ECONOMIC ANALYSIS OF POPLAR BASED AGRO-FORESTRY SYSTEM AND ITS ADOPTION BEHAVIOUR IN PUNJAB

Thesis

Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
in
AGRICULTURAL ECONOMICS
(Minor Subject: Statistics)

By

Mandeep Singh
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LUDHIANA – 141 004

2018

CERTIFICATE I

This is to certify that the thesis entitled, **"Economic Analysis of Poplar Based Agro-forestry System and Its Adoption Behaviour in Punjab"** submitted for the degree of **M.Sc.** in the subject of **Agricultural Economics** (Minor subject: **Statistics**) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Mr. Mandeep Singh (L-2012/13-BS-329-M)** under my supervision and that no part of this thesis/dissertation has been submitted for any other degree.

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

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CERTIFICATE II

This is to certify that the thesis entitled, **"Economic Analysis of Poplar Based Agro-forestry System and Its Adoption Behaviour in Punjab"** submitted by **Mr. Mandeep Singh (L-2012/13-BS-329-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Agricultural Economics** (Minor subject: **Statistics**) has been approved by the Student's Advisory Committee along with Head of the Department after an oral examination on the same, in collaboration with an external examiner.

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ABSTRACT

The present study was conducted to analyze economics of poplar cultivation and its adoption behaviour in Punjab based on primary data collected from a sample of 60 adopters and 32 non-adopters of agro-forestry from 4 clusters of villages from Ludhiana and Ropar districts of Punjab state pertaining to year 2013-14. Two types of agro-forestry systems AFS-I (wheat + kharif fodder during 1st four years of poplar cultivation) and AFS-II (sugarcane for first two years and wheat during 3-4 years) were identified. The establishment cost on per acre basis was estimated at ₹8,034, ₹7,731, ₹7,849 and ₹7,871 for small, medium, large and overall farm size categories. The operational cost was worked out at ₹3,724 per acre during 1-4 years and ₹2,919 per acre during 5-6 years of plantation in AFS-I on overall basis. The operational cost in AFS-II on overall basis was estimated at ₹1,904 during 1-2 years, ₹5,071 during 3-4 years and ₹3,630 during 5-6 years of poplar plantation on per acre basis. Returns varied directly with farm size and age of harvesting. The per acre net returns were ₹2,02,463, ₹2,05,283 and ₹2,29,720 in AFS-I and ₹2,19,015, ₹1,78,832 and ₹2,00,639 in AFS-II at 4th, 5th and 6th years of harvesting on overall basis. Returns from wheat-paddy crop rotation cultivated by non-adopter farmers varied directly with farm size and average net returns were ₹40,744 per acre. The annuity value of net present worth in poplar cultivation estimated at 12 per cent discount rate was higher than net returns from wheat-paddy cultivation indicating poplar cultivation was more profitable than wheat-paddy cultivation. The benefit-cost ratio was the highest at 5th year of harvesting in case of AFS-I and AFS-II. Age, education and extension contacts of the sample farmers was positively correlated with adoption behavior, whereas working members in agriculture and off-farm income was negatively correlated with the adoption behaviour of poplar cultivation.

Keywords: Economics of poplar cultivation, Diversification of agriculture, Benefit-cost ratio, Logistic regression model

Signature of Major Advisor **Signature of the Student**

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ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Agro-forestry is an age-old land use practice, which has been practiced by farmers in various forms in different parts of India. In recent years, researchers, planners, policy makers and even farmers have recognized the importance of scientific agro-forestry and experimented considerably with new forms of agro-forestry. The systems have been designed to meet a range of challenges posed by rapid intensification and deforestation to protect soil and water resources, increase productivity and profitability.

Punjab is an agricultural state. Wheat and paddy crops occupy more than 80 percent cropped area of the state, but only 6.5 percent area is under forests (2017). The excessive use of agro-chemicals in rice and wheat rotation has depleted and deteriorated soil health and water resources in the state. This declining diversity has severe effect in terms of overuse of water resources, soil nutrients and ecological problems such as air, water and soil pollution. Over time technology fatigue manifested in terms of declining/stagnation in the productivity of major crops had further aggravated the problem of lowering down income of the farmers. The stagnation in the state agriculture requires corrective policy measures to increase the productivity on farms (Singh *et al.* 2000). The situation demands some concrete solutions which can augment the income of the farmers and save them from suffering. There are several ways to accelerate agricultural growth and enhance livelihood of the farmers. The need of diversification had some alternative remunerative crops/cropping system. Agro-forestry has eventually been identified as one of the potential alternatives which will improve the economy of the farmers besides taking care of natural resources. Farmers are willing to diversify the present cropping rotation provided the assured market of input and output of alternative crops available. Diversification in rice-wheat crop rotation has strongly been advocated in irrigated agro-ecosystem. The financial analysis of different farming systems based on the benefit-cost ratio, net present value, internal rate of return and payback period indicates that all the agro-forestry systems analyzed were profitable and economically viable (Sharma and Kumar, 1998).

National Forest Policy (1988) suggested that to maintain ecological balance and to meet the wood based needs there is a need to have at least one-third area of the country under forests. It further states that at least 60 per cent area in hills and 20 per cent in plains should be under forest cover. The demand for timber and other tree-based products is increasing day by day. Only feasible alternative to fulfill such a demand would be adoption of agro-forestry practice as this is one system that can provide both wood and food while at the time conserve and rehabilitate eco-system.

As per the Forest Survey of India 2011 report, there is an increase of 10,000 ha of area under forests in the state of Punjab, which is mainly attributed to introduction of short

rotation tree based agro-forestry systems on farmers' fields. Owing to the immediate need, the state government has envisaged to bring 2.0 lakh ha under agro-forestry over the next five years. Complementing the diversification plan is the 'Green Punjab Mission' under which the state government envisages to increase the area under trees from the exiting 5.57 per cent. To encourage 'Crop Diversification' The Department of Forests and Wildlife Preservation Punjab is distributing superior plants of clonal eucalyptus and poplar free of cost to farmers of state. The income from harvest of trees raised under this scheme will be of the farmers.

Agro-forestry is one of the important components which are gaining importance in irrigated agro-ecosystem, and it is being felt as the need of the day for sustainable production and economic up-liftment of the farmers. According to World Bank in developing countries, about 1.2 billion people rely on agro-forestry farming systems that help to sustain agricultural productivity and generate income (World Bank, 2002). The agro-forestry which envisages the integration of trees, herbaceous crops and animals on the same land unit seems to hold promising potential in this regard. Moreover, it is a natural resource conserving system and is gaining importance as an approach for diversifying traditional agriculture. Poplar (*Populus deltoides*) has become an important tree component of agro-forestry systems in north-western part of the country due to high returns, short gestation period, compatibility with farming systems and good market demand. The importance of Poplar in Indian agro-forestry was realised in the early 1980s (Chaturvedi, 1982). Poplar has become the most preferred cash crop in north-western states (Chandra, 1986). Poplar has played a significant role in enhancing the income of the farmers and average economic returns per hectare of poplar based agro-forestry is two to five times more than traditional crop rotation (Joshi, 1996; Dwivedi *et al.*, 2007). Poplars increase productivity of land and its wood is used for forming well crabs, lacquer work, turnery, match splints, plywood, cheap cricket bats, shoe heels, wood wool, pencils, artificial limbs, bobbins etc. Crops which can be produced along with poplar plantation are sugarcane, wheat, pea, rapeseed, berseem, potato, sunflower, lentil, barley and oats. Agro-forestry gives more income to the farmer per unit of land than pure agriculture or forestry. Several studies in different parts of India suggest that agro-forestry is more profitable than agriculture or forestry (Chaturvedi, 1981; Lahiri, 1983; Mathur *et al.*, 1984; Chandra, 1986 and Patel, 1988). In general, yield and income from crops grown under trees are reduced than their pure cropping, but these reductions are compensated by relatively higher biomass production from trees in agri-siviculture system. Progressive farmers of Punjab and adjoining states have adopted agro-forestry but in spite of ecological and economic viability of the system, not even one percent area of Punjab is under agro- forestry system. It is, however, difficult for a new system (agro-forestry) to enter into the traditional system (rice-wheat rotation), which have proved worth. The adoption of any new system depends upon the user's awareness level, attitudinal behavior, positive perception and above

all the capacity to take risk and overcome the constraints. Jain and Singh (2000); Kumar *et al.* (2004) estimated the economic profitability of poplar based agro-forestry interventions higher than many other major crop rotations and stressed that better economics in agro-forestry is due to the higher timber market value, which will always remain high due to huge gap of demand and supply for industrial wood. Poplar (*Populus deltoides*) based agro-forestry systems are one of the viable alternative land use systems to diversify the rice-wheat rotation, prevent further degradation and obtain biological production on a sustainable basis. This species has been grown by farmers as boundary or block plantation, which improves the physical-chemical properties of soil through addition of organic matter in the soil and provides alternative sources of income and employment to the rural poor. Moreover, the small farmers cannot afford to raise block plantation at the cost of agricultural crop yield.

Agro-forestry seems to be a most benefiting system in the state, but still profitability of any agro-forestry system beset with many problems, at the production stage, which increase the costs and the factors that lowers the productivity of trees as well as at the marketing stage which through operation of various malpractices reduces the net price received by the farmers. A study conducted by Sekhon (2003) has arrived at an estimate that farmers were facing various problems during production and marketing of poplar. The major problems faced by the growers in production of poplar were shade of poplar tree, which reduces the yield of intercrops and impossibility of growing paddy in an agro-forestry system. In case of marketing problem the risk in price fluctuation and fluctuating industry demand were the major problems. Hence, the present study was formulated with the following specific objectives:

i) to examine costs and returns in agro-forestry system vis-à-vis crop farming in Punjab,
ii) to analysis financial viability of agro-forestry system; and
iii) to determine factors influencing adoption behaviour of agro-forestry system.

CHAPTER II

REVIEW OF LITERATURE

The present chapter has been designed to throw light on various aspects and issues of agro-forestry. These aspects have been grouped into following sections according to the objectives of the study:-

2.1 Studies related to the economic analysis and financial viability of agro-forestry and its importance.

2.2 Studies related to determine factors influencing adoption behaviour of agro-forestry system.

2.1 Studies related to economic analysis and financial viability of agro-forestry and its importance

Hussain *et al.* (1988) studied the economics of poplar for agro-forestry. They found that poplar plantations in all farms either in block or in row or along sides the roads were economical. The net income from poplar plantation at the age of harvesting of 5 year fetched returns of ₹22,048 per hectare per year. The study further revealed that poplar tree grown along farm boundary equal growth at 3 years of age as compared with block plantation for the age of 5 years with a net income of ₹11,067 in 3 years to ₹41,250 in 7 year period.

Khan and Betters (1990) studied the economic analysis of agro-forestry options for small irrigated farms in Punjab Province, Pakistan. It was observed that agro-forestry on small irrigated farms may represent opportunities for solving Pakistan wood supply problems. An economic analysis was applied to single and joint crop production possibilities and then these possibilities were analyzed under typical farm constraints and requirements using a linear programming (LP) technique. The combinations analyzed were poplar alone (2.5*2.5 m spacing), wheat alone, and wheat-poplar at avenue spacing's of 2.5*10, 30 or 50 m. Net present values (NPV) were derived over a period of 10 year. The LP technique analyzed the use of various wheat and poplar combinations (the joint alternative was best at a poplar spacing of 2.5*10 m) in combination with other production alternatives (in this case fodder and vegetables). The results showed that applying agro-forestry practices could increase the overall farm production and income.

Verma (1990) conducted a study on agro-forestry practices in Gujarat state. The survey was carried out in 1987. A sample of 563 farmers was selected using stratified random sampling of agro-climatic zone. They observed that boundary plantation was more preferred in case of unirrigated conditions, whereas both type of plantations boundary as well as blocks were preferred equally in case of irrigated conditions. Agro-forestry had been adopted by all categories of farm size viz., small, medium and large. Eucalyptus species were planted by 90 per cent of the farmers in agro-forestry system. The most common spacing was 1 m preferred. Diversified views were expressed by farmers w.r.t. effect of trees on the yield of crops

annually, 50 percent revealed to change, 34 per cent decline in yield about 15 per cent reported even the increase in yield. This might be due to better management practices followed after the tree plantation.

Parvej (1990) studied the economics of eucalyptus based agro-forestry system and its effect on crop yield in Haryana state. Three rotations of eucalyptus (8, 9 and 10 year) based agro-forestry were selected for comparative purpose and relative loss to the crops. The optimum rotation i.e. the one giving maximum internal rate of return (IRR) with minimum loss to the agricultural crops was found to be 8 years.

