

AGROFORESTRY FOR LIVELIHOOD AND SUSTENANCE IN KASHMIR VALLEY AND LADAKH

Abstract

Agroforestry practices in temperate regions are probably as old as agriculture itself, and it is considered as a way of life of traditional farmers, although systematic research on it started only about 35 years ago. Many of the traditional systems viz; shifting cultivation or slash-and-burn, home gardens and compound farms, forest gardens/agroforests, trees on farmlands (boundary plantings, scattered trees), parkland systems are base to maintain valued biological interactions and biodiversity at higher levels than some of the new agroforestry technologies (Leakey, 1998). Agroforestry provides opportunities to increase the value of total production through marketing of multiple products from a given unit of land. The traditional agroforestry systems identified in Kashmir Valley include; boundary plantations, agri-silviculture, horti-silvi-pasture, horti-agriculture, horti-agri-silviculture, home gardens, horti-pastoral and silvi-pastoral systems.

Keywords: nurturing trees, farms, marketing, horti-agriculture, Kashmir valleys

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I. INTRODUCTION

Agroforestry as a land use has a long tradition since dawn of the civilization. Agroforestry is a collective term used for land use system involving trees combined with crop and/or animals on the same land management unit. Agroforestry practices in temperate regions are probably as old as agriculture itself, and it is considered as a way of life of traditional farmers, although systematic research on it started only about 35 years ago. Many of the traditional systems viz; shifting cultivation or slash-and-burn, home gardens and compound farms, forest gardens/agroforests, trees on farmlands (boundary plantings, scattered trees), parkland systems are base to maintain valued biological interactions and biodiversity at higher levels than some of the new agroforestry technologies (Leakey, 1998).

The benefits accrued from agroforestry systems on farmers' fields which are location specific are underexploited in comparison to its potential. Agroforestry has the potential to improve the local economy by increasing economic stability, diversification of local products and rural skills, improved food and fuel security and landscape diversification.

In India, farmers practice different types of agroforestry systems that integrate trees on farms and in the agricultural landscape. It leads to a more diversified and sustainable production system than many treeless alternatives and provides increased social, economic, and environmental benefits for land users at all levels. Vegetation and soil are two major sink to sequester the atmospheric carbon dioxide, which contributes nearly 60% of the greenhouse gasses. According to Kyoto protocol, the drawing CO₂ from air into biomass is the only practical and economical way for mitigating the CO₂ from the atmosphere (Qaisaret. al., 2018). The main role of agroforestry in relation to climate change is to mitigate the emission of CO₂ by sequestering carbon from the atmosphere and tangible benefits like production of food/fruit/fiber/fodder/medicinal plants and above all benefits,agroforestry also reduces the pressure on forest for fuel, fodder, timber and other non-wood forest products. A number of studies have estimated the potential of agroforestry systems to act as effective carbon sinks (IPCC, 2000; Montaginini and Nair (2004)).

Kashmir region of Jammu and Kashmir represents a typical temperate ecosystem. The physiographic of Kashmir is a fertile basin of valley measuring 187 km to 115 km along the Srinagar latitude. Out of total geographical area of 10.138 million ha, 63% (6.358 million ha.) is under permanent snow cover, glaciers and cold deserts. Potential land resources of Jammu and Kashmir have thus been constricted to 3.780 million ha only. Nearly 2.809 million ha (72.29 percent) of Potential land resource (including demarcated forests-2.023-million ha permanent pastures and grazing lands-0.128 million ha and revenue land-0.658 million ha.) constitute forest of Jammu and Kashmir. Contrary to this agriculture, horticulture and allied sectors occupy just 15.6 percent of potential land resources. Demarcated forests (2.023 million ha) sustain total growing stock of 227.388 million m³, yield 0.055 million m³ of wood and 0.02 million tons of firewood annually against demand of 6.428 million m³ of timber, 1.394 million tons of firewood and feeding 10.99 million cattle and livestock requires 20.05 million tons of fodder per year @5kg fodder/animal/day (Qaisar,2014). Forestry/Agroforestry is an important field of interest in Jammu and Kashmir after horticulture. In the present context of shortages, agroforestry is the only integrated approach to supplement the fuel, fodder, timber, food and fiber needs of the ever-increasing human as well as their livestock population of the Union territory of Jammu and Kashmir as well as country.

In Jammu and Kashmir, the agroforestry systems were built on the foundation of protecting and planting trees. Because of these systems, hill people were self-sufficient and well nourished. Agroforestry is now being seen as an alternative paradigm for rural development worldwide which is centered on species-rich, low input agricultural techniques including indigenous tree crops and staple food crops. However, there is need for improvement in these systems so that they will remain sustainable and adaptability will be more and more by the rural people.

II. IDENTIFIED AGROFORESTRY SYSTEMS OF KASHMIR VALLEY

Agroforestry is one of the sustainable approaches to land-use management where both agriculture and forestry combine into an integrated production system to get maximum benefits. Agroforestry has received widespread attention in tropical and temperate regions of the world for providing ecosystem services such as carbon sequestration, biodiversity conservation, soil quality, and preserving air and water quality (Nabi, 2016 a; Bardhanet. al., 2012).

Agroforestry provides opportunities to increase the value of total production through marketing of multiple products from a given unit of land. The traditional agroforestry systems identified in Kashmir Valley include; boundary plantations, agri-silviculture, horti-silvi-pasture, horti-agriculture, horti-agri-silviculture, home gardens, horti-pastoral and silvi-pastoral systems. These systems are being practiced by farmers to meet out their livelihood needs (Dar et al. (2018); Nabiet al. (2016 b), and Mughal, and Bhattacharya, 2002). The management of agroforestry lands in the Kashmir valley by growing multipurpose trees species and intercropping understory crops, fruits, and livestock for variety of services is an adaptive indigenous practice of the rural communities Table-1.

