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System units under prevalent agroforestry systems in north-western Himalaya and their constraints

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Abstract
Our objective to observed the system units of different agroforestry systems and major constraints in North-Western Himalaya under Sirmaur district of H.P. The study area had three prevailing agriculture based agroforestry systems viz. agri-silvi-culture, agri-horticulture and agri-silvi-horticulture system as well as pasture based agroforestry systems viz. agri-silvi-pasture, silvi-pasture, pastoral-silvi-culture and pastoral-silvi-horticulture system at three altitudinal zones representing three categories of farmers. The results showed that ASH system attributed various economic important crops viz. tomato, garlic, pea etc. and numerous forest and fruit trees which is important to people livelihood and lack of improve technologies is major drawback which has to be overcome under this study area.

Keywords: System-units, agri-silvi-horticulture; agri-horticulture; livelihood; study area

Introduction
Agroforestry has long tradition in Himalayan region of India, where trees are cultivated extensively in the combinations of crops and/or livestock production system. The most prevalent land use system in Himalaya includes pure horticultural crop, horticulture based inter-cropping, forestry, agroforestry and dairy farming. A number of grain crops, rhizomatous crops and vegetables are being grown with number of fruit, timber and fodder trees in different agro-climatic zones. The prosperity of the hill communities has traditionally been depended on forest, farming and livestock (Yadav *et. al.*, 2016) [9]. Existing agroforestry systems in the Himalayan region play a vital role for fulfilment of the basic needs of the rural community. These agroforestry systems helped in increasing the overall productivity and catering the daily domestic needs of farmers. With such economic benefits, agroforestry promotes the sustainable alternative livelihood, improves soil quality, empowers rural community particularly vulnerable population groups including women, and enhance their participation in productive activities. The agroforestry systems of this state are quite mature and ecologically in the steady state.
North-western Himalyas particularly Sirmaur district of Himachal Pradesh, which falls in the transition zone between lesser to greater Himalayas, has got two conspicuous types of land features i.e. valley areas and mountainous region. This district is well known for its rich biodiversity, magnificent forest, apple orchards, off-season vegetables and traditional field crops.
Over the years (particularly 1960s onward), the farmers have developed their own agroforestry systems. But the weak scientific knowledge base about socio-economic and technical aspects of agroforestry system and the values of local farmers' experiences make on farm research important in agroforestry. Moreover, diagnosis and design research methodology is required prior to long term experimental programs. In order to improve the efficiency of indigenous agroforestry system, as well as to assess the performance of improved technologies, we need to have a systematic procedure to evaluate such systems. These studies also help in assessment of prevelant agroforestry system and their components as well as major constraints to acess acceptability of the systems.

Material and methods
The study was carried out in Sirmaur district of H.P., bounded by latitude 30°22'30"–31°01'20"N and longitude 77° 01'12"–77°49'40"E having elevation range from < 1000 m to >2000 m in Sirmaur district of North West Himalaya (Himachal Pradesh), India. The climate of Sirmaur district is sub-tropical to temperate depending upon the elevation (Figure-1). The study sites was selected through multistage stratified random sampling technique and Sirmaur

district was divided into three altitudinal ranges viz. Range I (< 1000 m amsl), Range II (1000-2000 m amsl) and Range III (>2000 m amsl). In each altitudinal range, four panchayats were selected randomly (Table-2) and from each selected panchayat, farmers were divided into three different farmers category on the basis of their land holding viz. marginal, small and medium (Table-1) and finally sample of five farmers from each category was taken as ultimate unit of the study. The relevant information about the study was collected through pre tested schedule by personal interview with each head of the household was made.

The entire study area was delineated into three altitudinal zones viz. Z1 (<1000 m), Z2 (1000– 2000 m) and Z3 (>2000 m), in each zone, four sites (approximately) were selected for identification of agroforestry systems, sampling of crops and measurement of trees. All the four sites in each elevation zone were surveyed. In total, 180 households according to farmer's category representing 12 panchayats were surveyed. Out of 180 households, 60 was marginal category, 60 was small category and 60 was medium category (Table-3)**.**

Agroforestry systems existing in the study area were identified on the basis of structure (nature and arrangement) and function (role/output) of components (Nair, 1985) [7]. However, stratified classification of agroforestry practices given by Zou and Sanford (1990) [10] was used to indicate the type of systems and system units. Systems types were named considering the major components, whereas system unit termed as basic function unit was identified as combination of specific crop species within a component with the species of other components. Hence, functional unit like food grain, vegetables and pulses in agriculture, specific fruit tree in horticulture, grasses in pasture and tree species in forestry components was described.

