone species within the ecosystem (Ramakrishnan, 2007). Such systems ensure sustained yield potentials, conservation benefits, and multiple output possibilities in resource holding units, whereas monoculture based agriculture or forestry may not be feasible or desirable. Therefore, there is a need to record the species composition, diversity and productivity in the existing land use systems. Agroforestry systems can take an almost infinite number of different forms, as they have the potential to

include any of the crops, animals, and tree species used in agriculture and forestry. This tremendous potential variability allows agroforestry systems to meet the needs of farmers under almost any set of environmental, economic and social conditions. The studies directed towards these determining factors will add to better understanding of land use systems and investigation of the main features of mixed tree farming system in the selected area, will help to understand the type of system, technology used, resource requirements, profitability and major constraints of the system. These studies also help in assessment of profitability and acceptability of the systems.

Material and Methods

The study was carried out in Shimla district of Himachal Pradesh that lies under North-western Himalayan region having 30°45" to 31°40" N latitude and 77°0" to 78 °19" E longitude. The altitude of the district ranges between 700-5500 m amsl as shown in Figure 1. The climate of the district varies from sub-tropical in low hills and valleys to sub-humid in the mid hills and temperate in high hills. Precipitation in the form of rainfall (average annual 1000mm), snowfall (in upper ridges) and hail is received in the area. Average minimum and maximum temperature of the district lies between -4 °C to 31 °C, respectively.

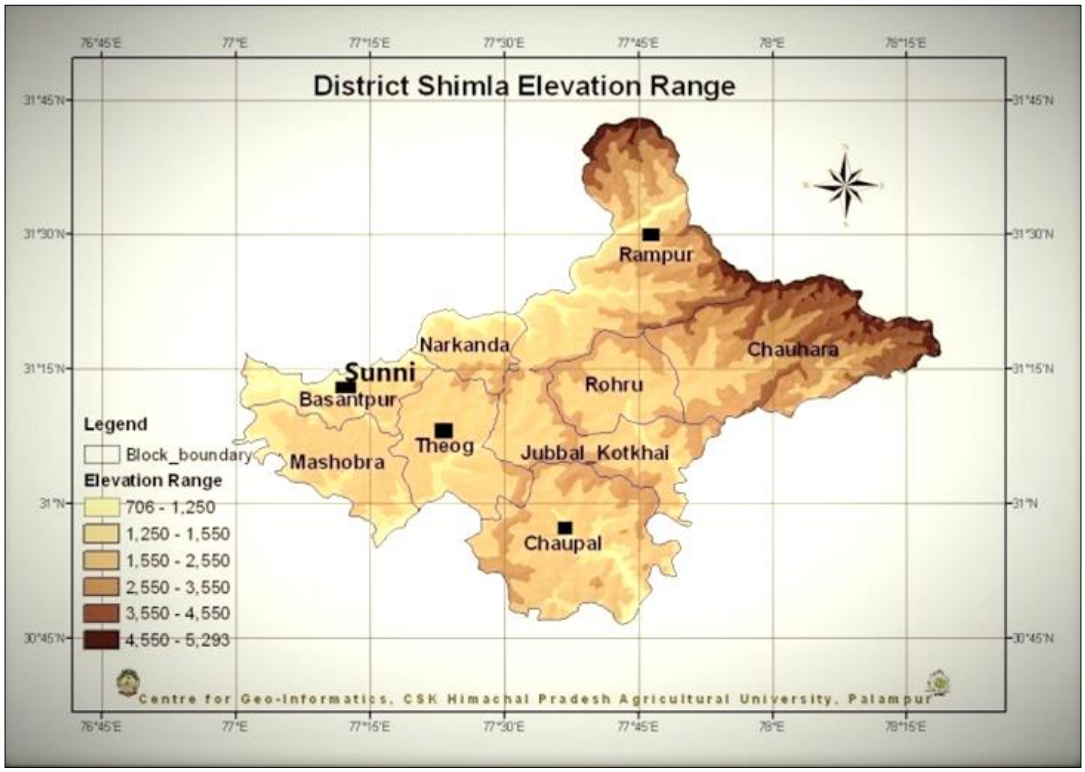

Fig 1: Location map of the study sites in Shimla district (H.P.)