Singhal and Panwar (1992) studied the commercial approach to poplar based agro-forestry system in north-western Uttar Pradesh. A detailed economic analysis was done for agro-silvicultural system practiced by farmers in Bijnor and Rampur districts of Uttar Pradesh using an 8 year cropping scheme. The trees were planted first year old seedlings and the crop sequence was main crop (first year), sugarcane (second year), wheat\jowar fodder (third-sixth year), and wheat\fallow (seventh-eighth year). Other crops which may be included were maize, potatoes, mustard, lentils, turmeric, fodder crops and aromatic herbs. The benefit cost ratio achieved was high (4.45) and the system also gives indirect benefits in erosion control and maintaince of soil fertility.

Dhalíwal (1994) studied the comparative economics of different agro-forestry systems that is poplar + sugarcane during first three years and poplar + wheat crop during rabi season and fodder during kharif season (AFS-I) and poplar + wheat-kharif fodder (AFS-II). The results showed that in case of poplar in plain region present net worth (PNW) at 12 per cent rate of discount was ₹38,228 and ₹46,428 in case of AFS-I and AFS-II for the eight years respectively. The BCR for the corresponding agro-forestry system was 2.22 and 2.51 respectively. IRR was 26.12 and 25.4 per cent and percentage change over the respective pure cropping systems (wheat + paddy) was -5.29 and +1 4.18 respectively. In sub-mountainous region, Present Net Value (PNV) was ₹28,532 and ₹34,179 at 12 per cent rate of discount in the fifth year in case of AFS-I and AFS-II respectively. The BCR for the corresponding agro-forestry system was 3.14 and 2.89 respectively. IRR was 67.09 and 63.3 and the percentage increase over the respective pure cropping systems was 66 and 72 respectively. Although agro-forestry was a profitable enterprise, but it was relatively less profitable in some situations.

Malik *et al.* (2000) analyzed the costs and returns from poplar plantation in Kurukshetra district. The data were collected pertaining to the year 1998-99 from 40 respondents of four selected villages from two blocks, viz Babain and Ladwa, using multi-stage random sampling technique. They reported that the cost of plant material was a share of 34 per cent of establishment cost. The operational cost was estimated at ₹2,800 per annum during the first six years at per acre basis. But in the seventh year, it increased up to ₹10,800

per acre because of harvesting of plant. The total annual costs varied from ₹14,079 in the first year to ₹20,448 in the seventh year due to increase in land rent. The total annual costs remained almost constant over the age of trees. The financial viability of poplar plantation results was constant and annual net returns of ₹22,156 and ₹29,332 per acre over its entire life without intercropping and with intercropping respectively. This indicated that poplar cultivation without intercropping and with intercropping was quite profitable. The marginal increase in net returns of poplar with intercropping over poplar without intercropping was due to growing of various intercrops like sugarcane, wheat, potato, berseem and oat. The benefit-cost ratio also favoured plantation of poplars in the region.

Chahal and Singh (2000) studied the present status of forest plantations in Punjab state, to work out the economics of different plantations prevalent in the study area and to suggest policy implications. A sample of 80 different sized farmers was selected from eight villages of four blocks from Amritsar and Ludhiana districts to represent the central Punjab. Hoshiarpur topped covering 33 percent of the area under forests, followed by Rupnagar, Gurdaspur, Patiala, Amritsar and Ludhiana. The remaining districts have less than 2 per cent of the area under forests. Poplar and eucalyptus were the most common plants grown as agro-forestry crops, followed both the block and boundary methods of plantations. Intercropping was mainly done in block method of poplar plantation. In the case of block plantations of poplar, maximum cost was incurred during the first four operational years, which accounted for more than 50 per cent of the total costs. Though the average costs incurred for block plantation of poplar were higher at ₹9,845 per acre as compared to ₹7,502 per acre for eucalyptus, the average net returns per acre from poplar were far higher at ₹1.28 lacks as against ₹93,000 for eucalyptus. Whereas the maximum returns from poplar were achieved during the eighth year, the eucalyptus gave maximum returns during the tenth year, thus making the latter more uneconomical for general plantations. The boundary plantations of eucalyptus gave marginally higher net returns than that of poplar at ₹703.21 per plant, but eucalyptus, however, lacked its economic advantage due to its more water consumption and due to delayed maturity by 2 to 3 years than the poplar. The average incremental increase in returns due to successive ageing in the case of poplar was also found to be far higher than that of eucalyptus. Based on cost and returns analysis, it is recommended that diversification of agriculture should be encouraged through poplar plantation in blocks to get the advantage of intercropping which ensures higher income within shorter period of time for the farmers. Eucalyptus block plantation could be encouraged on inferior soils. Both poplar and eucalyptus could be grown on boundaries of the fields, paths, roadsides, water channels, etc., to achieve higher level of social forestry.

Dhillon *et al.* (2001) examined to analyze the cost and returns from poplar plantation in Haryana state. The required data were collected from 50 poplar growers of five villages in

chhhachhrauli block of Yamunagar district of Haryana, using multi-stage random sampling design. The data pertained to the year 1998-99. The study revealed that the total annual cost of poplar cultivation did not vary much with the age of plant; land rent accounted for the maximum of total annual cost. The net returns from poplar plantation worked out to be ₹1.64 lakhs in the seventh year, whereas it was ₹3,898 in the first year from intercropping which increased to ₹6,939 during the second and third year. For the remaining years, the net returns worked out to be ₹4,782 per annum. The total net returns from intercropping with poplar plantation were estimated at ₹2 lakhs. Further, it was found that the net present values of total net returns per acre was ₹53,476 and ₹88,749 respectively for poplar without intercropping and with intercropping poplar with was quite remunerative and paid much more than the opportunity cost of investment. It was mainly due to higher productivity of poplar with intercropping than poplar without intercropping. The benefit-cost ratio of poplar cultivation also favored in the study area. However, the farmers favored poplar without intercropping because of sustained returns due to better quality of its timber and longer interval between harvesting.

Nanda *et al.* (2001) studied the adoption behavior of poplar based agro-forestry system in Punjab. A sample of 108 adopters and 108 non-adopter farmers of agro-forestry were selected using multistage sampling technique. Adopter farmers of poplar based agro-forestry system were more aware than the non-adopters of agro-forestry system.

Kumar *et al.* (2001) revealed that the impact of poplars leaf on intercrop of wheat yield. The disintegration of poplars leaf waste is very slow and its harmful effect on wheat intercrop yield. Continued existence and yield of late-sown variety of intercropped wheat were considerably increased through weekly taking away of poplar leaf garbage in 4^{th} year of four poplar cultivation. Though, in spite of removal of leaf waste at such normal intervals, yield of intercropped wheat crop is fairly low in comparison with open field.

Sharma *et al.* (2001) studied poplar based agro-forestry systems in western Uttar Pradesh state. No significant adverse effect was noticed on wheat crop when girth of poplar plants during 6-12 years in block plantation as well as in boundary plantation under different agro-forestry systems in northern part of India. On the other hand, a major decline of 15.5 per cent was recorded up to a distance of 3m from the tree base due to 4^{th} year of plantation. Water use of the system increased up to 6m from the tree line which caused moisture stress to the wheat crop. At the same time boundary plantation of poplar had positive impact on the micro-climate which improve the status of soil moisture between 6-9m distances and increase the water use effectiveness. Competition for natural resources was reduced between weeds and wheat due to reduction in weed population and biomass in the system.

Sekhon (2003) studied the economics of poplar under agro-forestry system (poplar + wheat + kharif fodder). The net present value method was used for calculating the economics

of poplar plantation. Since majority of farmers are harvesting poplar at the end of the sixth year, so the net present value is calculated for the sixth year only at 12 percent rate of discounting which comes out to be ₹1,02,167.

Sharma (2003) found that area under poplar decreased from ₹50,000 acres to ₹35,000 acres. While poplar trees with a girth of form and above used to fetch farmers ₹180 per quintal earlier on, the price has gone down to only ₹145 after deduction in the absence of regulation of market per wood. Poplar below 70 cm girth fetches between ₹60 to ₹115 per quintal.

Singh and Dhaliwal (2005) studied the economic analysis of poplar production and processing based agro-forestry system in Ludhiana and Ropar districts of Punjab state. Three agro-forestry systems (AFS) were studied; AFS-I (wheat during rabi season and fodder during kharif season), AFS-II (sugarcane during first three years and then wheat and fodder during rabi and kharif season respectively) and AFS-III (potato during rabi season and fodder during kharif season. The net present value (NPV) estimated at ₹1.16 Iakh and ₹1.27 lakh in Ludhiana and Ropar districts respectively for AFS-II on per acre basis. Annuity value was also highest for AFS-II in the sixth year in both the districts. Internal rate of return was the highest for AFS-II in both districts, i.e., 53.82 per cent in Ludhiana and 51.72 per cent in Ropar district. The benefit-cost ratio was the highest in the sixth year, i.e., 4.79 for AFS-II in Ludhiana and 5.43 for AFS-3 in Ropar district. In the case of processing units the net return was the highest in large units (₹13.8 lakh) as compared to the medium (₹8.49 lakh) and small units (₹3 lakh). Break-even level of production as a percentage of actual production was 47.63 per cent for small, 48.53 per cent for medium and 45.63 per cent for large units. Payback period was 6.16 years for small, 4 years for medium and 3.69 years for large units. The major problems faced by AFS systems were inter-cultivation in block plantations, unregulated markets and shortage of electricity for plywood units. It is concluded that poplar cultivation and plywood processing units are remunerative ventures. However, their profitability can be further enhanced through Government intervention and better management of both poplar plantation and processing units.

Chaudhry *et al.* (2007) compared the poplar based agro-forestry system with conservative wheat-paddy crop rotation. Poplars were planted at a density of 455 trees/ha, 305 trees/ha, and 230 trees/ha at the spacing of 3.66 x 6.10 m (D1), 3.66 x 9.10 m (D2), 3.66 x 12.10 m (D3), 3.05 x 3.05 m (D4) and 1.52 x 6.10 m (D5) respectively. Agricultural crops were grown namely, wheat during rabi season and fodder maize during kharif season as intercrop in the study year. To compare the differences between crop and intercropping the wheat and fodder-maize were also sown in separate plots (Dw/f). Maximum net benefits (51495 ₹/ha) was observed in the treatment D2 whereas lowest net benefits (10904 ₹/ha) from

wheat and fodder maize crops (Dw). The Maximum BCR (1.10%) was recorded in treatment D2 and lowest BCR (0.65%) in treatment D4. The highest IRR was also (21.91%) observed in treatment D2 and lowest (0.7 per cent) for treatment D4. In the analysis, it was observed that Treatments D4, D1 and D5 were dominating in comparison to D2 and D3 treatments. The curve shows that net benefits were highest in treatment D2 whereas lowest in treatment D1 with increasing cost. The marginal rate of return was maximum in treatment D2 and lowest in treatment Dw (Wheat + fodder maize). It was concluded in the sensitivity analysis that if the future input prices increased by 10 per cent even then it was economical for treatment D2 and D3.

Anjum *et al.* (2011) compared the cost and returns of sugarcane cultivation with agro-forestry system (poplar + sugarcane) in Toba Take Singh district of Pakistan state. Financial parameters e.g. NPW and BCR were used for examine the financial viability among sample farmers. A sample of 40 adopters and 40 non-adopters of agro-forestry were selected for comparison purpose. Discounting criteria was used to work out the cost and returns at 12 per cent rate of discount. The benefit cost ratio of sugarcane system was computed as 2.26 while net present worth was found as ₹1,49,810 on per acre basis and benefit cost ratio of poplar with sugarcane crop was computed at 2.28 while net present worth was found to be ₹1,51,098 per acre. Net benefits of tree based sugarcane system were computed as 0.86 per cent more than sugarcane crop. So farmers were recommended to adopt poplar and sugarcane combined in comparison to sugarcane alone. Therefore, study indicated that poplar based agro-forestry system was more profitable than the common crop rotation.

Chauhan *et al.* (2012) conducted the study in the central zone of Punjab at Rajowal district, Ludhiana for examine the quantitative performance of wheat crop under 1-5 year old poplar plantations in irrigated agro-ecosystem was studied to ascertain the biological yield of tree and crop. Results revealed that growth and yield of wheat decreased significantly with the increase in poplar age. The net yield of grain reduces estimated at 17 per cent during 1st year and 52.15 per cent during 5th year of poplar plantation. The values of micro-meteorological parameters (light intensity and air temperature) were also low under plantations than in open condition and decreased with increase in plantation age. The current and mean annual increments in biomass and carbon storage curves exhibited a sharp increase of up to three years which thereafter increased with decreasing order. The carbon storage in the poplar biomass was estimated to be 34.075t/ha at the age of five years, which can be fixed as the maximum volume production rotation of this species under the prevailing conditions.