The land and crop management practices prevailing among the farmers were compared and contrasted with the standard recommended practices for the region in terms of agriculture crops, tree species and allied activities to point out technological gaps.

Results and discussion

Agroforestry systems and their system units

Altitudinal zone I (<1000 m amsl)

In altitudinal zone I, seven agroforestry systems have been identified among different farmers category. These systems were Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Agri-silvi-pasture (ASP), Pastoralsilviculture (PS), Silvi-pasture (SP) and Pastoral-silvi-horticulture (PSH) (Table-4).

The specific system units under agricultural components in the study area of altitudinal zone I in all farmers category were paddy, maize and wheat as the primary components where as secondary components were capsicum, moong bean, urd bean, sesame, turmeric, chili, pea, potato, coriander, mustard, tomato, garlic, onion, radish and cauliflower. Under horticulture components *Mangifera indica, Citrus limon, Psidium guajava, Citrus sinesis, Litchi sinesis, Citrus aurantifolia, Carica papaya* and *Juglans regia* were identified as functional units. The forestry components consisted of *Toona ciliata, Bahunia variegata, Acacia catachu, Morus alba, Terminalia bellerica Grewia optiva, Eucalyptus, Anogeisus latifolia, Shorea robusta, Melia azadirachta etc.* Major grass species viz. *Chrysopogon martinii, Heteropogon contortus, Chrysopogon montanus, Dichanthium annulatum, Panicum coloratum* and *Panicum maximum* were present in this altitudinal zones (Table-5).

Altitudinal zone II (1000-2000 m amsl)

In this altitudinal zone six different agroforestry system type were identified in different farmer's category, these systems types were Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Pastoral-silviculture (PS), Silvi-pasture (SP) and Pastoral-silvi-horticulture (PSH) (Table-4).

In the altitudinal zone II, the specific system units under agricultural components in all farmers category were tomato, maize and wheat as the primary components where as secondary components were capsicum, bean, colocassia, ginger, urdbean, garlic, pea, potato and onion. Under horticulture components *Prunus domestica, Prunus persica, Pyrus communis, Prunus armeniaca, Litchi sinesis, Psidium guajava, Citrus limon* and *Juglans regia* were identified as functional units. The forestry components consisted of *Toona ciliata, Bahunia variegata, Morus alba, Grewia optiva, Eucalyptus, Celtis australis, Anogeisus latifolia, Bombax ceiba, Leucaena leucocephala, Salix alba etc.* Major grass species viz. *Apluda mutica, Heteropogon contortus, Cymbopogon martini, Chrysopogon montanus, Dichanthium annulatum* were present in the altitudinal zone II (Table-6).

Altitudinal zone III (>2000 m amsl)

There were six agroforestry system types predominant in the altitudinal zone III of Sirmaur District among various farmers category, the systems were Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Pastoral-silviculture (PS), Silvi-pasture (SP) and Pastoral-silvi-horticulture (PSH) (Table-4).

The specific system units in altitudinal zone III, irrespective of all farmers category under agricultural components were ginger, cauliflower, garlic as the primary components where as secondary components were capsicum, bean, calocassia, tomato, maize, kidney bean, chili, turmeric, pea, wheat, coriander and onion. Under horticulture components *Prunus domestica, Malus domestica, Pyrus communis, Prunus armeniaca and Juglans regia* were identified as functional units. The forestry components in this altitudinal zones consisted of *Grewia optiva, Toona ciliata, Bahunia variegata, Morus alba, Celtis australis, Bombax ceiba, Populas deltoides, Ficus Palmata etc.* Major grass species present were *Arundinella nepalensis, Ischaemum aristatum, Cymbopogon martinii, Apluda mutica, Ischaemum spp, Themeda anathera* (Table-7).

The study showed that there were seven Agroforestry Systems (AFS) in the zone I whereas six AFS in the zone II and zone III. Among different AFS in the study area the most predominant AFS were Agri-horticulture (AH), followed by Agri-silviculture (AS) and Agri-silvi-horticulture (ASH).