Table 1: Identified agroforestry systems and crop combinations

Sl. No	Nature of system	Tree component	Fruit tree component	Crop component	
				Kharief	Rabi
1.	Home gardens	Salix, Poplar, Ulmus villosa, Robinia pseudoacacia, Ailanthus altissima, Aesculusindica, Morusalba	Punicagranatum, Malussp., Prunuspersica, Prunusamygdalus, Vitisvinifera, Prunusavium, Juglansregia	spinach, knoll khol, carrot, kale, cauliflower, maize, Brinjal	Pea, Onion, garlic, Oat, Mustard, kale, Turnip, raddish, cabbage, Brassica,
2.	Horti-agriculture	-	Malus sp., Prunuspersica, Prunusamygdalus, Vitisvinifera, Prunussativum	Beans, knol-khol, chillies, potato tomato, Kale, maiz	Oats, Mustard, Kale, Turnip, knol-khol, Radish

3.	Boundary planataion	Salix alba, Populusdeltoides, Ulmusvillosa, Aesculusindica	-	Rice Oats / mustard	Oats / mustard
4.	Horti-silvi-pasture	Salix spp, poplar spp, Robiniapseudoacacia, Ulmusvillosa	Malusspp., Prunusamydalus, Prunus species, Vitisvinifera, Punicagranatum	Trifoliumrepens, Trifoliumpratense, Aegilopstauschii, Amaranthussp., Echinochola crus-galli, Loliumperenne, Bromusjaponicus, Avenasativa, Loliummultiflorum	
5.	Agri-silviculture	Poplar. Salix spp, Ulmusvillosa, Aesculusindica	-	Brinjal, chillies, potato, Beans	Mustard, garlic, onion, turnip, raddish, peas, knol-khol, cabbage
6.	Horti-agri-silviculture	P.deltoides, Salixalba, Ulmus villosa, P.nigra, R.pseudoacacia, Ailanthus altissima	Juglans.regia, Malusspp, Prunusspecies, P.amygdalus	Knolkhol , cucumbe r, cabbage, spinach	Oats Mustard, garlic, onion, turnip, radish, peas
7.	Hortipastoral	-	Malusspp, Prunusamydalus, Prunus species, vitisvinifera, Punicagranatum	Trifoliumrepens, Trifolium pratense, Amaranthussp., Echinochola crus-galli, Loliumperenne, Bromusjaponicus, Avenasativa, Loliummultiflorum, Poa spp. Cynodondactylon	
8.	Silvopastoral	Salixalba, Populusdeltoides, Ulmusvillosa	-	Trifoliumrepens, Trifoliumpratense, Aegilopstauschii, Amaranthussp., Echinochola crus-galli, Loliumperenne, Bromusjaponicus, Avenasativa, Loliummultiflorum, Poa spp. Cynodondactylon	

III. AGROFORESTRY TREE SPECIES IDENTIFIED FOR KASHMIR VALLEY

Following 12 multipurpose tree species have been identified as the most promising with respect to their potential in agroforestry systems. (Mughal, 2017)

Table 2-Important Multipurpose trees species of Kashmir

Species	Method of planting	Uses				
		Fruit	Fodder	Fuel wood	Timber	Soil conservation
<i>Aesculusindica</i>	D.S	-	+++	++++	+++++	++
<i>Ailanthus altissima</i>	D.S	-	-	+	+++	+++++
<i>Juglansregia</i>	D.S	+++++	-	+++++	+++++	+++
<i>Morus spp.</i>	E.P	+++++	+++	+++	+++	++++
<i>Populus spp.</i>	B.P	-	+++	+++++	++++	+++
<i>Prunusarmeniaca</i>	D.S, E.P	+++++	+++	+++++	+++	+++++
<i>Prunuscerasus</i>	D.S, E.P	+++++	+++	+++++	+++	++++
<i>Prunuspersica</i>	D.S, E.P	+++++	+++	+++++	+++	++++
<i>Pyruscommunis</i>	E.P	+++++	+++	+++++	+++	++++
<i>Robinia pseudoacacia</i>	R.S	-	+++++	+++++	+++	+++++
<i>Salix spp.</i>	B.P	-	+++++	++++	++++	+
<i>Ulmusvillosa</i>	E.P	-	+++++	+++++	+++	++++
D.S- Direct sowing E.P- Entire planting B.P- Branch/cutting planting R.S- Root sucker		- No use + Ocassional/ poor ++ Satisfactory +++ Good ++++ Better +++++ Best				

IV. IMPORTANT AGROFORESTRY TREE SPECIES OF KASHMIR AND THEIR POTENTIAL USES

1. **Populus spp.:** Poplar belongs to family Salicaceae and comprises of about 25-35 species of deciduous trees. Commonly known as Poplar, Aspen and locally known as Phrass (Kashmiri) or Safeda (Gojri/ Hindi). It grows well in temperate regions and is well distributed in the Kashmir valley. The most common species of Poplars in Kashmir include *Populus nigra* (native), *Populus deltoids* (exotic) and lesser common ones include *Populus Alba*, *Populus balsamiferous* and *Populus ciliate*.

- **Propagation**

- One year old branch cutting should be selected from phenotypic ally superior and disease free trees.
- Size of cutting should be 22cm with at least 4 buds and should be from semi hard portion of the branch with diameter of 1.5 cm and above.

- Cuttings should be prepared after leaf fall in the month of December after giving a slanting cut on top of cutting.
 - Prepared cutting should be buried under soil till nursery planting starting from last week of February to March
 - Cuttings should be inserted in the nursery beds at an angle of 45° at a distance of 25cm x 25cm. Sixteen cuttings can be accommodated in bed size of 1m x 1m.
 - After inserting cuttings in the bed, soil around the cutting should be compacted and watered.
 - The nursery beds should be regularly watered preferably through flood irrigation
 - Urea should be applied in two splits doses of 75kg/ ha in the month of April and last week of June.
 - To ensure good and vigorous growth of seedlings weeding of nursery beds should be carried out regularly without disturbing the cuttings.
 - Singling of shoots should be carried out in the month of July-August and vigorously growing shoot be retained.
 - The ETP's on the best site during one growing season attain a height suitable enough to be transplanted in the field.
 - Interested farmers can raise ETP's in polyhouse also for faster and better growth.
- **Management:** Number of diseases and insects pests such as leaf spots, blight/defoliators etc. attack during developmental stage in nursery and can be easily managed by using fungicides and pesticides. 0.1 % drenching with Metalaxyl or carbendazim followed by foliar spray with mancozeb @ 0.3 % will take care of disease, whereas insects can be controlled by spraying endosulphan @ 0.1% or chloropyrifos @ 0.1%.
 - **Economics:** Poplar is mostly grown in the valley for its wood used to make packing boxes, lumber etc. In a study conducted at Faculty of Forestry in the year 2018, poplar plantation of 7 years rotation has been found to provide a benefit cost ratio of around 2.34 and can be increased if intercrops are raised in the plantation upto an age of 4-5 years (canopy closure).
2. **Salix spp.:** Salix also belongs to the family Salicaceae and includes around 400 species worldwide and 35 species in India. Commonly known as willows and locally known as veer in Kashmir. Kashmir is rich in the diversity of willow cultivars and various economically important Salix species are grown here like Salix alba (Cricket bat willow), Salix fragilis (Kashmir willow), Salix caprea (Goat willow), Salix matsudana (corkscrew willow), Salix babylonica (weeping willow as ornamental) and some osier willows like Salix triandra, Salix dickymat, Salix viminalis and Salix purpurea.

