SOCIO ECONOMIC SURVEY OF EXISTING AGROFORESTRY SYSTEMS IN DEHRA TEHSIL OF HAMIRPUR DISTRICT, HIMACHAL PRADESH, 2022

Thesis

By

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(NF-2020-11-M)

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CERTIFICATE-I

This is to certify that the thesis entitled **"Socio-economic Survey of Existing Agroforestry Systems in Dehra Tehsil of District Kangra, Himachal Pradesh"** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **AGROFORESTRY** to Dr. Yashwant Singh Parmar University Of Horticulture and Forestry, Nauni, Solan (HP) is a record of bonafide research work carried out by **Mr. Shelar Rushikesh Mangesh (NF-2020-11-M)** son of Mr. Mangesh Balkrishna Shelar under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place: Neri, Hamirpur
Dated: 16/05/2023

Dr. Atul Gupta
Chairman
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CERTIFICATE-II

This is to certify that the thesis entitled **"Socio- economic Survey of Existing Agroforestry Systems of Dehra Tehsil of District Kangra, Himachal Pradesh"** submitted by **Mr. Shelar Rushikesh Mangesh (NF-2020-11-M)** son of Mr. Mangesh Balkrishna Shelar to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173230 India in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **AGROFORESTRY** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, **"Socio-economic Survey of Existing Agroforestry Systems in Dehra Tehsil of District Kangra, Himachal Pradesh"** submitted to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) by **Mr. Shelar Rushikesh Mangesh (NF-2020-11-M)** son of Mr. Mangesh Balkrishna Shelar in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **AGROFORESTRY.**

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Place: Neri, Hamirpur

Dated: 20/05/2023 **(Shelar Rushikesh Mangesh)**

CONTENTS

LIST OF ABBREVIATIONS

%	:	Per cent
AFS	:	Agroforestry Systems
AH	:	Agri-horticulture
AHS	:	Agri-horti-silviculture
amsl	:	Above mean sea level
AS	:	Agri-silviculture
ASH	:	Agri-silvi-horticulture
BC	:	Benefit Cost
CV	:	Co-efficient of variation
dbh	:	Diameter at breast height
et al.	:	et alii (co-workers)
etc.	:	Et cetera
H.P.	:	Himachal Pradesh
i.e.	:	That is
ICRAF	:	International Council for Research inAgroforestry
IPCC	:	Inter Governmental Panel on Climate Change
Kg	:	Kilogram
kg/tree	:	Kilogram per tree
Mg/ha/yr	:	Mega gram per hectare per year
mha	:	Million hectare
plants/ha	:	Plants per hectare
PS	:	Pastoral-silviculture
Q	:	Quintal
spp.	:	Species
t/ha	:	Tonne per hectare
t/ha/yr	:	Tonne per hectare per year
Rs. /ha/yr	:	Rupees per hectare per year
viz.	:	Videlicet (namely)
SMAF	:	Sub-Mission on Agroforestry

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Chapter-1

INTRODUCTION

Agriculture, is the largest livelihood provider in India, more so in the vast rural areas and also contributes a significant figure to the Gross Domestic Product (GDP) of the country. The share of agriculture was 19.9% in GDP in 2020-21. In India most of the working population earn their livelihood through agricultural works. Other sectors have failed to generate much of employment opportunity due to the growing populations. It plays vital role in internal and external trade of the country. Internal trade in food-grains and other agricultural products helps in the expansion of service sector. About two-thirds of the small timber demand, 70-80% of the plywood requirement, 60% of the raw material for the paper pulp industry, and 9-11% of the green fodder needs many sources. (Hindustan times, 2022). In addition to working in the farms, sectors like animal husbandry and agricultural machinery which are connected to the performance of the agroforestry sector since they provide support to this sector offer employment therein. As a self-employment there are lot of people in India who feed their families by selling various kinds of agricultural commodities in markets. Traditional agricultural practices have been an integral part of food production in India since ages. These practices have the potential to mitigate the adverse effects of climate change with spatial and sequential diversity. Double cropping, mixed cropping, crop rotation, agroforestry, use of local varieties and resources with host-pathogen interaction are some of the prominent traditional agriculture practices in India which have to be strengthened in view of the environment and food security (Patel *et al.,* 2020).

The increasing human population puts pressure on natural resources and produces scarcity of the resources, this leads to adaptation of improved agroforestry to meet the daily demands of populations. Agroforestry systems has the potential for solving the current problems like the increasing human population, deforestation and environmental degradation (Banyal *et al.,* 2015). As area under agriculture is increasing because of high demand for agro-based products, the expansion of monoculture system took place. This monoculture system requires large area to perform which was the main cause for deforestation at large scale (Oxfam Case Study, 2011). Such practice of deforestation gave negative impacts on environment by means of forest degradation, habitat fragmentation and climate change (Wong, 2001; Walls, 2006). Along with environmental issues, this also impacts on socio-economic aspects of the people (Butler, 2005). The monoculture systems tend to farmers to use huge number of chemical fertilizers and agrochemical products such as pesticides and herbicides, etc. which adversely effects on soil conditions (e.g., organic matter content, soil structure, etc.). The use of chemical inputs, genetic enhancement and mechanization has now become traditional to achieve increased yields. But, this net gain of well-being and economic development has been achieved at the cost of degradation of natural resources. Conventional agriculture has also been a major cause of various social and environmental issues, including climate change, the loss of biodiversity and the integrity of habitats, land degradation, water shortages, etc. In the recent past, this realization has led to an uproar for sustainable agroecological approaches which increase soil organic matter and other soil-based ecosystem services that can meet the trajectory of this intensification which can sustain in long run and can feed this rapidly growing human population. Thus, the practice of monoculture system should be replaced by performing agroforestry as it is one of the sustainable agriculture practices. Agroforestry opens up new possibilities for farmers to earn well while also repairing and restoring unhealthy ecosystems.

Agroforestry is the collective term for land use system and technologies in which woody perennials (e.g., trees, shrubs, palms and bamboos) and crops or grasses and or animals are used deliberately on the same piece of land in some form of spatial or temporal arrangement (Lundgren 1982). A total of 53.32Mha of global forest area, representing about 17.57% of the total geographical area of India. (Dhyani *et al.*, 2013). Agroforestry is known to have the potential to mitigate the climate change effects through microclimate moderation, conservation of natural resources and creation of additional source of livelihood and income opportunities. In order to make agriculture less vulnerable to climatic aberrations, Government of India formulated the National Agroforestry Policy in 2014. The policy recommends for setting up of a Mission or Board to address development of agroforestry sector in an organised manner. The Sub-Mission on Agroforestry (SMAF) under NMSA is an initiative to this end. The aim of the submission is to expand the tree coverage on farmland in complementary with agricultural crops. In the 2022-23 Union Budget, the Finance Minister of India announced that the Government of India would promote agroforestry. However, the Ministry of Agriculture and Farmers' Welfare merged the Sub-mission on Agroforestry with the Rastriya Krishi Vikas Yojana which deprived the agroforestry sector of its flagship implementation arm. In fact, resources attained from agroforestry plays an important role in the economic, cultural and social lives and supporting rural livelihoods and food security (Kumar and Saikia. 2020). Agroforestry practices helps for diversification of existing land-use patterns, their beneficial impacts on environment and higher returns than single cropping system (Sharma *et al.*, 2017). The implementation of agroforestry systems also reduces the pressure on available forests. The tree component generates biological niches for a variety of creatures above as well as below land. The life cycles and food chains linked with diversification start an agroecological succession which results in productive agroecosystems with long-term viability agroforestry has now become an accepted land use system.

Agroforestry systems are socially practiced by mountain communities for conserving soil, water, and improving fertility, food, timber, fodder and many other non-timber forest products (NTFP). The Indian Himalayan Region is divided into two distinct geographical belts i.e., Western Himalayan Region and Eastern Himalayan Region which including 14 Indian states. The Western Himalayan Region includes regions such as Jammu and Kashmir, Himachal Pradesh, Shivalik's of Punjab and Haryana, and Uttarakhand. From many years, farmers have cultivated several tree species on agricultural lands, which evolved into the extant agroforestry practices. Local people from these regions designed woody perennial-based systems for meeting their livelihood requirements, especially during lean periods (Kala, 2010).

Agroforestry systems show significant carbon accumulation in living biomass as well as soil carbon, demonstrating the potential to offer the environmental service of carbon sequestration. Furthermore, agroforestry systems can contribute to reducing carbon emissions by avoiding burning of forest-based fuelwood and conserving soil. Tree-based farming is an established nature-based activity that can aid carbon-neutral growth. It enhances tree cover outside forests, works as a surrogate for natural forests sequestering carbon, keeps the pressure off natural forests, and helps increase farmers' income. Besides the potential of agroforestry system could evolve into a technological alternative for reducing deforestation rates in tropical zones while also offering a wide variety of products and services to rural communities (Murthy *et al.*,2013).

In Himachal Pradesh 80 percent of its total population lives in rural areas. Their economy is from agriculture, horticulture and animal husbandry. The practice of pure agriculture in Himachal Pradesh is sufficient for the inhabitants to sustain only their food requirements but, for other needs people are forced to exploit forests. The forest area in Himachal Pradesh is 68.16 per cent of the total state's geographical area (India State of Forest Report, 2021). Agroforestry is well known in Himachal Pradesh and other Himalayan regions but it has been practiced traditionally since time immemorial (Nautiyal *et al.*,1998). Although various agroforestry systems are practiced in sub-tropical low hill zone of Himachal Pradesh, but they are not managed properly and gives less produce due to their improper management. It is therefore important to study the Socio-economic status of existing agroforestry systems of the area before recommendation of development program. Before any research, extension and execution programs for sustainable land-use, the socio-economic survey of the area must be undertaken to understand the problems and design a suitable system to fulfill the basic needs of the people.

Studies of socioeconomic processes relating to the generation of local knowledge and its distribution, and of socially differentiated communication patterns within and between rural communities, can enable researchers to better focus their efforts. The study covers the identification of agroforestry systems which consist of agricultural crops, horticultural crops and multipurpose trees, pastoral crops and animal and their pros and cons in human development.

Therefore, present study on the **"Socio-economic survey of existing agroforestry systems in Dehra Tehsil of Kangra District, Himachal Pradesh"** was undertaken with the following objectives:

1. **To identify the existing agroforestry systems.**
2. **To assess the biological yield and economic returns from the agroforestry systems.**
3. **Relevance of agroforestry systems to meet social as well as technological constraints in farming system.**

Chapter-2

REVIEW OF LITERATURE

The relevant literature pertaining to the present study entitled **“Socio-economic survey of existing agroforestry systems in Dehra Tehsil of Kangra District, Himachal Pradesh”** is presented here under the following heads:

2.1 Identification of agroforestry systems

2.2 Biological yield and economics returns from the agroforestry systems

2.3 Relevance of agroforestry systems research to overcome the technological gaps in farming system.

2.1 Identification of agroforestry systems

Jain (2000) analyzed the most prevalent practices of Silvo-Agriculture system in UP in following ways, i.e., scattered trees, boundary and block plantation. The system of planting scattered trees on farm land is most common in unirrigated areas. In irrigated areas, the most common species are eucalyptus, *Dalbergia sissoo, Acacia nilotica, Populus deltoides, Artocarpus heterophyllus, Syzygium cumini, Albizia lebbeck*, etc. *Of late, Bombax ceiba, Tectona grandis, Morus alba, Grevilea robusta, Meila azedarach*, etc. have also been planted on farms. Among all species, eucalyptus sp. is most widely planted in the Gangetic plain areas, whereas *Populus deltoids* is the most common forest crop in the Tarai and some parts of the Gangetic plain. Eucalyptus trees are commonly planted along field boundaries, whereas *Populus deltoides* is planted in blocks, rows and on farm boundaries. The most commonly planted tree species in the boundaries of fruit orchards are Eucalyptus hybrid, *Dalbergia sissoo*, *Syzygium cumini*, *Acacia nilotica*, etc. In agricultural crops, rice and wheat were the most prominently practiced in study area.

Goswami (2009) reported five agroforestry systems which are agri-silviculture, agri-horticulture, agri-horti-silviculture, agri-silvi-horticulture, silvi-pastoral systems in Kwaal Khad watershed in Solan District, Himachal Pradesh.

Rajput (2010) reported four Agroforestry systems viz; Agri-Horticulture (Maize, Blackgram, Cauliflower and Apple), Agri-Silviculture (Maize, Wheat, Grewia and Celtis), Agri-Horticulture (Maize, Wheat, Tomato, Apple and Grewia) and Silvi-Pasture (Grewia, Chir pine, Bauhinia and grasses) in Kullu valley of Himachal Pradesh.

Bijalwan *et al.* (2011) identified the practicing agroforestry systems in Gharwal region. They found the following traditional agroforestry systems viz., agri-silviculture, agri-horti-silviculture and agri-horticulture. The major tree based agri-silviculture system included the tree species like *Grewia optiva, Celtis australis, Melia azedarach, Ficus roxburghii*, etc. along with agricultural crops. The agri-horti-silviculture, the combination of *Grewia optiva* + *Malus domestica* + wheat; *Quercus leucotrichophora* + *Malus domestica* + wheat/potato; *Grewia optiva* + *Prunus domestica*

+ barnyard millet etc. The major fruit-tree based Agri-Horticulture systems were comprised of *Malus domestica, Prunus domestica* and *Prunus armeniaca* along with routine agricultural crops. In addition, Agri-Silvi-Pasture, Silvi-Pasture and Horti-Silviculture systems were also observed in the few parts of region.

Poonam *et al*. (2011) identified and categorized five different types of agroforestry systems which were agri-silviculture, agri-horticulture, agri-silvi-pastoral, silvi-pastoral and horti-pastoral in Lahaul and Spiti District of Himachal Pradesh.

Rizvi *et al.* (2011) identified prominent agroforestry systems practiced by farmers in Saharanpur District, western UP, viz., agri-silviculture, agri-horticulture and agri-horti-silviculture. Dominant woody perennials that prevail in this district are Eucalyptus hybrid. *Eucalyptus tereticornis*, *P. deltoides* (Poplar), inter-sparse plantations of *Sizygium cumini* (Jamun) and *Dalbergia sissoo* (Shisham). *Mangifera indica* (mango) is the dominant fruit tree in Agri-Horticulture. Wheat, mustard, sugarcane and paddy are the dominant crops grown by the farmers.

Dhanya *et al.* (2014) studied coffee agroforestry systems (CAFS) in Kodagu and Mandya Karnataka. There were indigenous trees like *Aporusa lindleyang* (Wt.) Baill, *Artocarpus heterophyllus Lam*., *Dalbergia latifolia Roxb*., *Artocarpus hirsutus Lam*., *Lagestroemia lanceolata Wt*., *Terminalia bellirica* (Gaetn.) *Roxb*, *Acrocarpus fraxinifolius* Wt. & *Olea dioica* Roxb., and *Grewia tilifolia.* Popular exotic shade species include *Grevillea robusta* and *Acacia mangium* Wild. Coffee AFS were initially developed with *Coffea arabica* L. species, which notably requires shade, but this has now been replaced by *Coffea canophora Pierre* ex Froehle (robusta coffee), which is higher yielding and less shade demanding. Ficus agroforestry systems (FAS) in Mandya, Karnataka trees of the genus Ficus are abundant in rainfed farmlands in association with field crops of millet, maize, pulses, and oilseeds. *Ficus benghalensis* L. is the major species of Ficus grown in these agroforestry systems, followed by *Ficus religiosa* L, *Ficus amplissima* Sm., *Ficus virens Aiton*, *Ficus racemosa* L., and *Ficus mysorensis* var. *pubescens.*

Bhusara *et al.* (2016) presented an investigation which was carried out in the year 2012-2013 in Valsad district of Gujarat in total three major agroforestry systems viz. agri-silviculture, agri-horticulture and horti-pasture were found. The system types were Teak + Paddy; Teak + Sugarcane; Teak + Banana; Teak + Okra; Mango + Paddy; Mango + Banana; Mango + Maize and Mango + Jowar under major agroforestry systems agri-silviculture, agri-horticulture and horti-pasture, respectively.

Mahato *et al.* (2016) conducted a survey in Garhwal district of Uttarakhand and pointed that Agri-Horti-Silviculture system is prevalent among the practitioners as it provides good revenue/income to the farmers of the Himalayan region.

Dager (2017) observed the traditional agroforestry systems in Sikkim based on indigenous farming practices i.e., agri-horti-pastoral system, agri-silvo-pastoral system, horti-silviculture system, Agri-Horti-Silvo-pastoral system, livestock based mixed farming, sericulture-based farming. These systems are designed and redesigned on a rotational basis according to situation, requirement and time. The agroforestry systems in Sikkim Himalaya in general include home gardens, alley cropping, growing multipurpose trees and shrubs on farmland, boundary planting, farm woodlots, orchards or tree gardens, plantation/crop combinations, shelterbelts, windbreaks, conservation hedges, fodder banks, live fences, trees on pasture, livestock and beekeeping as was described by Nair (1993) and Sinclair (1999). The traditional agroforestry practices under are broadly categorized into five systems: farm-based, forest-based, Alnus-cardamom-based, forest-cardamom-based and Albizia-mixed tree-mandarin-based system.

Islam *et al.* (2017) carried out a survey in Kashmir valley and identified the traditional agroforestry systems viz. Boundary plantations, Agri-Silviculture on sloping lands, Agri-Silviculture in hills and forests, Agri-Silviculture in flat or plain lands, Horti-Silviculture, Horti-Silvi-pasture, Horti-Silvi-Agriculture and home gardens. In agri-silviculture system, maize was raised as main crop. During winter, mustard and at some places vegetables like brassica, carrot, reddish, turnip etc. were grown. The trees identified were *Robinia pseudoacacia*, *Ailanthus altissima*, *Aesculus indica*, *Populus nigra*, *Salix alba*, *Ulmus wallichiana* and *Juglans regia*. In Horti-Silviculture system, forest trees species raised are *Aesculus indica, Ailanthus altissima, Populus deltoides, P. nigra, Salix alba. Robinia pseudoacacia and Ulmus wallichiana*. Fruit trees include *Juglans regia, Prunus cerasus, P. amygadalus, Malus pumila,* Peach, Plum, Cherry, Apricot etc. In Horti-Silvi-Pasture system, above crops and addition pasture grasses (*Festuca pretense/ Dactylis glomerata*). legumes (*Trifolium pretense, T. repens*) or *Avena sativa*. In Horti-Agri-Silviculture system, vegetables such as knol-khol, cabbage, cauliflower, turnip, radish, carrot, onion, peas. spinach, garlic, tomato, brinjal, chilies, capsicum, french beans, cucumber, bottle gourd, bitter gourd, pumpkin, potato etc. were cultivated along with trees and fruit components are same as that of Horti-silviculture system.

Tiwari *et al.* (2018) observed the system units of different Agroforestry systems and major constraints in North-Western Himalaya under Sirmaur district of H.P. The study area had three prevailing agriculture-based agroforestry systems viz. agri-silvi-culture, agri-horticulture and agri-silvi-horticulture system as well as pastured based agroforestry systems viz. agri-silvi-pasture, silvi-pasture, pastoral-silvi-culture and pastoral-silvi-horticulture system at three altitudinal zones representing three categories of farmers.

Deshmukh *et al*. (2020) reviewed the work done by various researchers on the existing agroforestry systems in South Gujarat and reported that minimum 2 and maximum 6 agroforestry systems are adopted by farmers in Gujarat viz agri-silvi-hoticultural system, agri-silvicultural system, agri-horticultural system, home gardens, horti-pastoral and silvi-pastoral.

Handa *et al.* (2020) stated that, the forest cover of Haryana state is 3.6% of its geographical area and the remaining about 3% area is under agroforestry in farmlands due to higher adoption of Poplar and Eucalyptus-based agroforestry systems in the state.

Negi (2020) explored the status of existing agroforestry systems on farmland in plain regions of Uttarakhand, North India. Results of their study had shown a wide adoptability (85.68%) of different agroforestry systems in the region. Total eight types of agroforestry systems were adopted by farmers among which agri-silviculture was highly practiced (59.07%), followed by silvo-pastoral system (24.51%). Short rotation fast growing tree species i.e., Poplar and Eucalyptus along with other horticulture tree species were dominant species in identified agroforestry systems. In accordance with adopted tree species, five different types of plantation patterns were also recorded, among which boundary plantation pattern was mostly preferred (84.34%), followed by block plantation (12.12%). In these patterns, maximum number of agriculture, fodder and vegetable crop combinations were found associated with poplar trees.

Sharma *et al*. (2020) conducted a survey at Bangana Tehsil of Una District, Himachal Pradesh with aim to assess the existing agroforestry systems, they found out that there were five agroforestry systems being practiced by farmers which were as agri-silviculture, agri-horticulture, agri-horti-silviculture, silvi-pastoral and horti-pastoral systems.

2.2.1. Biological Yield

Chauhan (2000) conducted experiment at the CIMAP field station in Pantnagar, Udhamsingh Nagar, Uttar Pradesh, India, during 1990-94 to determine the performance of aromatic crops viz. lemon grass (*Cymbopogon flexuosus*), *Citronella java* (*C. wintrianus*), Palmarosa (*C. martinii*) and Japanese mint (*Mentha arvensis*) for five consecutive years in a Poplar (*Populus deltoides*) plantation. Intercropping of aromatic crops with poplar increased diameter at breast height (dbh) and height of the trees as compared to sole cropping. Growing aromatic species as intercrops with poplar has made it possible to produce a very high level of biomass with higher economic returns. In general, herb and oil yield from a sole crop was higher compared to the intercropped yields. Significant reduction in herb and oil yield started after the third year in *Citronella java*, Palmarosa and Japanese mint, while that of Lemon grass yield decreased slightly after the fourth year of the crop cycle. Lemon grass showed the best performance with respect to sustained herb and oil yield during entire growth period. Average net returns were Rs.25 (690/ha/year) from the sole plantation of trees and Rs.43 (590/ha/year) from Lemon grass, Rs.39 (670/ha/year) from Palmarosa and Rs.36 (370/ha/year) from Japanese mint using poplar-based agroforestry system for five year.

Vishwanath S. *et al.* (2000) studied traditional agroforestry systems in Madhya Pradesh and found that, *Acacia nilotica* (L) trees, locally known as babul, in rice fields are grown by small land holder farmers. The farms had an average of 20 babul trees, ranging in age from <1 to 12 years, per hectare in upland rice fields, the tree-stand density being greater on smaller than on larger farms (>8 ha). Over a ten-year rotation period, the trees provide a variety of products such as fuelwood (30 kg/tree), brushwood for fencing (4 kg/tree), small timber for farm implements and furniture (0.2 cubic m), and non-timber products such as gum and seeds.

Das (2005) investigated allometric equations for above and belowground tree components, crop and plantation floor biomass and litter fall estimation at Pusa, Bihar, India. Biomass, floor litter mass, litter fall and net primary productivity (NPP) of plantations increased with an increase in age of trees whereas, crop biomass for any specific crop interplanted with poplar decreased with the age of the plantation. The total plantation biomass increased from 12.08 to 90.59 Mg/ha^{-1} and NPP varied from 5.69 to 27.9 Mg/ha year. The biomass accumulation ratio ranged from 2.1 to 3.2.