Study sites were selected through stratified multistage random sampling technique and the District was divided into five altitudinal zones (Table 1) *viz*., Zone I (500-1000m amsl), Zone II (1000-1500m amsl), Zone III (1500-2000m amsl), Zone IV (2000-2500m amsl) and Zone V (>2500m amsl). In each altitudinal zone, four panchayats were selected randomly and from each selected panchayat, farmers were divided into three different categories on the basis of their land holding *viz*., marginal (< 1 ha), small (1-2 ha) and medium (2-5 ha). A random sample of five farmers from each category was taken as ultimate unit of study (Table 1)**.** Relevant information from farmer's was collected on pre-structured schedules and open ended interviews with each household head.

Agroforestry systems existing in the study area were identified on the basis of structure (nature and arrangements) and function (role of output) of the components (Nair, 1985) [8]. However, stratified classification of agroforestry practices given by Zou and Sanford (1990) [14] were used to indicate the type of systems and system units. The land and crop management practices present among the farmers were compared and contrasted with the stranded recommended practices for the region in terms of agricultural crops, tree species and allied activities to point out technological gaps and suitable interventions to bridge those gaps.

Table 1: Category wise number of farmers in the study area

Altitudinal Zone	Shimla district		
	Farmer's category		
	Marginal	Small	Medium
Zone –I (500-1000 m)	20	20	20
Zone –II (1000-1500 m)	20	20	20
Zone –III 1500-2000 m)	20	20	20
Zone –IV (2000-2500 m)	20	20	20
Zone –V (>2500 m)	20	20	20
Total	100	100	100

Results and Discussion

Agroforestry systems and their system units

Altitudinal Zone-I (500-1000m amsl) and Altitudinal Zone-II (1000-1500 m amsl)

In altitudinal Zone-I and Zone-II, five different agroforestry systems have been identified among three farmer's category. These systems were Agri-silviculture, Agri-horticulture, Silvi-pastoral, Pastoral-silviculture and Pastoral-horti-silviculture (Table 2). The specific system units present in identified agroforestry systems in both altitudinal zones are given in Table 3.

Table 2: Comparative status of various agroforestry system types in different Altitudinal zones and farmers category of Shimla District of H.P.

AFS Type	Altitudinal zone-I			Altitudinal zone-II			Altitudinal zone-III			Altitudinal zone-IV			Altitudinal zone-V		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AS	17	13	9	15	13	11	-	-	-	-	-	-	-	-	-
AH	10	9	11	12	14	10	14	10	10	10	9	10	9	10	7
HA	-	-	-	-	-	-	14	17	12	11	12	12	15	14	12
HP	-	-	-	-	-	-	-	9	10	11	10	10	16	9	14
PHS	-	8	9	-	-	10	12	-	8	-	-	-	-	-	8
PS	-	10	-	-	8	9	-	9	-	-	-	8	-	8	-
SP	15	-	11	13	7	-	-	-	-	10	9	-	-	-	-

Where twenty farmers were interviewed in each farmer's category

Table 3: System units of existing agroforestry systems in Shimla district under Altitudinal Zone –I (500-1000 m amsl.) and Zone-II (1000-15000 m amsl.)

Agroforestry Systems (AFS)	Crops		Vegetation pattern	
	Main crops	Subsidiary crops	Tree species	Pastures
Agri-Silviculture (AS)	*Triticum aestivum, Hordeum vulgare, Zea mays, Oryza sativa, Capsicum Annun L., Phaseolus vulgaris, Solanum lycopersicum*	*Colocasia esculenta, Sesamum indicum L., Curcuma longa, Brassica nigra, Allium sativum, Raphanus sativus, Brassica oleracia, Pisum sativum, Solanum tuberosum, Corriandrum sativum*	*Acacia catechu, Anogeissus latifolia, Terminalia bellerica, Bauhinia variegata, Morus alba, Grewia optiva, Leucaena leucocephala, Toona ciliata, Melia azedarach, Celtis australis, Ficus palmata, Quercus glauca, Pinus roxburghii*	---
Agri-Horticulture (AH)	*Triticum aestivum, Hordeum vulgare, Zea mays, Oryza sativa, Capsicum Annun L., Phaseolus vulgaris*	*Pisum sativum, Solanum tuberosum, Coriandrum sativum, Colocasia esculenta, Sesamum indicum L. Curcuma longa, Brassica nigra, Allium sativum, Brassica oleracea, Solanum lycopersicum*	*Citrus limon, Punica granatum, Citrus aurantifolia, Mangifera indica, Prunus domestica, Prunus persica, Prunus armeniaca, Juglans regia, Citrus pseudolimon, Pyrus communis*	---
Silvi-Pastoral (SP)	--------	--------	*Acacia catechu, Anogeissus latifolia, Terminalia bellerica, Bauhinia variegata, Morus alba, Grewia optiva, Leucaena leucocephala, Toona ciliata, Melia azedarach, Celtis australis, Ficus palmata, Quercus glauca, Pinus roxburghii*	*Chrysopogon montanus, Panicum coloratum, Dichanthium annulatum, Cymbopogon martinii, Heteropogon contortus*
Pastoral-Silviculture (PS)	---------	-------	*Acacia catechu, Bauhinia variegata, Morus alba, Melia azedarach, Toona ciliata, Celtis australis, Leucaena leucocephala, Eucalyptus* spp., *Ficus palmata, Quercus glauca, Pinus roxburghii, Salix alba*	*Chrysopogon martinii, Heteropogon contortus, Chrysopogon montanus, Dichanthium annulatum, Panicum maximum, Apluda mutica*
Pastoral-Horti-Silviculture (PHS)	--------	------	*Psidium guajava, Leucaena leucocephala, Mangifera indica, Citrus aurantifolia, Punica granatum, Grewia optiva, Morus alba Citrus limon, Toona ciliata, Juglans regia, Bauhinia variegata, Quercus glauca, Prunus persica,Prunus domestica, Prunus armeniaca, Pyrus communis*	*Cymbopogon martinii, Chrysopogon montanus, Panicum maximum, Apluda mutica, Dichanthium annulatum,*

