

Sustainable Agroecosystems for Livelihood Security in Indian Himalayas

Ram Prakash Yadav, Jaideep Kumar Bisht,
Vijay Singh Meena and Mahipal Choudhary

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.74495>

Abstract

Agroforestry systems are an age-old practice in the Indian Himalayan region. Agroforestry deals with the combination of tree species with crop plants, fisheries, animals, bee keeping, and so on, and it is based on the principle of optimum utilization of land. Agrihorticulture, silvhorticulture, hortipastoral, and silvipastoral systems are diversified land use options for agroforestry in the hill region. The study was conducted at experimental farm Hawalbagh (29°36'N and 79° 40' E, 1250 m amsl) of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, India. Study in an agri-horti system revealed that ragi (*Eleusine coracana*) and soybean (*Glycine max*) during *kharif* (rainy season) and wheat (*Triticum estivum*) and lentil (*Lens esculenta*) during *rabi* (winter season) can be grown successfully with pecan nut (*Carya illinoensis*) tree without significant reduction in the yield of the crop. However, grain yield of these crops was numerically higher in the field without pecan nut tree. In fruit-based agri-horti system four fruit crops, hill lemon (*Citrus limon*), pear (*Pyrus communis*), plum (*Prunus domestica*), and apricot (*Prunus armeniaca*) were planted with soybean in *kharif* and dual purpose wheat during *rabi* season. During initial years, no significant effect on grain yield was observed with the presence of different fruit trees. Green forage yield varied from 4600 to 5900 kg/ha in different treatments. In different treatments, ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*), turmeric and taro (*Colocasia esculenta*), and two varieties of turmeric (Pant Pitabh and Swarna) were grown under *Grewia optiva*, *Quercus leucotrichophora*, *Bauhinia variegata*, and *Celtis australis*. Turmeric and ginger produced significantly higher yield (12.04 and 7.99 t/ha) under oak. The highest rhizome yield was obtained under *Quercus leucotrichophora* (11,738 kg/ha) followed by *Bauhinia variegata*. Pant Pitabh gave significantly higher yield (10,860 kg/ha) than swarna. Improved systems with five tree species, that is, *Grewia optiva*, *Quercus leucotrichophora*, *Bauhinia retusa*, *Melia azedarach*, and *Morus alba* and four grasses, that is, *Setaria kazugulla*, *Setaria nandi*, Congo signal, and Broad leaf paspalum (*Paspalum* spp.) were tested under the silvipastoral system. *Quercus leucotrichophora* yielded (10,675 kg/ha) significantly higher green biomass than others, and the

lowest green biomass was harvested from *Grewia optiva*. Among grasses, *Setaria nandi* produced the highest green forage (6234 kg/ha). Thus, in hilly terrain, planting of inter-spatial woody perennials, with least negative influences on the agronomic crops, seems productive in agroforestry system for settled farming. Therefore, agroforestry is a set of land use alternative, which if developed for resource poor farmers, can provide increased values and reduced risks and it should be made more popular in the rural areas.

Keywords: agroforestry systems, Himalaya, crop yield, agrihorticulture, woody perennials, silvihorti, silvipastoral, sustainability

1. Introduction

Agroforestry systems are an age-old practice in the Indian Himalayan region. Agroforestry deals with the combination of tree species with crop plants, fisheries, animals, bee keeping, and so on, and it is based on the principle of optimum utilization of land. Agrihorticulture, silvihorticulture, hortipastoral, and silvipastoral systems are diversified land use options for agroforestry in the hill region. These agroforestry systems play a vital role in the livelihood of the hill people [1, 2]. The production and availability of green fodder is not uniform throughout the year, available in plenty during monsoon and remaining period, that is, winter and summer are miserable in hilly areas of Himalaya. The leaves of some identified evergreen fodder trees are given to animals during acute winter period [3]. *Grewia optiva*, *Quercus leucotrichophora*, *Quercus dilatata*, *Quercus semecarpifolia*, *Ficus nemoralis*, *Ficus palmata*, *Ficus roxburghii*, and so on are the main winter fodder trees [1, 2].

In the Himalayan region, several indigenous agroforestry systems based on people's needs and site-specific characteristics have been developed over the years. Agroforestry practices have wide and promising potential to store carbon and remove atmospheric carbon dioxide through enhanced growth of trees. However, little has been reported regarding carbon sequestration potential of agroforestry systems in Indian Himalaya. In this scenario, it is imperative that the carbon sequestration potential for agroforestry practices in the region is also investigated. The structural and functional aspects of tree species in traditional agroforestry systems greatly affect the overall productivity of the system. Generally, the overall productivity (crops + trees) in agroforestry systems is higher than that in sole cropping systems [4]. Nair [5] defined agro-forestry as "a land use system that involves deliberate retention, introduction or mixture of trees or other woody perennials in crops and animal production to benefit from the resultant ecological and economical intersections. Hence, the basic objective of the study is (1) what are the land uses for improved farm production, income generation, and livelihood security (2) to investigate ecosystem services of these land uses, which are maintaining their sustainability.