In terms of agroforestry potential, the two species of Salix Alba and Salix fragilis are very commonly grown on agricultural lands. They are found growing as pure stands on canals, wastelands, irrigation channels, roadside, on boundaries of fields, bunds, and also scattered under different Agroforestry Systems. The wetlands located at Harran, Hygam, Hokur-sur, Mirgund, Mamandangi, GundJehangir and Shahgund were brought under the willow plantation and at present about 1,400 km² of land is under its cultivation (Masoodi et. al., 2013). The main uses of these species include manufacture of cricket

bats, packing cases, biomass energy or fuel wood, soil conservation, Phytoremediation, production of fodder, medicinal properties and rooting stimulant.

- **Propagation:** Cricket bat willow is commonly propagated by using sets – a carefully selected large sized cutting (from quality stock) which is pushed into the ground in a hole prepared with a metal bar. These sets are planted in December to February with a crowbar or similar. A 45 degree angle is made by cutting a portion of basal part of the set and a little water poured into the hole prior to pushing it to the bottom of the hole. It is essential that the sets are in the upright position. 'Firming up' should take place in March, taking care not to break the newly formed roots. After one year's growth the rooted cuttings are lifted from the ground, cut back to a single stout bud, and then replanted in the nursery. The solitary bud grows as a straight 'set' and the 'rooted sets' are then planted out at a wide spacing, usually 4mx6 m apart. When the saplings reach the pole stage, sleeves around the stem are recommended to prevent grazing stock and wild animals eating the bark and killing the tree. In practice cattle should not be grazed in blocks with newly planted poles.
 - **Management:** Growers have to tend the trees carefully to sell their trees to cricket bat makers. The most important tending operation is the removal of small epitomic shoots on the stem. Thus the side buds/newly sprouted shoots should be rubbed off at least up to the height of 84 inches (213.5cm) from ground level. The first five years are the most difficult to carry out maintenance after which the bark will harden up and the side shoots become less evident.
 - **Economics:** The cricket bats manufactured from Kashmir willow in Kashmir are exported and also supplied to the domestic market of the country. At present the industry directly or indirectly provides employment to about 50, 000 people. It has also been found that Salix based bat industry has a BCR of around 1.69 for small scale industry, 2.05 for medium scale and 2.29 for large scale industry with an overall average of around 2.01.
3. **Ulmusvillosa:** Ulmusvillosa belongs to the family Ulmaceae and is commonly distributed in western Himalayas and endemic to the valley of Kashmir at an elevation of 1200-2500 m. It is commonly known as Cherry-bark Elm or Marn Elm and locally known as Bren (Kashmiri). Flowers are borne on leafless twigs in spring. They are minute, reddish in color, fruit winged rounded and peppery 9-13 mm in diameter with a seed in centermost of the seeds were unfilled. Studies conducted to find out the optimum time when a large number of viable and germinated seeds can be collected, revealed that 3rd to 4th week of march is most suitable time for collection of Ulmusvillosa seeds in the valley depending upon environmental conditions particularly temperature. Therefore, seeds should be collected at proper time. Seeds of Ulmusvillosa do not have any kind of dormancy so do not require any kind of treatment. (Bhatet.al., 2007)
- **Propagation**
 - Elm is hard to root species, studies undertaken to propagate it vegetative by means of cuttings treated with plant growth regulators enhances rooting percentage.

- The hard wood cuttings should be taken from phenotypic ally superior trees and should be treated with 2000 ppm IBA for 24 hours.
 - After that they should be planted in well prepared beds under controlled conditions.
 - In one growing season the seedlings attain height of nearly one meter.
 - The seedlings can be uprooted from beds and can be planted at plantation site after one growing season if the area of plantation is properly fenced.
 - Otherwise thinning should be done and seedlings can be transplanted in transplant beds at spacing of 30cm x 30cm for one more season.
 - The tree species grows under water stress conditions but has vigorous growth under assured supply of irrigation.
 - Under block plantation 3m x 3 m species is recommended and 1,111 plants can be accommodated in one hectare of land. The spacing can be increased or decreased than the above mentioned spacing depending upon objective of planting.
- **Economic uses:** Elm timber is used for timber, packing cases, furniture making, agriculture tool handles. Almost all parts of the tree are used for various purposes viz. Leaves (Fodder) ,Bark (Making Sandals ,ropes and ointment to heal broken bones and cuts), Branches (firewood).

4. **Morus spp.:** Morus belongs to the family Moraceae and comprises of about 10-16 species of deciduous trees commonly known as mulberry and locally known by names like tuth (Arabic), tul (Kashmiri). The most common species of mulberry in India include Morusalba, Morusindica and Morusnigra (shah tul). Many varieties/clones also have been developed worldwide like Goshoeرامي, Chinese white, Ichinose, etc. Mulberry grows up to an altitude of 3300 m and requires moist temperate climate to grow. In Kashmir valley, mulberry is mostly grown for silkworm rearing and it also provides fuel wood, fodder and fruits.

In Kashmir, mulberry is commonly cultivated with vegetables and pulse crops in an intercropping system. Mughal (2000) has reported that mulberry lactates have been found to have stimulatory effects on various crops like peas and beans up to a concentration of 50 % and 25% for lentils as legume. As per study conducted by Temperate Sericulture Research Institute, SKUAST-Kashmir mulberry based agroforestry system can provide revenue of around Rs.50,000-75,000/ha/yr. In another study by Mir et al. (2018), it was reported that there was an increase of around 206.16% in the average annual income of a household, through the integration of vegetables and pulses with mulberry trees in the PirPanjal area.

- **Propagation : Mulberry is mostly raised from cuttings in nursery condition as follows:**
 - Disease free cuttings of 15 -20 cm length and 1.2 -1.5 cm diameters with 3-4 active buds are to be selected from 8-10 months old shoots.
 - The cuttings should be treated with 0.02% Bavistin solution at the cut ends for half an hour to ensure protection against fungal diseases.

