**Agroforestry for livelihood and sustenance in Kashmir valley and Ladakh**

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**1. 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. Farmers integrate different woody perennials in their cropping system along with the animal unit depending upon the physiographic and climatic conditions. It is well proven fact that such adopted systems/practices are location specific and information on such systems is very limited. Therefore, the benefits accrued from such systems are underexploited in comparison to its potential.

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). Integrating trees into the agricultural landscape has the potential to impact the local economy through increasing economic stability, diversification of local products and economies, diversification of rural skills, improved food and fuel security, improvements to the cultural and natural environment, 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. Over the past two decades climate change has evolved from a debate about whether the planet is really warming to an increased focus on how to mitigate and adapt to its impacts, mainly due to growing acceptance among scientists, policy makers and even the general public that climate change is real and happening. Vegetation and soil are two major sink to sequester the atmospheric carbon dioxide, which contributes nearly 60% of the greenhouse gasses. Kyoto protocol recognized that drawing CO2 from air into biomass is the only practical and economical way for mitigating the CO2 from the atmosphere (Qaisar *et. al*., 2018). The greatest role of agroforestry in relation to climate change is perhaps in mitigating the emission of CO2 by productively sequestering carbon from the atmosphere and tangible benefits like production of food/fruit/fibre/fodder/medicinal plants and above all benefits, agroforestry also supplements 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 physiography 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 state as well as country besides agroforestry may provide a viable combination of carbon storage.

In Jammu and Kashmir, the agroforestry systems have been practiced since millennia and passed from generation to generation. These systems were built on the foundation of protecting and planting trees. It is because of these systems which in the past has made hill people self-sufficient and well nourished. Agroforestry is now being seen as an alternative paradigm for rural development worldwide that is centered on species-rich, low input agricultural techniques including a diverse array of new indigenous tree crops rather than on high –input monocultures with only a small set of 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.

1. **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. According to a report in the world, around 1.2 billion rural people currently practice agroforestry the world over. In this era of global warming, fast degradation of land productivity and other environmental hazards, agroforestry is indeed a stake for natural resources and socio-economic sustainability. 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; Bardhan *et. al*., 2012).

Agroforestry, like multifunctional agriculture, 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); Nabi *et al*. (2016 b), and Mughal, and Bhattacharya, 2002). The farmers have integrated crops, trees and animals in their farming and land management systems reasonably for solving the problem of acute shortages of fuel wood, fodder and other produce. The management of lands in the Kashmir valley by growing multipurpose trees species and intercropping understory crops, fruits, livestock raising and protection of adjacent forests for variety of services is an adaptive century-old indigenous practice of the rural communities Table-1.