1.1. Area and climate

The Indian Himalayas cover an area of 53.7 Mha, which ~17% of total geographical area of the country. Out of 21 agro-ecological regions of the country, four regions are enclosed entirely and one partially in the hilly agro-ecosystem. All five agro-ecological zones surround a broad

distinction in their environment ranging from cold arid to warm per humid. The mean annual precipitation in the area ranged between 150 and 4000 mm. The average annual temperature fluctuated between 8 and 22°C. The yearly variation in cultivation phase of diverse crops varies from 90 to ~270 days. The major soils groups of the region are skeletal and calcareous to brown forest podzolic [6], which are alkaline and acidic by nature. The natural flora is alpine, temperate, wet evergreen and tropical deciduous forest in the Indian Himalayan region.

1.2. Land utilization and population

In the Himalayan region, population is ~39 million, which is ~4% of the total population of the India; the primary source of income here is agriculture, which contributes ~45% of the total regional income.

Himalayan area is sparsely inhabited (627 people/1000 ha). However, in this region, the genuine stress on farming land is much high as ~15% of the reporting area is net cultivated area. Availability of land for cultivation in hilly region of Himalaya is just ~ 0.17 ha per capita. In the Himalayas, woodland covers ~ 47% of total reporting area of hills, and it is the main land use, whereas ~ 13% area of the region comes under permanent pastures and grazing lands.

Horticulture has its advantage in the Himalayan ecosystem due to its particular ecological condition and numerous micro-situations. This region has a subtropical to temperate climatic condition, and the broad choice of fruits, such as apple (*Malus domestica*), banana (*Musa bauensis*), pomegranate (*Punica granatum*), citrus (*Citrus* spp.), mango (*Mangifera indica*), peach (*Prunus persica*), plum (*Prunus domestica*), and walnut (*Juglans regia*); vegetables, such as brinjal (*Solanum melongena*), cabbage (*Brassica oleracea* var. *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), garlic (*Allium sativum*), onion (*Allium cepa*), pea (*Pisum sativum*), potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), and so on; and spices, such as chilies (*Capsicum annum*), ginger (*Zingiber officinale*), and turmeric (*Curcuma longa*) is cultivated [2]. According to Tulachan [6], under horticulture (fruits and vegetable), ~ 13–15% is the gross cropped area.

1.3. The forests

The non-arable land occupies ~84% out of which forest land constitutes ~ 60% of the total geographical area [7]. Forest plays a vital role to the sustenance of agrarian economy, and inhabitants withdraw resources such as forage material, fuelwood, non-timber forest product, and livestock grazing. These forests on account of heavy pressure are under degradation at a rapid pace. In the Himalayan region, agriculture has been convoluted integration with forestry practices. However, the increased availability of fodder, fuelwood, and minor forest products including ecological security, larger driving force is needed to put on agroforestry [1].

2. Agroforestry systems

Agroforestry is intentional incorporation of agriculture, forestry, animals and/or pastures, which are managed intensively and in an integrated manner and each component interacts

with each other to obtain ecological, monetary, and societal benefits. It is a science that provides information on the impact of the variables such as tree species, tree-spacing, orientation of trees, rotation of crops, pruning types and intensity, quantity and timing of litter addition, thinning and felling, which can be managed by the farmer. Trees not only supplement the fodder, fuel, fiber, fruits, and so on, but also accumulate biomass and sequester carbon [1, 2, 8, 9]. Dhyani *et al.* [10] asserted that agroforestry is key path to prosperity for millions of farm families leading to extra income, employment generation, greater food and nutrient security, and meeting other basic human needs in a sustainable manner. It is more pertinent to hilly regions where existence without agroforestry is difficult.

2.1. Objectives of agroforestry

- To utilize available farm resources properly
- To maximize per unit production of food, fodder and fuel
- To optimize biological and physiological resources
- To maintain ecological balance
- To check soil erosion, conserve soil moisture, and increase soil fertility

2.2. Identification of agroforestry systems

Structural (nature, arrangement) and functional (outputs role) basis [11] was adopted for identification and naming agroforestry systems prevalent in the study area. System types