- Well punctured polythene bags (4.5 inches diameter and 11 inches height) should be filled with rooting medium comprising sand, soil and well decomposed FYM in the ratio of 6:3:1. The treated cuttings should be gently inserted in polybags without damaging the bud keeping the upper most bud exposed and finally these bags placed in the polyhouse.
 - The insertion/plantation of cuttings should be done during the last week of March to first week of April.
 - Optimum hygrothermic conditions viz, 25 -30°C temperature and 75 -80 % humidity should be maintained in polyhouse.
 - Irrigation should be carried out as and when needed. However there should be proper drainage of water from the polybags as otherwise the saplings would decay.
 - Fertigation should be carried out after 40 days.
 - After 75 to 90 days saplings should be transplanted to the main field and planted at a distance of at least 9" x 9".
 - Immediately after transplantation sufficient irrigation should be given to enable saplings to get established. During hot days frequency of irrigation should be maintained as per requirement. In addition, the field/nursery should be kept weed free as far as possible.
 - 1–2-year-old sapling is fit for transplanting in the field.
- **Management:** Mulberry is prone to pests like *Glyphodespyloalis*, and can cause defoliation beyond proportions. Initially when the infestation is less, the infested leaves can be plucked and collect them for burning. In case the infestation is very high, any type of contact insecticide can be prescribed.
 - **Economics:** As per study conducted by Temperate Sericulture Research Institute, SKUAST-Kashmir mulberry based agroforestry system can provide revenue of around Rs.50,000-75,000/ha/yr. In another study by Mir et al. (2018), it was reported that there was an increase of around 206.16% in the average annual income of a household, through the integration of vegetables and pulses with mulberry trees in the PirPanjal area.
5. **Malus domestica:** Malus belongs to family Rosaceae and is commonly known as apple and locally known as “Czehunth”. Apple has been classified into the subfamily Pomoideae. The flower of most varieties requires cross pollination for fertilization. In Kashmir valley, Malus is mostly grown for commercial purposes. Scientists in SKUAST-K in past two decades have developed varieties such as Shireen, Firdous, LalAmbri, Shalimar and Akbar and the results of these indigenous varieties are encouraging.

Table 3: Production and percentage contribution of temperate agroforestry systems in Central Kashmir (Nabi, 2016a)

Land use system	Agriculture/Horticulture crop		Production(kg yr ⁻¹)		Amount (Rs)		Gross Production	% (Gross Production/Total*100)	
	Kharif	Rabi	Self-consumption	Sale	Self consumption	Sale			
Horti-agricultural system	Kale		34.00	25.00	2040.00	1500.00	3540.00	0.22	
	Maize		29.00	28.00	435.00	420.00	855.00	0.05	
	Potato		40.00	30.00	1000.00	750.00	1750.00	0.11	
	Rajmash		25.00	25.00	3000.00	3000.00	6000.00	0.38	
	Apple		50.00	10980.00	2500.00	5,49000.00	551500.00	35.10	
	Pear		40.00	9000.00	2000.00	4,50000.00	452000.00	28.76	
	Plum		60.00	10000.00	3000.00	5,00000.00	503000.00	32.01	
		Kale		38.00	190.00	2280.00	11400.00	13680.00	0.87
		Radish		40.00	150.00	1400.00	5250.00	6650.00	0.42
		Turnip		50.00	250.00	3000.00	15000.00	18000.00	1.14
		Apple pruning		1000.00	0	6000.00	0	6000.00	0.38
		Pear pruning		450.00	0	2700.00	0	2700.00	0.17
		Plum prunings		920.00	0	5520.00	0	5520.00	0.35
		Total				34875.00	1536320.00	1571195.00	100
Horti-silvi-pasture system	Apple		20.00	11610.00	1000.00	5,80500.00	581500.00	36.33	
	Plum		30.00	10900.00	1500.00	5,45000.00	546500.00	34.14	
	Pear		20.00	8500.00	1000.00	4,25000.00	426000	26.61	
		Apple prunings	990.00	0	5940.00	0	5940.00	0.37	
		Kikarprunings	600.00	0	3600.00	0	3600.00	0.22	
		Plum Prunings	890.00	0	5340.00	0	5340.00	0.33	
		Poplar pruning	1050.00	0	6300.00	0	6300.00	0.39	
		Willow prunings	800.00	0	4800.00	0	4800.00	0.30	
		Tree fodder	8000.00	0	16000.00	0	16000.00	1.00	
		Grass fodder	2180.00	0	4360.00	0	4360.00	0.27	
	Total				49840.00	1550500.00	1600340.00	100	

A socio-economic study conducted by Nabi (2016a) in Central Kashmir with respect to agroforestry systems and their contribution towards livelihood upliftment revealed *Malus domestica* (Apple) as the prime contributor towards annual income generation of the farmers, generating an amount of Rs. 5,49,000 yr⁻¹(35.10%) followed by *Prunus domestica* (Plum) (32.01%) intercropped with various agricultural crops like *Phaseolus vulgaris* (Rajmash) (0.38%) and *Brassica oleracea*(Kale) (0.22%) and *Brassica rapa*(Turnip) (1.14%) in Horti-agricultural system. Likewise, in Horti-silvi-pasture system, the gross production percentage contribution of *Malus domestica* was found to be highest (36.33%)and most promising, producing an amount of Rs 5,80,500 yr⁻¹ followed by *Prunus domestica* Rs. 5,45,000 yr⁻¹ (34.14%) (Table-3).

Zahoor (2017) also reported highest total returns of Rs. 4, 83,052 ha⁻¹ under apple + rajmash& oats with lowest income returns of Rs78, 243 ha⁻¹ under control (green gram & oats). (Table-4).It is suggested that the cultivation of pulses & oats in apple-based agroforestry system may be recommended for better economic returns (Zahoor et.al.2021)

Table 4: Net returns from apple based agroforestry system intercropped with pulses and oats

Treatments	Gross returns from intercrop (Rs ha ⁻¹)	Cost of cultivation of intercrops (Rs ha ⁻¹)	Net returns from intercrop (Rs ha ⁻¹)	Gross returns from Apple trees (Rs ha ⁻¹)	Cost of cultivation of Apple trees (Rs ha ⁻¹)	Net returns from Apple trees (Rs ha ⁻¹)	Total Net returns from system (Rs ha ⁻¹)
T ₁ (Apple + Rajmash- Oats)	1,00,540	33,063	67,477	4,61,625	46,050	4,15,575	4,83,052
T ₂ (Apple + French beans- Oats)	1,01,520	37,001	64,519	4,04,437	46,050	3,58,387	4,22,906
T ₃ (Apple + Green gram- Oats)	94,197	29,423	64,774	4,20,937	46,050	3,74,887	4,39,661
T ₄ Control(Rajmash - Oats)	1,19,900	40,172	79,728	-	-	-	79,728
T ₅ Control (French beans - Oats)	1,24,140	44,458	79,682	-	-	-	79,682
T ₆ Control (Green gram - Oats)	1,13,784	35,541	78,243	-	-	-	78,243
T ₇ Control (Only Apple)	-	-	-	3,89,250	46,050	2,98,200	2,98,200

6. Prunusdomestica: Plum, an important temperate stone fruit belongs to family Rosaceae. It is a fairly good source of citric acid, sugars and vitamin A and has medicinal properties (Westwood, 1993). As per Jammu and Kashmir Horticulture departmental statistical data, The UT produces 11860 tonnes of plums in the year 2020 (Anonymous, 2020).