## Table-1. Identified agroforestry systems and crop combinations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.No. | **Nature of system** | **Tree component** | **Fruit tree component** | **Crop component** | |
| **Kharief** | **Rabi** |
| 1. | Home gardens | *Salix, Poplar, Ulmus villosa, Robinia pseudoacacia, Ailanthus altissima, Aesculus indica, Morus alba* | *Punica granatum, Malus sp., Prunus persica, Prunus amygdalus, Vitis vinifera, Prunus avium, Juglans regia* | spinach, knoll khol, carrot, kale, cauliflower,maize, Brinjal | Pea, Onion, garlic, Oat, Mustard, kale, Turnip, raddish, cabbage, Brassica, |
| 2. | Horti- agriculture | - | *Malus sp., Prunus persica, Prunus amygdalus, Vitis vinifera, Prunus sativum* | Beans,  knol-khol, chillies, potato tomato, Kale, maize | Oats, Mustard, Kale, Turnip, knol-khol, Radish |
| 3. | Boundary planataion | *Salix alba, Populus deltoides, Ulmus villosa, Aesculus indica* | - | Rice Oats/mustard | Oats/mustard |
| 4. | Horti-silvi- pasture | *Salix spp, poplar spp, Robinia pseudoacacia,*  *Ulmus villosa* | *Malus sp., Prunus amydalus, Prunus species,* Vitis vinifera, *Punica granatum* | *Trifolium repens, Trifolium pratense, Aegilops tauschii, Amaranthus sp, Echinochola crus-galli, Lolium perenne, Bromus japonicus, Avena sativa, Lolium multiflorum* | |
| 5. | Agri- silviculture | *Poplar. Salix spp, Ulmus villosa, Aesculus indica* | - | Brinjal,  chillies,  potato, Beans | Mustard, garlic, onion, turnip, raddish, peas, knol-khol,  cabbage |
| 6. | Horti-agri- silviculture | *P.deltoides, Salix alba, Ulmus villosa, P. nigra, R. pseudoacacia, Ailanthus altissima* | *Juglans.regia, Malus spp, Prunus species, P. amygdalus* | Knol khol, cucumber, cabbage,  spinach | Oats Mustard, garlic, onion, turnip, radish, peas |
| 7. | Hortipastoral | - | *Malus spp, Prunus amydalus, Prunus species, vitis vinifera, Punica granatum* | *Trifolium repens, Trifolium pratense, Amaranthus sp., Echinochola crus-galli, Lolium perenne, Bromus japonicus, Avena sativa,Lolium multiflorum, Poa spp. Cynodon dactylon* | |
| 8. | Silvopastoral | *Salix alba, Populus deltoides,Ulmus villosa* | - | *Trifolium repens, Trifolium pratense, Aegilops tauschii, Amaranthus sp., Echinochola crus-galli, Lolium perenne, Bromus japonicus, Avena sativa,Lolium multiflorum, Poa spp. Cynodon dactylon* | |

1. **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** |
| *Aesculusindica* | D.S | - | +++ | ++++ | +++++ | ++ |
| *Ailanthus altissima* | D.S | - | - | + | +++ | +++++ |
| *Juglansregia* | D.S | +++++ | - | +++++ | +++++ | +++ |
| *Morus spp.* | E.P | +++++ | +++ | +++ | +++ | ++++ |
| *Populus spp.* | B.P | - | +++ | +++++ | ++++ | +++ |
| *Prunusarmeniaca* | D.S, E.P | +++++ | +++ | +++++ | +++ | +++++ |
| *Prunuscerasus* | D.S, E.P | +++++ | +++ | +++++ | +++ | ++++ |
| *Prunuspersica* | D.S, E.P | +++++ | +++ | +++++ | +++ | ++++ |
| *Pyruscommunis* | E.P | +++++ | +++ | +++++ | +++ | ++++ |
| *Robinia pseudoacacia* | R.S | - | +++++ | +++++ | +++ | +++++ |
| *Salix spp.* | B.P | - | +++++ | ++++ | ++++ | + |
| *Ulmusvillosa* | 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 | | | |

**4. Important Agroforestry tree species of Kashmir and their potential uses**

**4.1. *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 deltoides* (exotic) and lesser common ones include *Populus alba, Populus balsamifera and Populus ciliata.*

**Propagation**

1. One year old branch cutting should be selected from phenotypically superior and disease free trees.
2. 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.
3. Cuttings should be prepared after leaf fall in the month of December after giving a slanting cut on top of cutting.
4. Prepared cutting should be buried under soil till nursery planting starting from last week of February to March
5. Cuttings should be inserted in the nursery beds at an angle of 45o at a distance of 25cm x 25cm. Sixteen cuttings can be accommodated in bed size of 1m x 1m.
6. After inserting cuttings in the bed, soil around the cutting should be compacted and watered.
7. The nursery beds should be regularly watered preferably through flood irrigation
8. Urea should be applied in two splits doses of 75kg/ ha in the month of April and last week of June.
9. To ensure good and vigorous growth of seedlings weeding of nursery beds should be carried out regularly without disturbing the cuttings.
10. Singling of shoots should be carried out in the month of July-August and vigorously growing shoot be retained.
11. The ETP’s on the best site during one growing season attain a height suitable enough to be transplanted in the field.
12. 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 chloropyriphos @ 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 rotationhas 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).