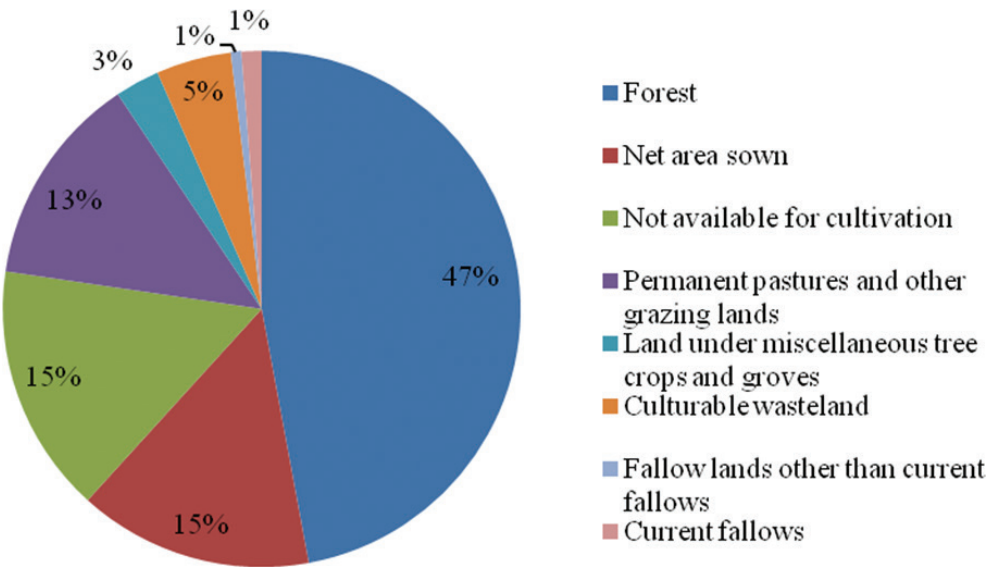


Figure 1. Land utilization pattern of North-West (Uttarakhand, Himachal Pradesh and Jammu & Kashmir) Himalaya.

and their system units were indicated using stratified classification of agroforestry practices as given by Zou and Sanford [12]. Considering the major components, a system type was named, whereas functional unit, that is, combination of specific tree species or other related components, was termed system unit. Hence, functional units such as cereals, pulses and vegetable in agriculture; in horticulture, specific fruit trees; in grasslands, grasses; and in silvipasture, trees/grass species were considered to identify systems and system units.

The different components of agroforestry systems were identified as primary and secondary. (1) Primary components: The components occupying the larger area of the total unit area and serving the major function, that is, production of primary output needed by the farmers was termed as primary component. (2) Secondary components: The component occupying relatively lesser area of the total unit area compared to area under primary component and yielding secondary needs of the farmers was termed as secondary component (**Figure 1**). Using abovementioned framework for identifying agroforestry systems, it can be classified as follows:

3. Agroforestry ecosystem services

3.1. Soil conservation

From the land a lot of losses of valuable is taking place in nature. These losses are in terms of water loss and soil loss through runoff and sedimentation, and precious top productive soil is being lost in a huge amount in this way. Estimates indicated that soil is displaced annually ~16 tones/ha which washed into the sea, which is greater than the permitted limit of 4.5 tones/ha/year. Agroforestry can be used to reduce this loss through putting it on barren lands of a watershed in the form of the land cover. Total annual accretion of litter fall in pecan nut (6 m × 7 m) based agri-horti system found $2.14 \text{ t ha}^{-1} \text{ yr}^{-1}$ and relative abundance of nutrients in litter fall of pecan nut tree were in the order of $\text{C} (901.9 \text{ kg ha}^{-1} \text{ yr}^{-1}) > \text{N} (57.44 \text{ kg ha}^{-1} \text{ yr}^{-1}) > \text{K} (43.29 \text{ kg ha}^{-1} \text{ yr}^{-1}) > \text{P} (3.21 \text{ kg ha}^{-1} \text{ yr}^{-1})$, which are supposed to help in nutrient buildups of the soil (**Figure 2** and **Table 1**) [13, 14].

3.2. Microclimate

Agroforestry will help in the moderation of microclimate around the trees. Microclimate amelioration, which involves air and soil moisture and temperature relations, results primarily from the use of trees in shade and live fences, growing crops in interspaces of the trees, creating shelterbelt and/or windbreak, and boundary plantation of trees. The condition of shade creates a net effect through complex interactions, and it expands further than the simply light and heat moderation [14]. Humidity, temperature and air movement as well as soil temperature and moisture of the soil directly influence transpiration, photosynthesis, and balance of energy of associated crops [15], and the overall influence may be translated into improved yields. The numerous practices that farmers conventionally have devised to achieve this objective confirm to the significance ascribed to microclimate moderation [16–18].