Shah (2012) evaluated bio-economics of the plum based agroforestry system intercropped with green gram plant sand reported that total net returns was higher in agroforestry system than in sole cropping. It is suggested that the cultivation of green gram by supplying organic manures in combination with inorganic fertilizers under plum based agroforestry system may be recommended for better economic returns (Table-5).

Table-5: Net returns of plum based agroforestry system intercropped with green gram

Treatment	Gross return from intercrop (Rs ha ⁻¹)	Cost of cultivation (Rs ha ⁻¹)	Net returns from intercrop (Rs ha ⁻¹)	Net returns from trees (Rs ha ⁻¹)	Total net returns from the system (Rs ha ⁻¹)
T ₁ (Control (only Plum))	-	-	-	188500.00	188500.00
T ₂ (Control (only Greengram))	50603.10	16050.00	345531.10	-	34553.10
T ₃ (FYM)	59853.10	17250.00	42603.10	190843.75	233446.85
T ₄ (Dalweed Manure)	54843.10	20050.00	34793.10	187843.75	222636.85
T ₅ (Biofertiliser (Rhizobium))	57401.43	16064.00	41337.13	188218.75	229555.88
T ₆ (Vermicompost)	65353.33	31050.00	34303.33	202843.75	237147.08
T ₇ (Biofertiliser + Vermicompost (50%))	62771.33	23564.00	39207.00	192062.50	231269.50
T ₈ (80% of recommended doses of NPK + FYM + Dalweed + Biofertiliser (Rhizobium))	74866.20	22976.00	51890.14	203781.25	255671.39
T ₉ (60% of recommended doses of NPK + FYM + Dalweed + Biofertiliser (Rhizobium))	68666.66	22548.00	46118.61	201343.75	247462.36

(Shah, 2012)

- 7. Carbon sequestration potential of Agroforestry systems in Kashmir:** Many studies have estimated the potential of agroforestry systems to act as carbon sinks. The carbon sequestration is influenced by factors such as climate, soil characteristics, topography, species, density and age of the biomass. Different trees behave differently under different soil and climate in terms of carbon assimilation. Average sequestration potential in agroforestry has been estimated to be 25 t C/ha over 96 million ha of land in India. Under different environmental conditions, average carbon storage by agroforestry practices has been estimated to be 9, 21, 50 and 63 t C/ha in semi-arid, subhumid, humid and temperate regions respectively. The apple based agroforestry systems in which forage combination is integrated is a useful strategy for mitigating the atmospheric CO₂. Jammu and Kashmir has emerged as the largest apple producing region in the country with a substantial area of 1, 07,177 ha under apple orchards. This quantum of land area holds promise for carbon mitigation by adopting apple-based agroforestry systems. In a study by Qaiser et al. (2018) revealed that perennial grasses /legumes like white clover, orchard grass, lucerne etc. when grown under apple improves the carbon sequestration potential of Horti pastoral system in comparison to mono cropping of apple (Plate-2). Highest CO₂ equivalent was sequestered under Apple + Lucerne system (35.08 t/ha) followed by apple + orchard grass (34.13 t/ ha). Extrapolating these results to the total area under apple cultivation, it can be concluded that the Lucerne based hortipastoral system can sequester around 3.76 million ton of CO₂ annually in the valley.
- 8. Traditional Agroforestry Systems:** Mughal and Khan (2007) reported the seven systems prevalent in Kashmir province. In another study Banyalet al.,(2017) reported that the total number of agroforestry system in the valley are nine which are briefly described below:

Table 6: Agroforestry systems prevalent in Kashmir.

System	Tree component	Fruit tree component	Agricultural/ fodder crop combination	
			Kharif	Rabi
Boundary plantation	Poplar and willow	-	Paddy/maize	Avenasativa(oats) and mustard
Agrisilviculture (sloping lands)	Robinia, Ailanthus, Poplar, Salix, Elm etc	-	Maize	Mustard
Agrisilviculture (plain lands)	Poplar and willow	-	Tomato, brinjal, chilli, capsicum, French beans, potato etc	Knoll khol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc
HortiSilviculture	Poplar, Willow, Elm, Horse chestnut, Robinia and Ailanthus	Apple, cherry, peach, pear, pomegranate, Almond, Walnut etc	-	-
Hortisilvipasture system	Poplar, Willow, Elm, Horse	Apple, cherry, peach, pear, almond, etc	Avenasativa, Trifolium spp., Dactylisglomerata, Festuca spp.	

	chestnut, Robinia and Ailanthus			
Hortisilvi agriculture	Poplar, Willow, Elm, Horse chestnut, Robinia and Ailanthus	Apple, cherry, peach, pear, almond, etc	Brassica potato, French beans, brinjal etc	Knolkhol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc.
Silvi pastoral	Poplar, Willow, Elm, Horse chestnut, Robinia and Ailanthus	-	Trifolium spp., Dactylisglomerata, Festuca spp.	
Horti pastoral	-	Apple, cherry, peach, pear, pomegranate, Almond, Walnut etc	Trifolium spp., Dactylisglomerata, Festuca spp.	
Homestead agroforestry	Poplar, Willow, Elm, Horse chestnut, Robinia and Ailanthus	Apple, cherry, peach, pear, pomegranate, Almond, Walnut etc	Brassica, potato, French beans, brinjal etc	Knoll khol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc.
Others (alley cropping, SRC, Kitchen gardens etc)	Poplar, Salix alba, Salix viminalis, Elm, H orse chestnut, Robinia and Ailanthus	Apple, cherry, peach, pear, almond, etc	Brassica, potato, French beans, bottle gourd, tomato, chillies	Knolkhol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc.

V. AGROFORESTRY SYSTEMS DEVELOPED FOR KASHMIR VALLEY

The AICRP- AF Centre at SKUAST K Srinagar after proper surveying of the Kashmir valley has developed different Agroforestry models for both plain and sloppy areas of Kashmir Valley. Traditionally large number of multipurpose trees are deliberately introduced and maintained by the farmers in their land-use systems. Among them prominent tree species identified suitable as multipurpose tree species under different systems are Salix spp, Poplar spp. Elm, Ailanthus, Robinia, and different fruit trees viz Apple, Almond, Peach, Plum, and Apricot etc. Among these species the nursery techniques of many important forest tree species have been developed for getting the quality planting stock to be planted in different developed models. Commercially important among the above tree species are Salix, Poplar and Elm. The various models developed are enlisted as:

- Agrisilvi culture model (Poplar and Willow based)
- Elm based agroforestry model,
- Horti-Agri Pastoral model,
- Horti pastoral system
- Agri-Horti Silvi culture model,
- Boundary plantation,

1. Agrisilvi culture model (Poplar and Willow based): Poplars and willows as mentioned earlier are important multipurpose, fast-growing broadleaved trees species of Kashmir valley. Different cultivars of poplars are found growing in Kashmir valley under different agroforestry systems. They are mostly grown by the farmers on boundaries of their lands, as pure stands, on banks of streams and Nallas, river banks. They are grown for use in light construction purposes, ply board industries, packing cases for fruits, fodder for cattle, twigs used as fuel wood, and also as windbreaks and shelterbelts. Both the tree species Salix and Poplar are recommended for growing in Kashmir valley under different Agroforestry systems which are tabulated below.