**4.2.*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 kashmiri. 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 large scale and commercial plantation of this species around the Wular Lake was undertaken by Forest Department during the year 1917. Thereafter, other wetlands located at Harran, Hygam, Hokur-sur, Mirgund, Mamandangi, GundJehangir and Shahgund were brought under the willow plantation and at present about 1,400 km2of land is under its cultivation (Masoodi et. al.,2013). These plantations were primarily meant to cater the needs of fuelwood requirements of towns of Kashmir. 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 animalseatingthe bark and killing the tree. In practice cattle should not be grazed inblocks with newly planted polesfor atleast oneand preferably two growing seasons.

**Management**

Growers have to tend the trees carefully if they are to sell their trees to cricket bat makers. The most important tending operation right from the early stages of growth is the removal of small epicormic shoots on the stem. If allowed to grow these shoots form a pin-sized knots in the wood which weakens it and hence reduces its value.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**

Kashmiri willow is known around the world and is second only to the famous English willow. The cricket bats manufactured 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.

**4.3 *Ulmus villosa***

*Ulmus villosa* 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).The tree comes into flowering early in spring. Flowers are borne on leafless twigs in spring .They are minute ,reddish in colour, fruit winged rounded and peppery 9-13 mm in diameter with a seed in centre most 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 *Ulmus villosa* seeds in the valley depending upon environmental conditions particularly temperature. Therefore, seeds should be collected at proper time .Seeds of *Ulmus villosa* do not have any kind of dormancy so do not require any kind of treatment. (Bhat *et.al.,* 2007)

**Propagation**

1. Elm is hard to root species, studies undertaken to propagate it vegetatively by means of cuttings treated with plant growth regulators enhances rooting percentage.
2. The hard wood cuttings should be taken from phenotypically superior trees and should be treated with 2000 ppm IBA for 24 hours.
3. After that they should be planted in well prepared beds under controlled conditions.
4. In one growing season the seedlings attain height of nearly one meter.
5. 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.
6. Otherwise thinning should be done and seedlings can be transplanted in transplant beds at spacing of 30cm x 30cm for one more season.
7. 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 light construction, packing cases, furniture, handles for agriculture tools. Its leaves are valued for good fodder and bark for sandals and ropes. The bark also contains 0.76 % of tannin. Its branches are used for firewood. Elm barks is also used in recipe for an ointment to heal broken bones and treatment of cuts.

**4.4. *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 *Morus alba, Morus indica* and *Morus nigra* (shah tul). Many varieties/clones also have been developed worldwide like Goshoerami, Chinese white, Ichinose, etc. Mulberry grows upto 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 leachates 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 Pir Panjal area.

**Propagation**

Mulberry is mostly raised from cuttings in nursery condition as follows:

1. Disease free cuttings of 15 -20 cm length and 1.2 -1.5 cm diameter with 3-4 active buds are to be selected from 8-10 months old shoots.
2. The cuttings should be treated with 0.02% Bavistin solution at the cut ends for half an hour to ensure protection against fungal diseases.
3. 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.
4. The insertion/plantation of cuttings should be done during the last week of March to first week of April.
5. Optimum hygrothermic conditions viz, 25 -300C temperature and 75 -80 % humidity should be maintained in polyhouse.
6. 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.
7. Fertigation should be carried out after 40 days.
8. After 75 to 90 days saplings should be transplanted to the main field and planted at a distance of at least 9″ x 9″.
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.
10. 1–2-year-old sapling is fit for transplanting in the field.

**Managemen**

Mulberry is prone to pests like *Glyphodes pyloalis*, 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 Pir Panjal area.