Total annual litter fall was in between 1.95 and 10.00 Mg/ha^{-1} year, of which 92-94% was contributed by leaf litter. Compartmental models were developed for dry matter distribution in agroforestry systems involving young (3-year-old) and mature (9-year-old) poplar trees interplanted with various crops, the crops being grown in two rotations maize (*Zea mays*)-wheat (*Triticum aestivum*) - turmeric (*Curcuma domestica*) and pigeon pea (*Cajanus cajan*). This study substantiates the potential of *Populus deltoides*, under agroforestry combinations.

Singh (2009) studied biomass and carbon allocation in 8-year-old Poplar (*Populus deltoides* M.) plantation in Tarai Agroforestry Systems of Central Himalaya, India. Tree density of 8-year-old *Populus deltoides* plantation was 500trees/ha and the total tree basal area was 30.1 m^2/ha. The total biomass of 8-year-old *Poplar deltoides* plantation was calculated 202.59 t/ha, and a single tree accounts about 0.405 t biomass. The above ground components were contributed 78.68% and below ground components were contributed 21.32% biomass to the total biomass.

Rizvi *et al.* (2011) noted growth data of poplar tree in Agri-Silviculture system in Saharanpur and Yamuna-Nagar. In Saharanpur, the estimated timber biomass and volume of poplar tree at the age of 3 years were 126.05 kg/tree and 0.091 m^3 /tree respectively, which became 267.34 kg and 0.279 m^3 respectively at the age of 7 years. Timber biomass and volume increased by more than two times and three times from age 3 to age 7 years. In the case of boundary system, growth of poplar tree was not as good as that in Agri-Silviculture system at the initial stage. Timber biomass and volume were estimated to be 80.59 kg/tree and 0.039 m^3 /tree respectively, at the age of 3 years, which reached up to 249.01 kg/tree and 0.254 m^3 /tree respectively, at the age of 7 years Timber production of poplar tree in boundary system was found to be lower than that in Agri-Silviculture system. In Yamuna-Nagar, Timber biomass and volume were estimated to be 130.22 kg/tree and 0.104 m^3 /tree respectively, at the age of 3 years. These two values became 226.55 kg/tree and 0.237 m^3 /tree respectively at the age of 7 years, was found to be less than those for Saharanpur at the same age. Tree growth of poplar in boundary system in Yamuna-Nagar revealed that timber biomass varied from 64.41 to 125.16 kg/tree at 3 years and from 194.64 to 263.96 kg tree at 7 years. Range of timber volume was 0.024-0.090 m^3 tree at 3 years and 0.182-0.275 m^3 tree at 7 years.

Thakur *et al*. (2011) studied Biomass production of under story vegetation (shrub and herb layer) in Kuthar forest range (village Krishangarh), district Solan of Himachal Pradesh, under three natural Agroforestry systems viz., Agri-silviculture (AS), Pastoral-silviculture (PS) and Pastoral-Silvi-Horticulture (PSH). Shrub layer was dominated by *Murraya koenigii* in all the three land uses, with maximum biomass production under PS (6852.04 kg/ha) PS system provided maximum biomass (11771.81kg/ha) from seven shrubs species encountered in this system.

Arvind (2012) recorded the biological productivity of agricultural crop under Agri-Horticulture system as 3501 kg/ha^1/year^1 compared to 5052. 3344 kg/ha^1/year^1 in sole agricultural system on the northern aspect and therefore, there was a reduction of 28.25% in the biological yield under Agri-Horticulture system. In the southern aspect the biological yield was noticed 3344 kg/ha/yr under Agri-Horticulture system while the sole crop yielded 5072 kg/ha/y^r, there was 28.82% reduction in biological in this aspect. The 4.48% reduction was observed in the biological yield under southern aspect as compared to northern under Agri-Horticulture system whereas in sole agriculture system the biological yield was 1.20% higher in southern aspect. The maximum reduction in the biological yield was observed in *Vigna umbellata* (44.57%) during summer and *Pisum sativum* (47.89%) during winter on the northern aspect compared to crops grown without tree. In the southern aspect the maximum reduction in biological yield was noticed in *Eleusine coracana* (72.65%) during summer and *Coriandrum sativum* (28.53%) during winter compared to sole agricultural crop.

Uddin (2016) conducted investigation to examine the biological performance of Indian spinach and papaya in litchi-based agroforestry system. Papaya was planted between two litchi plants in each line and Indian spinach varieties were grown in the inter-space of two lines of litchi plant as well as control (farmers practice) in. Yield and yield contributing characters of Indian spinach varieties grown as litchi-papaya based agroforestry system and control did not vary. However, sprout plant and sprout weight of Indian spinach varieties grown in litchi-papaya based system were significantly influenced while the other parameters did not vary. Sprout plant of KS green (2.97) and local (2.89) variety were identical but higher over KS red variety (2.57). Sprout weight of KS red variety was the highest (85.80g) while KS green and local variety gave lower and identical sprout weight. Though the yield did not vary among the varieties, KS red gave the highest yield (36.32t/ha) followed by local (34.61t/ha) and KS green (34.00t/ha). In case of growth of litchi, plant height and stem diameter increment were 21.39 and 44.94 % over the eleven months observation period. The yield of papaya was quite satisfactory with an average 42 fruits per plant with 23.71t/ha Therefore, in the Litchi-Papaya-Indian spinach-based system, Indian spinach varieties could be ranked as KS red> Local> KS green.

Satyawali *et al.* (2018) A field trial-based Agroforestry system was established at Pantnagar during Rabi season 2012-13 for predicting the effect of spacing on growth and yield of wheat (*Triticum aestivum* L.) under *Eucalyptus camaldulensis* and *Melia azedarach*. The experiment was carried out in split-plot design consisting of two tree species in main plot, viz. *Eucalyptus camaldulensis* and *Melia azedarach* and four spacing treatments in sub-plot viz. 3.0m x1.0m, 3.0m x1.5m, 3.0m x 2.0m and 3.0m x 2.5m with three replications. The wheat crop variety"UP-2338" was sown on December 06, 2012 and harvested on April 27, 2013. Among the tree species, the maximum (15.1 q/ha) and significantly higher grain yield with 21.8% increment was recorded under Melia as compare to Eucalyptus. Whereas, among the different spacings, the wheat growth in terms of dry biomass at 120 DAS (495.4m^2), yield attributes and yield in terms of grain (16.0 q/ha), straw (29.4 q/ha) and biological yield (45.4 q/ha) under Melia was significantly higher at 3.0m x 2.5m spacing as compared to other planting density.

Devi *et al.* (2019) classifies the *Toona ciliata* of different diameter classes viz. D (28-30 cm), D (30-40 cm), D (40-50 cm) and D (50-60cm) crop production of *Triticum aestivum, Hardeum vulgare*. *Pisum sativum* and *Coriandrum sativum* in Sirmour district of Himachal Pradesh. Crop production was studied under trees of different diameter classes at the distances (2.45m from tree trunk and outside the canopy) yield of *Triticum sativum* increased significantly with distance from the free trunk and highest production (2309kg/ha was recorded outside tree canopy respective of distance us under 28-30cm DBH class trees gave significantly higher economic yield (2130 kg/ha) and biological yield (3807kg/ha Economic yield of salt with the distance from tree trunk being maximum (11620kg/ha) outside tree canopy and minimum (8140kg/ha was registered at 2m distance trunk).

Kumar *et al.* (2019) did a field experiment on wheat varieties was carried out at Agroforestry Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar. The experimental plots were laid out in randomized block design with two associate farming systems, open farming and poplar-based agroforestry system, and four varieties of wheat, viz. PBW-373, PBW-343, UP-262 and VL-907, with three replications. The yield characters of wheat, such as biological yield (112.01q/ha), grain yield (42.19q/ha), straw yield (69.93q/ha) and harvest index (39.82) were recorded maximum in VL-907 followed by PBW343, except for straw yield. Above-ground, below-ground and total biomass, carbon stock and carbon sequestration were significantly higher in agroforestry system (130.42, 17.75, 148.17. 65.20 and 239.27q/ha respectively) compared to open farming.

Kumar *et al.* (2019) performed field experiment on Effect of organic manure and irrigation schedule on growth and yield of Sarpagandha under teak and Poplar based Agroforestry system under the Agro-climatic conditions of Northern India. The experiment was laid out in Randomized Block Design. Application of T_{12} 100% FYM+ 20 days Irrigation resulted in higher plant growth viz. plant height (67.58cm), number of leaves per plant (220.25), number of branches per plant (32.25), collar diameter (15.70cm) and root length (55.41cm) and yield parameters viz. root fresh weight (30.52gm), root dry weight (14.52gm), root yield (44.63g) plant^{-1}. root yield (847.97kg) plot and root yield (22.04q/ha).

Sharma *et al*. (2020) conducted a survey at Bangana Tehsil of Una District, Himachal Pradesh with aim of the appraisal of biological yield and revealed that five agroforestry systems were practiced in study area among which Silvi-pastoral system gives highest (31.02 t ha^{-1}yr^{-1}) yield due to large number of middle-aged and matured trees along with the good growth of grasses.

Sharma and Shah (2020) studied the comparative performance of wheat varieties (UP-2526, UP2565, UP-2628, and DPW-621-50) under poplar and Eucalyptus based Agroforestry system. Experiment was laid out in Split plot design with three main plots (Open farming, Poplar and Eucalyptus Agroforestry system) and four sub plots (different wheat varieties). The observations on growth and yield parameters of wheat crop were recorded during rabi season. Germination count, plant height, number of tillers and dry matter accumulation were higher under open farming system than Agroforestry system (Poplar and Eucalyptus). Among wheat varieties UP-2526 showed higher germination count and maximum height, number of tillers and dry matter accumulation. Yield attributes like grain yield was higher in open farming (3.55t ha) system as compared to Agroforestry system. Among wheat varieties grain yield was significantly higher in UP-2628 (3.13t ha).

Chittapur (2021) studied productivity of Teak based agroforestry system in Yadagir district of Northeastern dry zone of Karnataka. Significantly lower pigeon pea grain yield (1766kg/ha) and biomass yield (8207kg/ha) in association with teak were recorded at 5m away from the tree line compared to the crop at a distance 10m (2345 and 10089 kg/ha, respectively) and 15m (8207, 10526 kg/ha, respectively) away from the tree line whereas harvest index remained unaffected. Nonsignificant differences were observed in grain yield and harvest index, albeit numerically higher grain yield was recorded in the control (2316kg/ha) without teak nearby compared to the agroforestry systems and within agroforestry systems boundary planting recorded numerically higher grain yield (2228kg/ha) than with bund planting (2081kg/ha). Significantly higher girth, volume and biomass of teak were recorded in bund planting (76.37 cm, 0.390m^3 and 215kg, respectively) followed by Silvi-Horti system (72.65cm, 0.381m^3 and 209kg, respectively) and boundary planting (69.10cm. 0.342m^3 and 215kg, respectively), whereas significantly lower girth, volume and biomass were recorded in block plantation (51.45cm, 0.182m^3 and 100kg. respectively). The study also revealed significantly lower crown spread in block plantation (2.85m) followed by boundary planting (4.63m).

Vijaykumar *et al.* (2021) conducted a trial at Forest Nursery and research Centre (College of Forestry) of Sam Higginbottom University of Agriculture, Technology & Sciences Prayagraj during kharif season of 2019-20 with sixteen treatments replicated thrice in a randomized block design to observe the performance of rice growth and yield under (*Moringa oleifera* L.) based Agroforestry system with utilization of various types of manures. The maximum performance of grain yield observed in T_6 (41.31q/ha) (50% Goat manure + 50% *Crotalaria juncea*) followed by T_{10} (41.21q/ha) (50% Goat manure + 50% *Pongamia glabra*) respectively and minimum grain yield recorded in T_0 (37.61q/ha) (control). The maximum performance of straw yield observed in T_6 (23.43q/ha) (50% Goat manure + 50% *Crotalaria juncea*) and minimum straw yield recorded in T_{10} (22.90q/ha) (control). The maximum performance of biological yield observed in T_6 (64.75q/ha and minimum biological yield recorded in T_0 (60.51q/ha) (control). The maximum performance of harvest Index observed inT_6 (63.78%) (50% Goat manure + 50% *Crotalaria juncea*) and minimum harvest Index recorded in T_0 (62.15%) (control) and benefit cost ratio 15.2) under *Moringa oleifera* based agroforestry system.

Zahoor *et al.* (2021) conducted a field experiment under temperate conditions in Kashmir valley. The main objective behind the study was to acknowledge the potential of apple-based agroforestry system for biomass production and carbon stock assessment for climate change mitigation. In 11-year-old apple plantation, green gram (*Vigna radiata*), rajmash (*Phaseolus vulgaris*), oats (*Avena sativa*), French bean (*P. vulgaris*) were used as an intercrop. The treatment, apple + rajmash + oats association displayed highest values for both total tree biomass (29.16 t/ha) and overall biomass of the system (33.00 t/ha). The highest ecosystem carbon was stored (64.18 t/ha) in the same treatment which was found 1.5 to 2 times higher than the agriculture-based system.

Tariyal *et al.* (2022) studied *Grewia oppositifolia* based agroforestry systems for the estimation of carbon stock and the production potential of barnyard millet (*Echinochloa frumentacea*) and finger millet (*Eleusine coracana*), with two elevational ranges, i.e 1000-1400 and 1400-1800 m amsl, in Garhwal Himalaya, India. The results of the investigation showed a decline in the growth and yield attributes of both the millet crops under the *G. oppositifolia* based agroforestry system at both elevations as compared to their respective control sites (sole crops). Among the elevations, the total number of tillers per plant (2.70 and 2.48), the number of active tillers per plant (2.18 and

2.25), panicle length (17.63 cm and 6.95 cm), 1000-seed weight (5.49 g and 4.33 g), grain yield (10.77 q/ha and 11.35 q/ha), straw yield (37.43 q/ha and 30.15 q/ha), biological yield (48.21 q/ha and 41.51 q/ha) and the harvest index (22.53% and 27.78%) were recorded as higher in the lower elevation in both *E. frumentacea* and *E. coracana*, respectively. The results show that the yield of *E. frumentacea* and *E. coracana* was not reduced so severely under the *G. oppositifolia* system. However, keeping in mind the other benefits of this multipurpose tree, carbon sequestration and socioecological relevance, farmers can get benefit from adopting these crops under *G. oppositifolia* based agroforestry systems.

2.2.2 Economic Return

Viswanath *et al.* (2000) estimated benefit/cost (B/C) ratio of babul + rice system i.e., 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten-year period, though at a low level of income. Babul trees account for nearly 10% of the annual farm income of smallholder farmers (<2 ha). By practicing the agroforestry (rice + babul) system, farmers get higher cash returns on a short-term (10-year) harvest cycle of trees.

Kaushik. (2003) investigated the effect of 20-year-old *khejri* (*Prosopis cineraria*) trees on the grain and fodder yield of arable crops under rain-fed conditions. The trees influenced the fodder (green and dry) yield of associated crops. Fodder yield during both rainy (kharif-July–September) and winter (rabi-October–January) seasons was more in association with khejri trees as compared to sole cropping of fodder crops. The economic analysis of the system showed that higher returns were obtained when any of the fodder crops in sequence was grown in association with khejri than in monocropping. Maximum net returns (Rs. 15,197/ha) and benefit–cost ratio (3.73) was obtained when pearl millet in kharif followed Todia (*Brassica tournefortii*) in rabi under khejri trees. Grain crops, both in kharif and rabi also earned more profit when grown with khejri than alone.

Kumar *et al.* (2004) poplar-based agroforestry models adopted by the farmers in Haryana and Uttarakhand states of India are very lucrative with NPV for different models on six years -1 -1 rotation varying from Rs. 27,000 to 73,000 ha/yr and B:C ratio from 2.4 to 3.7; far better than pure (seasonal) crop rotations.

Kareemmulla *et al.* (2005) investigated that Poplar based agroforestry is one of the major commercial agroforestry systems practiced by the farmers in Western Uttar Pradesh of India. The tree density in poplar-based (*Populus deltoides*) bund/boundary system was 146 trees ha^{-1}, as against 481 trees ha^{-1} in Agri-Silviculture. Additional income (<70%) and an emergency source of cash (nearly 20%) were the farmers major reasons for adopting agroforestry. The financial and economic analyses indicated that net present value (NPV) in case of bund system with an eight years rotation were Rs.137,000/-, Rs.127,000/- and Rs.18,000/- at discount factors of 8, 10 and 12 percent, respectively, with a Benefit Cost Ratio (BCR) of 2.8 for all the three discount factors. In the case of Agri-Silviculture with a rotation of seven years, the NPV at the respective discount factors were Rs.1,23,000/-, Rs.1,11,000/- and Rs.1,01,000/-, respectively, while the BCRs were 2.18, 2.15 and 2.12—compared to the conventional crop rotations with a BCR of 1.34 to 1.42 Both poplar-based agroforestry systems were more profitable than pure agricultural crop systems. Additional employment generation due to Agri-Silviculture was just under 11 man-days ha^{-1} yr^{-1}.

Poplar and Eucalyptus based agroforestry systems in Indo-Gangetic region; Eucalyptus and Leucaena based agroforestry in Andhra Pradesh and other southern states; Ailanthus based in Gujarat are few successful examples of commercial agroforestry where the returns are quite high. Poplar based agroforestry models adopted by the farmers in Haryana, Punjab and Western Uttar Pradesh are highly lucrative, therefore, attracting farmers in a big way (Singh and Sharma, 2007; Sidhu and Dhillon, 2007; Dhillon *et al.*, 2009; Gill *et al.*, 2009).

Patil *et al.* (2010) stated long-term agroforestry experiment consisting of arable crops (Paddy, maize, sun hemp). Silvicultural trees viz., *Eucalyptus tereticomis*, *Casuarina equisetifolla*. *Albizia molucana*, *Tectona grandis*, *Dalbergia sissoo*), Horticultural tree (sapota) and pasture crop (Guinea grass) was initiated on black clayey soils at Prabhunagar (Dharwad) during 1976. Sapota (*Achras sapota*) was planted at 10 m apart and three tree species were planted in between 2 Sapota plants. Guinea grass (*Panicum maximum*) slips were planted on either side of sapota and tree species in a small strip of 1 m width. At the end of 17 years (felling all short rotation trees and only adjoining long rotation trees), economic analysis Indicated that, benefit cost ratio and internal rate of returns were highest in agroforestry system with *T. grandis* (1.67.1 and 23.2%, respectively) and were lowest in sapota + *C. equisetifolia* (0.99:1 and 12%, respectively). The economic analysis at the end of 28 years (felling trees) indicated that benefit cost ratio was higher in sapota + *T. grandis* + field crops (3.23:1) followed by sapota + *Lagerstroemia lanceolata* + field crops (2.71:1) and sole sapota (2.36:1). Therefore, teak-based agroforestry model is economically viable agroforestry system.

Verma *et al.* (2010) Studies on effect of tree-crop combinations and nitrogen levels on economic returns from *Withania somnifera* L. Dunal, based agroforestry systems were carried out during 2004-2005 and 2005-2006, in experiment of Department of Silviculture and Agroforestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh *W. somnifera* was grown in association with *Prunus persica* (Peach), *Grewia optiva*, *Morus alba*, *Setaria sphacelate.* The tree-crop combinations (agroforestry systems) formed were, Peach + Grewia + *Setaria somnifera*, Peach + Morus + *Setaria* + *W. somnifera*, Peach + *Setaria* + *W. somnifera*, *Grewia* + *Setaria* + *W. somnifera*, Morus + *Setaria* + *W. somnifera*, and *W. somnifera* as sole crop. Three nitrogen doses applied to *W somnifera* was 80 and 120 kg/ha. The net returns were calculated on financial (farmer's land) and economic (rented land) ban maximum net financial returns amounting to Rs 11377/ha accrued from Ashwagandha roots, were obtained under Grewia and Setaria followed by Rs 11321/ha under Peach + Morus + Setaria. The Peach and Setaria under Peach + *Setaria* agroforestry system gave maximum net returns to the tune of Rs. 39691/ha, followed by Rs 36772/h. Peach, Morus and *Setaria* under Peach + Morus + *Setaria* system. The agroforestry system, Peach *W. somnifera* gave maximum net returns of Rs. 50116/ha, followed Paech + Morus *Setaria W. somnifera* with amounting to Rs 48093/ha. The maximum benefit cost ratio (B:C ratio) values to the tune of 3:87 was obtained in *Manus Setaria*. *W somnifera* system on farmers land (financial perspective), whereas it was 160 *Setaria, W. somnifera* system assuming the enterprise have been taken on rented land.

Chisanga (2012) conducted a study on bio-economic appraisal of different land use systems in dry temperate north western Himalayas and found that maximum net profit was attained in Agri-horticulture system (Rs.13,10,000/-) which was closely followed by horticulture (Rs.11,65,852/-). Net returns achieved in other land use system viz. agriculture, Agri-horti-silviculture, Silvi-pasture and barren land were quite lower in comparison to fruit-based land use systems.

Mosquera *et al.* (2012) expressed that Agroforestry continued to be practiced only where it enabled farmers to obtain economic returns from lands that were otherwise relatively unproductive and mostly limited to Silvi-pastoral practices. Since the mid-1990s, however, European policies have encouraged land management systems that combine production, environmental services (biodiversity, carbon sequestration, nutrient cycling and water quality) and social benefits, and this has created a new interest in Agroforestry systems. Today, the major Agroforestry practices in Europe include Silvi-pasture.

Khatun (2015) carried out a survey at Chapai Nawabganj District to identify the mango-based agroforestry systems, mango-based agroforestry system is profitable and has a great opportunity to increase national production to feed the growing population. There is a scope of adopting improved management practices and it may increase the total production. Based on crop condition with mango forest, a total of 12 mango-based agroforestry systems were identified. The most frequent observed mango-based agroforestry systems were Mango + Turmeric (85.00%) and Mango + Ginger (78.75%). Maximum respondents (72.50%) commented that 10-12-year aged mango tree performed best yield.

Singh *et al*. (2015) concluded that in Himachal Pradesh, 80 per cent of its total population lives in villages. Their economy depends on agriculture, horticulture and animal husbandry. The practice of pure agriculture in Himachal Pradesh is sufficient for the inhabitants to sustain only their food requirements, but for other needs people are forced to exploit forests. The investigation was carried out in Giri catchment located between 30º33'48" and 31º16'08" N latitude and 77º02'32" and 77º38'22" E longitude in Himachal Pradesh. The net returns from agroforestry systems decreased in the order of Agri-Silviculture system (Rs.2,77,415/-ha/yr.)>Agri-Silvi-Horticulture system (Rs.2,70,747/-ha/yr.)>Agri-Horticulture system (Rs.2,69,033/-ha/yr.) >Agri-Horti-Silviculture (Rs.2,25,880/- ha/yr.).

Bhusara *et al.* (2016) investigation was carried out in the year 2012-2013 in Valsad district of Gujarat in total three major agroforestry systems viz. Agri-Silviculture (AS), Agri-Horticulture (AH) and Horti-Pasture (HP) were found. The timber yield (20-year aid teak trees) as 3 maximum (43.92m^3 ha^{-1}) under Agri-Silviculture system (Teak + Rice) followed by teak banana system type. The economic yield of mange was recorded 15, 14.82 and 6.57 t/ha under Agri-Horticulture (Mango + banana) Horti-Pasture (Mango + sorghum and Mango + maize system) respectively. Among intercrops under different AF systems, the highest economic yield was of sugarcanes under teak + sugarcanes Agri-Silviculture system (55.36 t/ha) followed by maize and sorghum under two HP system types i.e., mango + maize and mango + sorghum. The maximum total economic yield is 16 may was recorded under teak sugarcane system followed by mango + sorghum and mango + banana with values to the tune of 39.07 and 33.72 t/ha respectively, the total net returns accrued highest 6,96,678 ha from Mango + Banana followed by system type Mango + Sorghum with net returns to the tune of 5, 95, 717 ha^{-1}. The net returns from woody component i.e, Teak and Mango comprising different tree crap combinations, were highest from Mango fruit yield under Mango + Banana.