Table7. Poplar and Salix based systems in Kashmir.

Agroforestry system	Functional Unit.		Major output/ Function	Remarks
	Kharif	Rabi		
Agrisilvi culture	Maize, French Beans	Oats and Mustard	Food,fodder, Rawmaterial for plywood, sports industries	Tress to be grown on boundaries of farmlands.
Agri horti silvi culture	Beans, Moong, vegetables Horticulture-Fruit trees-Apple, Cherry, Almond, Plum , Apricot, (perennials)	Fodders-oats, orchard grass, Tall fescue	Food, Fruits, Fodder,Small timber, Raw materials for industries	Apple is grown in almost all districts of valley, Almond in Karavas, and rest fruit trees were grown by farmers on boundaries of land.Apple Production is satisfactory in Plain areas.
Home gardens	Agriculture-vegetables,maize, Horticulture- pear, peach, Apple, Plum,C. fodder-M.P.Cherry, Buffalo, Sheep, Trifolium, Poultry Animals and ox, Birds Cow, goat,	Vegetables- Carrot, Spinach, Kail, Fodder- Oats	Fodder,Fruit, Milk,Vegetables,Meat,E ggs, Skin,	Practiced throughout rural areasofKashmir.
Boundary Plantation	Paddy, Maize,	Mustard, Fodder Crops	Live fence, fodder, poles, Timber, Raw material for industries windbreaks	Almost in whole valley Poplars and willows are mainly grown on Boundaries of Fields, Orchards, Home gardens

In addition to this many tree species are grown mixed with these two important multipurpose species which include ailanthus, Aesculus, Robinia, Acer, etc

2. Elm based Agri-silvi culture systems (Alley Cropping for karewa lands of Kashmir)

- **Agriculture (Vegetable crops) Kharif crops:** Tomato and Potato; Rabi crops: Garlic and Peas
- **Forest tree:** *Ulmus villosa* (Cherry bark Elm) Elm is grown for its multiple uses and has become a preferred tree species for agroforestry. It is often planted around villages, along banks of stream, on dry ridges and on sloppy lands etc. It is also grown around boundaries of fields in some places. Elm has been found to be suitable under moisture stress conditions of kandi areas in Kashmir valley. Agri silvi pasture model developed for denuded slopes of the valley is recommended for adoption on a 30-40 % of sloping lands. The model has been found very useful in converting the denuded sloping land into cultivable area. Besides conserving moisture and checking soil erosion with hedgerows, the model produces crops, fuel wood, grasses and tree leaf fodder. The yields obtained of arable crops are comparatively less to their standard yields. Elm (*Ulmus villosa*) delineated as best Multipurpose Tree Species (MPTS) in the species evaluation trial under stress conditions is recommended as tree component. Tree spacing of 2.0 m across the slope on contours is recommended. Different arable crops (beans, Tomato, Pea, Potato, garlic, maize) are recommended for cultivation in alley of trees. The crop should be grown in 6x4 m alleys in between the hedge rows with trees pruned at 3 m height. The tree could be lopped for green fodder and fuel wood twice in a year, besides the grasses planted in buffer zone (Red clover+ Red fescue +Meadow fescue) provided green fodder (Plate- 1). A study by Qaiser et al. (2009) reported that maximum production of potato (61.0 q/ha) and garlic (16.79 q/ha) was recorded maximum at 2.0 m x 4.0 m (wider spacing) between the elm trees and hence maximum profit (Rs.1, 10,341.00/ha/yr) was recorded at the given spacing Whereas, the green fodder and fuel wood production decreased at wider spacing.

3. Agri horti pastoral system (AHPS)

- **Horticulture (Fruit tree):** Malus spp.
- **Agriculture (vegetable):** Beans, Peas
- **Grasses:** *Trifolium repense*, *T. alexandrinum*, *Dactylis glomerata*, *Medicago sativa*

The main focus of such system is the fruit production. It was observed that areas suitable for agriculture (Paddy) are converting to orchards, though horticulture is considered as back bone of Economy of State. Traditionally farmers were raising maize as kharif crop and Wheat as Rabi crop, both of the crops are heavy feeders so it was need of the hour to develop a model which is high in productivity, sustainable and adaptable to the farmers. Therefore, an Apple based system was developed in which different fodder crops like white clover, Lucerne, orchard grass, and *Artemisia* (as medicinal plant) and agriculture crops beans and peas were cultivated. System showed promising results as the highest fruit yield was recorded in Apple +White clover (24.2 kg/tree or 14.76 t ha⁻¹) followed by Apple +Beans-Pea (22.16 kg/tree or 13.51 t ha⁻¹). The control (Apple + natural sward) yielded lowest fruit yield 3.5 kg/tree or 2.13t ha⁻¹. Apple+ Orchard grass recorded maximum yield of green fodder 23.0 t ha⁻¹ followed by Lucerne (*Medicago sativa*) 21 t ha⁻¹. Cost of cultivation is Rs.73,600 ha⁻¹ yr⁻¹ while as income averaged at Rs.1,28,900 ha⁻¹ yr⁻¹. The overall net income per hectare per year with Apple +Lucerne and Apple + Orchard grass is Rs.1,34,400/- and

Rs.1,23,400/- ha⁻¹ yr⁻¹ respectively (SKUAST-K, 2012). This model is adopted in every part of valley by the progressive farmers which has increased their income and improved soil physical properties and has resulted in as a source of carbon sink also.