**4.5.*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, Lal Ambri, Shalimar and Akbar and the results of these indigenous varieties are encouraging.

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* engendering *Rs.*5,00000 yr-1(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-3: Production and percentage contribution of temperate agroforestry systems in Central Kashmir**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Land use system** | **Agriculture/Horticulture crop** | | **Production(kg yr-1)** | | | **Amount (Rs)** | | **Gross Production** | **% (Gross Production/ Total\*100)** |
| **Kharif** | **Rabi** | **Self-consumption** | | **Sale** | **Self consump-tion** | **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 |
|  | Kikar prunings | | 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** |

**(Nabi, 2016a)**

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)** |
| **T1 (Apple + Rajmash- Oats)** | 1,00,540 | 33,063 | 67,477 | 4,61,625 | 46,050 | 4,15,575 | 4,83,052 |
| **T2 (Apple + French beans- Oats)** | 1,01,520 | 37,001 | 64,519 | 4,04,437 | 46,050 | 3,58,387 | 4,22,906 |
| **T3 (Apple + Green gram- Oats)** | 94,197 | 29,423 | 64,774 | 4,20,937 | 46,050 | 3,74,887 | 4,39,661 |
| **T4 Control(Rajmash - Oats)** | 1,19,900 | 40,172 | 79,728 | - | - | - | 79,728 |
| **T5 Control ( French beans -Oats)** | 1,24,140 | 44,458 | 79,682 | - | - | - | 79,682 |
| **T6 Control (Green gram -Oats)** | 1,13,784 | 35,541 | 78,243 | - | - | - | 78,243 |
| **T7Control (Only Apple)** | - | - | - | 3,89,250 | 46,050 | 2,98,200 | 2,98,200 |

**4.6 *Prunus domestica*:** Plum, an important temperate stone fruit belongs to family Rosaceae. It ranks next to peaches in economic importance. Being a delicious juicy fruit, it is used both as fresh and in preserved form. Besides having medicinal properties, it is a fairly good source of citric acid, sugars and vitamin A (Westwood, 1993). In Jammu and Kashmir, the area under plum is 4,397 hectares with an annual production of 8603 metric tonnes (Anonymous, 2011).

Shah (2012) evaluated bio-economics of the plum based agroforestry system intercropped with green gram plants and 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 greengram**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **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)** |
| T1(Control (only Plum)) | - | - | - | 188500.00 | 188500.00 |
| T2(Control (only Greengram)) | 50603.10 | 16050.00 | 345531.10 | - | 34553.10 |
| T3(FYM) | 59853.10 | 17250.00 | 42603.10 | 190843.75 | 233446.85 |
| T4(Dalweed Manure) | 54843.10 | 20050.00 | 34793.10 | 187843.75 | 222636.85 |
| T5(Biofertiliser (Rhizobium)) | 57401.43 | 16064.00 | 41337.13 | 188218.75 | 229555.88 |
| T6(Vermicompost) | 65353.33 | 31050.00 | 34303.33 | 202843.75 | 237147.08 |
| T7(Biofertiliser + Vermicompost (50%)) | 62771.33 | 23564.00 | 39207.00 | 192062.50 | 231269.50 |
| T8(80% of recommended doses of NPK + FYM + Dalweed + Biofertiliser (Rhizobium) | 74866.20 | 22976.00 | 51890.14 | 203781.25 | 255671.39 |
| T9 (60% of recommended doses of NPK + FYM + Dalweed + Biofertiliser (Rhizobium) | 68666.66 | 22548.00 | 46118.61 | 201343.75 | 247462.36 |

**(Shah, 2012)**

**5. Carbon sequestration potential of Agroforestry systems in Kashmir**

The greatest role of agroforestry in relation to climate change is perhaps in mitigating the emission of CO2 by productively sequestering carbon from the atmosphere. A number of studies have estimated the potential of agroforestry systems to act as effective 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. Through regional studies, potentiality of different land use systems should be evaluated to estimate the quantum of carbon each can sequester and agroforestry is one of the important land use system of Kashmir. 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. Several studies have shown that inclusion of woody component in agricultural landscape often improves the productivity of systems while providing opportunities to create carbon sinks. 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 monocropping 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) and lowest was reported under control Apple+ natural sward (29.21 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.