Kaler *et al.* (2017) studied the existing agroforestry systems and economic returns from the systems in Kangra district of Himachal Pradesh. The bio-economics of the different systems were analyzed by calculating the cost of cultivation, gross return per ha, net return per ha and BC ratio. The higher net return of agroforestry systems among different farmers category was observed maximum in agri-silviculture, large farmers category (Rs.2,40,734.32/-) and benefit cost ratio of agroforestry system among farmers category was observed maximum in Agri-silvi-horticulture, large farmer's category (2.00).

Dhillon *et al.* (2018) recorded an experiment, *Sesbania aculeata* (kharif) and Hordeum vulgare (rabi) were intercropped in three spacing geometry of Eucalyptus (till the harvesting of trees) and also compared with mono cropping up to eight years of plantation. The results showed that 17m×1m×1m spacing of Eucalyptus registered the highest NPV @ 12 percent discounting of (Rs.1,85,336) followed by spacing of 6m×1.5m (Rs.1,40,975). The B:C ratio of these agroforestry system was recorded maximum in wider spacing (17m×1m×1m) and ranging from 1:1.57 and followed by 1:1.44 (6m×1.5m), 1:1.25 (sole Eucalyptus) and 1:1.2 (sole agricultural crops). The all the agroforestry system had an IRR ranging from 15 to 32 percent. Therefore, on the basis of economic analysis, the study conclude that the Eucalyptus based agroforestry intercropped with *S. aculeata* and *H. vulgare* cropping system performed most efficient in 17m×1m×1m as compared to other Eucalyptus spacing and sole cropping of Eucalyptus and crops.

Kumar *et al.* (2018) calculated total biomass (AG+BG) of crops grasses and trees to obtain total biomass (C+G+T) of agroforestry system. The order of decrease in grand total biomass for different categories of farmers in AS was small (19.21t ha^{-1} yr^{-1}) medium (18.85 t ha^{-1} yr^{-1}) marginal (18.28 t ha^{-1} yr^{-1}) in ASP medium (19.84 t ha^{-1} yr^{--1}) > marginal (18.48 t ha^{-1} yr^{-1}) > small (17.46 t ha^{-1} yr^{-1}). In ASH small (21.02 t ha^{-1} yr^{-1}) > marginal (17.48 t ha^{-1} yr^{-}1) > medium (16.83 t ha^{-1} yr^{-1}). In AHS medium (13.79 t ha^{-1} yr^{-1}) > marginal (13.12 t ha^{-1} yr^{-1}) > small (12.16 t ha^{-1} yr^{-1}), in HP medium (15.36 t ha^{-1} yr^{-1}) > small (13.34 t ha^{-1} yr^{-1}) and in SP medium (24.88 t ha^{-1} yr^{-1}) > small (23.24 t ha^{-1} yr^{-1}) > marginal (22.13 t ha^{-1} yr^{-1}). Net returns of marginal farmers decreased in the order of AHS (Rs.297952 ha^{-1} yr^{-1}) >AS (Rs 235059 ha^{-1} yr^{-1}) >ASH (Rs.225557 ha^{-1} yr^{-1}) >ASP (196173 ha^{-1} yr^{-1}) >SP (Rs.33232 ha^{-1} yr^{-1}), while for small farmers the order of decrease was ASH (Rs.269744 ha^{-1} yr^{-1}) >AHS (Rs.259336.01 ha^{-1} yr^{-1}) >HP (Rs.242041 ha^{-1} yr^{-1}) >ASP (Rs.210521 ha^{-1} yr^{-1}) >AS (Rs.198888 ha^{-1} yr^{-1}) >SP (Rs.43085 ha^{-1} yr^{-1}). In medium category net returns exhibited order of AHS (Rs.250870 ha^{-1} yr^{-1}) >HP (Rs.232803 ha^{-1} yr^{-1}) >ASH (Rs.223230 ha^{-1} yr^{-1}) >AS (Rs 213595 ha^{-1} yr^{-1}) >AS (Rs.185707 ha^{-1} yr^{-1}) >SP (Rs.39072 ha^{-1} yr^{-1}). So, he concluded that agroforestry systems contribute greatly in biomass production as well as help in socio-economic upliftment of farmers.

Sharma *et al*. (2020) conducted a survey at Bangana Tehsil of Una District, Himachal Pradesh. In these studies, they found that the under Agri-silviculture systems, the net return was found highest (Rs.1,51,761/- ha^{-1} yr^{-1}) in the small category followed by marginal (Rs.1,25,549/- ha^{-1} yr^{-1}) and medium (Rs.61,288/- ha^{-1} yr^{-1}) category of farmer.

Chittapur (2021) observed in investigation was done in southern peninsula of India undertaken to assess the economics and energy use efficiency of different neem (*Azadirachta indica* A.) and teak (*Tectona grandis* L.) based agroforestry systems in rainfed and irrigated ecosystems respectively in north-eastern dry zone of Karnataka, India. The economic analysis of neem-based agroforestry systems under rainfed condition revealed higher net returns and B:C ratio with crop alone (control) (515 \$ ha^{-1} $year^{-1}$, 2.00 respectively) over different agroforestry systems. While, in teak-based agroforestry systems under irrigated ecosystem higher B:C ratio were recorded (4.07 to 5.71) over control (2.87). However, energy analysis revealed that both neem (3.99 to 4.15) and teak based agroforestry systems (4.48 to 7.74) were energetically superior to control (3.32 and 4.21 respectively).

Tripathy *et al.* (2021) calculated the B: C ratio of eucalyptus and paddy-based Agri-silviculture system (2.55) with compare to control farming (2.22). In comparison to control farming Eucalyptus-based Agri-silviculture system provides more benefit. There is a significant difference in D.B.H of eucalyptus at before planting of paddy and after harvesting of paddy. D.B.H of eucalyptus has increased after harvesting of paddy from the D.B.H of eucalyptus before planting of paddy. The initial mean D.B.H of eucalyptus was 24.23cm and after harvesting of paddy the D.B.H of eucalyptus increases to 24.96cm. In agroforestry system, the maximum gross return or B-C ratio was obtained from the Eucalyptus-Paddy (Pooja variety) based Agri-silviculture system, and on the other hand gross return or B-C ratio from control farming was found lower than Eucalyptus-paddy (Pooja) based Agri-silviculture system. The region of Kendrapada district of Odisha for more economic benefit from a single piece of land by appropriate utilization of moisture and nutrient of the land through agroforestry system. The tree planted on field bund having positive impact on microclimate of field and in maturity it provides lot of income through wood biomass this system is very sustainable agriculture system. Rathore *et al.* (2022) studied the integration of perennial fruit trees with seasonal crops may enhance farm productivity, economic returns, and environmental sustainability. Integration of Phalsa (*Grewia asiatica*) with Mung bean (*Vigna radiata*) + Potato (*Solanum tuberosum*) system recorded the highest system productivity (25.9 Mg/ha) followed by phalsa with cowpea (*Vigna unguiculata*) + mustard (*Brassica juncea*) systems (21.2 Mg/ha). However, Karonda (Carissa sp.) with Mung bean + potato system recorded maximum net return (3529.1 US\$/ha), and water use efficiency (33.0 kg/ha-mm). Concerning the benefit-cost (B:C) ratio, among the agroforestry systems, the karonda + cowpea + mustard system registered a maximum BC ratio (3.85). However, SOC density remained higher (9.10 Mg/ha) under the phalsa + cowpea + mustard and Moringa + mung bean + potato system (9.16 Mg/ha).

Singh *et al.* (2022) did a survey based on a pre-tested interview schedule was used for primary data collections from 160 farms respondents of wheat agriculture system and Eucalyptus + wheat-based Argoforestry system in Prayagraj and Kaushambi districts. The cost of cultivation was followed in order: Rs.42,213.15 ha^{-1} and Rs.40,178.70 ha^{-1} (small farms) > Rs.40,211.16 ha^{-1} and Rs.37,793.35 ha^{-1} (medium farms) > Rs.39,214.50 ha^{-1} and Rs.36,791.30 ha^{-1} (large farms) in Prayagraj and Kaushambi, respectively. The B:C ratio was also followed in same trends as 1:1.60 and 1:1.65 (small farms) > 1:1.54 and1:1.60 (medium farms) > 1:1.51 and 1:1.58 (large farms) in wheat agriculture system and Eucalyptus + wheat-based AFs. But the value of gross income was reversed and followed the order: Rs.67,733.50 ha^{-1} and Rs.66,300.00 ha^{-1} (large farms) > Rs.61,917.50 ha^{-1} and Rs.60,546.00 ha^{-1} (medium farms) > Rs.59,329.00 ha^{-1} and 58,124.00 ha^{-1} (small farms) in Prayagraj and Kaushambi, respectively. Similarly, the value of overall net income, farm business income, family labour income, and farm investment income were higher under Eucalyptus + wheat-based agroforestry system in Kaushambi than the wheat agriculture system in Prayagraj.

2.3 Relevance of Agroforestry System to Meet Social as well as Technological Constraints in Farming Systems:

Mughal *et al.* (2000) evaluated the socio-economic aspects of agroforestry in rural Srinagar of Kashmir valley. They reported that people in the study area planted only three tree species i.e., *Populus deltoides*, *Salix alba* and *Robinia pseudoacacia* under agroforestry system, which were not sufficiently efficient to meet people requirement of food, fodder and fuel wood for whole year from these models. In order to make these scientific models efficient, productive and generate interest from them, energy need to be diverted for farm experiments so that people can judge by themselves the performance of scientific models, which in turn will go a long way in fulfilling the requirements of farmers to a great extent. Model devised should be economically feasible so that they can be adopted without much resistance.

Salam *et al.* (2000) observed that in recent years, farmer's decision of whether to plant or not to plant trees have been based primarily on economic rather than ecological concerns. It is concluded that the improvement in homestead forestry may result in the reduction of poverty in the livelihood of rural people by increasing overall household income. To this end, they were suggested that forestry extension workers work more closely with the local people in order to implement homestead forestry.

Kumar *et al.* (2005) conducted research studies pertaining to analysis of agroforestry system in Punjab with physical and biological aspects. The information from the findings of this studies offered direct benefits at local level to the farmers by way of getting better understanding their constraints and perception about the Poplar based agroforestry system. The biological, environmental, economic and social relationship within and among the agroforestry system are yet not fully well been realized. For its successful development, there is a great need for strengthening research besides suitable policy and marketing structure. Poplar based agroforestry system in Punjab has proved itself ecologically and economically viable land use system and help in diversification of unsustainable traditional rice-wheat rotation.

Smith *et al.* (2007) observed that in Tanzania, the farmers face a number of challenges that hide them from establishing and using improved fallows. Lack of awareness and poor knowledge on improved fallow is most critical compared to other problems. This is followed by lack of interest to plant trees, the long time it takes to realize benefits from trees, as farmers have to wait for two years before getting benefits from improved fallow and lack of seeds/seedlings. In addition, farmers mentioned that livestock grazing is becoming a serious problem because of the land tenure system in which land is communally owned and free livestock grazing. Lack of effectiveness of the bylaws was due to lack of understanding of the exact provisions of the bylaws by various components of the community.

Sharma *et al.* (2009) observed that the farmers of western districts of Uttar Pradesh are suffering with low price of their crops since they are completely in the hand of middle man or contractor. To overcome this star has taken major step to return back their crop directly on market rates. The farmers of western districts of Uttar Pradesh are confronting with following problems such as, lack of proper valuation of crop, levies laws, lack of awareness to adopt and cultivation of superior Eucalyptus clones and Poplar Clones of high yield, invasion of epidemic disease like gall, availability of labour, soil fertility and productivity.

Bhan (2014) revealed the constraints for adoption of conservation agriculture (CA), a mental change of farmers, technicians, extensionists and researchers away from soil degrading tillage operations towards sustainable production systems like no tillage is necessary to obtain changes in attitudes of farmers. However, he noted that probably the most important factor in the adoption of Conservation Agriculture is overcoming the bias or mindset about tillage. It is argued that convincing the farmers that successful cultivation is possible even with reduced tillage or without tillage is a major hurdle in promoting CA on a large scale. In many cases, it may be difficult to convince the farmers of potential benefits of CA beyond its potential to reduce production costs, mainly by tillage reductions. CA is now, considered a route to sustainable agriculture. While the basic principles which form the foundation of conservation agriculture practices, that is, no tillage and surface managed crop residues are well understood, adoption of these practices under varying farming situations is the key challenge. These challenges relate to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance, developing crop harvesting and management systems.

MBow (2014) revealed that agroforestry has real potential to contribute to food security, climate change mitigation and adaptation, while preserving and strengthening the environmental resource base of Africa rural landscape. It has a key role to play in landscape scale mitigation schemes under the agriculture, forestry and other land use concepts. For millions of African farmers whose livelihoods are threatened by climate change and land degradation, agroforestry offers a pathway toward more resilient livelihood. But knowledge gaps in agroforestry are greater than the actual body of knowledge on most aspects. It is therefore essential that research efforts on these important cropping systems are intensified, so that future scaling-up of agroforestry can be rooted in robust scientific findings rather than in intuition.

Oberg (2014) examined the socio-economic factors that affect agroforestry adoption by smallholder farmers in Ghana. Primary data was collected from 80 randomly selected farmers from four farming communities in Ghana. Socio-economic factors which tend to influence the decision to adopt agroforestry practices were identified. These included level of education, age, income, years of farming experience, household farm labour, farm size, land tenure arrangement, knowledge on agroforestry practices, access to extension services, farmers' value of forest, proximity to a forest reserve area and farmers' willingness to plant trees. Logit regression model was employed to determine how these factors influence farmers' adoption decision. The regression results indicated that, gender, total household size, number of years of farming experience, proximity to a forest reserve area, access to extension information and willingness to plant trees on farms have positive influence on adoption of agroforestry practices. However, only total household labour measured as household size and willingness to plant trees on farms predicted the decision to adopt agroforestry practices at a statistically significant level (p=0.05). Land ownership type (land acquired through a farmer's family lineage categorized as inheritance) had a significantly negative influence on the adoption decision. The study provides useful information for extension services regarding planning and adoption strategies of developed Agro-based practices such as agroforestry systems to smallholder farmers in different farming communities.

Saravanan (2017) conducted a study in Erode and Coimbatore districts of Tamil Nadu, to find out the problems faced by the *Melia dubia* Cav. growers in its adaptation in these block plantation as well as in agroforestry systems. The data were collected from 120 Melia growers through structured questionnaire method. It was found than the recommended practices did not reach to farming communities or did not practice by them. Most of the farmers do not purchase quality planting material. *Melia* growers were needed to be addressed and convinced about the usefulness of these silvicultural practices for better growth condition and higher economic returns. Being a agroforester, how-to species introduced along the farming community, the cultivation techniques were to be brought out in local language for better understanding of the farmers. The major problems faced by the turning immunity were non-availability of quality planting materials high cost for seedling from private nursery pest and disease management, marketing, non-availability of loan or use of insurance and tree cultivation techniques *Melia* plantation is generally not adopted by the farmers due to the non-availability of technical inputs and proper extension education.

Suman *et al.* (2017) studied the constraints regarding adoption of fodder production technology in Bundelkhand region. In the study it was found that 84 1% of respondents expressed that small landholding among these was the printery constraint for lesser adoption of fodder production technology in area about 75% of farmers identified lack of imitation as the second most important reason is less adaptation of fodder technology. The main reason for less Knowledge of fodder production technologies were lack of awareness about improved technologies followed by lack of a farm guidance, lack of lesser resources and lesser literacy among them.

Verma *et al.* (2017) observed that In India, *G. arborea* being such a wonder substitute of Teakwood, it has not scaled up in plantations as well as in agroforestry in various regions due to several reasons including dearth of proper tree improvement, silvicultural practices and inappropriate knowledge of insect pest management. The major hitches faced by the farming community/growers are non-availability of quality planting material, costly seedling, unfledged marketing linkages, etc. Recently one monophagous coleopteran insect *Craspedonta leayana* defoliating is reported from North-Eastern region of India. It has the tendency to develop heavy branches and forks, with a crooked and tapered stem. There is also need to make some better clones of the tree as the tree species is vulnerable to insect attacks and disease which is limiting plantation expansion and acceptance. It also has low wood density than most commercial species of Eucalyptus and Acacia which limits pulp yields and product strength of the wood which should be overcome with the aid of technologies and science.

Tiwari *et al.* (2018) studied identification of existing agroforestry practices and systems in the Sirmaur district have helped for identifying social, technical, infrastructural and miscellaneous constraints/gaps inflicting the tree crop production systems. Land utilization patterns and management practices for crops, trees, pastures and animal prevalent in the area have shown inherent weakness and also the potentials for the improvement. Besides that, unawareness of govt. sponsored welfare schemes and lack of facilities. Keeping in view the major social, technical and infrastructural constraints/gaps have been identified and have been described collectively for all the altitudinal zones.

Gebru *et al*. (2019) farmers in Southern Tigary of Ethiopia avoid natural calamities and soil erosion by planting multi-purpose tree species. Agroforestry strengthens the farmer's resilience by offering fuel wood, fodder, timber and non-timber services as well as generate employment.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **"Socio-economic survey of existing agroforestry systems in Dehra Tehsil of Kangra District, Himachal Pradesh"** was conducted during the year 2021-2022. The methodology used for the study consists of site selection, sampling procedure, identification of existing agroforestry systems, data collection, analytical framework and valuation. A detail of the study area and methods adopted for the study is given below:

3.1 Study Area:

The present socio-economic survey was conducted in Dehra Tehsil of Kangra District of Himachal Pradesh which in lies between 31^{o}90'N latitude and 76^{o}22'E longitude. The Dehra is situated at an elevation of 503 m above mean sea level on the left bank of Beas River at a distance of 36 kms from Kangra. The climate of Dehra is mostly Sub-tropical and receives an average rainfall of about 1633mm having average annual temperature 23^{o}C.

The study was conducted by random stratified sampling method in which 13 Gram Panchayats was choosed.

Table 1: List of panchayats in Dehra tehsil

S. No.	Name of Panchayats
1	Paisa Khas
2	Bankhandi
3	Kallar
4	Gher
5	Khundian
6	Tip
7	Landyara
8	Tipri
9	Dadsibha
10	Ghiyori
11	Thill
12	Bhihan
13	Dohag

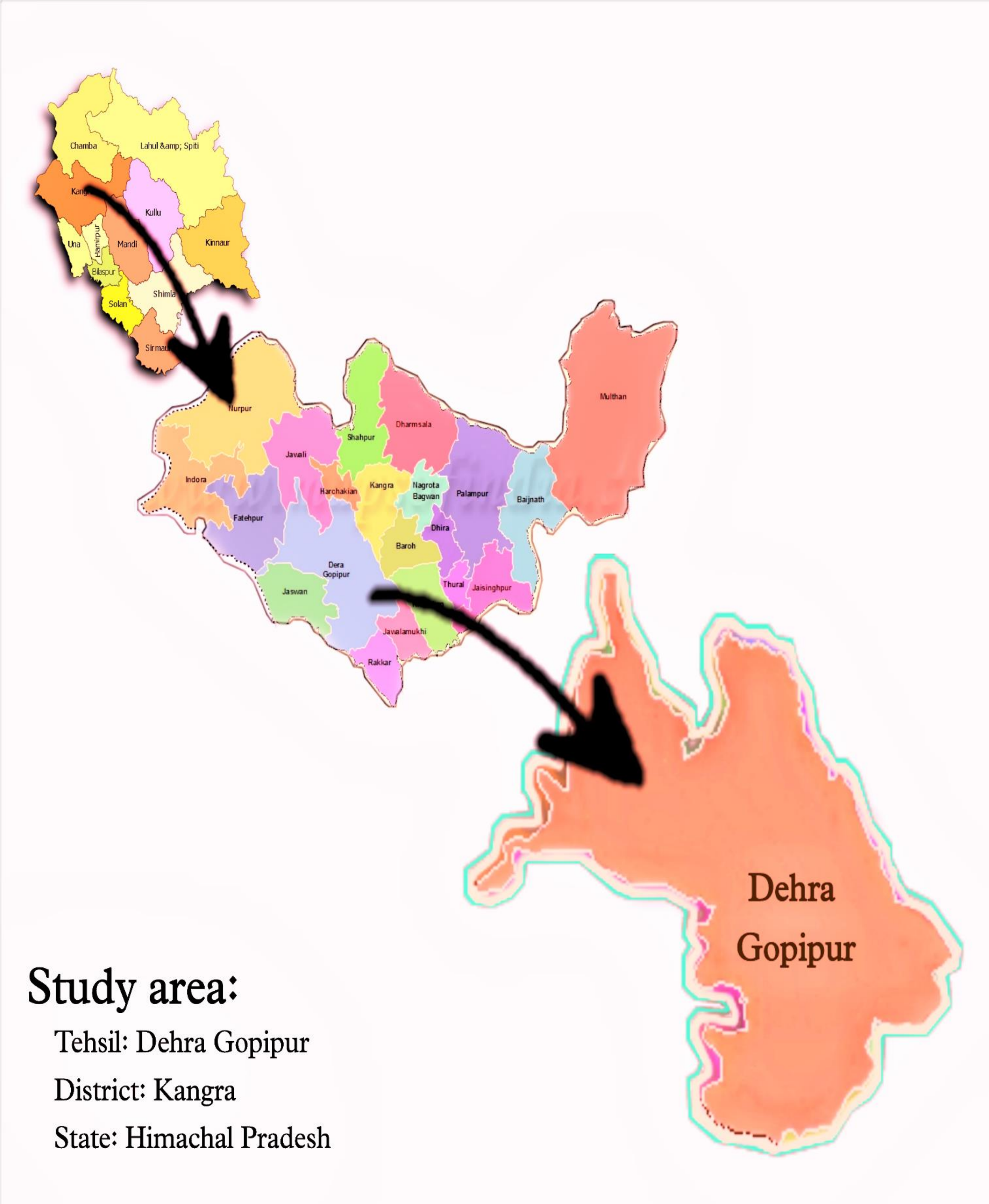


Plate 1: - Location map of the study area

3.2 Sampling Procedure:

From each Panchayat farmers was divided into three different categories on the basis on their land holdings i.e., marginal (<1 ha), small (1-2 ha) and medium (2-5 ha) and from each category 12 farmers were taken. The relevant information about the study was collected through pre-tested schedule by personal interviews with each head of the household.

Table 2: Farmers category on the basis of land holdings

S. No.	Farmers category	Size of operational landholding
1.	Marginal	<1ha
2.	Small	1-2ha
3.	Medium	2-5ha

3.3 IDENTIFICTION OF EXISTING AGROFORESTRY SYSTEMS

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

3.3.1 Primary Components

The components which occupy the larger area of the total unit area and serve the major function i.e., production of primary output needed by the farmer was considered as a primary component.

3.3.2 Secondary Components

The components which occupy relatively lesser area of the total unit area compared to area under primary component and yielding the secondary output needed by farmers was considered as secondary component.

3.4 DATA COLLECTION

The observations were recorded on the below mentioned parameters.