The most predominant AFS of study area were AH, AS and ASH, these systems may be attributed to local ecological condition. The Sirmaur district of Himachal Pradesh has highly diverse agro-ecological conditions due to wide altitudinal range, accompanied by variation in properties of edaphic strata viz. soil pH, fertility, soil structure, slope, aspect etc. Rainfall exhibits in the study area has wide variability and extremely cold and dry conditions occur with the climate of sub-tropical to temperate. These ecological variations have resulted in high plant biodiversity and consequently variations in agroforestry systems. Farmers manage their farming system for obtaining diversified products and higher returns. The similar agroforestry systems have been identified and reported by many workers. Kachru (1997) [3] reported eight agroforestry systems namely, agri-

silviculture (Maize, Wheat, Blackgram and Grewia, Morus), agri-horticulture (Wheat, Mustard and Pear), agri-silvi-horticulture (Wheat, Mustard, Grewia and Apricot), pastoral-silviculture (Grewia, Bauhinia and grasses), pastoral-horti-silviculture (Pear, Plum, Grewia and grasses), agri-horti-silviculture (Maize, Blackgram Pear and Grewia), pastoral-silviculture (Chir pine, Acacia and grasses), and pasture in mid-hills of Himachal Pradesh. Results were also close conformity with the findings of Murthy *et. al.* (2013), Kumari *et. al.* (2008) and Goswami (2009) [6, 4, 5].

Technological constraints/gaps in the system

Studies on identification of existing agroforestry practices and systems in the study area have helped for identifying social, technical, infrastructural and miscellaneous constraints/gaps inflicting the tree crop production systems. Land utilization patterns and management practices for crops, trees, pastures and animal prevalent in the area have shown inherent weakness and also the potentials for the improvement. Besides that unawareness of govt. sponsored welfare schemes and lack of facilities especially in altitude zone II and III, due to inaccessible area also plays an important role for constraints in the system. Keeping in view the major social, technical and infrastructural constraints/gaps have been identified and have been described collectively for all the altitudinal zones as under (Table 8).

Table 1: Farmer category on the basis of operational land holdings size

S. No.	Farmers categories	Size of operational land holding
1.	Marginal	<1 ha
2.	Small	1-2 ha
3.	Medium	2-5 ha

*As per classification of government of Himachal Pradesh

Table 2: Category wise number of farmers found in the study area

Particular of study area	Study area		
	Sirmaur District		
	Farmers category		
	Marginal	Small	Medium
Altitude Zone –I	20	20	20
Altitude Zone –II	20	20	20
Altitude Zone –III	20	20	20
Total	60	60	60

Table 3: Altitude wise selected panchayats of Sirmaur district of H.P.

Study sites of Sirmaur District	
Name of the panchayats	Altitude
Sainwala, Dhola Kuan, Kolar and Satiwala	<1000 m
Dimbar, Kothia jajar, Thor niwar and Nehar pab	1000-2000 m
Nohra, Ghanduri, Deona and Devamanal	>2000 m

Table 4: Comparative status of various agroforestry system types in different Altitudinal zones and farmers category of Sirmaur District of H.P.

AFS Type	Altitudinal zone- I			Altitudinal zone- II			Altitudinal zone- III		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AS	-	12	9	7	12	7	6	-	8
AH	10	-	11	13	8	8	8	14	12
ASH	10	8	-	-	-	5	6	6	-
ASP	8	11	-	-	-	-	-	-	-
PS	-	9	-	20	-	8	9	11	20
SP	12	-	14	-	14	-	11	-	-
PSH	-	-	6	-	6	12	-	9	-

Table 5: System units of Sirmaur District under altitudinal zone I (<1000m)

Agroforestry systems	Vegetation pattern			
	Crops		Tree species	Pasture
	Primary	Secondary		
Agri-silviculture system(AS)	Paddy, Maize-Wheat, Barley	Ginger, Capsicum, kidney bean, Horse gram, Moong bean, Urdbean, Sesame, Turmeric, Chili- Pea, Potato, Coriander, Carrot, Turnip, Lentil, Mustard, Tomato, Garlic, Onion, Radish, Cauliflower	*Toona ciliata, Bahunia warrigata, Acacia catachu, Morus alba, Terminalia bellerica Grewia optiva, Eucalyptus, Anogeisus latifolia, Shora robusta, Melia azadirachta*	-
Agri-horticulture system(AH)	Paddy, Maize - Wheat, Barley	Capsicum, Moong bean, Urd bean, Sesame, Turmeric, Chili- Pea, Potato, Coriander, Mustard, Tomato, Garlic,	*Mangifera indica, Psidium guajava, Citrus limon, Citrus sinesis, Litchi sinesis, Citrus aurantifolia, carica papaya,*	-