**6. Traditional Agroforestry Systems**

Mughal and Khan (2007) reported that there were only seven systems prevalent in Kashmir province. On the basis of latest records by Banyal *et al.,*(2017) the total number of agroforestry system in the valley are 9 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 | *Avena sativa*(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 chestnut, Robinia and Ailanthus | Apple, cherry, peach, pear, almond, etc | *Avena sativa*,*Trifolium spp., Dactylis glomerata, Festuca spp.* | |
| Hortisilvi agriculture | Poplar, Willow, Elm, Horse chestnut, Robinia and Ailanthus | Apple, cherry, peach, pear, almond, etc | Brassica, potato, French beans, brinjaletc | Knolkhol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc. |
| Silvi pastoral | Poplar, Willow,  Elm,Horse chestnut, Robinia and Ailanthus | - | *Trifolium spp., Dactylis glomerata, Festuca spp.* | |
| Horti pastoral | - | Apple, cherry, peach, pear, pomegranate, Almond, Walnut etc | *Trifolium spp., Dactylis glomerata, 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,Horse chestnut, Robinia and Ailanthus | Apple, cherry, peach, pear, almond, etc | Brassica, potato, French beans, bottle gourd, tomato, chillies etc | Knolkhol, cabbage, onion, cauliflower, turnip, radish, peas, garlic, carrot etc. |

**7. 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:

1. Agrisilviculture model (Poplar and Willow based)

2. Elm based agroforestry model,

3. Horti-Agri Pastoral model,

4. Hortipastoral system

5. Agri-Horti Silviculture model,

6. Boundary plantation,

**7.1. Agrisilviculture 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 |
| Agrisilviculture | Maize, French Beans | Oats  and Mustard | | Food, fodder,  Raw material for plywood, sports industries | Tress to be grown on boundaries of farmlands. |
| Agrihortisilviculture | 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,  Trifolium,  Animals and Birds Cow, goat, Sheep, ox, Buffalo, Poultry | Vegetables- Carrot, Spinach, Kail,  Fodder-  Oats | | Fodder, Fruit,  Milk, Vegetables, Meat, Eggs, Skin, | Practiced throughout rural areas of Kashmir. |
| 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

**7.2. Elm based Agri-silviculture systems (Alley Cropping for karewa lands of Kashmir )**

a. Agriculture (Vegetable crops): *Kharif*: Tomato and Potato ;*Rabi*: Garlic and Peas

b. Forest tree: *U. Villosa* (Elm)

Elm is grown for its multifarious uses and has become a preferred tree species in our agroforestry system. 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. Agrisilvipasture 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, fuelwood, 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 fuelwood 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.

**7.3. Agrihortipastoral system (AHPS**)

a. Horticulture (Fruit tree): *Malus* spp.

b. Agriculture (vegetable): Beans, Peas

c. 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.

**7.4. Hortipastoral system (HPS**)

a. Horticulture (Fruit tree): *Malus* spp.

c. Forage Grasses and legumes : *Trifolium repens, T. pratense* , *Dactylis glomerata, Festuca arundinacea*

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 understorey 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(cm2) | Yield efficiency  (kg/cm2) |
| T1: White clover + 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 |

|  |  |  |  |
| --- | --- | --- | --- |
| 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 |

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

**7.5. Agri-horti-silviculture 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 to grow 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* sp., *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 glomerata* usually growing as understory. Pasture grasses should be grown only when the fruit trees are in juvenile stage.