3.4.1 Socio-economic Status:

3.4.1.1 Demographic features

1. Name of the farmers
2. Family members (no. of male and female)
3. Education
4. Occupation
5. Land holding
6. Land use pattern
7. Income

3.4.2 Agroforestry System Components

3.4.2.1 Cereals/pulses/vegetables

1. Kharif crops
2. Rabi crops
3. Crop rotation
4. Crop yield
5. Management and cultural operations

3.4.2.2 Fodder/timber trees/fuel wood

1. Tree species
2. Number of trees of a species
3. Lopping frequency
4. Tree biomass
5. Yield/hectare

3.4.2.3 Fruit tres

1. Number of fruit tree species
2. Number of individual trees of each species
3. Bearing/Non-bearing trees

4. Yield/hectare

3.4.2.4 Animal husbandry

1. Total number of cattle and their types
2. Feed consumption
3. Milking procedure followed
4. Management practices followed
5. Breeding techniques followed
6. Use of FYM

3.4.3 Financial Return of Each System

3.4.3.1 Material cost

1. Cost of seed
2. Farmyard manure cost
3. Fertilizer cost
4. Insecticide cost

3.4.3.2 Labour cost

1. Preparatory tillage cost
2. Family labour cost
3. Hired labour cost
4. Harvesting cost
5. Thrashing cost (cereals)
6. Lopping frequency
7. Pruning cost
8. Floor management operations of fruit crops
9. Other miscellaneous costs

3.5 BIOLOGICAL YIELD

3.5.1 Agriculture Crop Biomass

The biomass production in cultivated land was determined by taking random samples of *Kharif* and *Rabi* crops on the farmer's field by making a quadrates of size 1m x 1m. Total harvest method was carried out by digging out the crop plant along with the root falling within the quadrate. The soil was gently removed by tapping. Roots and shoot of crops were segregated and stored in different paper bags. All crop samples were washed to remove the soil and oven dried at 70°C till a constant weight was achieved. The dried samples of root and shoot of each crop species were weighed to determine above ground and below ground biomass of each species.

3.5.2 Grasses

The grass biomass was calculated after harvesting grasses by laying out quadrate of size 50cm × 50cm. The soil was gently removed by tapping. Roots of different species were segregated and stored in different paper bags. All plant samples were oven dried at 70°C till a constant weight was achieved. The dried samples of root and shoot of each species were weighed to determine above ground and below ground biomass of each species.

3.5.3 Trees

3.5.3.1 Above ground tree biomass

The estimation of above ground tree biomass was done by non-destructive method using local volume equation developed by FSI (2015). For the biomass study, the trees falling in the plot ($30 \times 10\ m^2$) were enumerated. The diameter at breast height(dbh) was measured with the help of tree caliper and height was measured with Ravi's multimeter (Chaturvedi and Khanna, 2013). The above ground biomass was calculated by multiplying stem wood volume with wood density and biomass expansion factor (BEF).

Total above ground biomass of trees was calculated by using the formula given by (Deb 2015).

Aboveground biomass (t/ha) = Stem biomass (t/ha) × Biomass expansion factor Stem biomass (t/ha) = Volume over bark × specific gravity.

Aboveground biomass (t/ha) = Volume over bark × specific gravity × Biomass expansion factor

- Stem volume estimation: Local volume equation developed for specific tree species is given in Appendix II.
- Specific gravity: The specific gravity for biomass estimation of various woody tree species was collected from the literature, given in the Appendix III.
- Biomass expansion factor: It is defined as the ratio of the above ground oven dry biomass of trees to oven dry biomass of the inventoried volume. It takes into consideration the biomass of the other above ground components of trees (leaves, twigs, branches etc.). The BEF for various tree species are given in Appendix IV.

3.5.3.2 Below ground biomass

Belowground biomass of a particular tree species was calculated by multiplying its above ground biomass with the root-shoot ratio. Root-Shoot ratio of different tree species was collected from available literature given in the **appendix V**. In unavailability of the root-shoot ratio, simple default value of 25 per cent (for hard wood species) and 21 per cent (for soft wood species) to the total above ground biomass recommended by (IPCC, 2006) was considered. The sum of aboveground and below ground biomass was taken as total biomass of tree.

Below ground biomass = Above ground biomass (t/ha) × Root shoot ratio

3.5.3.3 Total biomass

Total biomass was calculated by summing the above ground biomass and below ground biomass of a particular tree species.

3.6 ECONOMIC RETURNS

The present harvestable biomass from each functional unit in a system was taken into account to determine total returns from the system, while total cost incurred on production and cultural management was taken into account to estimate the net returns.

3.6.1 Production Cost (Cost of cultivation)

Production cost refers to the total expenses incurred in producing one hectare of crop.

It was worked out as per the prevalent rates in the market.

3.6.2 Gross Returns

The utilizable biomass of each functional unit in a system was given the current market value for estimating total returns from a system.

3.6.3 Net Returns

Net returns = Gross returns – Production cost

3.6.4 Benefit: Cost ratio

The net returns per rupee invested ratio was calculated as per following formula

Benefit cost ratio= Total discounted benefits/ Total discounted costs

3.7 ANALYTICAL METHOD USED

3.7.1 Tabular Method

The data collected on survey schedules were tabulated to work out averages, ratios, percentages, etc. Tabular method was employed to estimate the socio-economic features viz. family structure, demographic feature, livestock status, animal husbandry practices, off-farm employment and land utilization pattern in the study area. The results were interpreted as sum total of biological production and economic returns, average or percentage depending upon various requirements of study.

3.7.2 Co-efficient of Variation

The co-efficient of variation was used to calculate relative variations in biomass yield levels and net returns of a system type among different category of farmers.

3.8. TECHNOLOGICAL GAPS AND THEIR SOLUTION

Farmers land and crop management practices were compared and contrasted with the regions standard recommended practices in terms of agriculture crops, tree species and allied activities to identify technological gaps and suggest appropriate measures to overcome those gaps

3.9. LIMITATIONS OF THE STUDY

i. Study was based on the data collected for one year only i.e. 2021-22 which may not necessarily hold true for other years as well.
ii. The data was collected by survey method through personal interviews, so there is possibility of memory bias of the farmers to some extent.

Chapter-4

RESULTS AND DISCUSSIONS

The results of present investigation the **"Socio-economic Survey of Existing Agroforestry Systems in Dehra Tehsil of Kangra District, Himachal Pradesh"** are presented in this chapter under following headings:

4.1 SOCIO-ECONOMIC STATUS OF THE FARMERS
4.2 IDENTIFICATION OF AGROFORESTRY SYSTEMS
4.3 BIOLOGICAL YIELD FROM AGROFORESTRY SYSTEMS
4.4 ECONOMIC RETURNS FROM AGROFORESTRY SYSTEMS
4.5 VARIATION IN BIOLOGICAL YIELD AND NET RETURNS FROM THE AGROFORESTRY SYSTEMS AMONG DIFFERENT CATEGORIES OF FARMERS
4.6 BENEFIT COST RATIO AMONG AFROFORESTRY SYSTEMS AMONG DIFFERENT AGROFORESTRY SYSTEMS
4.7 TECHNOLOGICAL GAPS AND AGROFORESTRY-BASED SOLUTIONS

4.1 SOCIO-ECONOMIC STATUS OF THE FARMERS

The socioeconomic and demographic characteristics of various farming communities influence the sorts of agroforestry systems that are already in place as well as the predominant degree of management in a given location. By gathering information from thirteen gram panchayats, the socioeconomic and demographic characteristics such as each household's family structure, educational level, off-farm income, employment status, livestock status, land holding, etc. were evaluated. The farmers were divided into three groups, namely medium (2–5 ha), small (1-2 ha), and marginal (<1 ha), to carry out this research activity. The information gathered about the aforementioned parameters has been summarized as follows.

4.1.1 Family Structure

The family structure reflects all members of the home, including adults, children, and the proportion of men and women in each category. Family structure describes the extent to which a population is reliant on natural resources as well as the accessibility of the family labour force in the agricultural sector. Table 3 represents the statistical data of the family structure of farmers in the studied area of Dehra Tehsil, District Kangra, Himachal Pradesh.

According to the data shown in Table 3, the overall family size was found to be 4.66 across the all categories also as shown in Figure, the largest family size was found out in the medium category (5.15 persons) followed by small category (4.46 persons) and the lowest in marginal category which was (4.34 persons). Yadav *et al.,* (2016) also found that the average family size lies between 4.3-5.0 at different elevation zones of Kumaon Himalaya, Uttarakhand, India. In case of adult males, maximum (43.31%) was found in marginal category followed by medium (41.48%) and small category (37.06%) categories of farmers. Whereas, in case of adult females, maximum (45.16%) was found in marginal category followed by small and medium with (44.83%) and (42.96%)

Table 3: Family structure of sampled households under different categories of farmers in the study area

Farmers category	Total no. of families	Average family size	Adults			Children			Sex ratio
			Male	Female	Total	Male	Female	Total	
Marginal	52	4.34 (100)	1.88 (43.31)	1.96 (45.16)	3.84 (88.47)	0.22 (5.06)	0.28 (6.45)	0.5 (11.53)	1073.39
Small	52	4.46 (100)	1.65 (37.06)	2 (44.83)	3.65 (81.89)	0.45 (9.93)	0.36 (8.18)	0.81 (18.11)	1075.75
Medium	52	5.19 (100)	2.15 (41.48)	2.23 (42.96)	4.38 (84.44)	0.38 (7.41)	0.43 (8.15)	0.81 (15.56)	1045.45
Total	156	4.66 (100)	1.89 (40.64)	2.06 (44.31)	3.95 (84.95)	0.35 (7.4)	0.35 (7.65)	0.71 (15.05)	1064.74

Types of family				
	Marginal	**Small**	**Medium**	**Total**
No. of nuclear family	24 (35.29)	25 (36.76)	19 (27.95)	68 (43.58)
No. of joint family	28 (31.82)	27 (30.68)	33 (37.5)	88 (56.42)

- Figures in parenthesis are percentages to the total.
- Sex ratio is known as gender ratio and can be determined by dividing the female population to male population multiplied by 1000.

respectively. Whereas in children population, highest population of male children (9.93%) was found in small category followed by medium (7.41%) and marginal (5.06%) category. The highest female children (1.18%) followed by medium category (1.81%) and marginal category (6.45%). The highest sex ratio was found to be in small category (1075.75) followed by marginal and medium category with the values of sex ratio (1073.39) and (1045.45). The overall sex ratio was determined to be (1064.74) females per thousand males which is higher than the state and national averages of 972 and 940 respectively. Regarding the gender of the kids, there was no difference as similar findings regarding family structure was made by Kumar (2016), who reported an overall sex ratio of 1038 in a sub-temperate region of the Solan district of Himachal Pradesh.

4.1.2 Type of The Family

The family has traditionally served as both the center of socioeconomic life and the primary provider of social security and support for members of the family in many nations. There were reported to be joint families and nuclear families in the Dehra tehsil of the district Kangra in Himachal Pradesh. Types of families in study area are constituted as joint and nuclear family in Table 4. The data in the Table 3 states that the highest percentage of joint families were found in medium category (37.5) followed by marginal category (31.82) and small category (30.68) whereas the highest percentage of nuclear families were recorded in small category (36.76) followed by marginal and medium category with the percentage of (35.29) and (27.95) respectively. Overall joint families were reported percentage (56.42%) which is higher than the nuclear families (43.58%).

4.1.3 Educational Status

Education plays in economic and agricultural prosperity so; the people nowadays are very appreciative of education because it gives them the skills to act honorably and react sanely to ambiguous social and economic events. Better education of the farmers will enable them to judge inputs, obtain important information, adopt new technology, and make production decisions. In the case of a family's educational level, each category varying levels, such as Primary, middle, metric, senior secondary, and graduate levels were considered. Individuals who are illiterate and do not attend school were also taken into consideration.

The information in Table 4 reveals the educational level of the sampled families. Among different categories of farmers, the literacy rate ranged from 88.28 to 89.22 percent. The category with the highest literacy rate (89.22%) was medium, followed by marginal (89.11%) and small farmers (88.28%). Among the male, the small category of farmers had the greatest literacy rate (93.67%), followed by medium (91.76%), and marginal (89.56%) category of farmers. The medium category of female farmers had the greatest literacy rate (87.67%) followed by small (84.45%) and marginal (80.45%) category of farmers. In all categories in the researched area, it was discovered that there are more male than female was found to be literate. In a socioeconomic review of various agroforestry systems in low hills of Himachal Pradesh, Jamwal (2017) observed an average literacy rate of 87.73 percent. The average literacy rate in the study area was determined to be higher than the literacy rate in HP (82.8%), according to our current data (Census, 2011). The overall literacy rate of Kumaon Himalaya, Uttarakhand, India, was established by Yadav *et al.* (2016) at 83.0%.

Table 4: Education status under different categories of farmers in the study area

Farmers category	Illiterate	Primary	Middle	Higher	Senior Secondary	Degree	Total	Literacy rate%	Male literacy rate (%)	Female literacy rate (%)
Marginal	0.11 (10.89)	0.22 (21.78)	0.31 (30.69)	0.22 (21.78)	0.08 (7.93)	0.07 (6.94)	1.01 (100)	89.11	89.56	80.45
Small	0.13 (11.72)	0.16 (14.42)	0.24 (21.63)	0.26 (23.43)	0.16 (14.42)	0.16 (14.42)	1.11 (100)	88.28	93.67	84.45
Medium	0.11 (10.78)	0.14 (13.73)	0.16 (15.68)	0.24 (23.53)	0.22 (21.56)	0.15 (14.71)	1.02 (100)	89.22	91.76	87.67
Overall	0.12 (11.13)	0.17 (16.65)	0.24 (22.66)	0.24 (22.92)	0.15 (14.64)	0.13 (12.02)	1.05 (100)	88.87	91.66	84.19

- Figures in parenthesis are percentages to the total.
- Primary- 1 to 5; Middle- 6 to 8; Matric- 9 to 10; Senior secondary- 11 to 12; Illiterate- devoid of any education.
- Literacy rate - Ratio of literates to the total members multiplied by 100.

4.1.4 Status of Occupation and Off-farm Employment

In addition to giving farmers extra income, off-farm work also offers an additional source of income in case of crop failure. It was discovered that the farmers in the study area made a living though government/private services, business, and wage labor.

The table 5.1 revealed that the 40 males and 10 females are working in government services whereas 88 males and 6 females are engaged in private services. In government services, the males from medium category (23) have the highest average annual income per person with Rs. 444000/- followed by small (15) and marginal (2) with average annual income Rs. 298173/- and Rs. 110666/- respectively. While among female, the small category has highest average annual income with Rs. 375000/- followed by medium category with average annual income of Rs. 296000/-. No female was found in marginal category doing government job.

In private services, 52, 27 and 9 males were present in the medium, small, and marginal categories of farmers with an average annual income of Rs. 123596/-, Rs. 74185/- and 40834/- respectively. While females in the small category (2) found out to be highest average annual income Rs. 214500/- followed by medium (4) and marginal (1) category with annual income of Rs. 50925/- and 30000/- respectively.

From the table 5.2, In business, medium category (3) shows the highest average annual income of Rs. 450000/- followed by small category (2) with Rs. 266666/-. No farmers were found doing business in marginal category. Also, no females were found doing business.

In wage labour (including agricultural and non-agricultural), 61,24 and 6 males whereas 36, 15 and 1 females were present in marginal, small and medium category respectively. The highest average annual income in males found in marginal category with Rs. 25425/- followed by medium and small category with Rs. 17000/- and Rs. 12958/- respectively. While in females, the categories ranked as marginal, medium and small with average annual income of Rs. 18707/- followed by medium and small category with annual income of Rs. 15000/- and Rs. 6866/- respectively. Government jobs and business were the two sources of the highest off-farm income. Additionally, the study reveals that, in comparison to men, women spend more time at home than anywhere else working. The farmer community can adopt better technologies and practices by using their increased risk-taking capacity from off-farm jobs.

4.1.5 Livestock Status

The economy of farmers is significantly influenced by the livestock. The farmers in India practice mixed farming, which combines crops and livestock and maximizes resource efficiency by using one enterprise's result as another's input. More than 70% of people living in rural areas keep some kind of livestock to supplement their family's income and support their way of life. Indian livestock is hardy and can endure the harsh tropical climate with little to no outside assistance. The main products of the livestock industry include milk, meat, eggs, manure, draft power, and others. These products aid in achieving nutritional security, enhancing soil health, supplementing household income, increasing export revenue, and creating year-round employment opportunities.

Table 5.1: Employment Status of different categories of farmers in different categories of farmers

Farmers category	Total no. of families	Total member	Government services					Private services				
			M	Av. Annual income per person (Rs)	F	Av. Annual income per person (Rs)	Total	M	Av. Annual income per person (Rs)	F	Av. Annual income per person (Rs)	Total
Marginal	52	109	2	110666	0	0	110666	9	40834	1	30000	70834
Small	52	92	15	298173	6	375000	673173	27	74185	2	214500	288685
Medium	52	93	23	444000	4	296000	740000	52	123596	4	50923	174519
Total	156	293	40	852839	10	671000	1523839	88	238615	6	295423	534038

- The average income per month is calculated on the basis of total number of beneficiaries only.
- M- No. of male engaged in services; F- No. of female engaged in services

Table 5.2: Status of off farm employment among different categories of farmers

Farmers category	Business					Wage labour (AG & NAG)				
	M	Av. Annual income per person (Rs)	F	Av. Annual income per person (Rs)	Total	M	Av. Annual income per person (Rs)	F	Av. Annual income per person (Rs)	Total
Marginal	0	0	0	0	0	61	25425	36	18707	44132
Small	2	266666	0	0	266666	24	12958	15	6866	19824
Medium	3	450000	0	0	450000	6	17000	1	15000	32000
Total	5	716666	0	0	716666	91	55383	52	40573	95956

- The average income per month is calculated on the basis of total number of beneficiaries only.
- M- No. of male engaged in services; F- No. of female engaged in services

The data tabulated in Table 6 formulate the livestock status of the marginal, small and medium category respectively. It states that the medium category has the highest no. of farmers having any livestock with 49 farmers followed by small and marginal with 48 and 45 farmers each. It is found that highest no. of cows and buffalos found to be in medium category followed by small and marginal. Also, the local breeds of cows and buffalos are owned by medium category of farmers followed by small and marginal.

It is found that the marginal category has the highest no. of improved varieties of buffalo i.e., 18.14% followed by small and medium category with 16.12% and 12.07% each. In case of cows, marginal category has highest 8.18% of improved varieties followed by medium and small category with 7.75% and 6.65% to its total population. Additionally, it was noted that among the marginal, small, and medium categories of farmers, respectively, 52.05, 50.55, and 46.55 percent of buffalos were observed to be lactating. In case of cows, the marginal, small, and medium categories of farmers, respectively, 24.56, 27.77, and 31.46% of cows were found to be milking. In the marginal, small, and medium categories of farmers, there were 0.28, 0.24, and 0.15 bullocks per family, respectively. The average no. of goats per family are recorded in medium category i.e., 0.35 followed by marginal and small 0.28 and 0.19 respectively. In the small, medium, and marginal categories, there were 0.6, 0.5, and 0.93 young stocks on average per family, respectively.

4.1.6 Livestock practices followed by different categories of farmers in the study area

Animal husbandry assists in the correct management of animals by giving domestic animals healthy food, shelter, and protection from infections. Many farmers benefited from it since it gives them jobs, raising their level of living. Proper management helps in improving environmental health and involves the ethical disposal of animal waste. The information in Table 6 illustrates the livestock techniques used by the different categories of farmers to ensure good animal cleanliness and hygiene. The methods used by various types of farmers included milking, breeding, routine de-worming, disease pest management, and washing of animals.

It is found that 100% of the farmers from all three categories preferred traditional milking method over scientific. It was noted that the percentage of the farmers using scientific breeding techniques is more than the farmers using traditional methods of breeding in all categories sequentially medium, small and marginal having percentage of 87.75, 83.34 and 80 respectively. Around 70.43% farmers from the total follows regular de-worming with the percentage of 64.44, 68.75 and 77.55, marginal, small and medium respectively. Whereas 29.57 percent of the total farmers follows disease pest management methods. It was found that the utilization of animal dung is more in crop production in all categories and the farmers utilizing dung in both as fuelwood and manure are 51.43% among all categories. Massingue (2007) and Singh (2017) both reported comparable data in their studies.

Table 6: Livestock status in different categories of farmers in study area

Livestock (Marginal)								Young stock	
Family having livestock	**Animals type**	**No. of animal**	**Av. Livestock per family**	**Local breed**	**Improved breed**	**Dry**	**Milking**	**No. of animals**	**Average no. per family**
45	Cow	48 (28.07)	0.96	34 (19.88)	14 (8.18)	6 (3.51)	42 (24.56)	8 (25)	0.15
	Buffalo	92 (53.81)	1.72	61 (35.67)	31 (18.14)	3 (1.75)	89 (52.05)	13 (40.62)	0.25
	Bullock	16 (9.35)	0.28	12 (7.03)	4 (2.33)	–	–	6 (18.75)	0.11
	Goat	15 (8.77)	0.28	15 (8.77)	–	–	–	5 (15.63)	0.09
	Total (%)	171 (100)	3.24	122 (71.35)	49 (28.65)	–	–	32 (100)	0.6
Livestock (Small)								**Young stock**	
48	Cow	56 (31.12)	1.07	44 (24.45)	12 (6.65)	6 (3.34)	50 (27.77)	6 (23.07)	0.12
	Buffalo	102 (56.66)	1.96	73 (40.56)	29 (16.12)	11 (6.62)	91 (50.55)	10 (38.47)	0.19
	Bullock	12 (6.66)	0.24	8 (4.44)	4 (2.23)	–	–	4 (15.38)	0.07
	Goat	10 (5.56)	0.19	10 (5.55)	–	–	–	6 (23.08)	0.12
	Total %	180 (100)	3.46	135 (75)	45 (25)	–	–	26 (100)	0.5
Livestock (Medium)								**Young stock**	
49	Cow	80 (34.48)	1.54	62 (26.73)	18 (7.75)	7 (3.02)	73 (31.46)	16 (33.34)	0.31
	Buffalo	126 (54.32)	2.43	98 (42.25)	28 (12.07)	18 (7.75)	108 (46.55)	21 (43.75)	0.41
	Bullock	8 (3.45)	0.15	8 (3.45)	–	–	–	2 (4.16)	0.04
	Goat	18 (7.75)	0.35	18 (7.75)	–	–	–	9 (18.75)	0.17
	Total %	232 (100)	4.47	168 (72.43)	46 (19.82)	–	–	48 (100)	0.93

- Figures in parenthesis are percentages to the total

Table 7: Livestock practices followed by different categories of farmers in the study area

Farmers category	No. of families having animals	Washing of animals	Milking Method		Breeding method		Disease management		Animal dung utilization	
			Traditional	Scientific	Traditional	Scientific	Regular De-Worming	Disease Pest Management	Crop Production	Fuel wood + Crop Production
Marginal	45 (100)	45 (100)	45 (100)	-	9 (20)	36 (80)	29 (64.44)	16 (35.55)	39 (86.66)	22 (48.88)
Small	48 (100)	48 (100)	48 (100)	-	8 (16.66)	40 (83.34)	33 (68.75)	15 (31.25)	41 (89.14)	24 (52.17)
Medium	49 (100)	49 (100)	49 (100)	-	6 (12.25)	43 (87.75)	38 (77.55)	11 (22.45)	44 (89.79)	26 (53.06)
Total	142 (100)	142 (100)	142 (100)	-	23 (16.19)	119 (83.81)	100 (70.43)	42 (29.57)	124 (88.57)	72 (51.43)

- Figures in parenthesis are percentages to the total

4.1.7 Land Use Pattern of Farmers in Dehra Tehsil of Kangra District (H.P.)

The wellbeing of the farmer is depending on their land holdings and land use pattern by them. It is easy for the farmers to produce more yield when farmer utilizes land properly. Land use had a direct impact on family finances, spending, and accumulation as it determines the capacity to produce food for family sustenance, beside farm earnings. The statistics on land use among various kinds of farmers are shown in Table 8.