Altitudinal Zone-III (1500-2000 m amsl): In this zone, five different agroforestry systems were identified among all the farmer's category, i.e., Agri-horticulture, Horti-agriculture, Horti-pastoral, Pastoral-silviculture, and Pastoral-horti-silvculture. The specific system units present in identified agroforestry systems in this zone are shown in Table 4.

Table 4: System units of existing agroforestry systems in Shimla district under Altitudinal Zone -III (1500-2000 m amsl.)

Agroforestry Systems (AFS)	Crops		Vegetation pattern	
	Main crops	Subsidiary crops	Tree species	Pastures
Agri-Horticulture (AH)	*Pisum sativum, Zea mays, Phaseolus vulgaris*	*Colocasia esculenta, Brassica oleracia, Solanum tuberosum, Capsicum annum, Coriandrum sativum*	*Malus domestica, Pyrus communis, Prunus domestica, Prunus armeniaca, Prunus persica, Juglans regia*	-----
Horti-Agriculture (HA)	*Pisum sativum, Zea mays, Phaseolus vulgaris*	*Colocasia esculenta Brassica oleracia, Solanum tuberosum, Capsicum annum, Coriandrum sativum, Hordium vulgare*	*Malus domestica, Pyrus communis, Prunus domestica, Prunus armeniaca, Prunus persica, Juglans regia*	----
Horti-Pastoral (HP)	---------	--------	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Juglans regia,*	*Themeda anathera, Cynodon dactylon, Andropogon*

			Prunus persica	*nardus, Pennisetum clandestinum, Apluda mutica,*
Pastoral-Silviculture (PS)	--------	-------	*Quercus leucotrichophora, Pinus wallichiana, Cedrus deodara, Salix alba, Ficus palmata, Rhododendron arboreum*	*Cynodon dactylon, Andropogon nardus, Pennisetum clandestinum, Themeda anathera, Apluda mutica*
Pastoral-Horti-Silviculture (PHS)	-------	------	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica, Quercus leucotrichophora, Pinus wallichiana, Cedrus deodara, Ficus palmata, Salix alba*	*Cymbopogon martinii, Themeda anathera, Cynodon dactylon, Apluda mutica*

Altitudinal Zone-IV (2000-2500 m amsl): In altitudinal Zone-IV, there were five different agroforestry systems prevalent among all the farmer's category, i.e., Agri-horticulture, Horti-agriculture, Horti-pastoral, Silvi-pastoral and Pastoral-horti-silviculture (Table 2). The system units of identified agroforestry systems in altitudinal Zone-IV are shown in Table 5.

Table 5: System units of existing agroforestry systems in Shimla district under Altitudinal Zone -IV (2000-2500 m amsl.)