Rani *et al.* (2015) conducted a field experiment during 2012-14 at farmer's field at Chabal village, TaranTaran district of Punjab state, India. Results of the study revealed that performance (plant height, no of grains per year, seed and straw yield) of agricultural crops (wheat and toria) was better in open environment than in association with tree. Returns from

poplar cultivation increases due to more girth of poplar plants. Benefit-cost ratio of wheat under poplar (1.26 and 1.32), under hard pear (1.19 and 1.57), and in open environment (2.22 and 2.64) were recorded during period of study. The corresponding values under agro-forestry (2.53) and agri-horticulture (oil+fruit crop, 1.74) were recorded after five years. Whereas, benefit-cost ratio of oil seed crop under hard pear was 0.21 and in open environment was 0.73. In comparison to all, agro-forestry land use system under wheat and poplar is viable and more profitable.

On the basis of various studies discussed above in relation to economic analysis and financial viability of agro-forestry system. It can be concluded that the agro-forestry system increased the income of farmers. The economic analysis of agro-forestry revealed that both poplar and eucalyptus were the most common plants grown as agro-forestry crops. It was found that plantations done in blocks or in a single row on fields, roads or along irrigation channels were economical. The returns from poplar cultivation increased with increase in age of the plants; the eucalyptus give maximum returns during the tenth year. The financial viability studies of other agro-forestry systems revealed that the Net Present Value and Internal Rate of Return were positive and more than the rate of interest respectively as represented by different studies. On the whole the studies pointed out that agro-forestry land use system under wheat, sugarcane and poplar were viable and more profitable.

2.2 Studies related to determine factors influencing adoption behaviour of poplar based agro-forestry system

Sharma (1997) examined the factors affecting adoption of reclamation technology through multivariate logistic regression model. Tenure status, social status, extension contacts, access to credit, education and age of the farmer were significant determinants of adoption of reclamation technology. Increasing extension visits and more liberal access to credit are likely to increase the adoption of alkali land reclamation technology. Therefore, more liberal credit policy and increasing the extension contacts between farmers and extension personnel are critical for policy designed to increase agricultural production through adoption of land reclamation technology.

Jain and Singh (1999) studied the performance of intercrops with poplar. In northern regions of India, Poplar being a fast growing and deciduous crop was grown along with agricultural crops on irrigated and fertile land. Inter-cultivation of compatible seasonal crops was for compensating the loss of agricultural commodities arising due to the transfer of land to tree plantation and also for generating uniform supplementary income. The study aimed at analyzing the performance of intercrops along with poplar. In the study area, the yield performance of sale crops was non-satisfactory; yield of intercrops with poplar was quite low, thereby providing low income to the farmers. Therefore, it was concluded that the inter spaces between poplar have not been properly used for intercropping. In the early stages,

intercropping of poplar with supplementary income and in later stages wheat can also provide income. Careful and suitable selection of intercrops and their varieties in the later along with poplar reduction in the trees intensity in the older age should in higher income from intercropping. Apart from this, the use of agricultural technology can play a vital role.

Sharma and Kumar (2000) examined the factors influencing the adoption of agro-forestry practices in north-western India through multivariate logit model. The findings of the study support the research hypothesis that socio-economic status, awareness, attitude and farm size of the participant farmers were significantly higher than those of the non-participants. Conversely, the average age of the non-adopters was higher than the adopters. Furthermore, the results of logit model revealed that the attitude of the households' towards socio-economic status, size of farm, awareness and off-farm income have a positive and significant impact on the adoption of agro-forestry innovations. However, age of the farm operator had negative significant influence on adoption of agro-forestry innovations. The study suggested that the government should initiate awareness campaigns/programmesto in order to provide knowledge for agro-forestry practices. The government should promote these farmers to plant trees on boundaries of the field as the two-thirds of the farmer's population being small and marginal and it would help creating additional employment opportunities and increasing the farm income.

Gill *et al.* (2004) evaluated the effect of age of poplar on turmeric during 2002 (2, 3 and 4 years poplar) and 2003 (1, 2 and 3 years poplar) at farmers' fields. The study revealed that the mean GBH of poplar increased significantly as age of poplar plantation increased. Fresh rhizome yield of turmeric decreased significantly as age of poplar increased. Maximum reduction in fresh turmeric yield (85.9%) was recorded under four year old poplar whereas reduction was minimum in one year old plantation (11%) as compared to pure crop of Turmeric.

Nouman *et al.* (2008) examined the farmers' attitude towards agro-forestry system. The main objective of this study was to investigate and analyze the reasons for non-adoption of agro-forestry and the problems being faced by the farmers in district Faisalabad. A sample of 125 respondents chosen randomly selected rural union councils from Faisalabad were interviewed through a structured interview schedule. The study concluded that the lack of awareness about the tree benefits was the main reason for non-adopters of agro-forestry. They revealed that the trees compete with agricultural crops nutrients uptake and water thereby degrade their farmlands. The government and training channel and orientation workshops provide awareness among the farmers. They also provide necessary guidance to the farmers for the plantation of the tree species when they grown on agricultural land.

Kabwe *et al.* (2009) studied factors influencing adoption of agro-forestry among smallholder farmers. In last two decades, Agro-forestry technologies have been introduced

and briefly researched to small category of farmers in Zambia. Although the research and extension attempt, many farmers have not adopted these technologies over time period. The study concluded that why agro-forestry technologies were not mortal taken up by exploratory factors that manipulate the adoption of agro-forestry practices. A sample of 388 farming households using statistical analysis showed an involvement between adoption of both improved fallows and biomass transfer technologies with ease of use of seed, knowledge of the technology and having the proper skills. Additionally, some household characteristics were found to be intersecting to the rate of adoption. On the other hand, the strong point of organization between these variables was low, giving a signal that there may be other factors play preventive agro-forestry adoption. It was estimated that these conclusion will point to other areas further than the family unit and the public level that need further looking at in order to understand factors encouraging agro-forestry adoption.

Lambert and Ozioma (2011) reported that the adoption of superior agro-forestry technology among all categories of farmers in Imo state, Nigeria. To attain the objectives of study, Comprehensive schedule was prepared for the collection of information from the selected households, keeping in view the objectives of the study. A sample of 90 farmers selected using multistage random sampling technique. Simple Regression and Pearson product moment correlation (PPMC) techniques were used to analyze the collected data. They found that the probability of a farmer adopting new crop depends on farm size, age, education and income. The results indicated that the adopter farmers of banana cultivation were basically sensitive of *Gnetum Africana*. The average rate of adoption of agro-forestry technology was 33.81 per cent. The main factors of the adoption of new technique were farmers' age, educational level, farm size, income, access to credit and extension contact as all these variables play a vital role. Age, education, farm size and extension contacts of the sample farmers was positively correlated with the adoption behaviour, whereas other remained variables were negatively correlated with the adoption behaviour of banana cultivation.

Chauhan *et al.* (2012) examined the wheat-paddy yield as well as distance from the bottom of poplar plant lines in all the four directions. Wheat-paddy yield was found maximum on Southern part (4.11t/ha and 5.06 t/ha, respectively), whereas, it was found minimum on Northern portion (2.5 t/ha and 4.13 t/ha, respectively). Distance from tree base also played an important role on the yield of grain crops. The yield of wheat crop as well as paddy crop increased with the increase in distance from the boundary plantation. Crop yield increased with increase in distance from 2m to 10m from the poplar plants (wheat: 2.85 t/ha to 3.63 t/ha and paddy: 3.22 t/ha to 5.66 t/ha). On the other hand, in well location wheat-paddy yield was 4.47 t/ha and 6.96 t/ha, respectively. There was a decline of 33.75 and 36.15 per cent in paddy and 26.68 and 25.69 per cent in wheat under 5^{th} and 6^{th} year of poplar

boundary plantation respectively. Soil parameters (organic carbon, total nitrogen, Available P and K) were also access to measure the cause of this system on nutrients on all the four directions beside with the carbon store in the biomass, which were appreciably unfair by the poplar plantation.

Sebukyu and Mosango (2012) studied adoption of agro-forestry system by farmers in in Masaka district of Uganda. This has lead to increased population pressure on land and decreased soil fertility. Despite of this, the Vi-Tree NGO Project had initiate a study to examine the adoption of agro-forestry systems by farmers in Masaka district with focus on the incorporation of multipurpose tree and shrub species, crops grown, farm size, land ownership, production and marketing problems. A sample of 88 farmers was selected randomly from 22 sub-countries of Uganda state. With explanatory statistical techniques, the data was analyzed. The study revealed that 81 woody species (75 trees and 6 shrubs) are used; out of this 69 per cent were indigenous. The most important species were Moraceae, Euphorbiaceae, Fabaceae, Combretaceae and Myrtaceae. The major crops were grown Bananas, cassava, beans, vegetables, maize and coffee. Primary production problems were pests and diseases while marketing problems were many including low prices, long distances from village to farm, lack of buyers and price fluctuations. The adoption of agro-forestry system by farmers was comparatively high in Masaka district. This was perhaps due to high demand for land, soil fertility decline, erosion problems, and demand for woody products (e.g., timber, fuel wood, and fodder, food), contact with the Vi-Tree NGO Agro-forestry Project extension agents, and need to increase crop yield. A high level of personal land tenure had probably contributed to the adoption of agro-forestry systems to promote long-term production.

Sekhon *et al.* (2013) analyzed the growth pattern, economics of hybrid maize production and adoption behavior of the farmers. Both primary and secondary data were used for the study. Eighty farmers of different farm size categories were selected from Hoshiarpur and SBS Nagar districts of Punjab. Area under maize showed negative growth rate during all the decades but productivity depicts positive growth rate in all the decades except eighties. The highest return over variable cost of maize was calculated as ₹11210 per acre by medium farm size category during 2010-11. Major items of costs were seed, FYM, fertilizer and machinery. Yield of maize crop varied among different categories of farmers and C.V. worked out at 41.45 percent. No doubt, that the returns from competing crop (paddy) were higher but in the long run if sustainability issues were considered it (maize) pays all dividends. It was often argued that if the electricity subsidy was withdrawn the relative profitability, particularly of rice, would be adversely affected; and it automatically promotes diversification to other crops like maize. A part of the saving of electricity subsidy, need to pass on, as incentives for maize growers to make it more profitable in context of diversification plan. On the other hand, more gap in crop yield among different farm size

categories e.g. small, medium and large needs to reduce by suitable procedures. They revealed that extension contacts, availability of hybrid-seed, low irrigation capacity and small farm size can favour for yield of maize crop among sample farmers.

Singh and Kumar (2014) studied the critical issue in poplar based agro-forestry system. Poplar was life line not only of the adopting farmers but also for the plywood industry in Northern India. Poplars have become significant resources in plantation forestry in India, which are ideally suited for supporting rural livelihoods, enhancing food security, alleviating poverty and contributing to sustainable development. They supply precious non-wood products and raw material provisions for industrial processing. Poplars were grown with wheat-paddy crops for enhanced income from intercrops than without intercropping and the girth of poplar plants vary under different agro-forestry systems. Poplar with wheat, maize in rabi season and fodder during kharif season as intercrop.

Jamilu *et al.* (2014) examined the factors influencing the adoption behaviour of agro-forestry system. The analysis of data demonstrates that the factors affecting farmers' adoption of agro-forestry practices have been varied depending on socio-economic characters, extension contacts and farm size of the farmers. Growing of trees was observed as a function of social and economic characteristics of the farming area. On-farm trees were grown for income generation, fuel-wood, timber, environmental purpose and for controlling erosion. Poor crop-stand, lack of markets, lack of nurseries, damage by animals and humans and lack of incentives were the major problems faced by the adopter farmers. Age, education, farm size and extension contacts of the sample farmers was positively correlated with the adoption behaviour, whereas agricultural working members and off-farm income was negatively correlated with the adoption behaviour of poplar cultivation.

Mwase *et al.* (2015) studied the factors affecting the adoption of agro-forestry system in Southern Africa. Agro-forestry practices, mainly evergreen and conservation agriculture with plants have emerged as sustainable measures to indicate the land degradation and defeat of soil fertility for increase the income of the farmers. The study revealed that the major factors affecting adoption of agro-forestry were maximum cost of agro-forestry practices (75%), low extension knowledge (69%) and unavailability of agro-forestry germplasm (69%). Up to 84 per cent of the key informants indicated that awareness of the connection between agro-forestry and land quality improvement could lead to wide scale adoption of the technology. The study concluded that Government policies can also influence adoption of agro-forestry systems. There was need to sustainable agricultural land management techniques through policy formulation, budgetary allocation for extension officers and farmers' training. Promotion of agro-forestry should be attached with provision of inputs in the initial stages, investment in awareness creation and farmer approaches in selection of

technology. Strong association with researchers, policy makers, and extension providers will be required to bring into line the adoption of agro-forestry systems.