		Onion, Radish, Cauliflower	*Juglans regia*	
Agri-silvi-horticulture system(ASH)	Tomato-Wheat	Maize, Capsicum, Bean, Turmeric, Chili- Garlic, Pea, Potato, Mustard	*Morus alba, Mangifera indica, Anogeisus latifolia, Grewia optiva, Psidium guajava, Bahunia warrigata, Acacia catachu, Shora robusta, Citrus limon, Citrus sinesis, Litchi sinesis, Punica granatum, Terminalia bellerica*	-
AGRI-SILVI-PASTORAL (ASP)	Maize -Wheat	Sesame, turmeric chili-Barley, mustard, potato, garlic, onion, cauliflower	*Toona ciliata, Shora robusta, Eucalyptus, Celtris australis, Bombax ceiba, Anogeisus latifolia*	*Heteropogon contortus, Chrysopogon montanus, cymbopogon martini, Panicum coloratum*
SILVI-PASTORAL (SP)	-	-	*Melia azadirachta, Bombax ceiba, Shora robusta, Terminalia chebula, Eucalyptus, Diospyrus melanoxylon, Anogeisus latifolia, Butea monosperma*	*Chrysopogon montanus, Panicum coloratum, Dichanthium annulatum, cymbopogon martini, Heteropogon contortus*
PASTORAL-SILVICULTURE (PS)	-	-	*Diospyrus melanoxylon, Butea monosperma, Terminalia bellerica, Celtris australis, Shora robusta, Anogeisus latifolia, Melia azadirachta, Eucalyptus*	*Chrysopogon martinii, Heteropogon contortus, Chrysopogon montanus, Dichanthium annulatum, Dichanthium annulatum, Panicum coloratum, Panicum maximum*
PASTORAL- SILVI-HORTICULTURE (PSH)	-	-	*Psidium guajava, Leucaena leucocephala, Bahunia varrigata, Mangifera indica, Eucalyptus, Anogeisus latifolia, Grewia optiva, Melia azadirachta, Citrus limon, Butea monosperma*	*Chrysopogon martinii, Heteropogon contortus, Chrysopogon montanus, cymbopogon martini, Dichanthium annulatum, Panicum coloratum, Panicum maximum*

Table 6: System units of Sirmaur District under altitudinal zone II (1000-2000m)

Agroforestry systems	**Vegetation pattern**			
	Crops		**Tree species**	**Pasture**
	Primary	**Secondary**		
Agri-silviculture system(AS)	Tomato, Maize -Wheat, Barley	Capsicum, Bean, Calocassia, Ginger, Urdbean- Garlic, Pea, Potato, Onion	*Toona ciliata, Bahunia warrigata, Morus alba, Grewia optiva, Eucalyptus, Celtris australis, Anogeisus latifolia, Bombax ceiba, Leucaena leucocephala, Salix alba*	-
Agri-horticulture system(AH)	Tomato, Maize -Wheat	Capsicum, Bean, kidney bean, Calocassia, Chili-Garlic, Pea, Coriander, Onion, Potato, Mustard	*Prunus domestica, Prunus persica, Pyrus cummunis, Prunus armeniaca, Litchi sinesis, Psidium guajava, Citrus limon, Juglans regia*	-
Agri-silvi-horticulture system(ASH)	Tomato-Wheat	Maize, Capsicum, Bean, Turmeric, Chili- Garlic, Pea, Potato, Mustard	*Toona ciliata Prunus domestica, Ficus Palmata, Anogeisus latifolia, Grewia optiva, Juglans regia, Prunus armeniaca, Psidium guajava, Albizia lebback, Litchi sinesis, Eucalyptus*	-
PASTORAL-SILVICULTURE (PS)	-	-	*Pinus roxburgii, Bahunia varrigata, Grewia optiva, Sapindus mukrossi, Eucalyptus, Ficus Palmata*	*Apluda mutica, Heteropogon contortus, cymbopogon martini, Chrysopogon montanus, Dichanthium annulatum*
SILVI-PASTORAL (SP)	-	-	*Anogeisus latifolia, Albizia lebback, Pinus roxburgii, Ficus Palmata, Quercus leuchotrichophora, Bahunia varrigata, Moringa oleifera, Eucalyptus*	*Heteropogon contortus, cymbopogon martini,, Dichanthium annulatum, Apluda mutica, Heteropogon contortus*
PASTORAL- SILVI-HORTICULTURE (PSH)	-	-	*Pinus roxburgii, Quercus leuchotrichophora, Juglans regia, Prunus armeniaca, Anogeisus latifolia, Bombax ceiba, Bahunia varrigata, Ficus Palmata, Psidium guajava*	*Chrysopogon montanus, Heteropogon contortus, Apluda mutica, Dichanthium annulatum, Themada anathera. cymbopogon martini*