4. Horti pastoral system (HPS)

- **Horticulture (Fruit tree):** Malusspp.
- **Forage Grasses and legumes :** Trifoliumrepens, T. pratense , Dactylisglomerata, Festuca arundinaceous Ahmad et al. (2018a) conducted a study on apple based Hortipasture system to evaluate the performance of fodder crops viz., tall fescue (IC-0615892), orchard grass (IC-0615914)and two legumes viz., white clover (IC-0615818) and red clover (IC-0615581) were tested under the 14-year-old established apple orchard of CITH, Srinagar, J & K, India revealed that the understory of each plot was intercropped with perennial temperate grasses and legumes both under sole as well as in combination. Growth parameters in terms of increment of plant height, plant girth, plant spread, fruit yield, trunk-cross sectional area and yield efficiency were found to be higher in legume as sole and grass/legume combination treatments than control and grasses as sole. Forage production and quality was significantly influenced by different grass//legume combinations and the maximum yield was recorded in tall fescue + red clover (10.72 t DM/ha) followed by orchard grass+ red clover with minimum in white clover + apple (9.38 t DM/ha) (Table-8&9).

Table-8: Effect of forage intercrops on growth and yield attributes of apple cv. Red Gold (Pooled)

Treatments	Increment of plant girth(cm)	Increment of plant height(cm)	Increment of plant spread(cm)	Fruit yield (t/ha)	Trunk cross-sectional area(cm ²)	Yield efficiency (kg/cm ²)
T1: Whiteclover + Apple	1.55	49.4	60.4	33.65	121.47	0.276
T2: Red clover + Apple	1.60	49.9	62.1	34.33	128.09	0.267
T3: Tall fescue+ Apple	1.34	42.8	51.7	27.45	110.48	0.249
T4: Orchard grass + Apple	1.40	41.8	51.3	28.27	111.07	0.255
T5: Tall fescue +White clover + Apple	1.52	45.7	56.3	30.96	120.23	0.257
T6: Tall fescue +red clover + Apple	1.50	46.2	56.4	30.63	115.02	0.266
T7: Orchard grass +white clover + Apple	1.52	44.7	55.9	30.56	116.54	0.262
T8: Orchard grass + red clover + Apple	1.53	45.9	56.1	30.65	115.33	0.266
T9: Control (clean cultivation)	1.25	43.3	52.9	26.93	106.97	0.252
CD_{0.05}	0.03	0.18	0.30	0.16	0.40	0.001

Table-9: Effect of forage intercrops on forage yield and quality (Pooled)

Treatments	Green fodder yield (t/ha)	Dry fodder yield (t/ha)	Crude protein yield (t/ha)
T1: White clover + Apple	14.77	5.28	1.27
T2: Red clover + Apple	19.47	6.33	1.37
T3: Tall fescue + Apple	24.42	8.02	0.84
T4: Orchard grass + Apple	22.32	7.39	0.77
T5: Tall fescue +White clover + Apple	24.35	9.38	1.60
T6: Tall fescue +red clover + Apple	29.47	10.72	1.63
T7: Orchard grass +white clover + Apple	23.93	8.03	1.27
T8: Orchard grass +red clover + Apple	26.72	9.13	1.31
CD_{0.05}	0.91	0.24	0.02

5. Agri-horti-silvi culture model: In this model Fruit trees should be grown at regular spacing ranging from 3m x 3 m to 3.5m x 3.5m depending upon the type of the fruit tree. Forest trees recommended growing on all sides of the orchard in single or paired rows along the boundary at closer spacing of 1.2m x 1.2m to 2m x 2 m. The forest trees planted around the orchards provide wind protection to fruit trees besides supplementing fuel wood, fodder and small timber for making the fruit boxes. The notable forest tree species include *P. deltoides*, *S. Alba*, *Ulmus. villosa*, *P. nigra*, *R. pseudoacacia*, *Ailanthus altissima*, etc. The fruit trees are *Malus* spp. *Prunus amygdalus*, and *Prunus* spp. The vegetable crops are cultivated under the fruit trees in the alley spaced at 6m x 6 m along with forest trees around the orchard in single or paired rows. Brassica, spinach, turnip, reddish, carrot, beans, knoll-khol, cabbage, cauliflower, brinjal, pumpkin, bottle & bitter guard, cucumber etc. were grown under the fruit trees. This system is recommended for the areas where irrigation facility is available round the year. The farmers can use one portion for vegetable production for domestic consumption and another for grasses. The grasses recommended for this system are *Trifolium repens*, *Festuca pretense* and *Dactylis glomer* at a usually growing as understory. Pasture grasses should be grown only when the fruit trees are in juvenile stage.

Another model developed under rain fed conditions in Kashmir with two commonly planted species *Populus deltoides* and *Catalpa big non iodides* with Kharif (*Sorghum* var. *M.P.Chari*) and Rabi (*Oats* var. *Sabzar*) fodder crops. The productivity of trees in combination of fodder crop was observed 85 and 87 percent more in terms of tree fodder + fuel wood yield. The fodder crop yield decreased in combination of trees + fodder when compared to sole fodder. (Qaisaret al., 2007).

6. Boundary Plantation: Tree component = Salix Alba, Populus deltoids Kharif crop=Rice/maize, Rabi crop =Mustard/ Oats this is the oldest traditional system practiced around the paddy fields and fruit orchards in the Kashmir valley. Boundary plantations are also available alongside the road and canal/irrigation channels and in the proximity of the agricultural fields to meet the multifarious and demands of fuel, fodder and small timber. Willows are preferred in and around the irrigation channel whereas, Populus deltoids, Populus nigra, Ulmusvillosa, Aesculusindica find place on other available lands. This system is being adopted by marginal as well as big farmers. Farmers opined that shading effect to paddy crop is responsible to lower its productivity. So to overcome the shading effect of willows on poplar following study was carried out for improvement of this model. The influence of white willow (Salix alba) grown as single row in east-west and north –south direction on the boundaries of the field was evaluated to find out the impact on the growth and yield of the rice in a traditional agroforestry system (Plate 4). The data recorded at various distances from the trees line on southern and western aspects of the east-west and north-south tree row directions respectively. The observations impact of trees was maximum up to longer distances on western aspect of north-south tree row. All the crop parameters except plants height were found significantly higher at all the distances on the southern aspect than western. The impact of the trees on both the aspects was higher than the nearest distances successively decreased with the increasing distances from the tree line. The study suggested that growing trees in a single row in east-west directions is more beneficial than growing trees in north-south directions in temperate regions (Fazli Ali et. al., 2009).

Out of the twenty-four (24) different seed sources of Elm (Ulmusvillosa) screened in nursery, 8 selections (best performing) were evaluated as boundary plantation. Seed sources from Pulwama performed comparatively better as exhibited maximum volume (0.571 m³/tree), total dry biomass (512.76 kg/tree) and carbon stock (247.20 kg/tree) (SKUAST,2018) (Plate-5)

VI. AGROFORESTRY OF LADAKH

Among the few cold arid zones of the world, cold arid zone of India is represented by Leh and Kargil districts of Ladakh and Lahaul Spiti and Kinnaur districts of Himachal Pradesh. The largest town in **Ladakh** is Leh, followed by Kargil. The Leh district contains the Indus, Shyok and Nubra river valleys. The Kargil district contains the Suru, Dras and Zaskar river valleys.