Another model developed under rainfed conditions in Kashmir with two commonly planted species *Populus deltoids* and *Catalpa bignonioides* 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 + fuelwood yield. The fodder crop yield decreased in combination of trees + fodder when compared to sole fodder. (Qaisar *et al.,* 2007).

**7.6 . Boundary Plantation**

*Tree component = Salix alba, Populus deltoides*

*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 deltoides*, *Populus nigra*, *Ulmus villosa*, *Aesculus indica* 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 (*Ulmus villosa*) 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)

**8. Adoption and constraints of Agroforestry in Kashmir**

A case study undertaken by Banyal *et al*. (2011) to explore the knowledge and attitude of farmers towards agroforestry practices especially in north Kashmir. The results revealed that the inhabitants were not well aware about the key points tested under knowledge of farmers about tree farming. Farmers were reluctant to go only for agroforestry practices due to small land holdings and subsidy was the only response holding the key as motivational factor for adoption of agroforestry practices in the region.

The temperate agroforestry systems are widespread and therefore ecologically and economically significant. The two major challenges for mankind are the production of food and the conservation of biodiversity. Agroforestry is such a land use system that has the capacity to provide the solutions for both. This can only be achieved if appropriate species are combined in correct and temporal arrangement. Temperate situations encounter below mentioned constraints in the low adoption and poor productivity of the prevalent agroforestry systems.

1. Lack of equal weightage to agroforestry at par with forestry and agriculture.
2. Linkages gap between technology developers and stakeholders.
3. Knowledge gaps in technical and economic know how of the existing systems.
4. Low yield of the agroforestry combinations.
5. Lack of efficient utilization of space and time.
6. Choice of tree species is limited with inadequate adoption of agroforestry.

**9. 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 Zanskar river valleys. Climate of the old arid zone is characterized by cool summer and extremely chilling winter. Mean annual precipitation is very low ranging from 80 to 300 mm which is mostly in the form of snow. The weather invariably remains dry with as many as 310 clear sky days with relative humidity varying from 20 to 40 percent.

Despite harsh climate, scanty rainfall, long severe winter, thin atmosphere with poor oxygen content, accompanied with steeper to very steep slope and coarse textured soils, agriculture is the main occupation of the people of the cold arid zone. However, due to extreme aridity and low temperature during most part of the year, lack of vegetation causing extensive soil erosion in the region, is a matter of concern for cultivating subsistence of various crops grown by the people.

Because of harsh climate natural forests are also limited. These are sporadically present near banks of the rivers, streams and glacial melt outlets. Although man made forestry is dominant yet the forest area is small which cannot improve the climate of the area. The people of the area have now realised the importance of the forests in ameliorating, stabilizing and rendering the climate more conducive not only for humans but also for animals and plants. Necessity of forests is felt more so by the people of Ladakh, who saw the trail of destruction during mid nights of August 4 and 5, and 5 and 6, 2010 with a cloud bursts at Cholamsar area (Leh) and flash floods, causing a great loss to human beings, houses, bus-stands, offices, vehicles, roads etc.

Although a number of attempts have been made for planting trees under Watershed Development Projects and Desert Development Programme yet it would be much better if priority be given to 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 needs of the people in respect of fuel, fodder, and timber and also make the climate healthier and more salubrious.

Agroforestry has been an old land use practice since long, especially in the temperate and tropical regions though the term has been coined recently. It generally refers to growing of both agricultural/horticultural/olericulture crops and perennials woody species to fulfill the basic requirements of food, fodder, fuel and small quantity of timber etc. Gupta 2012 mentioned the important agroforestry systems of the Ladakh region as:

**Agroforestry systems:** In agroforestry systems there are both ecological and economical interactions between different components. In cold arid zone, however, the trees are generally grown along the field bunds and water channels because of high wind and water erosion. Some of the protective higher yielding agroforestry systems are: Agri-Silviculture, Silvi-Pastoral system, Agri-Silvi-pastoral System, Horti-Pastoral System and Multipurpose Forest Tree Production System.