The review of studies related to factors influencing adoption behavior of agro-forestry systems revealed that farm size, off-farm income, socio-economic status; awareness, attitude of the respondents significantly influenced the adoption of agro-forestry systems. Though, age of the farm worker has appreciably negative input on acceptance of agro-forestry innovations.

CHAPTER III

MATERIAL AND METHODS

The quality of any research is judged on the basis of its methodological approach. It is the way to systematically solve the research problem. It explains not only the steps adopted by a researcher in studying the research problem but also the logic behind them. The methodological frame work adopted for the study has been discussed under the following headings:

3.1 Locale of the Study

In order to achieve the stipulated objectives, present study was conducted in the Punjab state. Two districts were selected for the study i.e. Ludhiana from central zone and Ropar from sub-mountainous zone. Agro-forestry plantation of poplar at the farm level in the block plantation was considered for the investigation.

3.2 Sampling Procedure and Sample Size

A multistage random sampling technique was adopted for selection of the sample households. In the first stage of sampling, Ludhiana and Ropar districts were selected having high concentration of poplar. In the second stage of sampling, two clusters of villages each comprising of four/five villages having high concentration of poplar were selected from the selected districts making a sample of four clusters. A sample of 15 adopters and 8 non-adopters representing different categories was selected from each cluster (Table 3.2.1). In the third stage of sampling, a list of all the adopters and non-adopters of agro-forestry were prepared and farmers were categorized into small farmers (≤ 5 acres), medium farmers (5.01-25 acres) and large farmers (>25 acres). The sample consisted of twenty adopters and ten to eleven non-adopters of agro-forestry from each category i.e. small, medium and large. Thus, a sample of 60 adopters and 32 non-adopters of agro-forestry were selected (Table 3.2.2).

Table 3.2.1: Sampling design of adopters and non-adopter farmers of poplar based agro-forestry system in Punjab

Districts	Clusters	Selected Villages	Number of farmers		Total
			Adopters	Non-adopters	
Ludhiana	Cluster- I	Humbran, Walipur Kalan, Walipur Khurd, Bharowal Kalan and Salempura	15	8	23
	Cluster- II	Bhatha Dhua, Sidhwan Bet, Gorahur, Pati Multani and Lodiwala	15	8	23
Ropar	Cluster- I	Bamma- kulia, Jagatpur, Asarpur, Sekhupur and Mazafat	15	8	23
	Cluster- II	Shahpur, Buraj, Bhalowal, Gobindpura and Laudipur	15	8	23
		Grand Total	**60**	**32**	**92**

Table 3.2.2: Distribution of respondents in different farm size categories in Punjab

Farm Size Category	Operational Holding (Acres)	Distribution of respondents		Total
		Adopters	Non-adopters	
Small	≤ 5 acres	20	10	30
Medium	5.01-25 acres	20	11	31
Large	>25 acres	20	11	31
Overall		**60**	**32**	**92**

3.3 Construction of interview schedule

Two comprehensive schedules were prepared for the collection of information from the adopter of agro-forestry and non-adopter farmers of agro-forestry, keeping in view the objectives of the study. Before starting the data collection work, pre-testing was done among respondents in the same study area. The questions which are undesirable, ambiguous or difficult to respond were simplified or deleted. Certain questions which emerged during the course of pre-testing and considered important were also included in the final schedule.

3.4 Collection of Data

The primary data were collected from the respondent farmers with the help of specially designed and pre-tested schedule through personal interview method. The information regarding establishment cost which includes cost of nursery, planting cost, transportation cost and the operational cost which includes costs of fertilizer, plant protection chemicals, irrigation and miscellaneous costs were collected. The information on costs and returns of intercrop was also ascertained. The separate schedule was prepared to collect information from non-adopter farmers of agro-forestry regarding the details of crops grown, their input use and output obtained, prices of input and output for comparison purpose.

3.5 Estimation of cost and returns of poplar based agro-forestry system vis-à-vis wheat and paddy rotation

Establishment cost: The establishment cost was assumed to be fixed cost for the remaining life of the plantation. It includes the cost of planting material, transportation, transplanting, plant protection chemicals, fertilizer cost, irrigation cost and cost of labour used in all operations.

Operational cost: The operational cost is the cost which incurred during the period after establishment till trees are harvested. It included the costs of manure and fertilizers, irrigation, plant protection chemicals, pruning etc. The operational cost varied according to the agro forestry system adopted. The operational cost of intercrops includes cost of seed, fertilizer, irrigation and harvesting. Labour cost was included in each operation.

Hired human labour: Actual cash wages plus imputed value of kind wages and perquisites were taken at the time of operations.

Purchased inputs: Actual costs were taken in the case of purchased inputs such as seed, fertilizers, insecticides, etc.

Owned inputs: Value of owned manure, seeds, etc. was imputed as per the prices prevailing in village market.

Hired machine labour: Actual hiring charges were taken for the hired machinery.

Irrigation charges: Electricity is free for running electric motor for irrigation. Cost of running diesel engine, repair and maintenance of irrigation machinery was estimated.

Gross Returns: Gross returns include returns from sale of poplar and intercrops which were calculated by multiplying produce of intercrop with the price of the crop and value of poplar sold.

Net Returns: Net incomes were estimated after deducting all expenses from the gross income generated by the sale of poplar and intercrop cultivation.

3.6 Analytical tools

Simple average method was applied to calculate cost and return structure of poplar cultivation and inter crops i.e. wheat, kharif fodder and sugarcane. To analyze the financial viability of agro-forestry following criteria were used:

i) Net Present Value (NPV)

ii) Benefit-Cost Ratio (BCR)

iii) Annuity Value (AV)

i) Net Present Value (NPV)

It is the present value of net benefits that the project will generate over and above that would be available, if the amount proposed to be invested in the project is invested at the current rate of interest elsewhere. In NPV, each item of the costs and benefits is discounted to its present value over the life of the project and then summed up to find out the net value.

The formula of NPV is as:

$$\text{NPV} = \sum_{i=1}^{n} \frac{Bi - Ci}{(1+r)^i}$$

Where,

B_i = Benefits in the ith year

C_i = Costs in ith year

i = year: 1, 2, 3….n

n = No. of years

r = Rate of interest

ii) Benefit-Cost Ratio (BCR)

It is the ratio of sum of discounted benefits to the sum of discounted costs. Using the same notations as NPV, BCR can be expressed as:

$$BCR = \frac{\sum_{i=1}^{n} \frac{Bi}{(1+r)^i}}{\sum_{i=1}^{n} \frac{Ci}{(1+r)^i}}$$

iii) Annuity Value (AV)

It is the equalized yearly value over the life of the project which discounted at a given rate will generate the NPV equal to that generated by the project at the same discount rate. Again, using the same notations as earlier, annuity value can be expressed as:

$$AV = \frac{NPV}{\sum_{i=1}^{n} \frac{1}{(1+r)^i}}$$

Logistic Regression Model

Logistic Regression Model was used to empirically quantifying the relative influence of various socio-economic parameters in adoption of poplar. The study has postulated that the probability of a farmer adopting new crop depends on socio-economic variables such as age, education and number of working members in agriculture, source of motivation, extension contacts and off farm income. The index variable L_i indicating whether a farmer is adopting new crop or not has been expressed as a linear function of the independent variables. Thus logistic model has been specified as:

$$L_i = B_0+B_1X_1+B_2X_2+B_3X_3+B_4X_4+B_5X_5+B_6X_6+ B_7X_7+U_t$$

Where,

X_1 = Age of the respondent (years)

X_2 = Education of the head of the family (in years)

X_3 = Farm Size (in acres)

X_4 = No. of working members in agriculture

X_5 = Extension contacts (if yes= 1, no= 0)

X_6 = Source of motivation (if yes= 1, no= 0)

X_7 = Off-farm income (if yes= 1, no= 0)

B_0 = Constant

B_i's = Parameters to be estimated and

U_t = Error term

CHAPTER IV

RESULTS AND DISCUSSION

The present study entitled, "Economic analysis of poplar based agro-forestry system and its adoption behaviour in Punjab" was designed to examine the costs and returns structure of agro-forestry system vis-à-vis crop farming, financial viability and the adoption behaviour of agro-forestry system in the Punjab state. The results are discussed under the following heads:

4.1 Socio-economic profile of sample farmers

4.2 Streams of cost and returns of poplar based agro-forestry systems

4.3 Streams of cost and returns structure of wheat and paddy cultivation

4.4 Financial viability of poplar based agro-forestry systems

4.5 Factors influencing adoption behaviour of agro-forestry systems

4.1 Socio-economic profile of the sample farmers

Socio-economic characteristics like age, family composition, education level, operational farm size etc. of the sampled respondents were the most important indicators affecting the decision making power in the various aspects of agriculture production process. The socio economic characteristics may have direct or indirect bearing on the decision making process in poplar cultivation in comparison to other competing crops like wheat and paddy. Therefore, it is relevant here to have an overview of socio-economic characteristics of the adopters and non-adopters of poplar based agro-forestry systems and the results has been discussed under the following heads:

Age

The data given in the Table 4.1.1 indicated that out of the total sample poplar growers (adopters) the highest proportion i.e. 45 per cent belonged to the age group of 40-50 years, followed by 36.67 per cent in the age group of 30-40 years and 11.67 per cent in the age group of 50-60 years. Only two farmers i.e. 3.33 per cent belong to age group of less than 30 years and above 60 years respectively. Farm category-wise, majority of the sample farmers (70%) in the case of small famers were in the age group of 30-40 years, while in the case of medium and large farmers, highest proportion of the sampled farmers were in the age group of 40-50 years.

In the case of non-adopters, the results presented in Table 4.1.1 indicate that out of the total 32 sample farmers the highest proportion i.e. 46.88 per cent belonged to the age group of 40-50 years, followed by 31.25 per cent in the age group of 30-40 years and 15.63 per cent in the age group of 50-60 years. Only one farmer (3.13%) belongs to age group of less than 30 years and above 60 years respectively. Farm category-wise, fifty per cent of small

famers were in the age group of 30-40 years, while in the case of medium and large farmers, the highest proportion of the sampled farmers were in the age group of 40-50 years.

Table 4.1.1: Age wise distribution of sample farmers in Punjab, 2013-14

Age of respondent (Years)	Small		Medium		Large		Total	
	Number	%age	No.	%age	No.	%age	No.	%age
Adopters (n=60)								
< 30	1	5.00	0	0.00	1	5.00	2	3.33
30-40	14	70.00	2	10.00	6	30.00	22	36.67
40-50	3	15.00	14	70.00	10	50.00	27	45.00
50-60	2	10.00	3	15.00	2	10.00	7	11.67
> 60	0	0.00	1	5.00	1	5.00	2	3.33
Total	**20**	**100.00**	**20**	**100.00**	**20**	**100.00**	**60**	**100.00**
Non-adopters (n=32)								
< 30	0	0.00	1	9.09	0	0.00	1	3.12
30-40	5	50.00	2	18.18	3	27.27	10	31.25
40-50	3	30.00	6	54.55	6	54.55	15	46.88
50-60	2	20.00	1	9.09	2	18.18	5	15.63
> 60	0	0.00	1	9.09	0	0.00	1	3.12
Total	**10**	**100.00**	**11**	**100.00**	**11**	**100.00**	**32**	**100.00**

Education

Education is an important determinant of socio economic condition of the farm family, particularly the education of head of the family. The results given in the Table 4.1.2 indicates the education level of sample farmers. The highest proportion, 45 per cent of the poplar growers have attained education up to matriculation level, followed by 20 per cent up to middle level, 13.33 per cent up to higher secondary level. The proportion of sample farmers having education up to primary as well as graduate level came out to be same i.e. 10 per cent each, while only one farmer (1.67%) in the total sample was found to be illiterate.

Compared to adopters, the highest proportion, 34.38 per cent of the non-adopters of agro-forestry have attained education up to middle level, followed by 31.25 per cent up to matriculation level, 25 per cent up to higher secondary level. The proportion of sample farmers having education up to primary level was 3.13 per cent, followed by 6.25 per cent up to graduate level and no farmer in the total sample were found to be illiterate. It indicates that the education level of adopters was better than non-adopters of agro-forestry system.