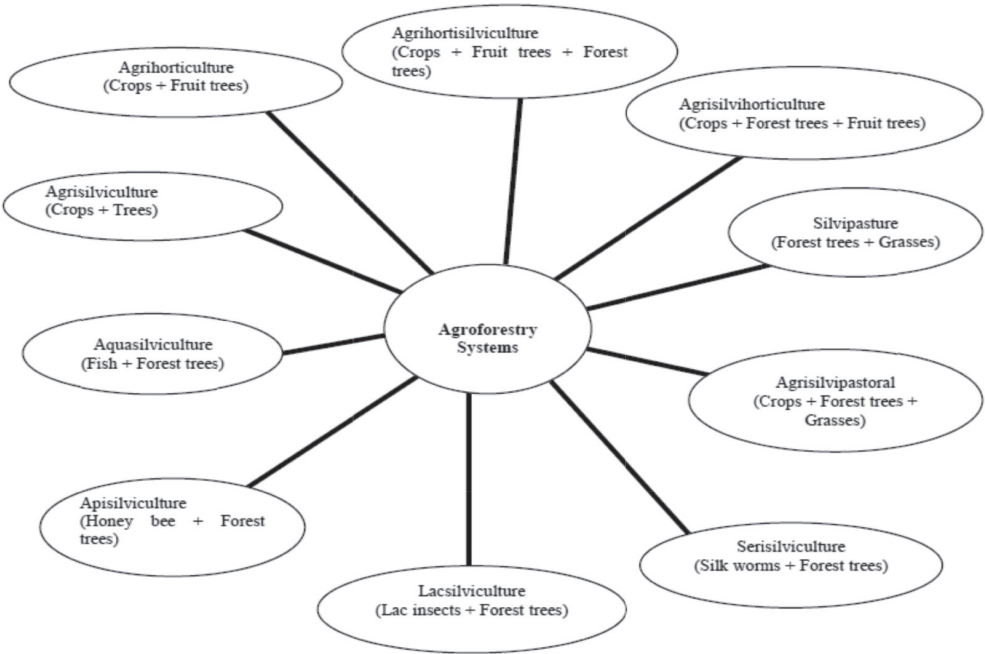


Figure 2. Classification of agroforestry system based on structure and function [8].

Nutrients	Concentration (%)	Potential nutrient return (kg ha ⁻¹ yr ⁻¹)
Carbon	42.1	901.9
Nitrogen	2.68	57.4
Phosphorus	0.15	3.2
Potassium	2.02	43.2

Table 1. The average concentration of nutrients in litter fall of pecan nut tree and potential amount of nutrients that could be released from pecan nut litter fall.

3.3. Watershed management

The watershed area can be utilized properly with adoption of agroforestry. This approach of watershed decides how to manage the land, that is, plan of crop management, development of pasture, plantations of forest, and so on, as per need of the watershed. Watershed management includes judicious use of natural resources, that is, water, land, plants and animals including human for conservation and regeneration purpose within the watershed area. As it is the human who is principally accountable for environmental degradation, this management of watershed maintains balance in the environment between natural resources including man and animals that inhabit the watersheds. Measures such as employment of people, planning from bottom-up approach, sustainability and equitable distribution of resources are the approaches for a good watershed management.

Approaches such as in situ conservation measures for soil and moisture, that is, bunding, vegetative barriers, terrace, trenching, treatment of drainage line by vegetative and engineering structures and developing small structures for water harvesting. Plantation of multi-purpose trees (MPTs), legumes, shrubs and sowing of grasses for grazing land development. In the watershed area promoting natural regeneration, encouraging creation of agroforestry & horticulture and establishment of woodlots to conserve common property resources and to meet demand of fuelwood are the activities need to promote.

3.4. Biomass production and carbon storage

The maximum production of biomass per unit area is a main objective of agroforestry. For the production of biomass, we can use the bunds, canal roads, farm ponds, lakes, water-logged area and ravines of a watershed in an economic way. Aboveground biomass production and carbon storage (**Figure 3**) in some of the important agroforestry systems viz., fruit tree-based agrihorticulture, oak high-density plantation (1×1 m), and pecan nut based agrihorticulture system was studied by Yadav et al. [9, 19–21]. Due to population explosion and increasing number of industries, pressure on forest is increasing day by day. Because of this population pressure, it is not possible to grow forest on agricultural lands. Through agroforestry, we can grow trees on marginal lands with crops. This will also restore the ecological balances.

3.5. Livelihood security

In watershed area, agro-based cottage industry can be promoted with the help of agroforestry. These will include paper pulp industry, herbal medicines, fiber production, piggery, poultry, aquaculture, beekeeping, dairying, sericulture, lac-culture and mushroom production. It will help in generating income and improving living standard of marginal farmers.

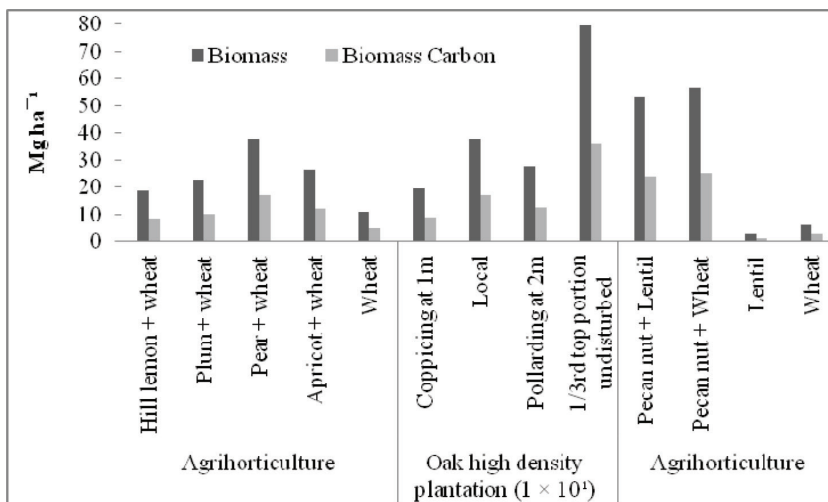


Figure 3. Aboveground biomass and biomass carbon in different systems of Central Himalaya [9, 19–21].