i) In Ladakh region, poplar and willow are the main timber trees grown under silviculture-agroforestry 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, some worth mentioning are : *Populus nigra, P alba, P ciliata, Salix alba, S excelsa, S. angustifolia*

ii) In agri-silviculture agroforestry system, a leguminous plant alfa-alfa, is grown in the plantation of poplar (*P. nigra* var italica) and Salix. This system of agroforestry is very popular in Ladakh. (Plate 6)

iii) In silvi-pastoral system, plantations are managed for producing fuel wood as well as rearing of animals. This agroforestry system can be practiced in high altitude pastures like Changthang of Ladakh. Caragana Hippophae and willows can be grown in the pastures.

iv) Agri– silvi- pastoral agroforestry system is designed for the concurrent production of agricultural crops, forest trees and rearing of domestic animals. Between the spaces of poplar and willows, wheat or barley is grown. Alfalfa can also be grown. Sometimes along with poplar and willow trees, Robinia species is also grown, the loppings of which can be used as fodder. Thus, this system of agroforestry provides food, fodder, fuel wood and timber.

v) Horti – pastoral-system, consists of growing of horticultural crops and raising of animals. As for instance, in the fields, alfalfa, forage grasses/ and or oat, mustard are grown with fruit trees like apricot or apple.

vi) 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.

vii) 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. For this purpose, planting of *Robinia pseudoacacia* has proved useful in cold and zone of Ladakh and Lahaul Spiti. This is called multipurpose forest tree production system. Lucerne, a perennial leguminous forage crop is suitable for cultivation in irrigated areas and can be grown during April.

Butola *et al.* 2012 reported that the local inhabitants of Ladakh region, a Cold Arid Desert, have their traditional Agroforestry system which plays an important role in meeting diverse subsistence needs particularly in xeric condition occurs during prolonged winter season. They assessed potential of traditional Agroforestry system in present livelihood perspectives and stressed upon development of an integrated Agroforestry system to provide sustainable livelihood and environmental security maintaining present standard of living in Ladakh region.

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 Popular (*Populus* spp.) species. The Nubra valley is covered with more than 5,75,000 plants of Willow and Popular. These are main source of fuel wood and fodder. Otherwise the requirement of fuel wood during winters when temperature goes down up to -30oC is met through cutting of dry as well as green plants or collection of fallen twigs in nearby forests. This unsustainable practice of harvesting has posed huge pressure on the wild stock. 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 a important species. Being a nitrogen fixing species, it is planted in Igoo-PHE canal as rehabilitation measures to the soil condition of the area and to support the agricultural crops. 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, the integration of agricultural crops are rarely seen with 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 in combination 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 monocropping (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 (i.e. are now a days diverting fastly and have diverted to fruit based farm systems either as pure horticulture or as fruit based agroforestry system).

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|  | DSCN0257 |
| 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)* | |
| E:\Dr. K. N. Qaisar\hortipasture photo\Apple + Lucerne & Orchard grass.jpg |  |
| Plate 2 Agri-Horti-Pasture Model (Apple+ Lucern/Orchard grass/White Clover-Beans/Pea | |
| C:\Users\HCL\Desktop\Agroforestry\Navid Sir 035.jpg | C:\Users\HCL\Desktop\Agroforestry\DSCN0272.JPG |
| Plate 3: Poplar + Catalpa based Silvi pasture model | Plate 4: Boundary Plantation of *Salix alba* with Rice |
| C:\Users\ACCOUNTS\Desktop\Ashfaq\CAMERA PIC\20170415_103306.jpg | C:\Users\vaio\Videos\Pictures\2018-10-12 photo october 2018\photo october 2018 932.jpg |
| **Plate 5: Boundary Plantation of Elm (*Ulmus villosa*)** | **Plate 6: Lucerne with Salix** |