Table 8: Land use pattern of farmers in Dehra Tehsil of Kangra District (H.P.)

Farmers Category	Arable land (ha)			Non-Arable land (ha)	Orchard	Total
	Irrigated land	Unirrigated land	Sub Total	Pasture		
Marginal	0.06 (12.25)	0.31 (63.26)	0.37 (75.52)	0.05 (10.21)	0.07 (14.28)	0.49 (100)
Small	0.04 (3.92)	0.75 (73.52)	0.79 (77.45)	0.19 (18.79)	0.04 (3.92)	1.02 (100)
Medium	0.11 (5.44)	1.41 (69.81)	1.52 (75.24)	0.41 (20.29)	0.09 (4.45)	2.02 (100)
Average land holding (ha)	0.13 (5.96)	1.53 (70.18)	1.66 (76.14)	0.65 (29.81)	0.14 (6.42)	2.18 (100)

- Figures in parenthesis are percentages to the total.
- 1 hectare= 25 kanal

The land is divided into arable and non-arable land which is further divided into irrigated, unirrigated land and pasture, orchard respectively. In arable land, unirrigated land comprises more share than the irrigated land which clearly states that the most of the farmers are dependable on rainfall. Similar results regarding irrigated and non-irrigated land were reported by Sharma *et. al* (2021) in Bangana Tehsil of Una District.

From Table-8, total average irrigated land is recorded 5.96 percent and highest percent of irrigated land seen in marginal category with 12.25 percent followed by medium and small with 5.44 and 3.92 percent respectively. The contribution of the pasture land is found to be 29.81 percent on an average. The highest area under pasture is found in medium category which is 20.29 percent followed by small and marginal with 18.79 and 10.21 percent respectively. The land utilized for orchard are seen in all categories, with an increasing rate from small < medium < marginal with 3.92 < 4.45 < 14.28 percent respectively. The maximum area was found under orchard in Marginal category due to introduction of cluster schemes such as HP Shiva Project (Himachal Pradesh Sub-tropical Horticulture, Irrigation and Value Addition Project) Average land holding was found to be 2.12 ha. The average arable land was recorded 0.13 ha and non-arable land was recorded 1.53 ha. Average orchard land recorded 0.14 ha.

4.2 IDENTIFICATION OF DIFFERENT AGROFORESTRY SYSTEMS

4.2.1 Agroforestry System Types

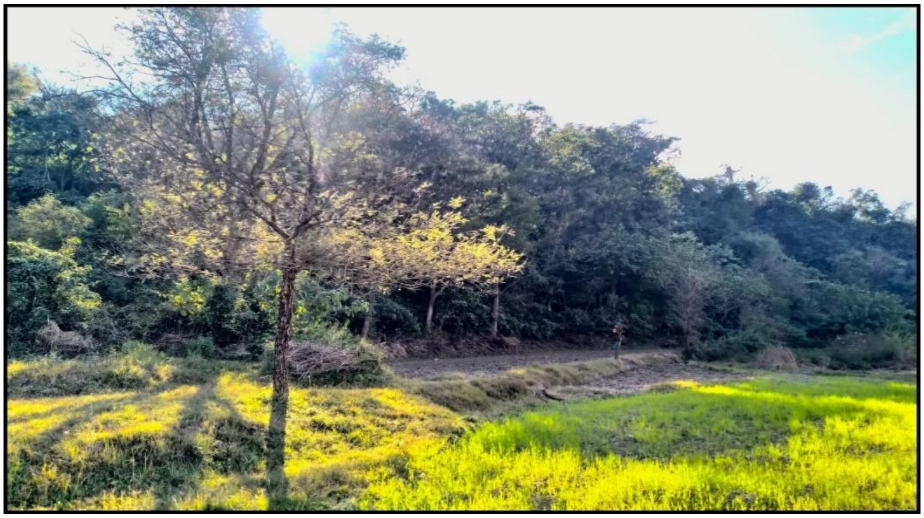
The table 9 reveals the data about agroforestry systems which has been identified during the research work in study area. Around 5 agroforestry systems were identified in marginal, small and medium categories those are Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Agri-silvi-pastoral (ASP) and Pasto-silviculture (PS).

Table 9: Existing agroforestry systems practiced by different category of farmers in Dehra Tehsil, Kangra (H.P.)

Agroforestry Systems	Marginal	Small	Medium	Total families
AS	32 (37.21)	25 (28.41)	13 (17.11)	70 (28.01)
ASH	14 (16.27)	26 (29.55)	32 (42.11)	72 (28.81)
AH	28 (32.56)	14 (15.91)	9 (11.85)	51 (20.41)
ASP	12 (13.95)	16 (18.18)	10 (13.15)	38 (15.21)
PS		7 (7.95)	12 (15.78)	19 (7.61)
Total families in each category	86 (100)	88 (100)	76 (100)	250 (100)

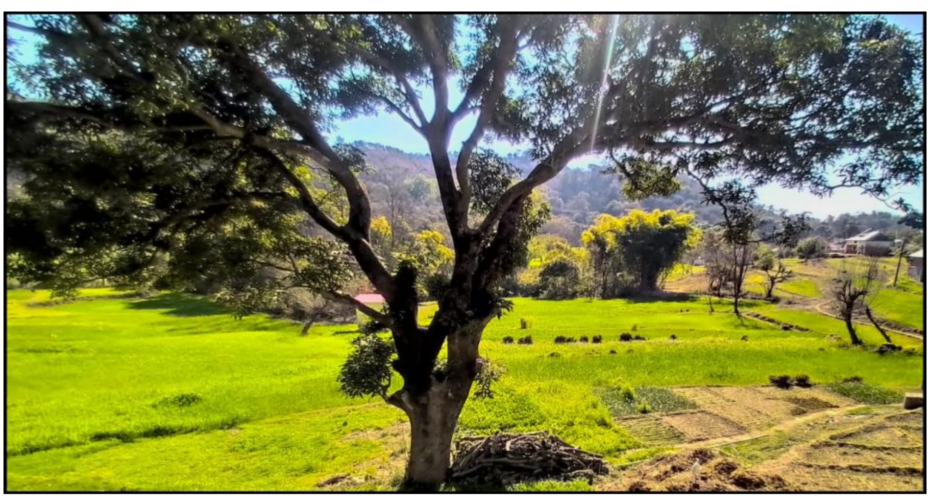
- Figures in parenthesis are percentages to the total.

Among different categories, in marginal category, Agri-silviculture is most traditionally practiced system 37.21 percent followed by Agri-horticulture 32.56 percent, Agri-silvi-horticulture 16.27 percent and Agri-silvi-pasture 13.95 percent respectively. Due to the small land holding Pasto-silviculture was absent in marginal category of farmers. In small category of farmers, Agri-silvi-horticulture was recorded to be most practiced system (29.55%) followed by Agri-silviculture (28.41%), Agri-silvi-pasture (18.18%), Agri-horticulture (15.91%) and Pasto-silviculture (7.95%). Also, in medium category, Agri-silvi-horticulture shows maximum 42.11 percent whereas Agri-horticulture shows least 11.85 percent of being practiced.



Agri-silviculture (Agricultural crops + Silvicultural crops

Agri-horti-silviculture (Agricultural crops + Horticultural crops + Silvicultural trees)



Agri-horticulture (Agricultural crops + Horticultural tree)

Plate 1: Agroforestry system types in Dehra Tehsil, District Kangra, H.P

Agri-silvi-pastoral (Agricultural crops + Silvicultural trees + Grasses)

Pasto-silviculture (Pasture + Silvicultural trees)

Plate 2: Agroforestry system types in Dehra Tehsil, District Kangra, H.P

Goswami (2009) reported five agroforestry systems which are Agri-silviculture, Agri-horticulture, Agri-horti-silviculture, Agri-silvi-horticulture, Silvi-pastoral systems in Kwaal Khad watershed in Solan District, Himachal Pradesh.

Bijalwan *et al.* (2011) identified the practicing Agroforestry systems in Gharwal region. They found the following traditional agroforestry systems viz., Agri-Silviculture, Agri-Horti-Silviculture and Agri-Horticulture. The major tree based Agri-Silviculture system included the tree species like *Grewia optiva, Celtis australis, Melia azedarach, Ficus roxburghii*, etc. along with agricultural crops. The Agri-Horti-Silviculture, the combination of *Grewia optiva* + *Malus domestica* + wheat; *Quercus leucotrichophora* + *Malus domestica* + wheat/potato; *Grewia optiva* + *Prunus domestica* + barnyard millet etc. The major fruit-tree based Agri-Horticulture systems were comprised of *Malus domestica, Prunus domestica* and *Prunus armeniaca* along with routine agricultural crops. In addition, Agri-Silvi-Pasture, Silvi-Pasture and Horti-Silviculture systems were also observed in the few parts of region.

Goswami *et al.* (2014) described five different types of agroforestry systems, including Silvi-pasture, Agri-silviculture, Agri-horticulture, and Agri-silvi-horticulture.

Sharma (2020) conducted a survey at Bangana Tehsil of Una District, Himachal Pradesh with aim to assess the existing agroforestry systems, they found out that there were five agroforestry systems being practiced by farmers which were as Agri-silviculture, Agri-horticulture, Agri-horti-silviculture, Silvi-pastoral and Horti-pastoral systems.

4.2.2 Agroforestry systems along with their functional units in different category of farmers

4.2.2.1 System units and their constituent agriculture crop and trees in different agroforestry systems under marginal category farmer's.

A. Agri-silviculture

1. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis* + *Grewia optiva* + *Melia azedarach*
2. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum* + *Acacia catechu* + *Toona ciliata*
3. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata* + *Dalbergia sissoo* + *Toona ciliata*
4. *Zea mays – Abelmoschus esculentus - Colocasia esculenta - / Triticum aestivum – allium sativum – Zingiber officinale* + *Grewia optiva* + *Ficus palmata*
5. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale* + *Bauhinia variegata* + *Acacia catechu*
6. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis* + *Populus deltoides* + *Melia azedarach*
7. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata* + *Grewia optia* + *Toona ciliata*
8. *Zea mays – Colocasia esculenta – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Zingiber officinale – Brassica oleracea* var. *botrytis* + *Toona ciliata* + *Dalbergia sissoo*

9. *Zea mays* – *Colocasia esculenta* – *Solanum lycopersicum* – *Curcuma longa* / *Triticum aestivum* – *Solanum tuberosum* – *Brassica oleracea* var. *capitata* + *Albizia lebbeck* + *Melia azedarach*
10. *Zea mays* – *Solanum lycopersicon* – *Curcuma longa* – *Colocasia esculenta* / *Triticum aestivum* – *Brassica oleracea* var. *botrytis* – *Solanum tuberosum* + *Ficus roxburghii* + *Leucaena leucocephala*
11. *Zea mays* – *Abelmoschus esculentus* – *Colocasia esculenta* / *Triticum aestivum* – *Solanum lycopersicum* – *Brassica oleracea* var. *capitata* + *Grewia optiva* + *Acacia catechu*
12. *Zea mays* – *Colocasia esculenta* – *Curcuma longa* / *Triticum aestivum* – *Solanum tuberosum* – *Zingiber officinale* – *Allium sativum* + *Albizia lebbeck* + *Toona ciliata*
13. *Zea mays* – *Abelmoschus esculentus* – *Colocasia esculenta* / *Triticum aestivum* – *Solanum tuberosum* – *Allium sativum* – *Zingiber officinale* + *Leucaena leucocephala* + *Melia azedarach*
14. *Zea mays* – *Colocasia esculenta* – *Abelmoschus esculentus* / *Triticum aestivum* – *Brassica oleracea* var. *capitata* – *Solanum tubersom* + *Grewia optiva* + *Melia azedarach*
15. *Zea mays* – *Solanum lycopersicum* – *Curcuma longa*- *Colocasia esculenta* / *Triticum aestivum* – *Solanum tuberosum* – *Zingiber officinale* – *Allium sativum* + *Acacia catechu* + *Dalbergia sissoo*
16. *Zea mays* – *Colocasia esculenta* – *Abelmoschus esculentus* / *Triticum aestivum* – *Solanum tuberosum* – *Allium sativum* + *Acacia catechu* + *Toona ciliata*
17. *Zea mays* – *Abelmoschus esculentus* - *Colocasia esculenta* - / *Triticum aestivum* – *allium sativum* – *Zingiber officinale* + *Grewia optiva* + *Ficus palmata*
18. *Zea mays* – *Abelmoschus esculentus* – *Curcuma longa* / *Triticum aestivum* – *Solanum lycopersicum* – *Brassica oleracea* var. *botrytis* + *Populus deltoides* + *Melia azedarach*
19. *Zea mays* – *Colocasia esculenta* – *Abelmoschus esculentus* – *Curcuma longa* / *Triticum aestivum* – *Zingiber officinale* – *Brassica oleracea* var. *botrytis* + *Toona ciliata* + *Dalbergia sissoo*
20. *Zea mays* – *Solanum lycopersicon* – *Curcuma longa* – *Colocasia esculenta* / *Triticum aestivum* – *Brassica oleracea* var. *botrytis* – *Solanum tuberosum* + *Ficus roxburghii* + *Leucaena leucocephala*
21. *Zea mays* – *Colocasia esculenta* – *Curcuma longa* / *Triticum aestivum* – *Solanum tuberosum* – *Zingiber officinale* – *Allium sativum* + *Albizia lebbeck* + *Toona ciliata*
22. *Zea mays* – *Colocasia esculenta* – *Abelmoschus esculentus* / *Triticum aestivum* – *Brassica oleracea* var. *capitata* – *Solanum tuberosum* + *Grewia optiva* + *Melia azedarach*
23. *Zea mays* – *Solanum lycopersicum* – *Curcuma longa*- *Colocasia esculenta* / *Triticum aestivum* – *Solanum tuberosum* – *Zingiber officinale* – *Allium sativum* + *Acacia catechu* + *Dalbergia sissoo*
24. *Zea mays* – *Abelmoschus esculentus* – *Colocasia esculenta* / *Triticum aestivum* – *Solanum tuberosum* – *Allium sativum* – *Zingiber officinale* + *Leucaena leucocephala* + *Melia azedarach*
25. *Zea mays* – *Abelmoschus esculentus* – *Colocasia esculenta* / *Triticum aestivum* – *Solanum lycopersicum* – *Brassica oleracea* var. *capitata* + *Grewia optiva* + *Acacia catechu*
26. *Zea mays* – *Colocasia esculenta* – *Solanum lycopersicum* – *Curcuma longa* / *Triticum aestivum* – *Solanum tuberosum* – *Beassica oleracea* var. *capitata* + *Albizia lebbeck* + *Melia azedarach*

27. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata + Grewia optia + Toona ciliata*
28. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Bauhinia variegata + Acacia catechu*
29. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Dalbergia sissoo + Toona ciliata*
30. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Grewia optiva + Melia azedarach*
31. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Albizia lebbeck + Toona ciliata*
32. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Dalbergia sissoo*

B. Agri-horticulture

1. *Zea mays – Colocasia esculenta- Zingiber officinale / Triticum aestivum- Allium sativum + Mangifera indica + Citrus limon*
2. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis – allium sativum + Syzygium cumini + Mangifera indica*
3. *Zea mays – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica Oleracea* var. *capitata + Citrus limon +Morus alba + Pinica granatum*
4. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Allium sativum – Solanum tuberosum + Litchi chinensis + Psidium guajava*
5. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis – allium sativum + Syzygium cumini +Mangifera indica*
6. *Zea mays – Colocasia esculenta- Zingiber officinale / Triticum aestivum- Allium sativum + Mangifera indica + Citrus limon*
7. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var, *capitata – Allium sativum – Solanum tuberosum + Citrus limon*
8. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Solanum lycopersicum + Citrus limon*
9. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Mangifera indica*
10. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Allium sativum + Litchi chinensis*
11. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Punica granatum.*
12. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Mangifera indica + Citrus limon*
13. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Morus alba*
14. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Syzygium cumini*

15. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Citrus limon*
16. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Psidium guajava.*
17. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Citrus limon*
18. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata + Morus alba + Punica granatum*
19. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Mangifera indica*
20. *Zea mays – Solanum lycopersicum – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis – Brassica oleracea var. capitata + Mangifera indica*
21. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Psidium guajava*
22. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Punica granatum*
23. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Punica granatum*
24. *Zea mays – Abelmoschus esculentus* - *Colocasia esculenta* - */ Triticum aestivum – allium sativum – Zingiber officinale + Citrus limon*
25. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Mangifera indica*
26. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis + Syzygium cumini + Mangifera indica*
27. *Zea mays – Solanum lycopersicum – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis- Brassica oleracea var. capitata + Mangifera indica*
28. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Punica granatum*

C. Agri-silvi-horticulture

1. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tubersum – Brassica oleracea* var. *capitata + Acacia catechu + Melia azedarach + Psidium guajava*
2. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Acacia catechu + Toona ciliata +Mangifera indica*
3. *Zea mays – Colocasia esculenta – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Melia azedarach + Syzygium cumini*
4. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis + Populus deltoides + Melia azedarach + Citrus limon + Punica granatum*

5. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata + Grewia optia + Toona ciliata + Morus alba + Psidium guajava*
6. *Zea mays – Solanum lycopersicum – Curcuma longa- Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Acacia catechu + Dalbergia sissoo + Mangifera indica*
7. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Albizia lebbeck + Toona ciliata + Litchi chinensis*
8. *Zea mays – Colocasia esculenta – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Zingiber officinale – Brassica oleracea* var. *botrytis + Toona ciliata + Dalbergia sissoo + Citrus limon*
9. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *capitata – Solanum tubersom + Grewia optiva + Melia azedarach + Morus alba + Mangifera indica*
10. *Zea mays – Solanum lycopersicon – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Solanum tuberosum + Ficus roxburghii + Leucaena leucocephala + Morus alba*
11. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Bauhinia variegata + Acacia catechu + Citrus limon + Punica granatum*
12. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Grewia optiva + Melia azedarach + Mangifera indica*
13. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Leucaena leucocephala + Melia azedarach + Psidium guajava*
14. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Albizia lebbeck + Toona ciliate + Citrus limon + Morus alba*

D. Agri-silvi-pasture

1. *Zea mays – Zingiber officinale – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *botrytis – Solanum Lycopersicum – Solanum tubersum + Grewia optiva + Melia azedarach + Trifolium alexandrium*
2. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Albizia lebbeck + Toona ciliata + Setaria sphacelata*
3. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *capitata – Solanum tuberosum + Grewia optiva + Melia azedarach + Cynodon dactylon*
4. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Acacia catechu + Dalbergia sissoo + Panicum maximum*
5. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum + Melia azedarach + Trifolium alexandrium*

6. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata + Grewia optiva + Acacia catechu + Cenchrus setiger*
7. *Zea mays – Colocasia esculenta – Solanum lycopersicum / Triticum aestivum – Solanum tuberosum + Albizia lebbeck + Melia azedarach + Trifolium alexandrium*
8. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata + Grewia optia + Setaria sphacelata*
9. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Bauhinia variegata + Acacia catechu + Cynadon dactylon*
10. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Toona ciliate + Cenchrus ciliaris*
11. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Grewia optiva + Melia azedarach + Trifolium alexandrium*
12. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium sativum + Albizia lebbeck + Toona ciliate + Setaria spacelata*

4.2.2.2 System units and their constituent agriculture crops and trees in different agroforestry systems under small category farmers.

A. Agri-silviculture

1. *Zea mays – Solanum lycopersicum – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis- Brassica oleracea var. capitata + Acacia catechu + Melia azedarach*
2. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Dalbergia Sissoo + Toona ciliata*
3. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Grewia optiva*
4. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu*
5. *Zea mays – Abelmoschus esculentus – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach*
6. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck*
7. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Ficus roxburghii + Toona ciliata*
8. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Ficus palmata + Acacia catechu*
9. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Grewia optiva + Bauhinia variegata*

10. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum – Brassica oleracea* var. *botrytis + Melia azedarach + Toona ciliata*
11. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea var. capitata – Solanum lycopersicum + Populus deltoides*
12. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa – Allium sativum + Toona ciliata + Grewia optiva*
13. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis – Allium sativum + Melia azedarach + Acacia catechu*
14. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Dalbergia Sissoo + Toona ciliata*
15. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Grewia optiva*
16. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu*
17. *Zea mays – Abelmoschus esculentus – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach*
18. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck*
19. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Ficus roxburghii + Toona ciliate*
20. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Ficus palmata + Acacia catechu*
21. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Grewia optiva + Bauhinia variegate*
22. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum – Brassica oleracea* var. *botrytis + Melia azedarach + Toona ciliate*
23. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata – Solanum lycopersicum + Populus deltoides*
24. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Grewia optiva*
25. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu.*

B. Agri-horticulture

1. *Zea mays – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Allium sativum – Brassica oleracea* var. *botrytis + Mangifera indica + Litchi chinensis*
2. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *capitata – Solanum lycopersicum + Syzygium cumini*
3. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Punica granatum + Citrus limon*
4. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Mangifera indica + Citrus limon*
5. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Psidium guajava + Morus alba*
6. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium sativum – Solanum lycopersicum + Litchi chinensis + Citrus limon*
7. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Mangifera indica*
8. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach*
9. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Mangifera indica + Syzygium cumini*.
10. *Zea mays – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Allium sativum – Brassica oleracea* var. *botrytis + Mangifera indica + Litchi chinensis*
11. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Punica granatum + Citrus limon*
12. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Psidium guajava + Morus alba*
13. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Mangifera indica*
14. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Mangifera indica + Syzygium cumini*.