In Indian Himalaya, livelihood security is reliant on traditional farming practices that include agroforestry beside forest produce; forests provide 73–79% of required energy from fuelwood and more than 81% fodder [2]. The income of people was positively correlated with livestock rearing and farming. The adoption of this type of integrated farming which includes agroforestry with livestock (dairy and poultry/goat rearing) will improve the income of the people and sustainability of farming. Awareness of agroforestry was significantly related to literacy rate, land holding size, and fuelwood consumption (**Table 2**). A significantly positive relationship was obtained among income, fodder consumption, fodder from forest, land holding size, and livestock size [2].

3.6. Climate change mitigation

The mitigation actions deal with the causes of the crisis ever-increasing greenhouse gases concentrations. Example includes reduction of energy consumption and promoting clean technologies could be mitigation measures. Mitigation is an international issue, as when a mitigation project related to agroforestry reduces emissions of greenhouse gases, it remunerates the entire globe. Many agroforestry activities contribute to climate change mitigation (**Figure 4**). C stocks can be increased by creating agroforestry through plantations [3]. As shown in the graph, the difference between the present growing stock and the baseline through creating plantations of agroforestry is a benefit. Reduced felling or no felling at all of trees is helpful to conserve existing growing stocks on agroforestry farm lands. With reference to the degradation or tree felling scenario, the benefit of conservation is estimated in this situation. In agroforestry activities, emissions can be reduced, with a reduction of energy or fertilizers in diverse agroforestry operations. From agroforestry products, biomaterials and

Parameter	Correlation									
	1	2	3	4	5	6	7	8	9	10
Annual income	0.703**	1								
Livestock size	0.865**	0.488**	1							
Fuel consumption	0.174	0.273	0.179	1						
Fodder from forest	0.551**	0.313	0.785**	0.307	1					
Family size	−0.132	0.007	−0.006	−0.020	0.033	1				
Sex ratio	0.181	0.032	0.151	0.240	0.192	−0.201	1			
Literacy rate	0.176	0.340	0.056	0.361	0.024	0.016	0.354	1		
Land holding size	0.530**	0.378*	0.447*	0.235	0.403*	−0.467**	0.495**	0.432*	1	
Agroforestry awareness	0.168	0.325	0.058	0.375*	0.026	0.000	0.352	0.998**	0.434*	1

Note: **Correlation significant at the 0.01 level. *Correlation significant at the 0.05 level.

Table 2. Pearson’s correlation coefficients between various parameters of Central Himalayan watershed [2].

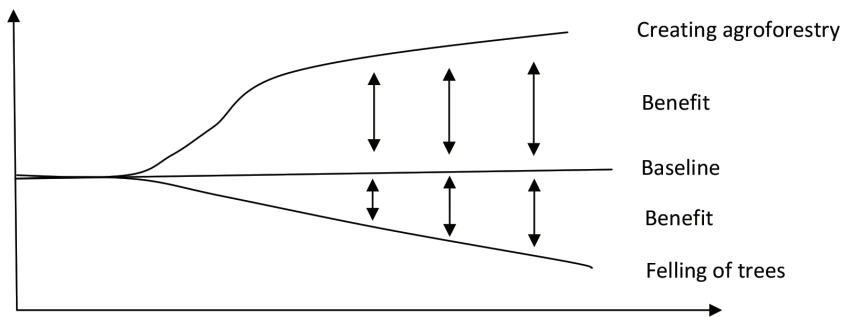


Figure 4. Carbon sequestration through creating agroforestry plantation and reduced felling of trees from agroforestry farmlands [8].

bioenergy can be produced to substitute materials or energy that generates GHGs. The first two activities refer to C sequestration in the agroforestry or any other ecosystem, while the last two refer to energy-related emissions [8].

4. Prevalent agroforestry system in the Himalayan region

Several agroforestry systems are common in the hill region [22]. Growing trees on the field bunds and around the fields is an age-old practice. Agrihorticulture, silvipasture, hortipasture and silvipasture systems are diversified land use options for agroforestry in the hill region [2]. These agroforestry systems play a vital role in the livelihood of the hill people [1, 2]. The study on some important agroforestry systems was conducted at experimental farm Hawalbagh (29°36'N and 79°40'E, 1250 m amsl) of Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, India. The most common agroforestry systems in hills are as follows:

4.1. Agrihorticulture system

Agrihorticulture systems are the most common systems, which are pervasive in Himalaya [2]. These systems (agriculture crops + fruit trees) are the combination of agriculture crops grown in the interspaces of fruit trees. These systems are the backbone of food, nutritional and livelihood security in hilly terrain. Though people do not follow specific spacing and orientation patterns for planting fruit trees but mainly aimed to obtain diversified outputs, these systems improved farm income and reduced risk.

Study in an agrihorticulture system revealed that ragi and soybean during *kharif* and wheat and lentil during *rabi* can be grown successfully with pecan nut tree without significant reduction in the yield of the crop [22]. However, grain yield of these crops was numerically higher in the field without pecan nut tree. In fruit-based agrihorticulture system, four fruit crops, hill lemon, pear, plum and apricot were planted with soybean in *kharif* and dual purpose wheat during *rabi* season. During initial years, no significant effect on grain yield was observed with the presence of different fruit trees (Table 3).