Table 7: System units of Sirmaur District under altitudinal zone II (>2000m)

Agroforestry systems	Vegetation pattern			
	Crops		Tree species	Pasture
	Primary	Secondary		
Agri-silviculture system(AS)	Ginger, Cauliflower-Garlic, Potato	Capsicum, Bean, Calocassia, Tomato, Maize, Kidney bean, Chili, Turmeric- Pea, Wheat, Coriander, Onion	*Grewia optiva, Toona ciliata, Bahunia warrigata, Morus alba, Celtris australis, Bombax ceiba, Populas deltoides, Ficus Palmata*	
Agri-horticulture system(AH)	Ginger, Cauliflower-Garlic, Pea	Capsicum, Bean, Chili- Potato, Coriander	*Prunus domestica, Malus domestica, Pyrus communis, Prunus armeniaca, Juglans regia*	
Agri-silvi-horticulture system(ASH)	Ginger, Cauliflower-Garlic, Pea	Bean, Tomato- Potato, Onion, Coriander	*Grewia optiva, Toona ciliata, Prunus domestica, Ficus Palmata, Juglans regia, Bahunia warrigata, Prunus armeniaca, Celtris australis, Bombax ceiba, Morus alba, Pyrus communis Populas deltoides*	
PASTORAL-SILVICULTURE (PS)	-	-	*Quercus dilatata, Bahunia warrigata, Pinus roxburgii, Quercus leuchotrichophora, Cedrus deodara, Ficus Palmata, Celtris australis, Rhododendron ponticum, Picea smethiana*	*Arundinella nepalensis, Ischaemum aristatum, cymbopogon martini, Apluda mutica, Ischaemum spp, Themada anathera*
SILVI-PASTORAL (SP)	-	-	*Ficus Palmata, Bahunia varrigata, Pinus roxburgii, Cedrus deodara, Quercus leuchotrichophora, Celtris australis, Bombax ceiba, Quercus dilatata*	*Ischaemum aristatum, cymbopogon martini, Apluda mutica, Ischaemum spp, Themada anathera, Arundinella nepalensis*
PASTORAL- SILVI-HORTICULTURE (PSH)	-	-	*Bahunia varrigata, Quercus leuchotrichophora, Juglans regia, Bombax ceiba, Prunus armeniaca, Pinus roxburgii, Prunus domestica, Cedrus deodara, Ficus Palmata, Malus domestica, Quercus dilatata, Juglans regia*	*Apluda mutica, Ischaemum spp, Themada anathera, Arundinella nepalensis, Ischaemum aristatum, cymbopogon martini*

Table 8: Technological constraints/gaps in the study area

S. No.	Constraints/ gaps
	Social
1	The main source of the off farm employment/income was government jobs, family business and employment as daily wagers either in private or public sector.
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. This practice was leading to less availability of FYM for their agricultural land and thus excessive use of fertilizers was observed and complete organic farming was missing from the study area.
3	Majority of animals in altitude zone-II and altitude zone-III reared by the farmers were of local breeds

S. No.	Constraints/ gaps	Solutions
	Scientific gaps	
1	Indigenous grass species were found on the bunds of agriculture field/ pastureland and no improved and multicut varieties of the grasses were used by the farming communities so as to improve the nutritional level of the livestock.	
2	Use of local seeds for some agricultural crops such as Calocassia, turmeric, wheat, rice, barley, maize and mustard etc. due to unawareness of High Yielding Variety seeds as these crops were raised as accessory components for their own consumption.	
3	Disproportionate applications of insecticides/pesticides and fertilizers were observed in the study area for different agricultural crops and it was also found that farmers were not following the recommended package of practices. (Based on Personal interview)	
4	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)	
5	It was observed that training and pruning were also found missing in fruit crops retained on the bunds of the farm as accessory components.	
6	Tomato, Garlic, Ginger, Capsicum, Bean and Pea were the most dominant agriculture cash crops grown by the farmers. So, most of the attention was paid for the cultivation of these cash crops and less attention was paid for the other agricultural crops.	
7	Occurrence of severe frost led to the drying of some young and old fruit trees especially in altitude zone - III	