C. Agri-silvi-horticulture

1. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var, *capitata – Allium sativum – Solanum tuberosum + Grewia optiva + Melia azedarach + Morus alba*
2. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Solanum lycopersicum + Populus deltoides + Citrus limon*
3. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Grewia optiva + Mangifera indica*
4. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Allium sativum + Melia azedarach + Acacia catechu + Litchi chinensis*
5. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Dalbergia Sissoo + Punica granatum*
6. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Grewia optiva + Mangifera indica + Citrus limon*

7. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Acacia catechu + Morus alba*
8. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Syzygium cumini*
9. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Citrus limon*
10. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Ficus roxburghii + Psidium guajava*
11. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Acacia catechu + Citrus limon*
12. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata + Grewia optiva + Morus alba + Punica granatum*
13. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Toona ciliata + Mangifera indica*
14. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata – Solanum lycopersicum + Populus deltoides + Litchi chinensis + Morus alba*
15. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Psidium guajava*
16. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Syzygium cumini*
17. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Ficus roxburghii + Citrus limon*
18. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Acacia catechu + Mangifera indica*
19. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Grewia optiva + Syzygium cumini*
20. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum – Brassica oleracea* var. *botrytis + Melia azedarach + Grewia optiva + Litchi chinensis*
21. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis- Brassica oleracea var. capitata + Acacia catechu + Melia azedarach + Morus alba + Citrus limon*
22. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Dalbergia Sissoo + Toona ciliata + Psidium guajava*
23. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Morus alba*
24. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu + Punica granatum*
25. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Mangifera indica*
26. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Ficus roxburghii + Toona ciliata + Litchi chinensis*

D. Agri-silvi-pasture

1. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Solanum tuberosum + Dalbergia sissoo + Melia azedarach + Setaria sphacelata*
2. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach + Panicum maximum*
3. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Panicum maximum*
4. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Ficus roxburghii + Toona ciliate + Trifolium alexandrium*
5. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Ficus palmata + Acacia catechu + Panicum maximum*
6. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Grewia optiva + Bauhinia variegate + Setaria sphacelata*
7. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum - Brassica oleracea* var. *botrytis + Melia azedarach + Toona ciliata + Cenchrus setiger*
8. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata + Populus deltoides + Lollium multiforum*
9. *Zea mays – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa – Allium sativum + Toona ciliata + Grewia optiva + Setaria sphacelate*
10. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Allium sativum + Melia azedarach + Acacia catechu + Trifolium alexandrium*
11. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Solanum lypersicum + Dalbergia Sissoo + Toona ciliate + Panicum maximum*
12. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Grewia optiva + Cenchrus ciliaris*
13. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu + Panicum maximum*
14. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach + Setaria sphacelata*
15. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Cenchrus ciliaris*
16. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Ficus roxburghii + Toona ciliata + Cenchrus ciliaris*

E. Agri-silvi-pasture

1. *Trifolium alexandrium + Populus deltoides + Grewia optiva*
2. *Lollium multiflorum + Melia azedarach + Grewia optiva*
3. *Trifolium alexandrium + Grewia optiva + Ficus palmata*
4. *Cenchrus ciliaris + Albizia lebbeck + Toona ciliata*
5. *Cenchrus ciliaris + Acacia catechu + Melia azedarach*
6. *Panicum maximum + Dalbergia sissoo + Toona ciliata*
7. *Trifolium alexandrium + Grewia optiva + Ficus palmata*

4.2.2.3 System units and their constituent agriculture crops and trees in different agroforestry systems under medium category farmer's.

A. Agri-silviculture

1. *Zea mays – Solanum lycopersicum – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis – Brassica oleracea var. capitata + Acacia catechu + Dalbergia sissoo*
2. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Grewia optiva + Melia azedarach*
3. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Acacia catechu + Toona ciliate*
4. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Dalbergia sissoo + Toona ciliate*
5. *Zea mays – Abelmoschus esculentus - Colocasia esculenta - / Triticum aestivum – allium sativum – Zingiber officinale + Grewia optiva + Ficus palmata*
6. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Bauhinia variegata + Acacia catechu*
7. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis + Populus deltoides + Melia azedarach*
8. *Zea mays – Solanum lycopersicum – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis- Brassica oleracea var. capitata + Acacia catechu + Melia azedarach*
9. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Dalbergia Sissoo + Toona ciliate*
10. *Zea mays – Curcuma longa – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Pinus roxburghii + Grewia optiva*
11. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Allium cepa – Brassica oleracea* var. *capitata + Toona ciliata + Acacia catechu*
12. *Zea mays – Abelmoschus esculentus – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach*
13. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck*

B. Agri-horticulture

1. *Zea mays – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Allium sativum – Brassica oleracea* var. *botrytis + Mangifera indica + Syzygium cumini*
2. *Zea mays – Colocasia esculenta – Curcuma longa – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Punica granatum + Citrus limon*
3. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Mangifera indica + Citrus limon*
4. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis – allium sativum + Syzygium cumini + Mangifera indica.*
5. *Zea mays – Colocasia esculenta – Zingiber officinale / Triticum aestivum – Solanum tuberosum – Brassica Oleracea* var. *capitata + Citrus limon +Morus alba + Pinica granatum*
6. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Allium sativum – Solanum tuberosum + Litchi chinensis + Psidium guajava*
7. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis – allium sativum + Syzygium cumini +Mangifera indica*
8. *Zea mays – Colocasia esculenta- Zingiber officinale / Triticum aestivum- Allium sativum + Mangifera indica + Citrus limon*
9. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var, *capitata – Allium sativum – Solanum tuberosum + Citrus limon*

C. Agri-silvi-horticulture

1. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *capitata – Solunum tuberosum – Grewia optiva + Melia azedarach + Psidium guajava*
2. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tubersum – Brassica oleracea* var. *capitata + Acacia catechu + Melia azedarach + Psidium guajava*
3. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum + Acacia catechu + Toona ciliata +Mangifera indica*
4. *Zea mays – Colocasia esculenta – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Melia azedarach + Syzygium cumini*
5. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *botrytis + Populus deltoides + Melia azedarach + Citrus limon + Punica granatum*
6. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Brassica oleracea* var. *capitata + Grewia optia + Toona ciliata + Morus alba + Psidium guajava*

7. *Zea mays – Solanum lycopersicum – Curcuma longa- Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Acacia catechu + Dalbergia sissoo + Mangifera indica*
8. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Albizia lebbeck + Toona ciliata + Litchi chinensis*
9. *Zea mays – Colocasia esculenta – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Zingiber officinale – Brassica oleracea* var. *botrytis + Toona ciliata + Dalbergia sissoo + Citrus limon*
10. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *capitata – Solanum tubersom + Grewia optiva + Melia azedarach + Morus alba + Mangifera indica*
11. *Zea mays – Solanum lycopersicon – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Solanum tuberosum + Ficus roxburghii + Leucaena leucocephala + Morus alba*
12. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Bauhinia variegata + Acacia catechu + Citrus limon + Punica granatum*
13. *Zea mays- Colocasia esculenta- Solanum lycopericum / Triticum aestivum- Solanum tuberosum- Brassica oleracea* var. *botrytis + Grewia optiva + Melia azedarach + Mangifera indica*
14. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Allium sativum – Zingiber officinale + Leucaena leucocephala + Melia azedarach + Psidium guajava*
15. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Albizia lebbeck + Toona ciliate + Citrus limon + Morus alba*
16. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var, *capitata – Allium sativum – Solanum tuberosum + Grewia optiva + Melia azedarach + Morus alba*
17. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Solanum lycopersicum + Populus deltoides + Citrus limon*
18. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium cepa + Grewia optiva + Mangifera indica*
19. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum lycopersicum – Allium sativum + Melia azedarach + Acacia catechu + Litchi chinensis*
20. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Allium sativum/ Solanum lypersicum + Dalbergia Sissoo + Punica granatum*
21. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Allium cepa – Allium sativum – Solanum lycopersicum + Grewia optiva + Mangifera indica + Citrus limon*
22. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *capitata + Acacia catechu + Morus alba*
23. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Syzygium cumini*
24. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Citrus limon*

25. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Allium sativum + Ficus roxburghii + Psidium guajava*
26. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Acacia catechu + Citrus limon*
27. *Zea mays – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata + Grewia optiva + Morus alba + Punica granatum*
28. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Toona ciliata + Mangifera indica*
29. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Allium cepa – Brassica oleracea* var. *capitata – Solanum lycopersicum + Populus deltoides + Litchi chinensis + Morus alba*
30. *Zea mays – Abelmoschus esculentus – Colocasia esculenta / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Melia azedarach + Psidium guajava*
31. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Syzygium cumini*
32. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Ficus roxburghii + Citrus limon*

D. Agri-silvi-pasture

1. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Solanum tuberosum + Ficus roxburghii + Albizia lebbeck + Pamicum maximum*
2. *Zea mays – Zingiber officinale – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *botrytis – Solanum Lycopersicum – Solanum tubersum + Grewia optiva + Melia azedarach + Trifolium alexandrium*
3. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Albizia lebbeck + Toona ciliata + Setaria sphacelata*
4. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Brassica oleracea* var. *capitata – Solanum tuberosum + Grewia optiva + Melia azedarach + Cynodon dactylon*
5. *Zea mays – Solanum lycopersicum – Curcuma longa / Triticum aestivum – Solanum tuberosum – Zingiber officinale – Allium sativum + Acacia catechu + Dalbergia sissoo + Panicum maximum*
6. *Zea mays – Abelmoschus esculentus – Solanum lycopersicum – Colocasia esculenta / Triticum aestivum – Brassica oleracea var. botrytis – Solanum tuberosum + Dalbergia sissoo + Melia azedarach + Setaria sphacelata*
7. *Zea mays – Abelmoschus esculentus – Curcuma longa / Triticum aestivum – Solanum tuberosum – Brassica oleracea* var. *botrytis + Celtis australis + Melia azedarach + Panicum maximum*
8. *Zea mays – Colocasia esculenta – Curcuma longa / Triticum aestivum – Allium cepa – Zingiber officinale + Leucaena leucocephala + Albizia lebbeck + Panicum maximum*
9. *Zea mays – Curcuma longa – Colocasia esculenta / Triticum aestivum – Brassica oleracea* var. *botrytis – Allium sativum + Ficus roxburghii + Toona ciliate + Trifolium alexandrium*

10. *Zea mays – Colocasia esculenta – Abelmoschus esculentus / Triticum aestivum – Solanum tuberosum – Zingiber officinale + Ficus palmata + Acacia catechu + Panicum maximum*

E. Pasto-silviculture

1. *Cenchrus ciliaris + Pinus roxburghii + Melia azedarach*
2. *Panicum maximum + Acacia catechu + Bauhinia variegata*
3. *Panicum maximum+ Grewia optiva + Leucaena leucocephala + Acacia catechu*
4. *Cenchrus ciliaris+ Acacia catechu*
5. *Panicum maximum + Acacia catechu + Pinus roxburghii*
6. *Setaria sphacelata + Acacia catechu*
7. *Panicum maximum + Pinus roxburghii + Acacia catechu*
8. *Cenchrus setiger + Grewia optiva + Albizia lebbeck + Leucaena leucocephala*
9. *Lollium multiflora + Celtis australis + Grewia optiva*
10. *Cenchrus ciliaris + Albizia lebbeck + Acacia catechu*
11. *Trifolium alexandrium + Acacia catechu + Grewia optiva*
12. *Cenchrus ciliaris + Albizia lebbeck + Acacia catechu*

4.3 BIOLOGICAL YIELD FROM DIFFERENT AGROFORESTRY SYSTEMS IN DIFFERENT CATEGORIES OF FARMERS (t/ha).

The total amount of living organic matter in trees expressed as oven-dry tons per unit area termed as biomass. It consists both aboveground and belowground biomass. The Table 10's analysis of data reveals the biological yield gathered from each functional unit under each system type in the study area for different farmer categories.

4.3.1 Above Ground Biomass (t/ha) Of Different Functional Components in Different Agroforestry Systems:

The information in Table 10 reveals the production of above-ground biomass by various agroforestry systems in the Dehra Tehsil of the District Kangra, (H.P.). The medium category poses maximum aboveground biomass in Agri-silviculture (16.07 t/ha) followed by small category (15.11 t/ha) and marginal category (13.45 t/ha). In Agri-horticulture system, medium category has highest biomass with (17.07 t/ha) followed by small (16.24 t/ha) and marginal (14.63 t/ha) category. Medium category shows maximum aboveground biomass in Agri-silvi-horticulture i.e. (19.48 t/ha) followed by small and marginal category of aboveground biomass (18.83 t/ha) and (16.81 t/ha) respectively. In Agri-silvi-pasture system the small category shows highest aboveground biomass i.e. (17.08 t/ha) followed my medium and marginal with yield of (16.75 t/ha) and (16.16 t/ha) respectively. In case of Pasto-silviculture small category (11.95 t/ha) shows more aboveground biomass than medium category (10.36 t/ha), so we can say that the small category is using available land more efficiently for Pasto-silviculture. The Pasto-silviculture system is absent in marginal category due to lack of available land.

In case of marginal category, the aboveground biomass can be arranged in decreasing order as ASH (16.81 t/ha) > ASP (16.16 t/ha) > AH (14.63 t/ha) > AS (13.45 t/ha). Whereas in case of small category, it can be arranged in decreasing order as ASH (18.83 t/ha) > ASP (17.08 t/ha) > AH (16.24 t/ha) > AS (15.11 t/ha) > PS (11.96 t/ha). The aboveground biomass can be

Table 10: Biological yield (t/ha) obtained from different agroforestry systems practiced by the farmers in the study area

AFS	Category	Biomass	Crops	Trees	Grasses	Total
AS	Marginal	AG	8.9	4.55	-	13.45
		BG	3.29	1.09	-	4.38
		Total	**12.19**	**5.64**	**-**	**17.83**
	Small	AG	10.72	4.39	-	15.11
		BG	4.82	1.1	-	5.92
		Total	**15.54**	**5.49**	**-**	**21.03**
	Medium	AG	10.62	5.45	-	16.07
		BG	4.71	1.92	-	6.63
		Total	**15.33**	**7.37**	**0**	**22.7**
AH	Marginal	AG	9.44	5.19	-	14.63
		BG	4.3	1.41	-	5.71
		Total	**13.74**	**6.6**	**0**	**20.34**
	Small	AG	9.22	7.02	-	16.24
		BG	4.56	1.76	-	6.32
		Total	**13.78**	**8.78**	**0**	**22.56**
	Medium	AG	10.39	6.65	-	17.04
		BG	4.93	1.64	-	6.57
		Total	**15.32**	**8.29**	**0**	**23.61**
ASH	Marginal	AG	9.66	7.15	-	16.81
		BG	3.64	1.83	-	5.47
		Total	**13.3**	**8.98**	**0**	**22.28**
	Small	AG	11.96	6.87	-	18.83
		BG	4.13	2.02	-	6.15
		Total	**16.09**	**8.89**	**0**	**24.98**
	Medium	AG	10.46	9.02	-	19.48
		BG	3.42	2.21	-	5.63
		Total	**13.88**	**11.23**	**0**	**25.11**
ASP	Marginal	AG	8.06	6.51	1.59	16.16
		BG	2.96	1.39	0.52	4.87
		Total	**11.02**	**7.9**	**2.11**	**21.03**
	Small	AG	8.69	6.25	2.14	17.08
		BG	2.82	1.45	0.75	5.02
		Total	**11.51**	**7.7**	**2.89**	**22.1**
	Medium	AG	8.95	6.15	1.65	16.75
		BG	3.55	2.15	0.42	6.12
		Total	**12.5**	**8.3**	**2.07**	**22.87**
PS	Marginal	AG	-	-	-	-
		BG	-	-	-	-
		Total	**-**	**-**	**-**	**-**
	Small	AG	-	9.95	2	11.95
		BG	-	2.52	0.64	3.16
		Total	**-**	**12.47**	**2.64**	**15.11**
	Medium	AG	-	8.31	2.05	10.36
		BG	-	1.28	0.54	1.82
		Total	**-**	**9.59**	**2.59**	**12.18**

Where, AS=Agri-silviculture, AH=Agri-horticulture, ASH=Agri-silvi-horticulture, ASP=Agri-silvi-pastoral and PS=Pasto-silviculture. AG=Aboveground, BG=Belowground sequenced in decreasing manner ASH (19.48 t/ha) > AH (17.04 t/ha) > ASP (16.75 t/ha) > AS (16.07 t/ha) > PS (10.36 t/ha). Overall, the ASH system reported the highest above-ground biomass output in the medium category (19.48 t/ha), whereas PS reported the lowest above-ground biomass production in the medium category (10.36 t/ha). Similar findings for above-ground biomass were made by (Gupta and Singh 1981), who reported that the pastoral-silviculture system in Nalagarh (H.P.) had the lowest rate (10.57 t/ha).

4.3.2 Below Ground Biomass (t/ha) Of Different Functional Components in Different Agroforestry Systems:

Table 10 provides information on below-ground biomass for various agroforestry systems and different types of farmers. As we can see in the table 11, the crop components show maximum belowground yield as compare to the trees in almost all agroforestry systems as well as in all three categories that are marginal, small and medium. Individually, for Agri-silviculture, the maximum belowground was recorded in medium category (6.63 t/ha) followed by small category and marginal category with yield of (5.92 t/ha) and (4.38 t/ha) respectively. The medium category shows highest belowground biomass (6.57 t/ha) in Agri-horticulture followed by small (6.32 t/ha) and marginal (5.71 t/ha) category. In case of Agri-silvi-horticulture, small category shows highest belowground yield of (6.15 t/ha) followed by medium category (5.63 t/ha) and marginal category (5.47 t/ha). In Agri-silvi-pastoral system, maximum belowground yield is seen in medium category (6.12 t/ha) followed by small and marginal category yielding (5.02 t/ha) and (4.87 t/ha) respectively. As we saw in case of aboveground biomass, the Pasto-silviculture shows lowest belowground yield comparing any other systems in all category. Here, small category (3.16 t/ha) has maximum belowground biomass than medium category (1.82 t/ha).

For the marginal category, the belowground biomass can be place in decreasing order as AH (5.71 t/ha) > ASH (5.47 t/ha) > ASP (4.87 t/ha) > AS (4.38 t/ha). For the small category the belowground biomass can be place in decreasing order as AH (6.32) > ASH (6.15) > AS (5.92) > ASP (5.02 t/ha) > PS (3.16 t/ha). The belowground biomass can be place in decreasing order for medium category as AS (6.63 t/ha) > AH (6.57 t/ha) > ASP (6.12 t/ha) > ASH (5.63 t/ha) > PS (1.82 t/ha). Overall, among all agroforestry system, maximum belowground biomass was recorded in medium category practicing Agri-silviculture (6.63 t/ha) and least belowground biomass was recorded in medium category practicing Pasto-silviculture (1.82 t/ha).

4.3.3 Total Biomass (t/ha) Of Different Functional Components in Different Agroforestry Systems:

The biomass that results from adding the aboveground and belowground biomasses and is influenced by the interactions between the system's constituent parts is referred to as total biomass. From the data tabulated in table 10 it is revealed that irrespective of all categories, the ASH system practiced by medium category shows maximum total biological yield i.e. (25.11 t/ha) and lowest in Pasto-silviculture in medium category which is (12.18 t/ha). Swamy and Puri (2005) and Oelbermann (2002) revealed that the capacity of any agroforestry system's basic components to produce in a particular environment, as well as the quantity, variety, and management of the species, are what determine how much is produced overall.

For marginal category, the total biomass obtained from different agroforestry systems can be placed in decreasing manner as ASH (22.28 t/ha) > ASP (21.03 t/ha) > AH (20.34 t/ha) > AS

(17.83 t/ha). For small category, total biomass can be placed in decreasing manner as ASH (24.98 t/ha) > AH (22.56 t/ha) > ASP (22.1 t/ha) > AS (21.03 t/ha) > PS (15.11 t/ha). For medium category, total biomass can be place in decreasing manner as ASH (25.11 t/ha) > AH (23.61 t/ha) > ASP (22.87 t/ha) > AS (22.7 t/ha) > PS (12.28 t/ha).

Abbas *et al*., (2017) revealed that the tree-based agroforestry systems produce more biomass than grasslands. The findings showed that the structure of systems, particularly the species and density of woody components, dominating species, and management of components and species richness, had an impact on the biomass production of systems. The maximum biomass may be influenced by a number of factors, including the size and abundance of trees as well as the increased productivity of agricultural products. In line with Beer *et al*., (1990). The amount of biomass produced depends on the management approach, age, structure, and other aspects of a system.

4.4 ECONOMIC RETURN FROM DIFFERENT AGROFORESTRY SYSTEMS IN DIFFERENT CATEGORIES OF FARMERS (Rs. /ha/yr.)

Table 11: Economic returns (Rs. ha^{-1} yr^{-1}) from different agroforestry systems under different category of farmers

Farmers category	Marginal			Small			Medium		
Agroforestry systems	Gross return	Cost of cultivation	Net return	Gross return	Cost of cultivation	Net return	Gross return	Cost of cultivation	Net return
AS	191017	104897	86120	216755	122041	94714	219982	120146	96998
AH	244350	130313	114037	253701	142945	110756	221859	126690	95169
ASH	233398	129174	104224	254685	137669	107016	253579	131555	122024
ASP	182198	106046	76152	147869	84892	62977	205125	112310	92815
PS	-	-	-	26142	14027	12115	19034	11257	7777

The data tabulated in table 11 reveals the economic returns (Rs. ha^{-1}yr^{-1}) from different agroforestry systems under different category of farmers which are marginal, small and medium. As we can see, the highest net returns are from the Agri-silvi-horticulture (Rs.122024/ha/yr) in medium category and lowest in Agri-silvi-pasture (Rs.62977 ha^{-1} yr^{-1}) in small category among all agroforestry system irrespective to the categories.

From data presented in table 11, in case of Agri-silviculture, maximum economic returns are by medium category (Rs.96998/ha/yr) followed by small category (Rs.94714/ha/yr) and marginal category (Rs.86120/ha/yr) while cost of cultivation found maximum in small category (Rs.122041/ha/yr) followed by medium category (Rs.120146/ha/yr) and marginal category (Rs 104897/ha/yr). In case of Agri-horticulture, marginal category shown the maximum returns (Rs.114037/ha/yr) followed by small and medium category with returns of Rs.110756/ha/yr and Rs.95169/ha/yr respectively. In case of Agri-silvi-horticulture, the maximum returns were calculated in medium category (Rs.122024/ha/yr) followed by small category (Rs.107016/ha/yr) and marginal category (Rs.104224/ha/yr). In case Agri-silvi-pastoral system, the net returns are ordered as medium > marginal > small with returns in Rs.92815/ha/yr, Rs.76152/ha/yr and Rs.62977/ha/yr. In case of Pasto-silviculture system, small category of farmers perceived more returns (Rs.12115/ha/yr) than medium category (Rs.7777/ha/yr). The biggest net returns in the AH system of marginal categories can be attributed to the system's two primary cash-producing components, namely, agriculture and tree components, which each contributed a sizable portion to the net returns. In a study on the bio-economic evaluation of agroforestry systems in Himachal Pradesh, Kumar (1996) discovered that the Agri-horticulture system had the highest net return, followed by Agri-horti-silviculture, Agri-silviculture, and solo cropping with the lowest return.

From the above tabulated data in table 12, the economic returns obtained by the marginal category from the different agroforestry systems can be placed in decreasing order as AH (Rs.114037/ha/yr) > ASH (Rs.104224/ha/yr) > AS (Rs.86120/ha/yr) > ASP (Rs.76152/ha/yr). While for the small category, the returns can be placed in decreasing order as AH (Rs.110756/ha/yr) > ASH (Rs.107016/ha/yr) > AS (Rs.94714/ha/yr) > ASP (Rs.62977/ha/yr) > PS (Rs.12115/ha/yr). Whereas for medium category, the returns can be placed as ASH (Rs.122024/ha/yr) > AS (Rs.96998/ha/yr) > AH (Rs.95169/ha/yr) > ASP (Rs.92815/ha/yr) > PS (Rs.7777/ha/yr). Wise and Cacho, (2002) states that the financial factors like output pricing, construction costs, labor expenses, and the discount rate may be associated with higher net profits. It might also be impacted by management choices like how much land is set aside for trees and crops.

4.5 VARIATION IN TOTAL BIOMASS PRODUCTION AND NET RETURNS FROM AGROFORESTRY SYSTEMS AMONG DIFFERENT CATEGORIES OF FARMERS.