Crop sequence	Grain yield (t ha ⁻¹)	
	Rabi	Kharif
With pecan nut tree		
Maize-pea	1.56	3.19
Soybean-wheat	2.96	1.50
Maize-wheat	3.00	3.47
Soybean-pea	1.82	1.62
Without pecan nut tree		
Maize-pea	1.75	3.75
Soybean-wheat	3.32	1.56
Maize-wheat	3.10	3.49
Soybean-pea	1.59	1.48

Table 3. Yield of field crops with and without pecan nut tree (average of 5 years).

4.2. Silvihorticulture system

Silvihorticulture systems (fodder trees + horticulture crops) are the combinations of the fodder trees and horticulture plantation crops. Fodder trees serve the purpose of forage supply to livestock, which are paramount to rural agrarian economy. Beside forage supply, these trees also fulfill energy (fuelwood) needs in the form of the rural inhabitants of the hilly region. Livestock rearing and horticulture plantations crops generate income to farming community.

Green forage yield varied from 4600 to 5900 kg/ha in different treatments in study on silvihorticulture. In different treatments, ginger and turmeric, turmeric and taro, and two varieties of turmeric (Pant Pitabh and Swarna) were grown under *Grewia optiva*, *Quercus leucotrichophora*, *Bauhinia variegata*, and *Celtis australis* [23]. Turmeric and ginger produced significantly higher yield (12.04 and 7.99 t/ha) under oak. The highest rhizome yield was obtained under *Quercus leucotrichophora* (11,738 kg/ha) followed by *Bauhinia variegata*. Pant Pitabh gave significantly higher yield (10,860 kg/ha) than swarna (**Table 4**).

4.3. Silvipastoral system

Silvipastoral systems (fodder trees + grasses) are managed on the barren and marginal land including community wasteland. In this system, both components provide fodder materials to livestock owners. Dairying industry helps farmers to fetch good income through selling milk and its byproducts. Draught animals are source of energy for agricultural and other domestic activities.

Improved systems with five tree species, that is, *Grewia optiva*, *Quercus leucotrichophora*, *Bauhinia retusa*, *Melia azedarach*, and *Morus alba* and four grasses, that is, *Setaria kazugulla*, *Setaria nandi*, Congo signal, and Broad leaf paspalum (*Paspalum* spp.) were tested under silvipastoral system [3]. *Quercus leucotrichophora* yielded (10,675 kg/ha) significantly higher green biomass than others, and the lowest green biomass was harvested from *Grewia optiva*. Among grasses, *Setaria nandi* produced the highest green forage (6234 kg/ha) (**Table 5**).

4.4. Hortipastoral system

For proper management of marginal land, the fruit trees are planted depending upon agro-climatic situations. In unutilized interspaces of the fruit trees grasses are cultivated to produce green forage to feed animals. In hortipastoral systems (fruit trees + grasses), one component sold directly in the market to generate income, whereas other component fulfills forage needs of the livestock. This system helps in generating income and improving living standard of rural populations.

In hortipastoral production system, four *rabi*, namely, perennial rye (*Lolium perenne*), tall fescue (*Festuca arundinacea*), hima 14 (*Festuca arundinacea* var. *hima*), and grassland manava (*Festuca jatia*) grasses with and without peach tree were grown for utilization of marginal land. Grassland manava produced significantly higher mean green forage yield (284.1 q ha⁻¹) fol-

Treatment	Yield (t ha ⁻¹)		
	1994–1995	1995–1996	Average
<i>Turmeric</i>			
Quairai	6.03	4.66	5.35
Kharik	12.77	8.57	10.67
Oak	15.00	9.08	12.04
Bhimal	7.70	5.70	6.70
Open	10.75	7.16	8.96
<i>Ginger</i>			
Quairai	5.78	3.15	4.47
Kharik	10.44	4.95	7.70
Oak	10.74	5.23	7.99
Bhimal	6.67	3.38	5.03
Open	9.12	3.91	6.52

Table 4. Rhizomes yield of ginger and turmeric with different fodder trees.

Grass species	Green forage yield (t ha ⁻¹)	
	Pine	Deodar
Pangola	14.01	13.66
Rhodes	4.78	3.06
Para grass	0.48	2.04
Guine	0.41	2.55
Local	0.25	0.22

Table 5. Performance of different improved and local grasses under pine and deodar.

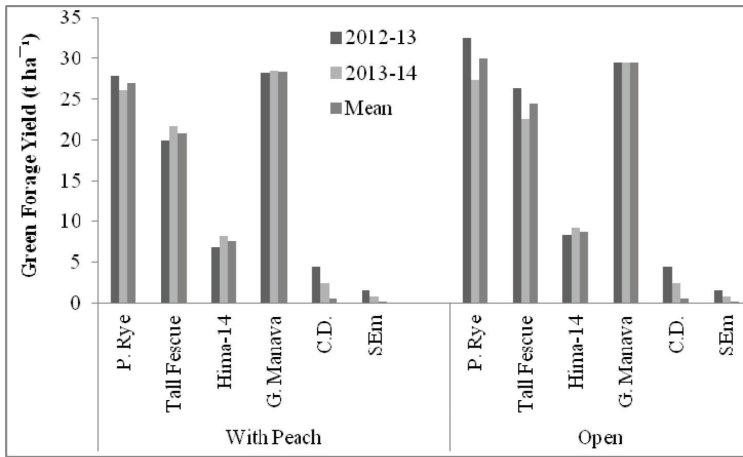


Figure 5. Green forage yield (q ha^{-1}) of winter grasses in peach-based hortipastoral production system [24].

lowed by perennial rye under peach tree, while in open perennial rye gave higher mean green forage yield 299.6 q ha^{-1} , which was at par with the grassland manava 294.7 q ha^{-1} (Figure 5) .