Agroforestry Systems (AFS)	**Crops**		**Vegetation pattern**	
	Main crops	**Subsidiary crops**	**Tree species**	**Pastures**
Agri-Horticulture (AH)	*Pisum sativum, Zea mays, Phaseolus vulgaris, Brassica oleracea*	*Brassica capitata, Hordeum vulagare, Solanum tuberosum, Colocasia esculenta, Coriandrum sativum, Capsicum annum*	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Juglans regia, Prunus persica*	-------
Horti-Agriculture (HA)	*Pisum sativum, Zea mays, Phaseolus vulgaris, Brassica oleracea*	*Hordeum vulgare, Solanum tuberosum, Coriandrum sativum, Colocasia esculenta, Capsicum annun*	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Juglans regia, Prunus persica*	-------
Horti-Pastoral (HP)	-----	------	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica, Juglans regia*	*Agrostis spp., Bromus inermis, Cynodon dactylon, Andropogon nardus, Apluda mutica*
Silvi-pastoral (SP)	-------	------	*Quercus dilatata, Cedrus deodara, Pyrus pashia, Picea smithiana, Rhododendron arboreum, Abies pindrow, Salix alba*	*Andropogon nardus, Agrostis* spp., *Chrysopogon montanus, Cynodon dactylon, Apluda mutica,*
Pastoral-Horti-Silviculture (PHS)	-------	----------	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Quercus dilatata, Cedrus deodara, Salix alba, Rhododendron arboreum*	*Arundinella nepalensis, Agrostis* spp., *Bromus inermis, Chrysopogon spp.*

Altitudinal zone-V (>2500 m amsl)

In this zone, five different agroforestry systems namely Agri-horticulture, Horti-agriculture, Horti-pastoral, Pastoral-silviculture and Pastoral-horti-silviculture were identified among all the farmer's category (Table 2). The specific system units present in identified agroforestry systems in this zone are shown in Table 6.

The study depict that there were total seven agroforestry system types identified in the study area. Whereas, five agroforestry systems (AFS) were prevalent in each zone. The most predominant agroforestry systems in the study area were AH, HA followed by HP and AS, the existence of these systems may be attributed to local ecological condition. The Shimla district of Himachal Pradesh has highly diverse agro-ecological conditions due to wide altitudinal range, accompanied by variation in edaphic properties, *viz*., soil pH, fertility, soil structure, slope and aspect etc. Rainfall exhibits in the study area has wide variability with extremely cold and dry conditions occur with the climate of sub-tropical to temperate. Snowfall is peculiar feature of precipitation in higher altitudinal ranges of the District. These ecological variations have resulted in high plant biodiversity and variations in agroforestry systems. Farmers manage their farming systems for obtaining diversified products and higher returns.

The similar agroforestry systems have been identified by many researchers, Kachru (1997) [4] reported eight different agroforestry systems. Kumari *et al.* (2008) [5] reported that the traditional agroforestry practices have helped people in meeting their diverse needs, *viz*., food, fodder, fuel wood and timber. Further, they reported AH, AS, ASP, PS and PH as prevalent AFS in Lahaul and Spiti and Kinnaur District of Himachal Pradesh. Goswami (2009) [3] reported five different agroforestry systems in Kwaalkhad watershed in district Solan, Himachal Pradesh. Rajput (2010) [10] reported four types of agroforestry systems in Kullu valley of Himachal Pradesh. Nayak *et al.* (2011) [9] identified and categorized five different types of agroforestry systems in Lahaul and Spiti district. Results also show close conformity with the findings of Murthy *et al.* (2013) [9].

Table 6: System units of existing agroforestry systems in Shimla district under Altitudinal Zone-V (above 2500 m amsl.)

Agroforestry Systems (AFS)	Crops		Vegetation pattern	
	Main crops	Subsidiary crops	Tree species	Pastures
Agri-Horticulture (AH)	*Pisum sativum, Zea mays,, Phaseolus vulgaris, Solanum tuberosum*	*Brassica capitata, Hordeum vulagare, Colocasia esculenta, Coriandrum sativum, Capsicum annum Brassica oleracea*	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Juglans regia, Prunus persica, Prunus persica*	------
Horti-Agriculture (HA)	*Pisum sativum, Zea mays,, Phaseolus vulgaris, Solanum tuberosum*	*Brassica capitata, Hordeum vulagare, Colocasia esculenta, Coriandrum sativum, Capsicum annum Brassica oleracea*	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica, Juglans regia*	------
Horti-Pastoral (HP)	--------	-------	*Malus domestica, Pyrus communis, Prunus persica, Prunus domestica, Prunus armeniaca, Juglans regia*	*Agrostis* spp., *Poa annua, Trifolium repens, Arundinella nepalensis*
Pastoral-Silviculture (PS)	-----	-----	*Quercus dilatata, Cedrus deodara, Salix alba Rhododendron arboreum, Picea smithiana, Abies pindrow, Quercus semicarpifolia*	*Arundinella nepalensis, Agrostis* spp., *Poa annua, Trifolium repens,*
Pastoral-Horti-Silviculture (PHS)	-------	-----	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Quercus semicarpifolia, Cedrus deodara, Salix alba Picea smithiana, Abies pindrow*	*Arundinella nepalensis, Agrostis* spp., *Poa annua, Trifolium repens,*