Because of harsh climate natural forests are limited. Trees are sporadically present near banks of the rivers, streams and glacial melt outlets. The people now have realized the importance of the forests in ameliorating, stabilizing and rendering the climate more conducive not only for humans but also for animals and plants.

Although a number of attempts have been made for planting trees under Watershed Development Projects and Desert Development Programmes and agroforestry owing to limited natural resources soil, water, growing season. Moreover, the cold arid areas being remote remain cut off from the rest of the country for major part of the year, so agroforests in the vicinity will fulfill the basic needs of the people of fuel, fodder, and timber.

Agroforestry has been an old land use practice since long, especially in the temperate and tropical regions though the term has been coined recently. Gupta 2012 mentioned the important agroforestry systems of the Ladakh region as:

- 1. Agroforestry systems:** In cold arid zone, the trees are generally grown along the field bunds and water channels. Some of the protective higher yielding agroforestry systems are: Agri-Silvi culture, Silvi-Pastoral system, Agri-Silvi-pastoral System, Horti-Pastoral System and Multipurpose Forest Tree Production System.
 - In Ladakh region, poplar (*Populus* species) and willow (*Salix* species) are the main timber trees grown under Agrisilvi culture system. Maharaja Gulab Singh and his General Zoravar Singh carried the pioneer work of their plantation in almost every village of Ladakh after its annexation with Jammu in 1840. There are about 20 species of local willows and 10 those of poplar growing at different attitudes of Ladakh. Out of them, Importance :*Populus nigra*, *P alba*, *P ciliata*, *Salix alba*, *S excelsa*, *S. angustifolia*
 - In Agri-silviculture system, a leguminous plant alfa-alfa, is grown under poplar (*P. nigra* var *italica*) and *Salix*. This system of agroforestry is very popular in Ladakh. (Plate 6)
 - In Silvi-pastoral system, plantations are grown for production of fuel wood and fodder for animals. This agroforestry system is practiced in high altitude pastures like Changthang of Ladakh. *Hippophae* (Seabuckthorn) and willows are grown in the pastures.
 - Agri- silvi- pastoral system is for the concurrent production of agricultural crops, forest trees and rearing of domestic animals. Inter spaces of poplar and willows, wheat or barley is grown. Alfalfa is grown for fodder. Sometimes along with poplar and willow trees, *Robinia* species is also grown for fodder. Thus, this system of agroforestry provides food, fodder, fuel wood and timber.
 - Horti – pastoral-system consists of horticultural crops and animals. In the fields, alfalfa, forage grasses/ and or oat, mustard are grown with fruit trees like apricot or apple.
 - In lower agricultural zone of Ladakh, the plantation of poplar and grape is done. Between the spaces of poplar and grape, alfa-afla is grown. This agroforestry is designated by the term horti- silvi- pastoral system.
 - Raising of fast-growing forest tree species particularly on gompa or village lands, has become very essential for cold arid zone for providing timber, fodder, fuel wood and fixing atmospheric nitrogen in soil. This is called multipurpose forest tree production system. Lucerne, a perennial leguminous forage crop is suitable for cultivation in irrigated areas with *Robinia pseudoacacia*.

Butola et al. 2012 reported that the local inhabitants of Ladakh region, a Cold Arid Desert, have their traditional Agroforestry systems which play an important role in meeting diverse subsistence needs particularly during prolonged winter season.

Traditional agroforestry system of the region exists in the form of agri-silviculture system that is the combination of agricultural crops with boundary plantations of Willow (*Salix* spp.) and Poplar (*Populus* spp.) species. The Nubra valley is covered with more than 5, 75,000 plants of Willow and Poplar. These are main source of fuel wood and fodder. The requirement of fuel wood during winters is met through cutting of dry as well as green plants or collection of fallen twigs in nearby forests. Almost all the woody species are used as a source of fuel wood in the valley. According to an estimation, every year these species are contributing 400 tonnes of leaf litter to ground and thus, being great source of organic carbon and responsible for sequestration of more than 75,000 tonnes of carbon (Kumar et al., 2009). In wild plants, Seabuckthorn (*Hippophae rhamnoides* L.), a multipurpose thorny shrub which the villagers use for food, fuel, fodder, medicine and for fencing their fields is an important multipurpose species.. The valley portion of Nubra is well vegetated with thickets of seabuckthorn compared to mountain slopes and remaining part of Ladakh region. In lower slopes, fruit trees as apple (*Malus pumila* Mill. or *M. sylvestris* (L.) Mill.), apricot (*Prunus armeniaca* L.), peach (*Prunus persica* (L.) Batsch), mulberry (*Morus alba* L.) and walnut (*Juglans regia* L.). Strawberry (*Fragaria vesca* L.) has been introduced with agricultural crops. The raising of some fruit tree species in kitchen garden is also well-established tradition of the region.

India needs to step up the production of fruits till the country becomes self-sufficient and process of fruit fall to the level at which both rich and poor can afford to buy. Such a challenge can be met by taking initiatives like fruit-based agroforestry systems where a mere small land holder can get more than one product to meet his food requirements on an average basis. Also, farmers practicing mono cropping (paddy cultivation) which renders farmers vulnerable to adverse market conditions (price volatility) due to non-availability of irrigation facilities and capital requirements and the lack of financial incentives for costly fertilizers. Some innovative farmers have developed strategies to cope with these shortcomings by introducing agro-biodiversity in farms (as fruit based agroforestry systems).

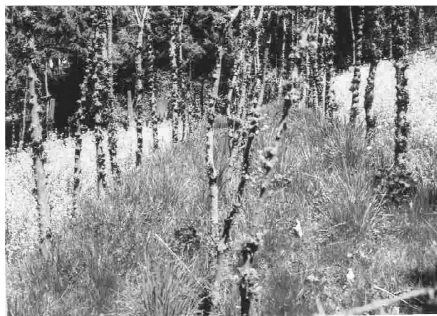


Plate 1. Alley cropping with Elm (*Ulmus villosa* + different agriculture crops-Tomato/Potato (Kharif) & Garlic/Pea (Rabi) + Buffer pasture grasses (*Festuca pretense*, *Festuca rubra* and *Trifolium pretense*)



Plate 2 Agri-Horti-Pasture Model (Apple+ Lucern/Orchard grass/White Clover-Beans/Pea



Plate 3: Poplar + Catalpa based Silvi pasture model



Plate 4: Boundary Plantation of Salix alba with Rice



Plate 5: Boundary Plantation of Elm (Ulmus villosa)



Plate 6: Lucerne with Salix

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