4.5. Energy plantation system

This system not only restores and conserves community lands but also improves its productivity through production of timber, fodder, and fuelwood. Energy plantation has been found a viable agroforestry system for the hills. For such system, Quairal (*Bauhinia variegate*), Bhimal (*Grewia optiva*), Batain (*Melia azedarach*), oak (*Quercus leucotrichophora*), kharik (*Celtis australis*), Bedu (*Ficus palmata*), and Paiya (*Prunus padam*) have been found suitable for energy plantation [25].

The green matter yields [25], however varied with the varying tree species recorded on an average, $50\text{--}250 \text{ q/ha}$ in 3rd year and $400\text{--}650 \text{ q/ha}$ in the subsequent years. In case of oak energy plantation, combined application of chemical fertilizers ($30 \text{ kg N} + 40 \text{ kg P}_2\text{O}_5/\text{ha}$) with manure (FYM @ 10 t/ha) produced 14.0% more leaf yield than chemical fertilizer ($30 \text{ kgN} + 40 \text{ kg P}_2\text{O}_5$) alone (12.4 tons/ha) and 11% higher than manure alone (12.7 tons/ha).

4.6. Agroforestry in cold arid zone

In Himalayan cold arid zone, agroforestry systems need to be stressed as follows:

- Agrisilviculture: Here legume plants are cultivated with densely planted poplar (*Populus nigra*), and it is well accepted in Ladakh region of Indian Himalaya [26].
- Silvipastoral: such agroforestry systems are dominated as pastures at high altitude of Ladakh Caragana, Hippophae (*Hippophae rhamnoides*) and willows (*Salix alba*) combinations are practiced. The junipers, birch and rhododendron are found in alpine zone of Spiti with Poa and Agropyron spp. of grasses are cultivated [27].
- Agrisilvipastoral: Crops like wheat or barley is grown in the interspaces of *Populus*, *Salix* and *Robina* spp. and lopped material are used as animal fodder.

iv. Hortipastoral: In alfalfa field, fruit plants such as apricot or apple are grown.

Thus, in hilly terrain, planting of interspatial woody perennials, with least negative influences on the agronomic crops, seems productive through agroforestry system for settled farming. Instead of this, these systems provide environmental benefits such as soil improvement and carbon sequestration [19, 28]. Therefore, agro forestry is a set of land use alternative, which, if developed for resource poor farmers, can provide increased values and reduced risks, and it should be made more popular in the rural areas. The mixed farming and alley cropping system appears to be viable alternatives for farmers practicing settled cultivation in hills' base and plain areas, while in hilly terrain, planting of interspatial woody perennials on terrace risers, with least negative influences on the agronomic crops, seems productive through agroforestry system for settled farming.

5. Conclusion

Agroforestry is a set of land use alternative, which, if developed for resource poor farmers, can provide increased values and reduced risks. This will help the poor farmer in overcoming the fuel and fodder shortage with increased productivity of the land and pressure on forest will be reduced. This will generate income to farmer in a drought year when crop is failed. This will have a positive effect on the environment as it reduces erosion and runoff, improves soil fertility, and mitigates climate change. Therefore, agro forestry should be made more popular in the rural areas through extension programs, and a top priority should be given in the watershed development.

Acknowledgements

The authors are grateful to the Director, Indian Council of Agricultural Research- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand for providing necessary support.

Conflict of interest

The authors hereby declare that there is no conflict of interest.