Standard deviation to mean ratio is known as the coefficient of variation (CV). The degree of dispersion around the mean is inversely proportional to the coefficient of variation. In most cases, it is expressed as a percentage. As it was found that farmers in the study area used a variety of agroforestry systems, with varying degrees of variation in net return and biological yield. The coefficient of variation was calculated to determine the relative variation in the biological yield levels and net returns of a system type among different categories of farmers. Systems with a high CV ratio were very unstable, whereas systems with a low CV ratio were relatively stable.

4.5.1 Coefficient of Variation (%) in Biological Yield.

In case of marginal category, the trend for the coefficient of variation of different agroforestry systems in decreasing order as AS (12.12%) > ASP (11.43%) > ASH (11.21%) > AH (10.15%). In case of small category, this trend goes in decreasing order as PS (14.22%) > AH (13.72%) > ASP (11.65%) > ASH (10.59%) > AS (9.08%). Whereas, in case of medium category, the trend for the coefficient of variation of different agroforestry systems in decreasing order as PS (18.29%) > ASH (13.6%) > ASP (12.38%) > AH (11.57%) > AS (8.46%). From table 12.

The Pasto-silviculture shows maximum variation in biological yield in both small (14.22%) and medium (18.29%) category comparing to agroforestry systems while, Agri-silviculture shows the lowest variation in biological yield in small and medium categories with 9.08% and 8.46% respectively. As Pasto-silviculture shows maximum variation in biological yield it is the most unstable agroforestry system, it can be attributed to the presence of varying number of tree species as well as the number of individuals of each species, the varying size of trees, different

Table 12: Variation in biological yield and economic returns from different agroforestry systems in study area

Coefficient of variation in biological yield (%) among various agroforestry systems practiced in Dehra Tehsil					
Farmers category	**AS**	**AH**	**ASH**	**ASP**	**PS**
Marginal	12.12	10.15	11.21	11.43	_
Small	9.08	13.72	10.59	11.65	14.22
Medium	8.46	11.57	13.6	12.38	18.29
Coefficient of variation in net returns (%) among various agroforestry systems practiced in Dehra Tehsil					
Farmers category	**AS**	**AH**	**ASH**	**ASP**	**PS**
Marginal	7.89	9.4	11.42	8.59	_
Small	7.47	12.43	13.17	9.87	18.1
Medium	8.2	12.49	8.68	14.08	17.3

level of management. In the sub-tropical region of Himachal Pradesh, Kumar (2004) claimed that the Pasto-silviculture system was the most unstable agroforestry system. Agri-silviculture system found to be more stable in small (9.08%) and medium (8.46%) while, Agri-horticulture was found to be more stable in marginal category.

4.5.2 Coefficient of Variation (%) in Net Returns.

In case of marginal category, the variation in net returns was maximum in ASH (11.42%) followed by AH (9.4%), ASP (8.59%) and AS (7.89%). In case of small category, the variation in net returns seen to be maximum in PS (18.1%) system followed by ASH (13.17%), AH (12.43%), ASP (9.87%) and least in AS (7.47%). Whereas in medium category the variation in net returns, Agri-silviculture shows lowest (8.2%) while, Pasto-silviculture system shows highest variation i.e. (17.3%) followed by ASP (14.08%), AH (12.49%) and ASH (8.68%). From table no. 12.

The Pasto-silviculture system is said to be most unstable system as it shows maximum variation in both small and medium category with values (18.1%) and (17.3%), Whereas, Agri-silviculture system can be said most stable agroforestry system in marginal, small and medium category with values (7.89%), (7.47%) and (8.2%) respectively.

The presence of variable numbers of woody trees of each species, with varying sizes and requiring different levels of management, may be the cause of the Pasto-silviculture system's high level of instability. These findings indicate that the Pasto-silviculture system requires appropriate interventions in order to become more stable. In the Chuhar Valley in the District Mandi in Himachal Pradesh, Thakur (2020) noted that pasture-based systems were much more unstable than agriculture-based systems.

4.6 BENEFIT-COST RATIO OF AGROFORESTRY SYSTEMS AMONG DIFFERENT CATEGORY OF FARMERS

The benefit-cost ratio (BCR) is a ratio used in a cost-benefit analysis to summarize the overall relationship between the relative costs and benefits of a proposed project. In agroforestry, the B/C ratio is calculated as gross income divided by cultivation costs. Benefit-cost ratio is a measure of the economic output by a particular agroforestry system and is determined by the type of farmer, the system, and the interactions within it. The data tabulated in Table-13 indicates the benefit-cost ratio among categories of farmers in the study area.

In case of Agri-silviculture system, the highest benefit-cost ratio was found in medium category (1.84) followed by marginal category (1.83) and small category (1.77) farmers. In Agri-horticulture, highest benefit-cost ratio was observed in marginal category (1.87) followed by small category (1.77) and least in medium category (1.75) farmers. Medium category showed highest benefit-cost ratio i.e. (1.93) followed by marginal category (1.87) and small category (1.85). In case of Agri-silvi-pastoral system, the benefit-cost ratios for marginal, small and medium category are (1.83), (1.75) and (1.72) respectively. In Pasto-silviculture, maximum benefit-cost ratio observed in small category (1.86) and lowest benefit-cost ratio observed in medium category (1.69). irrespective to all categories, maximum benefit cost ratio was observed in Agri-silvi-pasture system (1.93) while, minimum benefit-cost ratio was observed in Pasto-silviculture (1.69)

Table 13: Benefit Cost Ratio of Agroforestry Systems Among Different Category of Farmers

Farmers category	Agroforestry systems				
	AS	AH	ASH	ASP	PS
Marginal	1.83	1.87	1.87	1.72	-
Small	1.77	1.77	1.85	1.75	1.86
Medium	1.84	1.75	1.93	1.83	1.69

4.7 TECHNOLOGICAL GAPS AND THEIR AGROFORESTRY-BASED SOLUTIONS.

In the research area, nearly all farmer categories had the same constraints or issues. Table-14 lists the significant gaps and limitations that farmers now face along with potential remedies.

Table 14: Technological gaps/constraints in the existing agroforestry system and their solutions

S. No.	Constraints/gaps	Solutions
1	Majority of the farmers was engaged in government and private sector and selected these sectors over farming for getting more income.	Small- scale agro-based cottage industries should be established at block, panchayat and village level to seek the attention of peoples toward this practice.
2	Farmers in studied area do not have proper irrigation facilities. Inappropriate irrigation facilities or absence of proper irrigation channels were observed.	Drip irrigation, rain water harvesting and watershed techniques etc. should be followed by the farmers.
3	Fragmented land holding was a major constraint for adopting agroforestry systems in the study area.	At different level the efforts should be made by the government to consolidate the fragmented land holdings.
4	Identified existing agroforestry system in the study area were traditional type and less productive.	Apiculture, floriculture, poultry, sericulture and medicinal plants etc. should be introduced in existing agroforestry system to make them more productive.
5	The management practices such as training, pruning, pollarding and lopping were found to be absent among horticultural and woody tree species which decreases the overall yield.	Proper management operations should be followed by the farmers so as to increase the overall yield from the trees.

6	Last year low quality/desi/local agricultural seeds were used by the farmers which in return reduce the total yield of an area	Training programs or camps should be organized to popularize the high-quality seeds among farmers.
7	Few farmers of the sampled area were not able to adopt the new technologies due to their poor financial condition.	It is necessary to aware farmer about the government implemented schemes like Pradhan Mantri Kisan Maan Dhan Yojna or Kisan Credit Card Scheme.
8	Majority of animals reared by the farmers were low yielding cattle (local breed)	Cattle show/Fair, Kisan mela etc. should be organized from time to time to popularize the improved breeds of animals.
9	Farmers do not have sufficient knowledge about subsidy schemes.	Efforts should be made for proper knowledge of subsidy schemes as well as technical guidance by authenticated authorities.
10	Wild/Stray animals like cow, bull, monkey, wild boar etc. were the major threat to the farmers. As they cause heavy damage to their crops.	The problem of wild/stray animals can be solved by applying proper solar fencing at the boundary of farm. Mukhya Mantri Khet Sarankshan Yojna was launched by the state government of Himachal Pradesh but not implemented properly in studied area.
11	Maximum farmers in the study area were not familiar to right doses of fertilizer/pesticides they apply inappropriate doses which reduces the productivity of the crop.	Horticulture and agriculture departments should work in collaboration with government and should launch several programs to provide proper assistance to the farmers.

Chapter-5

SUMMARY AND CONCLUSION

The present study entitled "Socio Economic Survey of Existing Agroforestry Systems in Dehra Tehsil of Kangra District, Himachal Pradesh" was carried out in 2021-22. The main objectives of the study were to identify the existing agroforestry systems, to assess the biological yield, economic returns from agroforestry systems and to find out the technological gaps in the systems and suggest various ways to remove these gaps. Results of the present study are summarized under following headings:

5.1 SOCIO ECONOMIC STATUS OF THE FARMERS
5.2 IDENTIFICATION OF AGROFORESTRY SYSTEMS
5.3 BIOLOGICAL YIELD FROM AGROFORESTRY SYSTEMS
5.4 ECONOMIC RETURNS FROM AGROFORESTRY SYSTEMS
5.5 VARIATION IN BIOLOGICAL YIELD AND NET RETURNS FROM THE AGROFORESTRY SYSTEMS AMONG DIFFERENT CATEGORIES OF FARMERS
5.6 BENEFIT COST RATIO AMONG AFROFORESTRY SYSTEMS AMONG DIFFERENT AGROFORESTRY SYSTEMS
5.7 TECHNOLOGICAL GAPS AND AGROFORESTRY-BASED SOLUTIONS

5.1. SOCIO-ECONOMIC STATUS OF FARMERS

Farmer's socio-economic level has been assessed by considering their typical family structure, gender ratio, and literacy rates of family members, livestock status, off-farm employment status, and land holding size.

The highest family size of 5.19 person per family was observed in medium category followed by small (4.46) and marginal category (4.34) persons per family. Overall average family size observed in study area was 4.66 person per family. The highest sex ratio was found in small category (1075.75) followed by marginal and medium category with ratio (1073) and (1045.45) respectively. The average sex ratio was observed to be 1064.74 which was higher than the national average sex ratio so it clearly indicates that there was no difference on the gender of the child at national level. It was found that the percentage of the joint family is more than the nuclear families in all categories of farmers in study area. Overall percentage on joint family was 56.42% whereas nuclear family comprises 43.58% to the total population in study area.

In case of literacy, medium category shown highest (89.22%) literacy rate followed by marginal category (89.11%) and small category (88.28%). Whereas overall literacy rate of the study area was found 88.87% which is higher than the literacy rate of Kangra district. Male found to be more literate in all three categories namely marginal (89.56%), small (93.67%) and medium (91.76%) while females found to be marginal (80.45%), small (84.45%) and medium (84.19%). In marginal category, highest percent of population (30.69%) studied till middle level while lowest percent (6.94%) was in degree level of education. In small category, maximum population was found studied till higher level whereas minimum 14.42% population studied till primary and senior secondary level. In case of medium category, highest percent of population (22.92%) were found studied till higher level of education, while there was minimum percent of population (12.02%) who studied up to degree level of education.

There were two different sectors of employment generation was found in studied area namely government and private sectors including business, private jobs, shopkeeping, agricultural and non-agricultural labour etc. Majority of male were engaged in private services whereas female in very lower percent were found. Also, in private sectors, males were seen dominating over female.

The livestock rearing was observed in the study area, buffalos were dominating over the population of cow and other animals. In case of buffalos, maximum average number per family was recorded in medium category, 2.43 followed by small 1.96 and marginal 1.72 category. In the study area, it was found that maximum farmers (83.81%) are following scientific method of breeding in animals, while milking method of animals was found traditional only. Farmers were also known to disease management and sanitation methods of the livestock.

Overall average land holding of 4.31 ha was recorded in all categories of farmers out of which, maximum area (3.34 ha) comes under arable land whereas, 0.97 ha comes under non-arable land. As per survey it was found that maximum number of farmers depend on rainfall for crop production, also no proper irrigation facilities were observed.

5.2. IDENTIFICATION OF AGROFORESTRY SYSTEM

In studied area, there was five types of agroforestry systems was recorded named as Agri-silviculture, Agri-horticulture, Agri-silvi-horticulture, Agri-silvi-pastoral and Pasto-silviculture. Among this systems, Pasto-silviculture was absent in marginal category. It was found that Agri-silviculture system was dominating or most practiced (33.34%) agroforestry system in studied area among all agroforestry systems.

5.3 BIOLOGICAL YIELD AND ECONOMIC RETURNS OBTAINED FROM AGROFORESTRY SYSTEMS

In studied area, for marginal category, biological yield obtained from different agroforestry systems in decreasing order as ASH (22.28 t/ha) > ASP (21.03 t/ha) > AH (20.34 t/ha) > AS (17.83 t/ha). In small category, the biological yield different agroforestry systems in decreasing order as ASH (24.98 t/ha) > AH (22.56 t/ha) > ASP (22.1 t/ha) > AS (21.03 t/ha) > PS (15.11 t/ha). In medium category, biological yield different agroforestry systems in decreasing order as ASH (25.11 t/ha) > AH (23.61 t/ha) > ASP (22.87 t/ha) > AS (22.7 t/ha) > PS (12.28 t/ha). It is revealed that irrespective of all categories, the ASH system practiced by medium category shows maximum total biological yield i.e. (25.11 t/ha) and lowest in Pasto-silviculture in medium category which is (12.18 t/ha).

In case of net returns obtained from different agroforestry systems, the studies revealed that maximum net returns are obtained from Agri-silvi-horticulture (Rs.122024/ha/yr), whereas minimum net returns were observed from Pasto-silviculture (Rs.7777/ha/yr). The economic returns obtained by the marginal category from the different agroforestry systems can be placed in decreasing order as AH (Rs.114037/ha/yr) > ASH (Rs.104224/ha/yr) > AS (Rs.86120/ha/yr) >

ASP (Rs.76152/ha/yr). While for the small category, the returns can be placed in decreasing order as AH (Rs.110756/ha/yr) > ASH (Rs.107016/ha/yr) > AS (Rs.94714/ha/yr) > ASP (Rs.62977/ha/yr) > PS (Rs.12115/ha/yr). Whereas for medium category, the returns can be placed as ASH (Rs.122024/ha/yr) > AS (Rs.96998/ha/yr) > AH (Rs.95169/ha/yr) > ASP (Rs.92815/ha/yr) > PS (Rs.7777/ha/yr).

Across all categories, the Agri-silvi-pasture system had the highest benefit-cost ratio (1.93) and the lowest benefit-cost ratio (Pasto-silviculture) (1.69).

5.4 VARIATION IN BIOLOGICAL YIELD AND ECONOMIC RETURNS OF THE AGROFORESTRY SYSTEMS AMONG DIFFERENT CATEGORY OF FARMERS

The coefficient of variation is a useful statistic for assessing the degree of variation between data series. In case of biological yield, Pasto-silviculture has the highest variation in biological yield in both the small (14.22%) and medium (18.29%) categories, while Agri-silviculture has the lowest variation in biological yield in both the small and medium categories, with 9.08% and 8.46%, respectively. Pasto-silviculture is the most unstable agroforestry system due to the maximum variation in biological yield.

In case of net returns, Pasto-silviculture system is said to be the most unstable system because it shows the most variation in both the small and medium categories with values of (18.1%) and (17.3%), respectively. The Agri-silviculture system is said to be the most stable agroforestry system in the marginal, small, and medium categories with values of (7.89%), (7.47%), and (8.2%).

5.5 TECHNOLOGICAL GAPS AND THEIR AGROFORESTRY BASED SOLUTIONS

Farmers were unaware of government-sponsored initiatives that could help them get past the various technical obstacles that prevented them from implementing potential agroforestry systems. Villages should be adopted voluntarily by organizations like state agriculture universities (Agriculture/Forestry/Horticulture) and various schemes and programs should be implemented effectively.

The "Kisan Credit Card Scheme" and other subsidy programs were not well known to farmers. Farmers should be given the technical direction they need from recognized authorities as well as the proper knowledge of subsidy programs. The crops faced a serious threat from wild animals. The preservation of wild animals' natural habitats and the promotion of solar fencing were suggested as solutions.

The improper irrigation facilities seen in the study area require major government action to solve this issue. The communication gap between labs and land constituted a significant obstacle to implementing novel scientific treatments for agroforestry systems due to the lack of a well-developed network for technology transfer in agroforestry.

Because of a lack of knowledge and the lack of high yielding variety seeds, farmers primarily use low yielding varieties of seeds. By providing farmers with appropriate demonstrations, lectures, and training, it is necessary to spread awareness of the high yielding agricultural seeds. The area's poor agricultural research and extension network can be overcome by collaborating with agricultural and horticulture universities to provide support to farmers.

CONCLUSION

After analyzing the collected data of **"Socio Economic Study of Existing Agroforestry Systems in Dehra Tehsil of District Kangra, Himachal Pradesh",** the study can be concluded as follows:

The average sex ratio in study area was 1064.74 with average family size 4.66 persons per family. Overall literacy rate noted as 88.87% with male literacy rate (91.66%) and female literacy rate (84.19%).

Five agroforestry systems was recorded in study area namely Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Agri-silvi-pastoral (ASP) and Pasto-silviculture (PS). Among all systems Agri-silviculture found to be most practiced agroforestry system. The ASH showed maximum biological yield i.e. (25.11 t/ha) and Pasto-silviculture showed minimum biological yield (12.18 t/ha). Maximum net returns are obtained from Agri-silvi-horticulture (Rs.122024/ha/yr), whereas minimum net returns were observed from Pasto-silviculture (Rs.7777/ha/yr). Because of non-fruiting trees, Pasto-silviculture was found to be the most unstable.

The observed technological gaps/constraints in the study area highlighted the inherent weaknesses of existing agroforestry systems. As a result, better land-use strategies should be implemented to increase productivity in the area under cultivation by utilizing the most recent scientific inputs and making the best use of available resources, so that educated people can also pursue a career in agroforestry farming. As a result, this research work provides a clear picture of biomass and economic analysis of existing agroforestry systems and will aid students, researchers, and policymakers in understanding the agroforestry systems of the study area in order to improve and develop technologies that will assist local farmers in meeting basic needs and overcoming existing constraints.

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APPENDIX- I

List of agricultural crops and trees found in Dehra Tehsil of Kangra District (H.P)

S. No.	Common name	Scientific name	Family
Agricultural crops			
1	Wheat	*Triticum aestivum*	Poaceae
2	Maize	*Zea mays*	Poaceae
3	Garlic	*Allium sativum*	Amaryllidaceae
4	Cauliflower	*Brassica oleracea* var. *botrytis*	Brassicaceae
5	Cabbage	*Brassica oleracea* var. *capitata*	Brassicaceae
6	Potato	*Solanum tuberosum*	Solanaceace
7	Colocasia	*Colocasia esculenta*	Araceae
8	Turmeric	*Curcuma longa*	Zingiberaceae
9	Tomato	*Solanum lycopersicum*	Solanaceace
10	Ginger	*Zingiber officinale*	Zingiberaceae
11	Okra	*Abelmoschus esculentus*	Malvaceae
12	Onion	*Allium sepa*	Amaryllidaceae
Forest trees			
1	Buel	*Grewia optiva*	Malvaceae
2	Darek	*Melia azedarach*	Meliaceae
3	Ficus	*Ficus palmata*	Moraceae
4	Kachnar	*Bauhinia variegata*	Fabaceae
5	Khair	*Acacia catechu*	Leguminosae
6	Khirak	*Celtis australis*	Cannabaeceae
7	Pine	*Pinus roxburghii*	Pinaceae
8	Poplar	*Populus deltoides*	Salicaceae
9	Shisham	*Dalbergia sissoo*	Leguminosae
11	Siris	*Albizia lebbeck*	Leguminosae
12	Su-babool	*Leucaena leucocephala*	Leguminosae
13	Tooni	*Toona ciliata*	Meliaceae
14	Thariyamalia	*Ficus roxburghii*	Moraceae
Horticultural crops			
1	Anar	*Punica granatum*	Lythraceae
2	Citrus	*Citrus limon*	Rutaceae
3	Guava	*Psidium guajava*	Myrtaceae
4	Jamun	*Syzygium cumini*	Myrtaceae
5	Litchi	*Litchi chinensis*	Lauraceae
6	Mango	*Mangifera indica*	Anacardiaceae
7	Mulberry	*Morus alba*	Moraceae
Grasses			
1	Bufel grass	*Cenchrus ciliaris*	Poaceae
2	Makoda grass	*Cenchrus setiger*	Poaceae
3	Guinea grass	*Panicum maximum*	Poaceae
4	Setaria grass	*Setaria sphacelata*	Poaceae
5	Malai grass	*Trifolium alexandrium*	Poaceae

APPENDIX- II

Volumetric equations used for estimation of different tree species volume observed under Dehra region

S. No	Name of species	Volume equation (FSI, 1996)
1	*Acacia catechu*	$V= 0.048535-0.183567\sqrt{D}+3.787825D^2$
2	*Albizia lebbeck*	$V= 0.007602/D^2\ 0.033037/D+1.868567+4.483454D$
3	*Bauhinia variegata*	$V= -0.04262+6.09491D^2$
4	*Celtis australis*	$V/D^2 = 0.007602/D2 –0.033037/D+1.868567+4.483454D$
5	*Citrus limon*	$V/D^2 = 0.007602/D2\ 0.033037/D+1.868567+4.483454D$
6	*Dalbergia sissoo*	$V= -0.013703+3.943499D^2$
7	*Ficus palmata*	$\sqrt{V}= 0.03629+3.95389D-0.84421\sqrt{D}$
8	*Ficus roxburghii*	$\sqrt{V}= 0.03629+3.95389D-0.84421\sqrt{D}$
9	*Grewia optiva*	$V= -0.44075+7.49221D-36.09962D^2+71.91238D^3$
10	*Leucaena leucocephala*	$V= 0.007602/D^2\ -0.033037/D+1.868567+4.483454D$
11	*Litchi chinensis*	$V/D^2 = 0.007602/D2\ 0.033037/D+1.868567+4.483454D$
12	*Mangifera indica*	$V= 0.288-2.913D+13.869D^2$
13	*Melia azedarach*	$V/D^2 = 0.007602/D2\ -0.033037/D+1.868567+4.483454D$
14	*Morus alba*	$V= 0.167174-1.735312D+12.039017D^2$
15	*Pinus roxburghii*	$V/D^2 = 0.167095/D2\ -2.085944/D+9.929936$
16	*Populus deltoides*	$V = 0.193297-2.267002D+10.679492D^2$
17	*Psidium guajava*	$V/D2 = 0.007602/D^2\ 0.033037/D+1.868567+4.483454D$
18	*Punica granatum*	$V/D^2 = 0.007602/D2\ -0.033037/D+1.868567+4.483454D$
19	*Syzygium cumini*	$V/D^2= 0.09809/D2\ -1.94468/D+13.36728-6.33263D$
20	*Toona ciliate*	$\sqrt{V}= -0.05514+2.67753D$