Table 4.1.2: Education level of sample farmers in Punjab, 2013-14

Education of respondent	Small		Medium		Large		Total	
	No.	%age	No.	%age	No.	%age	No.	%age
Adopters (n=60)								
Illiterate	1	5.00	0	0.00	0	0.00	1	1.67
Primary	2	10.00	3	15.00	1	5.00	6	10.00
Middle	5	25.00	4	20.00	3	15.00	12	20.00
Matriculation	10	50.00	9	45.00	8	40.00	27	45.00
Higher Secondary	1	5.00	2	10.00	5	25.00	8	13.33
Graduate and above	1	5.00	2	10.00	3	15.00	6	10.00
Total	**20**	**100.00**	**20**	**100.00**	**20**	**100.00**	**60**	**100**
Non-adopters (n=32)								
Illiterate	0	0.00	0	0.00	0	0.00	0	0.00
Primary	1	10.00	0	0.00	0	0.00	1	3.13
Middle	5	50.00	3	27.27	3	27.27	11	34.38
Matriculation	3	30.00	5	45.45	2	18.18	10	31.25
Higher Secondary	1	10.00	2	18.18	5	45.45	8	25.00
Graduate and above	0	0.00	1	9.09	1	9.09	2	6.25
Total	**10**	**100.00**	**11**	**100.00**	**11**	**100.00**	**32**	**100.00**

Family Size

The size of family is an important factor to determine the family labour force. The figures in the Table 4.1.3 indicate the family size of the respondents. It shows that most of the sample respondents came in family size of 4-6 members. Around 75 per cent farmers; 65 per cent medium farmers and 50 per cent large farmers had family size of 4-6 members. The family size of less than 4 members was observed in 20 per cent small farm category and 5 per cent among medium and large farm categories.

In case of non-adopters of agro-forestry system, the results presented in the Table 4.1.3 depicts that 6.25 per cent non-adopters have small families with less than 4 members followed by 56.25 per cent households with 4 to 6 members, 31.25 per cent farm households with 6 to 8 members and 6.25 per cent households with more than 8 members in the family.

Table 4.1.3: Family size of sample farmers in Punjab, 2013-14

Family Size (Members)	Small		Medium		Large		Total	
	No.	%age	No.	%age	No.	%age	No.	%age
Adopters (n=60)								
< 4	4	20.00	1	5.00	1	5.00	6	10.00
4 – 6	15	75.00	13	65.00	10	50.00	38	63.33
6 – 8	1	5.00	5	25.00	7	35.00	13	21.67
> 8	0	0.00	1	5.00	2	10.00	3	5.00
Total	**20**	**100.00**	**20**	**100.00**	**20**	**100.00**	**60**	**100.00**
Non-adopters (n=32)								
< 4	1	10.00	0	0.00	1	9.09	2	6.25
4 – 6	7	70.00	7	63.64	4	36.36	18	56.25
6 – 8	2	20.00	3	27.27	5	45.45	10	31.25
> 8	0	0.00	1	9.09	1	9.09	2	6.25
Total	**10**	**100.00**	**11**	**100.00**	**11**	**100.00**	**32**	**100.00**

Workers in agriculture

Table 4.1.4 presents the number of members working in agriculture. It is clear from the table that the maximum of the respondents were having two working members in agriculture in the family i.e. 60 per cent in case of small farm size categories, followed by 55 per cent medium and 50 per cent large farmers while the number of the respondents having three working members in agriculture in the family were 45 per cent in case of large farm size category, followed by medium (40%) and small (35%) farmers. It is clear from the table that only 5 per cent small farm households had one family member working in agriculture.

Whereas in case of non-adopters, the highest proportion of the respondents were having two working members in agriculture in the family i.e. 63.64 per cent in case of large farm size categories, followed by small (60%) and medium (45.45%) farmers. The respondents having three working members in agriculture in the family were 36.36 per cent in case of medium farm size category, followed by small (20%) and large (9.09%) large farmers. On the other hand, the respondents having one working member in agriculture in the family were 20 per cent in case of small farm size categories, followed by large (18.18%) and medium (9.09%) farmers. Thus, from the above results it is revealed that agriculture sector is still main source of employment in rural Punjab and there was high dependency of workers in both adopters and non-adopters with the two working members in agriculture in the family.

Table 4.1.4: Working members in agriculture of the sample farmers in Punjab, 2013-14

Working member in agriculture	Small		Medium		Large		Total	
	No.	%age	No.	%age	No.	%age	No.	%age
Adopters (n=60)								
1	1	5.00	0	0.00	0	0.00	1	1.67
2	12	60.00	11	55.00	10	50.00	33	55.00
3	7	35.00	8	40.00	9	45.00	24	40.00
4	0	0.00	1	5.00	1	5.00	2	3.33
Total	**20**	**100.00**	**20**	**100.00**	**20**	**100.00**	**60**	**100.00**
Non-adopters (n=32)								
1	2	20.00	1	9.09	2	18.18	5	15.63
2	6	60.00	5	45.45	7	63.64	18	56.25
3	2	20.00	4	36.36	1	9.09	7	21.88
4	0	0.00	1	9.09	1	9.09	2	6.25
Total	**10**	**100.00**	**11**	**100.00**	**11**	**100.00**	**32**	**100.00**

Operational area and area under poplar

The size of operational holding of the adopters and non-adopters of sample households has been given in the Table 4.1.5. The table reveals that overall operational holding size of adopters was 20.75 acres while it was 16.39 acres for non-adopters of agro-forestry. The relative share of owned land in adopters was 75.04 per cent in total operational holding followed by leased in 24.96 per cent. On the contrary, the proportion of owned land was 70.16 per cent of total operational holding in non-adopters followed by proportion of leased in land 29.84 per cent. Thus, the proportion of respondents taking land on lease was more in non-adopter category. As far as farm size category is concerned, proportion of area under lease-in was nil in case of small farmers and increased with increase in farm size having 17.93 and 16.67 among medium farm size categories and 29.32 and 39.49 per cent among large farmers in adopter and non-adopter categories respectively. This shows a reverse tenancy system among different farm size categories.

Table 4.1.5: Size of operational holding of sample households, 2013-14

(In acres)

Operational holding	Small	Medium	Large	Overall
Adopters (n=60)				
Owned land	3.25 (100.00)	12.64 (82.08)	30.82 (70.69)	15.57 (75.04)
Leased-in land	0.00 (0.00)	2.76 (17.93)	12.78 (29.32)	5.18 (24.96)
Operational holding	3.25 (100.00)	15.40 (100.00)	43.60 (100.00)	20.75 (100.00)
Area under agro-forestry	1.78 (54.77)	5.80 (37.66)	20.00 (45.87)	9.19 (44.29)
Non-adopters (n=32)				
Owned land	3.35 (100.00)	12.50 (83.33)	18.65 (60.51)	11.50 (70.16)
Leased-in land	0.00 (0.00)	2.50 (16.67)	12.17 (39.49)	4.89 (29.84)
Operational holding	3.35 (100.00)	15.00 (100.00)	30.82 (100.00)	16.39 (100.00)

Figures in parenthetic are percentage to operational holding.

Source of motivation for agro-forestry among the adopter farmers

The perusal of Table 4.1.6 shows that 35 per cent of the farmers got motivation for poplar plantation through fellow farmers. As much as 30 per cent farmers started poplar plantation by self-motivation, followed by 20 per cent of the farmers was motivated by relatives and friends for poplar plantation. Only 15 per cent of them started poplar plantation motivated by agriculture departments. Therefore, fellow farmers emerged as the powerful source of motivation for poplar plantation. Thus, the demonstration effect in this regard is much stronger than the other factors.

Table 4.1.6: Source of motivation for agro-forestry among the adopter farmers in Punjab, 2013-14

(Multiple response)

Source of motivation	Small		Medium		Large		Overall	
	No.	%age	No.	%age	No.	%age	No.	%age
Relatives/Friends	3	15.00	4	20.00	5	25.00	12	20.00
Fellow farmers	8	40.00	6	30.00	7	35.00	21	35.00
Self-motivation	7	35.00	7	35.00	4	20.00	18	30.00
Agri. Departments	2	10.00	3	15.00	4	20.00	9	15.00

Extension contact of the sample farmers

Table 4.1.7 shows that majority i.e. 53.33 per cent of the farmers had extension contacts with PAU scientists on regular basis and PAU Research Stations, followed by an equal proportion i.e. 23.33 per cent of them maintained extension contacts through kisan melas and field experts in case of adoption of poplar based agro-forestry system.

In case of non-adopter farmers of agro-forestry system, 46.87 per cent farmers had extension contacts with PAU scientists, followed by 31.25 per cent of them maintained extension contacts through field experts and 25.00 per cent farmers maintained extension contacts through kisan melas shown in Table.

Table 4.1.7: Extension contacts of sample farmers in Punjab, 2013-14

(Multiple response)

Extension contacts	Small		Medium		Large		Overall	
	No.	%age	No.	%age	No.	%age	No.	%age
Adopters (n=60)								
Visits to PAU/Research stations	10	50.00	12	60.00	10	50.00	32	53.33
Visits to Kisan Melas	6	30.00	4	20.00	4	20.00	14	23.33
Visits to Field experts	4	20.00	4	20.00	6	30.00	14	23.33
Non-adopters (n=32)								
Visits to PAU/Research stations	4	40.00	6	54.54	5	45.45	15	46.87
Visits to Kisan Melas	3	30.00	2	18.18	3	27.27	8	25.00
Visits to Field experts	3	30.00	4	36.36	3	27.27	10	31.25

The above discussion on socio-economic profile and its impact on adoption of agro-forestry system is conclusive of the facts that the farmers in age group of 40-50 years were more responsive to the adoption of agro-forestry system as it help in increasing their income. The other factors such as education, family composition, earning members, members working in agricultural, fellow farmers and extension contacts exercised considerable influence on adoption of agro-forestry system. The analysis revealed that nearly 45 per cent adopters have attended school till matriculate level and majority of the families had two members working in agriculture. The fellow farmers who have adopted the cultivation of agro-forestry system emerged as the powerful source of motivation for poplar plantation. 53.53 per cent farmers have benefitted from the extension contacts they have with PAU scientists.

4.2 Economics of poplar based agro-forestry systems

Poplars are planted either on the boundary of the fields or throughout the field. The practice of growing trees in rectangular or square planting pattern throughout the field is referred as block plantation of poplar. Farmers having large land holding mostly adopt this arrangement of poplar tree and other categories of farmers were also adopting this practice. Many agricultural crops i.e. wheat, kharif fodder, potato, berseem and sugarcane etc. can be profitably raised/intermixed with block plantation of poplar trees. The present study analyzed the economics of poplar cultivation as a block plantation.

This section includes information relating to establishment cost of poplar plantation; operational cost of poplar cultivation, returns from poplar; cost, yield, price, gross returns from intercrops cultivated by the farmers.

Cost of poplar cultivation

The cost of cultivation of poplar has been divided into establishment cost and operational cost. The establishment cost was assumed to be fixed cost for the remaining life of the plantation. It includes the cost of planting material (nursery), transportation, labour charges, transplanting and plant protection chemicals charges. The operational cost is the cost which incurred during the period after establishment till trees are harvested. It included the costs of manures and fertilizers, irrigation, plant protection chemicals and pruning etc.

Establishment cost of raising poplar

The establishment cost of poplar cultivation has been discussed category-wise. It has been worked out per acre basis for different farm size categories and presented in the Tables 4.2.1 to 4.2.4. The perusal of the table 4.2.1 revealed that small farmers incurred ₹8,034 per acre on poplar plantation. So far as the composition of total cost is concerned, the major expenses incurred were on plant material (nursery) i.e. 62.43 per cent, followed by 16.04 per cent cost of planting (contract basis), 9.53 per cent on transportation of nursery and 6.87 per

cent and 5.13 per cent on plant protection chemicals and fertilizers respectively. Therefore, some farmers prepared the nursery on their own fields and some purchased from the nurseries. The cost of nursery varied among different farm size categories due to this factor.

Table 4.2.1: Establishment cost of raising poplar in case of small farmers in Punjab, 2013-14

(₹/acre)

Particulars	**Average cost**	**Percentage**
Cost of nursery	5016	62.43
Cost of planting	1289	16.04
Fertilizers	412	5.13
Transportation cost	765	9.53
Plant protection chemicals	552	6.87
Total cost	**8034**	**100.00**

Note: Labour cost is included in the above given operations.

Table 4.2.2 shows the establishment cost of raising poplar in case of medium farmers. The perusal of the table revealed that medium farmers incurred ₹7,731 per acre on poplar plantation. The establishment cost includes the expenditure on nursery plant and on planting to the tune of ₹4,916 and ₹1,235 per acre respectively. The next major expense of ₹730 was incurred on transportation followed by ₹478 on plant protection chemicals and on ₹372 on fertilizers per acre of poplar cultivation.