S. No.	Constraints/ gaps	Solutions
	Scientific gaps	
8	Lack of adequate knowledge regarding selection of location specific varieties of fruit trees was observed among the farmers.	
9	Hand weeding was a common practice. Being more time intensive, many times it become impractical to execute due to shortage of labour at peak period. Subsequently it reduces the production.	
10	Agroforestry system identified were traditional and less productive	
	Infrastructural gaps	
1	Occurrence of fragmented landholdings was a major hurdle in adopting potential agroforestry interventions.	
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)	
3	Communication gap between lab to land was a hurdle in adopting new scientific interventions for any further improvement in agroforestry systems.	
4	Unusual behavior of extension staff towards the problems of farmers.(Based on personal interview)	
5	Farmers were scared to adapt new technologies due to lack of risk bearing capabilities.	

S. No.	Constraints/ gaps	Solutions
	Infrastructural gaps	
6	Lack of agro processing facilities and sound marketing network at village, panchayat and block level.	
7	Farming communities were not adequately benefited by the government sponsored schemes due to the indifferent attitudes of some of the stakeholders towards the farmers of the area. (Based on personal interview)	
8	Lack of government sponsored schemes so as to abridge the various technical constrains faced by farmers in adopting potential agroforestry systems.	
9	Lack of irrigation facilities therefore whole cultivation in the study area were rainfed.	
10	Lack of success stories of agroforestry.	
	Miscellaneous	
1	Farmers do not have knowledge about subsidy schemes. (Based on personal interview)	
2	Wild and stray animals especially monkey were a serious problem of the farmers as they caused heavy damage to the crops.	

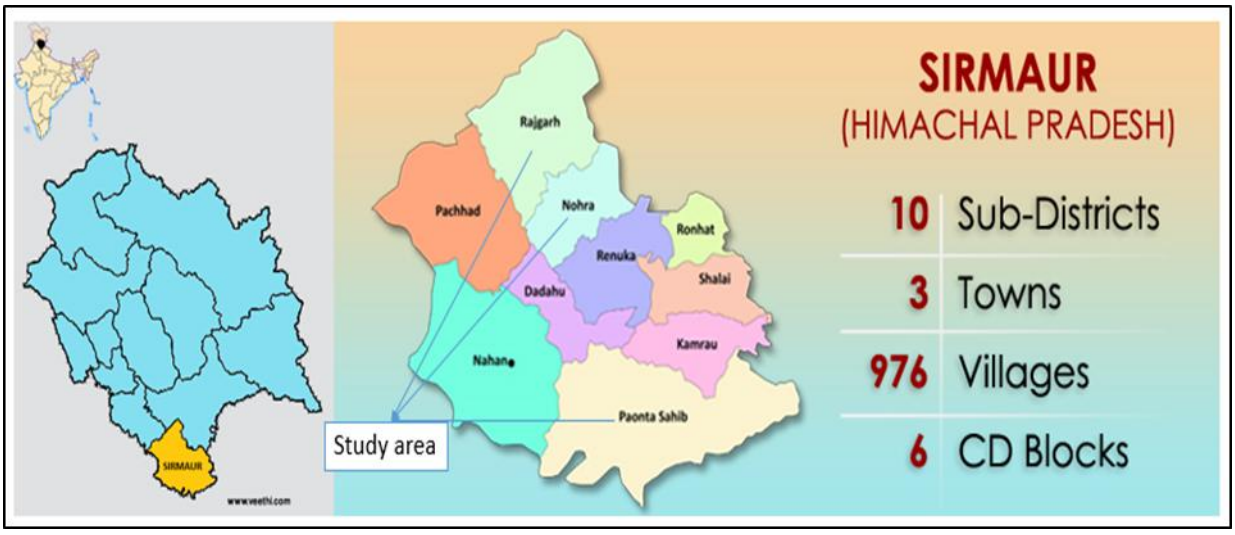

Fig 1: Location map of the study site in Sirmaur district (H.P.)

Conclusion

In India, North-Western Himalayan region where people's dependence on forest resources is high, agroforestry systems can play an important role in environmental and ecological sustainability. Seven types of agroforestry systems have been identified among different altitudinal zones. Farming communities were not adequately benefited by the government sponsored schemes due to the unawareness and unusual attitudes of implementing agencies towards the farmers of the area. Our study reveals that a lack of improve technologies is major constraints in the north-western Himalyas.

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