APPENDIX- III

Specific gravity of different woody trees species

S. No	Name of species	Specific gravity	Reference
1	*Acacia catechu*	0.88	Gisel *et al.* (1992)
2	*Albizia lebbeck*	0.60	FSI (1996)
3	*Bauhinia variegata*	0.67	IPCC (2003)
4	*Celtis australis*	0.71	Sheikh *et al.* (2011)
5	*Citrus limon*	0.59	Reyes *et al.* (1992)
6	*Dalbergia sissoo*	0.55	Gisel *et al.* (1992)
7	*Ficus palmata*	0.57	Mehraj *et al.* (2011)
8	*Ficus roxburghii*	0.39	Reyes *et al.* (1992)
9	*Grewia optiva*	0.68	Singh (1994)
10	*Leucaena leucocephala*	0.74	Mehraj *et al.* (2011)
11	*Litchi chinensis*	0.88	Reyes *et al.* (1992)
12	*Mangifera indica*	0.59	Gisel *et al.* (1992)
13	*Melia azedarach*	0.69	Sheikh *et al.* (2011)
14	*Morus alba*	0.60	IPCC (2003)
15	*Pinus roxburghii*	0.72	Mahato *et al.* (2019)
16	*Populus deltoides*	0.40	Satish (1998)
17	*Psidium guajava*	0.59	Kanawjia *et al.* (2013)
18	*Punica granatum*	0.99	Felter and Llyod (1898)
19	*Syzygium cumini*	0.70	Gisel *et al.* (1992)
20	*Toona ciliata*	0.45	Chaturvedi *et al.* (2012)

APPENDIX- IV

Biomass expansion factor of different woody tree species

S. No.	Name of species	Biomass expansion factor (BEF)	References
1	*Acacia catechu*	2.52	Gurumurthi *et al.* (1986)
2	*Bauhinia variegata*	1.40	IPCC (2003)
3	*Celtis australis*	1.32	Rawat and Tondon (1993)
4	*Ficus palmata*	1.40	Hidayat and Simpson (1994)
5	*Grewia optiva*	2.01	Behra and Misra (2006)
6	*Mangifera indica*	1.40	IPCC (2003)
7	*Morus alba*	1.30	IPCC (2003)
8	*Pinus roxburghii*	1.91	Rawat and Tondon (1993)
9	*Toona ciliata*	1.40	IPCC (2003)
10	*For remaining trees*	1.50	Brown and Lugo (1992)

APPENDIX- V

a. Biological yield (t/ha) among marginal category of farmers from different agroforestry systems

Agroforestry systems	Components	Proportionate area (ha)	Above ground	Below ground	Total
AS	***Kharif crops***				
	Maize	0.38	3.77	1.07	4.84
	Colocasia	0.24	0.45	0.57	1.02
	Tomato	0.25	0.26	0.15	0.41
	Rabi crops				
	Wheat	0.38	3.27	0.97	4.24
	Potato	0.25	0.78	0.36	1.14
	Cauliflower	0.24	0.37	0.17	0.54
	Trees	0.13	4.55	1.09	5.64
	Total	**1**	**13.45**	**4.38**	**17.83**
AH	***Kharif crops***				
	Maize	0.39	3.6	1.05	4.65
	Colocasia	0.25	0.35	0.43	0.78
	Ginger	0.22	0.41	1.1	1.51
	Rabi crops				
	Wheat	0.38	3.28	0.98	4.26
	Tomato	0.22	0.7	0.2	0.9
	Garlic	0.24	1.1	0.54	1.64
	Trees	0.18	5.19	1.41	6.6
	Total	**1**	**14.63**	**5.71**	**20.34**
ASH	***Kharif crops***				
	Maize	0.38	3.89	0.96	4.85
	Colocasia	0.24	0.32	0.39	0.71
	Okra	0.22	0.21	0.12	0.33
	Rabi crops				
	Wheat	0.37	3.76	1.1	4.86
	Potato	0.16	0.74	0.43	1.17
	Cabbage	0.11	0.29	0.1	0.39
	Turmeric	0.16	0.45	0.54	0.99
	Trees	0.2	7.15	1.83	8.98
	Total	**1**	**16.81**	**5.47**	**22.28**
ASP	***Kharif crops***				
	Maize	0.35	3.45	0.85	4.3
	Ginger	0.11	0.21	0.57	0.78
	Colocasia	0.07	0.08	0.11	0.19
	Okra	0.09	0.07	0.05	0.12
	Rabi crops				
	Wheat	0.32	3.25	0.95	4.2
	Cauliflower	0.09	0.16	0.07	0.23
	Tomato	0.12	0.47	0.14	0.61
	Potato	0.09	0.37	0.22	0.59
	Trees	0.23	6.51	1.39	7.9
	Grasses	0.15	1.59	0.52	2.11
	Total	**1**	**16.16**	**4.87**	**21.03**

b. Biological yield (t/ha) among small category of farmers from different agroforestry systems

Agroforestry systems	Components	Proportionate area (ha)	*Above ground*	Below ground	Total
AS	***Kharif crops***				
	Maize	0.38	*3.9*	0.99	4.89
	Tomato	0.19	*1.12*	0.18	1.3
	Colocasia	0.15	*0.27*	0.38	0.65
	Ginger	0.12	*0.29*	0.79	1.08
	Rabi crops				
	Wheat	0.39	*4.02*	1.04	5.06
	Potato	0.16	*0.45*	0.39	0.84
	Cauliflower	0.16	*0.43*	0.15	0.58
	Cabbage	0.13	*0.24*	0.9	1.14
	Trees	0.16	*4.39*	1.1	5.49
	Total	**1**	***15.11***	**5.92**	**21.03**
AH	***Kharif crops***				
	Maize	0.39	*3.63*	1.02	4.65
	Colocasia	0.24	*0.63*	0.71	1.34
	Ginger	0.19	*0.42*	1.04	1.46
	Rabi crops				
	Wheat	0.38	*3.53*	1.01	4.54
	Garlic	0.25	*0.54*	0.57	1.11
	Cauliflower	0.24	*0.47*	0.21	0.68
	Trees	0.2	*7.02*	1.76	8.78
	Total	**1**	***16.24***	**6.32**	**22.56**
ASH	***Kharif crops***				
	Maize	0.38	*4.02*	1.1	5.12
	Okra	0.18	*0.43*	0.48	0.91
	Tomato	0.14	*0.59*	0.17	0.76
	Colocasia	0.12	*0.29*	0.34	0.63
	Rabi crops				
	Wheat	0.37	*4.54*	0.97	5.51
	Cabbage	0.19	*0.46*	0.18	0.64
	Garlic	0.14	*0.98*	0.45	1.43
	Potato	0.12	*0.65*	0.44	1.09
	Trees	0.21	*6.87*	2.02	8.89
	Total	**1**	***18.83***	**6.15**	**24.98**
ASP	***Kharif crops***				
	Maize	0.35	*3.59*	0.91	4.5
	Okra	0.11	*0.25*	0.27	0.52
	Tomato	0.07	*0.42*	0.06	0.48
	Colocasia	0.09	*0.16*	0.23	0.39
	Rabi crops				
	Wheat	0.32	*3.29*	0.85	4.14
	Cauliflower	0.15	*0.43*	0.15	0.58
	Potato	0.14	*0.55*	0.35	0.9
	Trees	0.24	*6.25*	1.45	7.7
	Grasses	0.15	*2.14*	0.75	2.89
	Total	**1**	***17.08***	**5.02**	**22.1**
PS	Grasses	0.58	*2*	0.64	2.64
	Trees	0.42	*9.95*	2.52	12.47
	Total	**1**	***11.95***	**3.16**	**15.11**

c. Biological yield (t/ha) among medium category of farmers from different agroforestry systems

Agroforestry systems	Components	Proportionate area (ha)	Above ground	Below ground	Total
AS	***Kharif crops***				
	Maize	0.37	4.01	1.03	5.04
	Tomato	0.17	1.01	0.19	1.2
	Colocasia	0.18	0.45	1.35	1.8
	Turmeric	0.14	0.26	0.31	0.57
	Rabi crops				
	Wheat	0.38	3.64	0.98	4.62
	Potato	0.19	0.42	0.19	0.61
	Cauliflower	0.16	0.56	0.37	0.93
	Cabbage	0.13	0.27	0.29	0.56
	Trees	0.14	5.45	1.92	7.37
	Total	**1**	**16.07**	**6.63**	**22.7**
AH	***Kharif crops***				
	Maize	0.38	3.69	0.99	4.68
	Ginger	0.16	0.37	1.06	1.43
	Tomato	0.19	0.69	0.36	1.05
	Colocasia	0.15	0.46	0.47	0.93
	Rabi crops				
	Wheat	0.37	3.38	0.95	4.33
	Cauliflower	0.19	0.42	0.44	0.86
	Garlic	0.15	0.79	0.31	1.1
	Potato	0.17	0.59	0.35	0.94
	Trees	0.19	6.65	1.64	8.29
	Total	**1**	**17.04**	**6.57**	**23.61**
ASH	***Kharif crops***				
	Maize	0.37	4.08	1.02	5.1
	Tomato	0.2	0.73	0.23	0.96
	Okra	0.15	0.38	0.2	0.58
	Turmeric	0.14	0.27	0.31	0.58
	Rabi crops				
	Wheat	0.38	3.72	0.91	4.63
	Cabbage	0.23	0.45	0.21	0.66
	Potato	0.25	0.83	0.54	1.37
	Trees	0.21	9.02	2.21	11.23
	Total	**1**	**19.48**	**5.63**	**25.11**
ASP	***Kharif crops***				
	Maize	0.32	3.53	0.88	4.41
	Turmeric	0.13	0.25	0.28	0.53
	Okra	0.12	0.31	0.16	0.47
	Ginger	0.1	0.26	0.72	0.98
	Rabi crops				
	Wheat	0.32	3.14	0.76	3.9
	Potato	0.14	0.49	0.33	0.82
	Garlic	0.11	0.71	0.33	1.04
	Cauliflower	0.1	0.26	0.09	0.35
	Trees	0.23	6.15	2.15	8.3
	Grasses	0.11	1.65	0.42	2.07
	Total	**1**	**16.75**	**6.12**	**22.87**
PS	Grasses	0.62	2.05	0.54	2.59
	Trees	0.38	8.31	1.28	9.59
	Total	**1**	**10.36**	**1.82**	**12.18**

APPENDIX- VI

S. No.	Particulars (Inputs)	Current price (Rs.)
1	**Labour cost:** 1. Labour charges in year 2021-22 per day	300
	2. Bullocks labour (per day)	100
	3. Ploughing by tractor (per hour)	1200
2	**Seed cost per kg:** 1. Wheat	30
	2. Maize	25
	3. Cauliflower	4500
	4. Cabbage	1420
	5. Potato	50
	6. Ginger	125
	7. Garlic	400
	8. Colocasia	40
	9. Turmeric	5600
	10. Okra	620
	11. Tomato	5500
	12. Onion	900
3	**Manures and fertilizers:** 1. FYM (per quintal)	250
	2. NPK (12:32:16) (per 50 kg)	1200
	3. Urea (per 50 kg)	900
4	**Pesticides and fungicides:** 1. Atrazine (24D) (1/2 kg)	200
	2. Bavistin (100 ml)	150
	3. Chloropyriphos (100 ml)	40
	4. Dithane M-45 (1kg)	450
No	**Particulars (Outputs)**	**Current price (Rs.)**
1	**Agriculture (per quintal):** 1. Wheat- Grains	2000
	Straw	700
	2. Maize- Grains	2000
	Straw	700
	3. Cauliflower	3000
	4. Cabbage	2500
	5. Potato	2000
	6. Ginger	5000
	7. Garlic	6000
	8. Colocasia	2900
	9. Turmeric	4000
	10. Okra	3000
	11. Tomato	3000
	12. Onion	2500
2	**Fruit (per quintal):** 1. Mango	6000
	2. Litchi	8000
	3. Guava	8000
	4. Jamun	9500
	5. Citrus	3000
	6. Anar	5500
3	**Fuel wood per quintal**	650
4	**Green leaf fodder**	730
5	**Pasture dry grass per quintal**	800

APPENDIX- VII

Economics of different AF system among marginal farmers in Dehra Tehsil of Kangra District, H.P. (Rs /ha/yr)

Agri-silviculture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.38		8.02	14436	8481	5955
	Colocasia	0.24		8.19	22932	12873	10059
	Turmeric	0.25		15.46	61840	32600	29240
Rabi crops	Wheat	0.39		8.76	17520	10145	7375
	Potato	0.25		8.96	22400	12761	9639
	Cauliflower	0.23		15.45	46350	24993	21357
	Fuel wood	0.13	7.96		4776	2643	2133
	Fodder		1,09		763	401	362
Total					**191017**	**104897**	**86120**

Agri-horticulture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.39		8.16	14668	7906	6762
	Colocasia	0.26		8.88	24864	15165	9699
	Ginger	0.21		9	45000	26227	18773
Rabi crops	Wheat	0.38		9.32	18533	12980	5553
	Tomato	0.23		21.35	64050	34282	29768
	Garlic	0.25		7.71	46235	17210	29025
	Fruits	0.14	8.56		31000	16543	14457
Total					**244350**	**130313**	**114037**

Agri-silvi-horticulture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.38		7.9	13784	9040	4744
	Colocasia	0.26		9.99	39960	23300	16660
	Okra	0.24		20.06	60226	32177	28049
Rabi crops	Wheat	0.37		8.87	17743	9942	7801
	Potato	0.18		7.06	17648	10417	7231
	Cabbage	0.13		19.89	35802	18367	17435
	Turmeric	0.2		7.45	29790	15765	14025
	Fodder	0.12	2.22		1555	851	704
	Fuel wood		8.89		5333	2887	2446
	Fruits		1.06		11557	6428	5129
Total					**233398**	**129174**	**104224**

Agri-silvi-pastoral							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.35		6.86	12351	6346	6005
	Ginger	0.11		5.19	26002	15760	10242
	Colocasia	0.07		2.66	11994	7787	4207
	Okra	0.09		8.26	24825	16440	8385
Rabi crops	Wheat	0.32		6.95	13907	7052	6855
	Cauliflower	0.09		7.21	21613	11307	10306
	Tomato	0.12		11.03	33075	17703	15372
	Potato	0.09		6.85	17148	9082	8066
Trees	Fodder	0.23	3.66		8111	5721	2390
	Fuel wood		5.28		10032	7028	3004
Pasture	Grasses	0.15		3.14	3140	1820	1320
Total					**182198**	**106046**	**76152**

Economics of different AF system among small farmers in Dehra Tehsil of Kangra District, H.P. (Rs /ha/yr)

Agri-silviculture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.38		7.9	12680	8650	4030
	Tomato	0.19		18.15	54450	29747	24703
	Colocasia	0.15		5.11	14308	8031	6277
	Ginger	0.12		6.11	30550	16892	13658
Rabi crops	Wheat	0.39	5.92	8.13	19223	10001	9222
	Potato	0.16		6.47	16175	9713	6462
	Cauliflower	0.16		14.41	43230	23503	19727
	Cabbage	0.13		11.66	20972	12300	8672
	Fodder	0.16	2.53		1771	1220	551
	Fuel wood		5.66		3396	1984	1412
Total					**216755**	**122041**	**94714**

Agti-horticulture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.39		7.2	12960	8288	4672
	Colocasia	0.25		8.53	23884	14567	9317
	Ginger	0.2		9.35	46750	25615	21135
Rabi crops	Wheat	0.38	4.77	7.07	16524	9271	7253
	Garlic	0.26		10.54	63240	34560	28680
	Cauliflower	0.25		19.05	57150	31417	25733
	Fruits	0.16	5.6		33193	19227	13966
Total					**253701**	**142945**	**110756**

Agri-silvi-horticulture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Khari crops	Maize	0.38	3.36	6.03	12529	8119	4410
	Okra	0.19		15.88	47676	25472	22204
	Tomato	0.15		11.91	35727	20824	14903
	Colocasia	0.13		7.77	21761	13001	8760
Rabi crops	Wheat	0.37	4.48	6.86	15968	9472	6496
	Cabbage	0.2		30.6	55080	28256	26824
	Garlic	0.15		3.64	21834	12575	9259
	Potato	0.13		7.29	18230	10899	7331
	Fodder	0.15	2.53		1768	1255	513
	Fuel wood		3.33		1993	1025	968
	Fruits		3.24		12119	6771	5348
Total					**244685**	**137669**	**107016**

Agri-silvi-pastoral							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.35		6.47	11646	7463	4183
	Okra	0.11		8.45	25350	14919	10431
	Tomato	0.07		5.93	17880	9988	7892
	Colocasia	0.09		3.42	15419	10012	5407
Rabi crops	Wheat	0.32		6.97	13940	7023	6917
	Cauliflower	0.16		10.65	31950	17434	14516
	Potato	0.14		10.29	25725	14772	10953
Trees	Fodder	0.23	2.07		1449	740	709
	Fuel wood		2.45		1350	710	640
Pasture	Grasses	0.15		3.16	3160	1831	1329
Total					**147869**	**84892**	**62977**

Pasto-silviculture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Pasture	Grasses	0.58		12.13	16180	8288	7892
Trees	Fodder	0.42	6.22		5516	3375	2141
	Fuel wood		4.25		4446	2364	2082
Total					**26142**	**14027**	**12115**

Economics of different AF system among medium farmers in Dehra Tehsil of Kangra District, H.P. (Rs /ha/yr)

Agri-silviculture							
Functional component		Proportionate area (ha)	Average yield of fruit/fodder/straw /fuel wood (Quintal)	Average yield (Quintal)	Gross returns (Rs)	Cost of cultivation (Rs)	Net returns (Rs)
Kharif crops	Maize	0.37	1.95	6.46	12605	7195	5410
	Tomato	0.17		14.94	44820	22045	22775
	Colocasia	0.18		11.76	32928	17025	15903
	Turmeric	0.14		7.34	29366	16370	12996
Rabi crops	Wheat	0.38	2.1	6.81	13723	8914	4809
	Potato	0.19		10.13	25325	15427	9898
	Cauliflower	0.16		12.52	37560	19685	17875
	Cabbage	0.13		11.58	20828	11995	8833
	Fodder	0.14	1.57		1099	459	640
	Fuel wood		2.88		1728	1031	697
Total					**219982**	**120146**	**99836**

Agri-horticulture							
Functional component		Proportionate area (ha)	Average yield of fruit/fodder/straw /fuel wood (Quintal)	Average yield (Quintal)	Gross returns (Rs)	Cost of cultivation (Rs)	Net returns (Rs)
Kharif crops	Maize	0.38	4.23	6.75	14263	8228	6035
	Ginger	0.16		5.3	26500	14023	12477
	Tomato	0.19		11.16	33480	18879	14601
	Colocasia	0.15		5.11	14308	8726	5582
Rabi crops	Wheat	0.37	6.29	5.85	14844	8299	6545
	Cauliflower	0.19		12.99	38970	22616	16354
	Garlic	0.15		6.08	36491	20512	15979
	Potato	0.17		11.35	28375	17018	11357
	Fruit	0.12	2.43		14628	8389	6239
Total					**221859**	**126690**	**95169**

Agri-silvi-horticulture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.37	4.67	6.29	13658	8456	5202
	Tomato	0.2		15.88	47636	27765	19871
	Okra	0.15		12.53	37618	20098	17520
	Turmeric	0.14		6.39	25560	14374	11186
Rabi crops	Wheat	0.38	3.98	7.52	17030	10064	6966
	Cabbage	0.23		35.19	63342	32494	30848
	Potato	0.25		18.44	46100	16511	29589
	Fuel wood	0.12	2.63		1578	1181	397
	Fodder		1.51		1057	612	445
Total					**253579**	**131555**	**122024**

Agri-silvi-pastoral							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Kharif crops	Maize	0.32		8.51	15318	8635	6683
	Turmeric	0.13		9.46	37378	18609	18769
	Okra	0.12		10.01	30030	18031	11999
	Ginger	0.11		5.19	25980	15746	10234
Rabi crops	Wheat	0.32		7.58	16863	8432	8431
	Potato	0.15		9.39	23475	12893	10582
	Garlic	0.11		4.23	25387	14270	11117
	Cauliflower	0.1		7.28	21840	11593	10247
Trees	Fuel wood	0.21	4.24		2968	1109	1859
	Fodder		4.16		2496	1256	1240
Pasture	Grasses	0.13		3.39	3390	1736	1654
Total					**205125**	**112310**	**92815**

Pasto-silviculture							
Functional component		**Proportionate area (ha)**	**Average yield of fruit/fodder/straw /fuel wood (Quintal)**	**Average yield (Quintal)**	**Gross returns (Rs)**	**Cost of cultivation (Rs)**	**Net returns (Rs)**
Pasture	Grasses	0.62		16.18	12130	7032	5098
Trees	Fodder	0.38	7.88		4354	2320	2034
	Fuel wood		7.41		2550	1905	645
Total					**19034**	**11257**	**7777**

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Title of Thesis	**:**	**"Socio-economic Survey of Existing Agroforestry Systems in Dehra Tehsil of Kangra District, Himachal Pradesh"**
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ABSTRACT

The present investigation entitled "**Socio-economic Survey of Existing Agroforestry Systems in Dehra Tehsil of Kangra District, Himachal Pradesh**" was carried out in the year 2021-22 with the aim to identify agroforestry system types; estimate their biological yield and economic returns; technological gaps and thereby propose suitable agroforestry solutions. Thirteen gram-panchayats were chosen and from each panchayat, twelve farmers and from each category four farmers were divided on the basis of their land holding viz. marginal category (< 1ha), small category (1-2 ha) and medium category (2-4 ha). Data was collected through field sampling and personal interviews. The study revealed that five different agroforestry systems were practiced by the farmers in the study area namely; Agri-silviculture (AS), Agri-horticulture (AH), Agri-silvi-horticulture (ASH), Agri-silvi-pastoral (ASP) and Pastoralsilviculture (PS) were identified. In medium and small category of farmers all five agroforestry systems were present while, in marginal category of farmers pastoralsilviculture system was absent. The average family size of sampled households was 4.66 person per household. The literacy rate was recorded highest (89.22%) in medium category of farmers. Wheat, potato, garlic, cauliflower and cabbage were rabi crops, whereas maize, colocassia, tomato, ginger and turmeric were crops of kharif season. Prominent tree components in agroforestry systems were *Acacia catechu, Grewia optiva*, *Celtis australis, Pinus roxburghii* , *Bauhinia variegata*, *Toona ciliata*, *Morus alba*, *Ficus roxburghii*, *Ficus palmata* and *Albizia lebbeck* found in pastureland and along the bunds of agriculture fields, whereas fruit trees of *Mangifera indica*, *Morus alba, Litchi chinensis, Syzygium cumini, Psidium guajava, Citrus limon* and *Punica granatum* were retained on and around the bunds of the agriculture field. In pasture, the dominant grass species observed were as follows: *Cenchrus ciliaris, Cenchrus setiger, Themada anathera, Panicum maximum* and *Setaria sphacelata*. Irrespective of farmers categories, the highest grand total biomass (25.11 t/ha) was observed in agri-silvi-horticulture system (ASH) and lowest (12.18 t/ha) in pastoralsilviculture system (PS). Among all the category of farmers the maximum net returns (1,22,024 Rs/ha/yr) was reported from agri-silvi-horticulture (AHS) and least (62,977 Rs. /ha/yr) from Agri-silvi-pastoral system. Technological gaps identifying the socio-economic and other constraints have highlighted the inherent weakness of existing AFS types. The most prominent among these constraints includes disproportionate applications of insecticides/pesticides and fertilizers, occurrence of fragmented landholdings, communication gap between lab to land, ineffective implementation of government sponsored schemes for the benefits of farming communities. Relevant agroforestry solutions include conducting location specific diagnostic survey, strengthening of agro- processing facilities, voluntarily adoption of some villages by state agriculture universities and other related institutions etc. From the above study it is concluded that ASH system type was found to be the best for economic point of view as well as more profitable by providing maximum BC ratio.

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