Table 4.2.2: Establishment cost of raising poplar in case of medium farmers in Punjab, 2013-14

(₹/acre)

Particulars	**Average cost**	**Percentage**
Cost of nursery	4916	63.59
Cost of planting	1235	15.97
Fertilizers	372	4.81
Transportation cost	730	9.44
Plant protection chemicals	478	6.19
Total cost	**7731**	**100.00**

The establishment cost of raising poplar in case of large farmers is presented in Table 4.2.3. It was found that a large farmers spent amount of ₹7,849 per acre on poplar plantation. Out of which 63.30 per cent was spent on nursery plant; 16.01 per cent was the cost of

planting; 9.54 per cent were transportation expenses. A small amount of 6.33 per cent and 4.82 per cent respectively was incurred on plant protection chemicals and fertilizers.

Table 4.2.3: Establishment cost of raising poplar in case of large farmers in Punjab, 2013-14

(₹/acre)

Particulars	Average cost	Percentage
Cost of nursery	4968	63.30
Cost of planting	1257	16.01
Fertilizers	378	4.82
Transportation cost	749	9.54
Plant protection chemicals	497	6.33
Total cost	**7849**	**100.00**

The perusal of Table 4.2.4 shows the establishment cost of raising poplar in case of overall farms. The perusal of the table revealed that an average farmer incurred ₹7,871 per acre on poplar plantation. On the break-up of the total cost it was found that the major expenses incurred were on nursery of plants i.e. to the tune of ₹4,967 followed by planting operation, transportation cost, plant protection chemicals and fertilizers with ₹1,260, ₹748, ₹509 and ₹387 respectively.

So far the farm size wise analysis is concerned; the results indicated that the highest establishment cost on per acre basis was incurred by small farmers with ₹8,034 followed by large and medium farmers with ₹7,849 and ₹7,731 respectively. Therefore, the component-wise analysis of the establishment cost structure over different size categories of farms revealed that by and large a consistent picture with the observations recorded in case of overall situation. However, some differentials in the relative magnitude of amount spend over different size categories in the study area were recorded. The comparative picture revealed that the medium farmers spent the highest proportion i.e. 63.59 per cent on nursery of plants in comparison to other farm size categories.

Table 4.2.4: Establishment cost of raising poplar in case of overall farms in Punjab, 2013-14

(₹/acre)

Particulars	Average cost	Percentage
Cost of nursery	4967	63.10
Cost of planting	1260	16.01
Fertilizers	387	4.92
Transportation cost	748	9.50
Plant protection chemicals	509	6.47
Total cost	**7871**	**100.00**

Operational cost of poplar plantation

Operational cost is the cost which incurred during the period after establishment of forestry till trees are harvested. The operational cost varied according to the agro forestry system adopted by the farmers and hence was estimated separately for the following two most important systems followed by the sample farmers.

Agro forestry system I (AFS-I): Poplar with wheat in rabi season followed by kharif fodder as intercrop.

Agro forestry system II (AFS-II): Poplar with sugarcane for first two years and then wheat for the next two years as intercrop.

It was observed during the survey that the farmers sold the poplar plants from the age of 4 years of poplar and maximum to the age of 6 years. The average annual operational cost for the first four years and from five to six years is given separately both for agro-forestry system-I and II among different farm size categories.

Agro-forestry system-I:

Poplar with wheat in rabi season followed by kharif fodder as intercrop is referred as agro-forestry system-I. The operational cost of poplar plantation among different farm size categories is given in the Tables 4.2.5 to 4.2.9 on per acre basis for agro-forestry system-I. Table 4.2.5 showed the operational cost of poplar plantation of small farmers in agro-forestry system-I (wheat and kharif fodder) on per acre basis. It was estimated that ₹4,093 per acre per annum of average cost was incurred by small farmers during 1-4 years and ₹3,158 per acre per annum of average cost was incurred during 5-6 years of plantation. Pruning constituted 37.23 per cent of costs, followed by 21.79 per cent on manure and fertilizers, 17.13 per cent on plant protection chemicals, 16.42 per cent on irrigations and 7.43 per cent spent on miscellaneous expenses during the first four years and during the 5-6 years of plantation, it was estimated that highest proportion 50.60 per cent was incurred on manure and fertilizer followed by 34.27 per cent on irrigations, 8.45 per cent and 6.68 per cent on plant protection chemicals and miscellaneous costs respectively and no cost on pruning. Though electricity is available free of cost to farmers in Punjab, but it was observed that at the time of harvesting of wheat in the month of April no electricity supply is available. Farmers used diesel engine to irrigate poplars.

Table 4.2.5: Operational cost of poplar cultivation in case of small farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Items	AFS-I			
	Age (Years)	Percentage	Age (Years)	Percentage
	During 1-4 years		During 5-6 years	
Manure & Fertilizer	892	21.79	1598	50.60
Irrigations	672	16.42	1082	34.27
Pruning	1524	37.23	-	-
Plant protection chemicals	701	17.13	267	8.45
*Misc.	304	7.43	211	6.68
Total cost	**4093**	**100.00**	**3158**	**100.00**

*Miscellaneous cost includes cost of hoeing and weeding, cultivation in between the rows to get rid of unwanted vegetation when no crop is raised.

Table 4.2.6 showed the operational cost of poplar plantation of medium farmers in agro-forestry system-I (wheat + kharif fodder) on per acre basis. It was estimated that on an average ₹3,562 per acre per annum was incurred by medium farmers during first four years and ₹2,881 per acre per annum was incurred during in the next years of plantation. Pruning constituted 31.47 per cent of costs followed by 24.54 per cent on manure and fertilizer, 18.30 per cent on plant protection chemicals, 18.14 per cent on irrigations and 7.55 per cent on miscellaneous costs during 1-4 years. It was obtained that during 5-6 years of plantation there was no pruning cost and the highest proportion of 53.28 per cent was incurred on manure and fertilizer followed by 34.33 per cent on irrigations, 7.32 per cent on plant protection chemicals, 5.07 per cent on miscellaneous costs. Irrigation cost also emerged as important cost component during 5-6 years and even during first four years of poplar plantation.

Table 4.2.6: Operational cost of poplar cultivation in case of medium farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Items	AFS-I			
	Age (Years)	Percentage	Age (Years)	Percentage
	During 1-4 years		During 5-6 years	
Manure & Fertilizer	874	24.54	1535	53.28
Irrigations	646	18.14	989	34.33
Pruning	1121	31.47	-	-
Plant protection chemicals	652	18.30	211	7.32
Misc.	269	7.55	146	5.07
Total cost	**3562**	**100.00**	**2881**	**100.00**

Table 4.2.7 showed the operational cost of poplar plantation of large farmers in agro-forestry system-I (wheat + kharif fodder) on per acre basis. It was estimated that ₹3,518 per acre per annum of average cost incurred by large farmers during 1-4 years and ₹2,717 per acre per annum during 5-6 years of poplar plantation. The expenditure on manure and fertilizer was ₹843 in the first four years and ₹1,408 in the next two years. An amount of ₹1,090 was spent on pruning in 1-4 years and no cost on pruning in 5-6 years.

Table 4.2.7: Operational cost of poplar in case of large farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Items	**AFS-I**			
	Age (Years)	**Percentage**	**Age (Years)**	**Percentage**
	During 1-4 years		**During 5-6 years**	
Manure & Fertilizer	843	23.96	1408	51.82
Irrigations	626	17.80	953	35.08
Pruning	1090	30.98	-	-
Plant protection chemicals	681	19.36	199	7.32
Misc.	278	7.90	157	5.78
Total cost	**3518**	**100.00**	**2717**	**100.00**

The overall operational costs of all the farm size categories were worked out and incorporated is Table 4.2.8. It was observed that on an average ₹3,724 were spent on poplar cultivation in 1-4 years and ₹2,919 were incurred in remaining two years of plantation. Pruning constituted 33.43 per cent of costs, followed by 23.36 per cent on manure and fertilizer, 18.21 per cent on plant protection chemicals, 17.40 per cent on irrigations and 7.60 per cent on miscellaneous costs during 1-4 years during the 5-6 years of plantation, it was estimated that highest proportion (51.87%) was incurred on manure and fertilizer followed by (34.53%) on irrigations.

Table 4.2.8: Operational cost structure of poplar in case of overall farms in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Items	**AFS-I**			
	Age (Years)	**Percentage**	**Age (Years)**	**Percentage**
	During 1-4 years		**During 5-6 years**	
Manure & Fertilizer	870	23.36	1514	51.87
Irrigations	648	17.40	1008	34.53
Pruning	1245	33.43	-	-
Plant protection chemicals	678	18.21	226	7.74
Misc.	283	7.60	171	5.86
Total cost	**3724**	**100.00**	**2919**	**100.00**

Summary of costs of poplar plantation for agro-forestry system-I category-wise is given in Table 4.2.9. It was estimated that the establishment cost of poplar plantation is ₹8,034, ₹7,849 and ₹7,731 per acre incurred by small, large and medium farmers respectively. During 1-4 years of plantation, ₹4,093 per acre per annum of average cost and ₹3,158 per acre incurred by small farmers followed by medium and large farmers with ₹3,562 per acre and ₹3,518 during 1-4 years and ₹2,881 and ₹2,717 per acre per annum respectively during 5-6 years. Therefore, the comparative picture revealed that small farmers spent more in comparison to other farm size categories i.e. medium and large in agro-forestry system-I and more cost is incurred in AFS-I during 1-4 years than the other remaining years i.e. 5-6 years.

Table 4.2.9: Summary of costs of poplar plantation category-wise in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Farm Category	Establishment Cost	Operational Cost	
		Age (Years)	
		During 1-4 years	During 5-6 years
Small	8034	4093	3158
Medium	7731	3562	2881
Large	7849	3518	2717
Overall	7871	3724	2919

Returns from poplar plantation (undiscounted) in agro-forestry system-I

The returns from poplar plantation include returns from the sale of poplar and the net returns from the poplar. As mentioned earlier the poplars were sold by the sample farm households at different age of the plant varied from four to the maximum of six years of age. It is also noted that more the age of the plant higher were the returns due to more girth of the plant. The returns are presented age wise at which the plants were harvested. The undiscounted returns from poplar plantation for agro-forestry system-I is shown in the Tables 4.2.10 to 4.2.13 for different farm size categories.

Table 4.2.10 showed the per acre basis returns from poplar plantation for agro-forestry system-I among small farmers. The farmers who have sold the poplar at the age of 4th year received ₹1,65,350 returns per acre, whereas the farmers who harvested the plants at the age of 5th and 6thyear of the age received returns ₹1,92,850 and ₹2,20,000 per acre respectively. The total cost came to be ₹24,406 per acre during 4th year which increased to ₹30,722 per acre during 6th year. The net returns worked out on per acre basis to be ₹1,40,944 during 4th year to ₹1,89,278 during 6th year of poplar plantation. Therefore, the increase in returns was due to the more girth of the plants.

Table 4.2.10: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of small farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost (Up to year of harvesting)	Total costs	Net returns
4	165350	8034	16372	24406	140944
5	182850	8034	18530	27564	165286
6	220000	8034	22688	30722	189278

Table 4.2.11 showed the undiscounted gross returns from poplar plantation of medium farmers on per acre basis were observed to be ₹1,75,600 in 4th year, ₹2,08,000 in 5th year and ₹2,31,800 in the 6th year of harvesting. The total cost ranged from ₹21,979 in the 4th year to ₹27,742 in the 6th year of plantation. The farmer appropriates ₹20,919 per acre more if the plant is harvested at the age of 6th year due to the increase in the girth and weight of plants.

Table 4.2.11: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of medium farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost (Up to year of harvesting)	Total costs	Net returns
4	175600	7731	14248	21979	153621
5	208000	7731	17129	24860	183140
6	231800	7731	20010	27741	204059

Table 4.2.12 depicts the costs and returns in poplar cultivation of agro-forestry system-I of large farmers in Punjab. The age-wise gross returns amounted to ₹1,88,500, ₹2,15,000, ₹2,37,360 per acre respectively for all the successive years starting from the age of 4th years to 6th years. The total cost on per acre basis incurred in 4th years was ₹₹21,921 and the net returns was estimated to be ₹1,66,579. Similarly the total cost amounted to ₹27,355 in the 6th year with a net return of ₹2,10,005 per acre.

Table 4.2.12: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of large farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost (Up to year of harvesting)	Total costs	Net returns
4	188500	7849	14072	21921	166579
5	215000	7849	16789	24638	190362
6	237360	7849	19506	27355	210005

Table 4.2.13 showed the per acre basis undiscounted returns from poplar plantation on overall farms. The average gross returns per acre came to be ₹1,76,483 if the plants were harvested at the age of 4th year whereas the farmers who harvested the plants at the age of 5th and 6th years then they received ₹2,05,283 and ₹2,29,720 returns respectively. The total cost came to be ₹22,767 per acre during 4th year which increased to ₹28,605 per acre during 6th year. The net returns worked out ₹1,53,716 during 4th year to ₹2,01,115 during 6th year of poplar plantation.