Author details

Ram Prakash Yadav*, Jaideep Kumar Bisht, Vijay Singh Meena and Mahipal Choudhary

*Address all correspondence to: rams34052@gmail.com

ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, India

References

- [1] Yadav RP, Bisht JK. Agroforestry: A way to conserve MPTs in North Western Himalaya. *Research Journal of Agriculture and Forestry Sciences*. 2013;1:8-13
- [2] Yadav RP, Gupta B, Bhutia PL, Bisht JK. Socioeconomics and sources of livelihood security in Central Himalaya, India a case study. *International Journal of Sustainable Development & World Ecology*. 2016;23:1-9. DOI: 10.1080/13504509.2016.1239233
- [3] Bisht JK, Yadav RP. Sustainable fodder production strategy through utilization of wastelands in hills. Book of Abstracts, 3rd World Congress on Agroforestry, Trees for life—Accelerating the impact of agroforestry. Nairobi: World Agroforestry Centre. 2014;24. www.worldagroforestry.org/downloads/Publications/PDFS/B17335.PDF
- [4] Chaturvedi AN. Poplar for planting. In: Uttar Pradesh Department Bull. India. 1981;no-50 Lucknow 27
- [5] Nair PKR. Soil Productivity Aspect of Agroforestry. Nairobi, Kenya: ICRAF; 1984
- [6] Tulachan PM. The state of mountain agriculture in India. In: Rana GM, Shrestha B, Joshi SM, editors. *State of Mountain Agriculture in the Hindu Kush-Himalayas: A Regional Comparative Analysis*. Kathmandu: ICIMOD; 2001. pp. 25-31
- [7] Alam A. Long-term Strategies and Programmes for Mechanization of Agriculture in Agro-Climatic Zone-I: Western Himalayan Region. 2016;78-86. <http://farmech.gov.in/06035-04-ACZ1-15052006.pdf>
- [8] Yadav RP, Bisht JK, Gupta B, Mondal T. Toward the sequestration potential of agroforestry practices to combat climate change in Kumaon Himalaya, India. In: Bisht JK, Meena VS, Mishra PK, Pattanayak A, editors. *Conservation Agriculture*. 2016;293-313. DOI: 10.1007/978-981-10-2558-7_11
- [9] Yadav RP, Bisht JK, Bhatt JC. Biomass, carbon stock under different production systems in the mid hills of Indian Himalaya. *Tropical Ecology*. 2017;58(1):15-21
- [10] Dhyani SK, Kareemulla KA, Handa AK. Agroforestry potential and scope for development across agro-climatic zones in India. *Indian Journal of Forestry*. 2009;32(2):181-190
- [11] Nair PKR. Agroforestry systems inventory. *Agroforestry Systems*. 1987;5:301-317
- [12] Zou X, Sanford RLJ. Agroforestry system in China: Survey and classification. *Agroforestry Systems*. 1990;11:85-94
- [13] Yadav RP, Bisht JK. Litter fall and potential nutrient returns from pecan nut (*Carya illinoensis*) in agroforestry system in Indian Himalaya. *International Journal of Herbal Medicine*. 2014;2:51-52
- [14] Willey RW. The use of shade in coffee, cocoa and tea. *Horticultural Abstracts*. 1975;45:791-798
- [15] Rosenberg NJ, Blad BL, Verma DB. *Microclimate: The Biological Environment*. 3rd ed. New York, USA: Wiley & Sons; 1983

- [16] Wilken GC. Microclimate management by traditional farmers. *Geographical Review*. 1972;**62**:544-566
- [17] Stigter CJ. Microclimate Management and Manipulation in Traditional Farming. CAgM Report No. 25. Geneva, Switzerland: World Meteorological Organization; 1988
- [18] Reifsnyder WS, Darnhofer TO, editors. *Meteorology and Agroforestry*. Nairobi, Kenya: ICRAF;1989
- [19] Yadav RP, Bisht JK, Pandey BM. Aboveground biomass and C stock of fruit tree based land use systems in Indian Himalaya. *Ecoscan*. 2015;**9**:779-783
- [20] Yadav RP, Bisht JK, Pandey BM, Kumar A, Pattanayak A. Cutting management versus biomass and stock of oak under high density plantation in central Himalaya, India. *Applied Ecology and Environmental Research*. 2016;**14**:207-214
- [21] Yadav RP, Bisht JK, Mondal T and Mishra PK. Agroforestry practices for sequestration in the mid hills of central Himalaya. In: Peshin R, Dhawan AK, Bano F, Resam KS, editors. *The Proceeding of the Natural Resource Management: Ecological Perspectives*, Indian Ecological Society International Conference-2016, SKUAST-Jammu. 2016;477
- [22] Bisht JK, Srivastva AK. Alternate land uses and agro-forestry systems in hills. In: Gupta HS, Srivastva AK, Bhatt JC, editors. *Sustainable Production from Agricultural Watersheds in NWH*. VPKAS. 2006;441-456
- [23] Bisht JK, Chandra S, Chauhan VS, Singh RD. Performance of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) with fodder tree based silvi-horti system in hills. *Indian Journal of Agricultural Science*. 2000;**70**(6):578-582
- [24] Yadav RP, Bisht JK, Mondal T, Pattanayak A. Forage Production in Peach Based Hortipastoral System in Indian Himalaya. *International Grassland Congress-2015* held at New Delhi from 20th–24th November, 2015
- [25] Bisht JK, Srivastva AK, Gupta HS. Sustainable fodder production management in NW Himalaya. *Technical Bulletin*. Almora: VPKAS. 2009;**32**(2):1-62
- [26] Sharma JP, Mir AM. *Dynaimcs of Cold Arid Agriculture*. Ludhiana, India: Kalyani Publishers
- [27] Gupta RD, Sharma PD and Verma KS. 2000. Environment and ecology of cold arid region – A case study of Lahaul and Spiti in Himachal Pradesh. In: Sharma, Mir, editor. *Dynamics of cold arid agriculture*. Ludhiana, India: Kalyani Publishers;2000
- [28] Yadav RP, Bisht JK. Agroforestry to combat climate change. *Kheti*. 2014;**66**:11-14. (In Hindi)