Table 7: Technological constraints/gaps in the study area and their solutions:

Sr. No.	Constraints/ gaps	Solutions
	Social	
1	The main source of the off farm employment/income were government jobs, family business and employment as daily wagers either in private or public sector.	Off farm employment/income may be generated by giving impetus to agro based small scale industries at village, panchayat and block level.
2	Most of the farming communities of the study area were not retaining bullocks for the purpose of ploughing the field. They were rather dependent on tractors for this purpose which leads to less availability of FYM for their agricultural land and thus excessive use of chemical fertilizers was observed and complete organic farming was missing from the study area.	Vermicomposting and more use of biofertilizers should be encouraged.
3	Majority of animals in altitude zone-II and altitude zone-III reared by the farmers were of local breeds	Farmers should be encouraged to adapt improved breeds for this cattle show/fair, Kisanmela etc. should be organized.
	Scientific	
1	Use of local seeds for some agricultural crops such as colocasia, turmeric, wheat, rice, barley, maize and mustard etc. due to unawareness of High Yielding Variety seeds of these crops were raised as accessory components for their own consumption.	Need popularization of High Yielding Variety seeds through demonstrations, exposure visits and training to the farmers.
2	Disproportionate applications of insecticides / pesticides and fertilizers were observed in the study area for different agricultural crops and it was also observed that farmers were not following the recommended package of practices. (Based on Personal interview)	Farmers need to be apprised of the balanced use of insecticides, pesticides and fertilizer application for their main cash crops so as to minimize the crop yield losses and to enhance the overall income from the same unit of land
3	Some farmers were adopting scientific breeding methods for their local breeds along with improved breeds but this practice was leading adverse impact on the health of local breeds especially during gestation period. (Based on Personal interview)	Local breeds must be kept pure and free without adopting scientific breeding methods/ techniques for purpose of Subhash Palekar natural farming.
4	Tomato, garlic, ginger, capsicum, bean and pea were the most dominant agriculture cash crops grown by the farmers.	Farmers should be made aware of the importance of other agricultural crops also so as to boost up overall income from same unit of land.
5	Agroforestry system identified were traditional and less productive	Poultry, apiculture, floriculture, medicinal and aromatic plants etc. could be introduced in the existing agroforestry systems to make them productive.
	Infrastructural gaps	
1	Occurrence of fragmented landholdings was a major hurdle in adopting potential agroforestry interventions.	Efforts at various levels should be made to consolidate the fragmented landholdings.
2	Farmers were not getting the fair price of their agricultural produce due to the absence of efficient marketing channels and government authorized sale centers near the villages. (Based on personal interview)	Govt authorized sale centers should be opened at accessible places and efficient marketing channels should be developed so that farmers may get fair price for their farm produce.
3	Communication gap between labs to land was a hurdle in adopting new scientific interventions for any further improvement in agroforestry systems.	Locality specific diagnostic survey should be conducted so as to identify various constraints faced by the farming communities and also there is a need to strengthen the extension network so as to impart accurate information to the farmers well in time.
4	Lack of agro processing facilities and sound marketing network at village, panchayat and block level.	Agro processing facilities and marketing network should be strengthened at village, panchayat and block level under small scale industries.
5	Farming communities were not adequately benefited by the government	Government and its various agencies should ensure that every

	sponsored schemes due to the indifferent attitudes of some of the stakeholders towards the farmers of the area. (Based on personal interview)	farmer should get the benefit of the various government sponsored schemes which are being implemented for improving the socio-economic status of the farming communities.

Conclusion

Agroforestry systems (AFS) can play a vital role in environmental and ecological sustainability in North-Western Himalayas. Seven types of different agroforestry systems were identified in all the altitudinal zones. The study revealed that the most pre-dominant agroforestry systems existing in study area were Agri-Horticulture (AH), Horti-Agriculture (HA), Horti-Pastoral (HP) and Agri-Silviculture (AS). Farming communities in the study area were facing the lack of government schemes related to their farming practices due to unawareness and unusual attitude of implementing agencies. Lack of improved technologies in farming practices is a major constraint in North-Western Himalayan region.

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