Table 4.2.13: Costs and returns of poplar cultivation (undiscounted) according to age of harvesting in case of overall farms in Punjab for agro-forestry system-I, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost (Up to year of harvesting)	Total costs	Net returns
4	176483	7871	14896	22767	153716
5	205283	7871	17815	25686	179597
6	229720	7871	20734	28605	201115

Costs and returns from intercropping in agro-forestry system-I

In this system, wheat crop is grown in rabi season followed by fodder in kharif season. The maximum age of poplar at the time of harvesting was 6 year among the sample households. Thus, up to 4 years farmers cultivated wheat and kharif fodder crops and no crop was grown in the 5th and 6th years.

Year-wise cost and returns from inter-cropping of wheat and kharif fodder among different farm size categories are shown in the Tables 4.2.14 to 4.2.19. Table 4.2.14 showed the per acre basis cost and returns of small farmers from intercropping.

The costs incurred on inter cropping of wheat and kharif fodder by small farmers varied from ₹18,450 during 1st year to ₹16,300 during the 4th year. It was due to the

decreasing area for agricultural crops year after year due to increasing canopy of the poplar. In this way, total cost incurred on wheat and kharif fodder decreased from 1st year to 4th year of plantation. The agricultural crops could not be sown after 4th year of poplar plantation.

The returns from intercropping diminished year after year due to competition and shading effects of plantation crop. However intercrop yield decreased with the increase in age of poplars. Thus, total returns on per acre basis from the agricultural crops decreased from 1st year to 4th year of poplar plantation with range from ₹37,675 during 1st year to ₹22,364 during 4th year. The net returns worked out at ₹19,225 during 1st year to ₹6,064 during 4th year of poplar plantation.

Table 4.2.14: Year-wise costs and returns from intercropping among small farmers in Punjab, agro-forestry system-I, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Wheat + kharif fodder	18450	37675	19225
2	Wheat + kharif fodder	17952	30120	12168
3	Wheat + kharif fodder	17606	27070	9464
4	Wheat	16300	22364	6064

Table 4.2.15 showed year-wise costs and returns among medium farmers from inter-cropping of wheat and kharif fodder. The estimates of cost incurred on inter-cropping of wheat and kharif fodder by medium farmers ranged from ₹20,797 during 1st year to ₹18,313 during the 4th year of poplar plantation. The gross returns and net returns also decreased from 1st year to 4th year of plantation due to increasing canopy of the poplar.

Table 4.2.15: Year-wise costs and returns from intercropping among medium farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Wheat + kharif fodder	20797	38850	19053
2	Wheat + kharif fodder	19744	32975	13231
3	Wheat + kharif fodder	19477	29550	10073
4	Wheat	18313	24575	6262

The streams of cost and returns in agro-forestry system-I among large farmers is presented in Table 4.2.16. The cost incurred on intercropping of wheat and kharif fodder was estimated to be ₹20,921 in first year, ₹19,870 in second year, ₹19,525 in third year and ₹18,533 in fourth years of plantation. The agricultural crop could not be sown after 4th year of poplar plantation. The gross returns from the sale of intercrops were estimated at ₹40,193 per acre in 1st year declined continues and were ₹25,738 in 4th year of plantation. The net returns were estimated at ₹19,272, ₹13,730, ₹10,495 and ₹7,205 from intercropping of wheat and fodder during 1st, 2nd, 3rd and 4th year respectively.

Table 4.2.16: Year-wise costs and returns from intercropping among large farmers in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Wheat + kharif fodder	20921	40193	19272
2	Wheat + kharif fodder	19870	33600	13730
3	Wheat + kharif fodder	19525	30020	10495
4	Wheat	18533	25738	7205

The streams of costs and returns of overall farm size categories from inter-cropping of wheat and kharif fodder is shown in Table 4.2.17. The overall analysis of all the categories of farmers in agro-forestry system-I in Punjab during the year 2013-14 highlighted that the costs and returns were inversely related to age of the plantation with the increase in age of the plantation from 1st to 4th year.

On the whole it can be concluded that large size farms obtained higher returns and incurred lower average costs in agro-forestry system-I in Punjab.

Table 4.2.17: Year-wise costs and returns from intercropping among overall farms in Punjab for agro-forestry system-I, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Wheat + kharif fodder	20056	39239	19183
2	Wheat + kharif fodder	19188	32231	13043
3	Wheat + kharif fodder	18869	28880	10011
4	Wheat	17715	24225	6510

Table 4.2.18 showed cost and returns for agro-forestry system-I from poplar plantation and agricultural crops on the per acre basis. The information has been compiled from the 4th year of harvesting of poplar to 6th year of harvesting of poplar as was the practice adopted by the sample households. The total costs incurred on poplar cultivation (establishment and operational cost) were more by small farmers in comparison to other farm size categories i.e. medium, large. Net returns from poplar cultivation were more for large farmers than other farm size categories. Thus, the comparative picture revealed that the returns from poplar plantation were the highest in case of large farmers at 4th, 5th and 6th years of harvesting followed by medium farmers and the lowest in case of small farmers.

Table 4.2.18: Comparative costs and returns (undiscounted) from poplar plantation in Punjab for agro-forestry system-I, 2013-14

(₹/acre)

Farm category	Cost incurred (Up to year of harvesting)			Gross Returns (Up to year of harvesting)		Net Returns
	Plantation crop*	Intercrop	Total cost	Plantation crop	Intercrop	
4th year of harvesting						
Small	24406	70308	94714	165350	117229	187865
Medium	21979	78331	100310	175600	126905	202195
Large	21921	78849	100770	188500	129551	239202
Overall	22767	75828	98595	176483	124575	202463
5th year of harvesting						
Small	27564	-	27564	192850	-	192850
Medium	24860	-	24860	208000	-	208000
Large	24638	-	24638	215000	-	215000
Overall	25686	-	25686	205283	-	205283
6th year of harvesting						
Small	30722	-	30722	220000	-	220000
Medium	27741	-	27741	231800	-	231800
Large	27355	-	27355	237360	-	237360
Overall	28605	-	28605	229720	-	229720

*Includes establishment and operational costs.

Agro-forestry system-II

Poplar with sugarcane for first two years and then wheat for the next two years as intercrop is referred as agro-forestry system-II. The information regarding per acre operational cost of poplar plantation among different farm size categories in agro-forestry

system-II (sugarcane and wheat) is given in Tables 4.2.19 to 4.2.21. None of the small farmer followed this agro-forestry system. Thus, analysis has been given for medium and large farmers. The operational cost of poplar plantation of medium farmers is summarized in Table 4.2.19. It was estimated that ₹1,945 per acre per annum incurred by medium farmers during 1-2 years of poplar cultivation. However, the input requirement of the poplar plants was fulfilled by the input given to sugarcane in the first two years in this system. Therefore, operational cost was incurred on pruning, plant protection chemicals and other minor costs in first two years in this system. Pruning constituted 51.29 per cent of costs, followed by 35.28 per cent on plant protection chemicals and 13.43 per cent on miscellaneous expenses during the first two years. During the 3-4 years of plantation, it was estimated that highest proportion 35.40 per cent was incurred on manure and fertilizer followed by 24.97 per cent on pruning, 21.40 per cent on irrigations, 12.80 per cent and 5.42 per cent on plant protection chemicals and miscellaneous costs respectively. During 5-6 years of plantation, a total ₹3,641 were spent on plantation crop out of which 49.02 per cent on manure and fertilizers, 40.68 per cent on irrigations, 6.32 per cent on plant protection chemicals, 3.98 per cent on miscellaneous costs and there was no pruning of plants during this period, hence, no cost on pruning.

Table 4.2.19: Operational cost of poplar cultivation in case of medium farmers in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Items	**AFS-II**					
	Age (Years)	**%age**	**Age (Years)**	**%age**	**Age (Years)**	**%age**
	During 1-2 years		**During 3-4 years**		**During 5-6 years**	
Manure & fertilizer	-	-	1804	35.40	1785	49.02
Irrigations	-	-	1090	21.40	1481	40.68
Pruning	997	51.29	1272	24.97	-	-
Plant protection chemicals	686	35.28	652	12.80	230	6.32
Misc.	262	13.43	276	5.42	145	3.98
Total cost	**1945**	**100.00**	**5094**	**100.00**	**3641**	**100.00**

*Miscellaneous cost includes cost of hoeing and weeding, cultivation in between the rows to get rid of unwanted vegetation when no crop is raised.

Table 4.2.20 showed the operational cost of poplar plantation of large farmers in agro-forestry system-II on per acre basis. It was estimated that on an average ₹1,863 per acre per annum incurred by large farmers during 1-2 years, ₹5,047 per acre per annum during 3-4 years and ₹3,619 per acre per annum during 5-6 years of poplar plantation. The expenditure

on pruning was ₹936 followed by ₹673 on plant protection chemicals and ₹254 on miscellaneous costs in the first two years and during 3-4 years of plantation crop ₹1,789 spent on manure and fertilizer followed by ₹1,265 on pruning, ₹1,074 on irrigations, ₹647 and ₹272 on plant protection chemicals and miscellaneous costs respectively. During 5-6 years of plantation there was no pruning cost and the highest cost ₹1,772 was incurred on manure and fertilizer followed by ₹1,487 on irrigations, ₹221 on plant protection chemicals and ₹139 on miscellaneous costs. Irrigation cost also emerged as important cost component during 5-6 years and even during first four years of poplar plantation.

Table 4.2.20: Operational cost of poplar cultivation in case of large farmers in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Items	**AFS-II**					
	Age (Years)	**%age**	**Age (Years)**	**%age**	**Age (Years)**	**%age**
	During 1-2 years		**During 3-4 years**		**During 5-6 years**	
Manure & fertilizer	-	-	1789	35.45	1772	48.96
Irrigations	-	-	1074	21.28	1487	41.09
Pruning	936	50.24	1265	25.06	-	-
Plant protection chemicals	673	36.13	647	12.82	221	6.11
Misc.	254	13.63	272	5.39	139	3.84
Total cost	**1863**	**100.00**	**5047**	**100.00**	**3619**	**100.00**

The operational cost of poplar plantation on overall farm basis was estimated and the information thus obtained is incorporated in Table 4.2.21. The operational cost was found to be ₹1,904 per acre per annum during 1-2 years, ₹5,071 during 3-4 years and ₹3,630 per acre per annum were incurred during 5-6 years of plantation. Pruning constituted 50.79 per cent of costs, followed by 35.71 per cent on plant protection chemicals and 13.50 per cent on miscellaneous costs in the first two years and during the 3-4 years of plantation, it was estimated that highest proportion 35.44 per cent was incurred on manure and fertilizer followed by 25.02 per cent on pruning, 21.34 per cent on irrigations, 12.80 per cent and 5.40 per cent on plant protection chemicals and miscellaneous costs respectively. During the 5-6 years of plantation crop, it was observed that highest proportion (49.01%) was incurred on manure and fertilizer followed by (40.88%) on irrigations.

Table 4.2.21: Operational cost of poplar cultivation in case of overall farms in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Items	AFS-II					
	Age (Years)	%age	Age (Years)	%age	Age (Years)	%age
	During 1-2 years		During 3-4 years		During 5-6 years	
Manure & fertilizer	-	-	1797	35.44	1779	49.01
Irrigations	-	-	1082	21.34	1484	40.88
Pruning	967	50.79	1269	25.02	-	-
Plant protection chemicals	680	35.71	649	12.80	225	6.20
Misc.	257	13.50	274	5.40	142	3.91
Total cost	**1904**	**100.00**	**5071**	**100.00**	**3630**	**100.00**

Summary of costs of poplar plantation for agro-forestry system-II category-wise is given in Table 4.2.22. It was estimated that the establishment cost of poplar plantation is ₹7,731 and ₹7,849 per acre per annum of average cost incurred by medium and large farmers. Medium farmers spent little more amount than large farmers during 1-2, 3-4 and 5-6 years on operational cost of poplar cultivation.

Table 4.2.22: Summary of costs of poplar plantation category-wise for agro-forestry system-II in Punjab, 2013-14

(₹/acre/annum)

Farm Category	Establishment Cost	Operational Cost		
		Age (Years)		
		During 1-2 years	During 3-4 years	During 5-6 years
Medium	7731	1944	5094	3641
Large	7849	1863	5047	3619
Overall	7871	1904	5071	3630

Returns from poplar plantation (undiscounted) in agro-forestry system-II

The returns from poplar plantation include returns from the sale of poplar and the net returns from the poplar. As mentioned earlier the poplars were sold by the sample farm households at different age of the plant varied from four to the maximum of six years of age. It is also noted that more the age of the plant higher were the returns due to more girth of the plant. The returns are presented age wise at which the plants were harvested. The undiscounted returns from poplar plantation for agro-forestry system-II are shown in the Tables 4.2.23 to 4.2.25 for different farm size categories.

Table 4.2.23 shows the undiscounted cost and returns from poplar plantation for agro-forestry system-II. As the age of poplar increase the gross returns per acre from the sale of poplar increased due to increased weight of the plant. The farmers who have sold the poplar at the age of 4th year received ₹1,75,600 returns per acre, whereas the farmers who harvested the plants at the age of 5th and 6thyear of the age received returns ₹2,08,000 and ₹2,31,800 per acre respectively. The total cost came to be ₹21,809 per acre during 4th year which increased to ₹25,450 per acre during 5th year and ₹29,091 per acre during 6th year. The net returns worked out on per acre basis to be ₹1,53,791 during 4th and increased to ₹1,82,550 during 5th year and to ₹2,02,709 during 6th year of poplar plantation. Therefore, the increase in returns was due to the more girth of the plants.

Table 4.2.23: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of medium farmers in Punjab for agro-forestry system-II, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost	Total costs	Net returns
4	175600	7731	14078	21809	153791
5	208000	7731	17719	25450	182550
6	231800	7731	21360	29091	202709

The gross returns, costs detail and net returns of large farmers in poplar plantation has been given in Table 4.2.24. At the age of 4th years the net returns was ₹1,66,831, ₹1,89,712 during 5th year and ₹2,08,453 during 6th year of poplar cultivation and total cost amounted to ₹21,669 during 4th year, ₹25,228 during 5th year and ₹28,907 during 6th year of plantation. The net returns at the age of 4th years was ₹1,66,831, ₹1,89,712 during 5th year and ₹2,08,453 during 6th year of plantation respectively. The information reveals that net returns are higher at the age of 6th years and lesser in the younger age of plant i.e. 4th year. This is mainly due to increase in girth of plants.

Table 4.2.24: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of large farmers in Punjab for agro-forestry system-II, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost	Total costs	Net returns
4	188500	7849	13820	21669	166831
5	215000	7849	17439	25228	189712
6	237360	7849	21058	28907	208453

Table 4.2.25 showed the overall analysis for agro-forestry-II of poplar plantation. The total cost of poplar cultivation was estimated at ₹21,821, ₹25,451 and ₹29,081 during 4th, 5th and 6th year respectively with ₹1,76,483, ₹2,05,283 and ₹2,29,720 of gross returns. The overall net returns in agro-forestry-II was estimated to be ₹1,54,662 in the 4th year, ₹1,79,832 in the 5th year and ₹2,00,639 in the 6th year.

Table 4.2.25: Cost and returns of poplar cultivation (undiscounted) according to age of harvesting in case of overall farms in Punjab for agro-forestry system-II, 2013-14

(₹/acre)

Harvesting Age (Years)	Gross Returns	Establishment cost	Operational cost	Total costs	Net returns
4	176483	7871	13950	21821	154662
5	205283	7871	17580	25451	179832
6	229720	7871	21210	29081	200639

Costs and returns from intercropping in agro-forestry system-II

In this system, sugarcane crop is taken for the first two years and then wheat for the next two years as intercrop. No crop was grown in the 5th and 6th year due to increasing canopy of plants.

Year-wise costs and returns from inter-cropping of sugarcane and wheat among different farm size categories are shown in the Tables 4.2.26 to 4.2.28. The per acre basis costs and returns of agricultural crops of medium farmers are presented in Table 4.2.26. The costs incurred on inter cropping of sugarcane was estimated at ₹44,870 during 1st year and ₹38,673 in 2nd year. The gross returns were ₹68,750 during 1st year and ₹52,500 per acre in 2nd year with ₹23,880 and ₹12,827 of net returns during 1st and 2nd year of sugarcane cultivation respectively. The cost estimates for 3rd and 4th years are for wheat cultivation only. The cost of wheat cultivation was estimated at ₹11,200 and ₹11,143 during 3rd and 4th year respectively with ₹23,387 and ₹20737 of gross returns. The agricultural crops could not be grown after 4th year of poplar plantation in this system. The intercrop yield decreased with the increasing age of poplars (Appendix V). In this way the net returns from wheat cultivation came to be ₹12,187 and ₹9,594 per acre in the 3rd and 4th year respectively.

Table 4.2.26: Year-wise costs and returns from intercropping in case of medium farmers in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Sugarcane	44870	68750	23880
2	Sugarcane	38673	52500	12827
3	Wheat	11200	23387	12187
4	Wheat	11143	20737	9594

Table 4.2.27 shows that the year-wise cost and returns from intercropping in case of large farmers in agro-forestry system-II. The cost incurred on intercropping of sugarcane was estimated to be ₹46,847 in first year, ₹40,907 in second year in poplar cultivation.

The returns from intercropping diminished year after year due to competition and shading effects of plantation crop. However, intercrop yield decreases with the increase in age of poplars. Thus, gross returns from sugarcane crop decreased from 1st year to 2nd year in poplar plantation from ₹73,550 to 57,723. The net returns from sugarcane cultivation worked out ₹26,703 during 1st year and ₹16,816 in the 2nd year of plantation. The costs incurred on inter cropping of wheat was estimated at ₹13,257 during 3rd year and ₹12,520 in 4th year in poplar cultivation in case of large farmers. The gross returns from intercrop of wheat were estimated at ₹27,136 per acre in 3rd year declined to ₹24,340 in 4th year. The net returns were estimated at ₹13,879 and ₹11,820 per acre from intercropping of wheat during 3rd and 4th year in poplar plantation respectively.

Table 4.2.27: Year-wise costs and returns from intercropping in case of large farms in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Sugarcane	46847	73550	26703
2	Sugarcane	40907	57723	16816
3	Wheat	13257	27136	13879
4	Wheat	12520	24340	11820

Table 4.2.28 shows the costs and returns structure of agro-forestry system-II among overall farms in Punjab. The cost of intercropping sugarcane amounted to ₹45,858 in the first year and decreased to ₹39,790 in the second year with ₹71,150 and ₹55,111 per acre of gross returns. The net returns worked out ₹25,292 during 1st year and ₹15,321 in the 2nd year of sugarcane cultivation. The cost of wheat cultivation was estimated at ₹12,228 and ₹11,831 during 3rd and 4th year respectively. The gross returns from wheat cultivation decreased from 3rd year to the 4th year due to increased canopy of poplar plantation with range from ₹25,261 to ₹22,538. In this way the net returns from intercropping came to be ₹13,033 and ₹10,707 per acre in the 3rd and 4th year of poplar cultivation respectively. The overall analysis in agro-forestry system-II highlighted that the costs and returns from intercropping were inversely related to age of the poplar plantation.

Table 4.2.28: Year-wise costs and returns from intercropping in case of overall farms in Punjab for agro-forestry system-II, 2013-14

(₹/acre/annum)

Age of poplar (Years)	Intercrop	Cost incurred	Gross Returns	Net Returns
1	Sugarcane	45858	71150	25292
2	Sugarcane	39790	55111	15321
3	Wheat	12228	25261	13033
4	Wheat	11831	22538	10707

Table 4.2.29 showed the per acre basis cost and returns for agro-forestry system-II from poplar plantation and intercropping among different farm size categories for various age of harvesting of poplar. The net returns from agro-forestry system-II were ₹2,19,015 at 4th year of harvesting of poplar and were ₹1,78,832 and ₹2,00,639 during 5th and 6th year of harvesting of poplar respectively. The total costs (establishment + operational cost) incurred on poplar plantation were more in case of medium farmers in comparison to large farmers and net returns from poplar cultivation were more for large farmers than the medium farmers. Thus, the comparative picture revealed that the large farmers earned little more than the medium farmers in agro-forestry system-II as shown in Table.

Table 4.2.29: Comparative costs and returns (undiscounted) from agro-forestry system-II in Punjab, 2013-14

(₹/acre)

Farm category	Cost incurred (Up to year of harvesting)			Gross Returns (Up to year of harvesting)		Net Returns
	Plantation crop*	Intercrop	Total cost	Plantation crop	Intercrop	
4th year of harvesting						
Medium	21979	105886	107693	175600	165374	233281
Large	21921	113531	135200	188500	182749	236049
Overall	22767	109707	131528	176483	174060	219015
5th year of harvesting						
Medium	24860	-	24860	208000	-	182552
Large	24638	-	24638	215000	-	189712
Overall	25686	-	25686	205283	-	178832
6th year of harvesting						
Medium	27741	-	27741	231800	-	202711
Large	27355	-	27355	237360	-	208453
Overall	28605	-	28605	229720	-	200639

*Includes establishment and operational costs.

4.3 Cost and returns structure of wheat and paddy cultivation

Cost structure of wheat cultivation

Wheat and paddy are the main crops cultivated during rabi and kharif season respectively and cover more than 80 per cent of cropped area in the Punjab state. Cost of cultivation of wheat-paddy crop rotation has been worked for the non-adopters of agro-forestry system to compare the returns with poplar cultivation. The information relating to cost of cultivation, gross returns, returns over variable cost from wheat and paddy has been estimated for the sample non-adopter farmers on per acre basis among different farm size categories and summarized in Tables 4.3.1 to 4.3.5. The examination of Table 4.3.1 shows that the overall variable cost on production of wheat came to be ₹12,588 per acre in case of large farmers; followed by medium and small farm categories i.e. ₹11,639 and ₹10,698 per acre respectively. On an average the cost of cultivation of wheat estimated at ₹11,641 per acre. Out of this, ₹4,964 were incurred on machine labour, ₹1,521 on fertilizer and FYM and ₹1,141 on seed. The human labour constituted ₹3,224; insecticides cost ₹507 by an average farmer. The lowest cost was estimated for irrigation ₹285. This constitutes 42.67 per cent on machine labour, 27.72 per cent on human labour, 13.07 per cent on fertilizer and FYM, 9.56 per cent on seed, 4.36 per cent on insecticides and only 2.62 per cent on irrigation. Therefore, machine and human labour emerged as the higher cost component and irrigation the lowest cost component on wheat production in case of all farm size categories i.e. small, medium and large respectively.

Table 4.3.1: Cost of cultivation of wheat in Punjab, 2013-14

Particulars	**Category-wise cost of cultivation of wheat (₹/acre)**							
	Small	**%age**	**Medium**	**%age**	**Large**	**%age**	**Overall**	**%age**
Seed	1024	9.57	1124	9.66	1275	10.13	1141	9.56
Human labour	2996	28.01	3246	26.89	3430	27.25	3224	27.72
Machine labour	4745	44.35	4999	42.95	5149	40.91	4964	42.67
Fertilizer and FYM	1291	12.07	1545	13.27	1725	13.70	1521	13.07
Irrigation charges	288	2.13	303	2.60	324	2.57	285	2.62
Insecticides	414	3.87	422	3.63	685	5.44	507	4.36
Total cost	**10698**	**100.00**	**11639**	**100.00**	**12588**	**100.00**	**11641**	**100.00**

Returns from wheat cultivation

The gross returns were worked out by multiplying the yield of wheat crop with price of the crop along with the value of by-product. The yield of wheat was estimated at 21.50, 22.25 and 22.15 quintals per acre for small, medium and large farmers respectively. The gross returns from wheat production came to be ₹31,430 per acre in case of medium farmers, followed by small and large farm size categories i.e. ₹30,100 and ₹31,010 respectively. The returns over variable cost were calculated by deducting variable cost from gross returns. The variable cost was estimated at ₹12,588 per acre in case of large farmers, followed by medium and small farmers i.e. ₹11,639 and ₹11,072 respectively. The returns over variable cost came to be ₹19,402, ₹19,791 and ₹18,422 per acre among small, medium and large non-adopter farmers of agro-forestry respectively. On overall basis the yield of wheat was estimated at 21.96 quintal per acre. The variable cost, gross returns and returns over variable cost were worked out at ₹11,641, 30,744 and 19,103 respectively as shown in Table 4.3.2.

Table 4.3.2: Returns from wheat cultivation in Punjab, 2013-14

Particulars	**Category-wise returns from wheat cultivation (₹/acre)**			
	Small	**Medium**	**Large**	**Overall**
Gross returns	30100	31430	31010	30744
Variable Cost	11072	11639	12588	11641
Yield (Qtls)	21.50	22.25	22.15	21.96
Price/Qtls	1400	1400	1400	1400
Returns over variable cost	19402	19791	18422	19103

Cost structure of paddy cultivation

Table 4.3.3 indicated that the total variable cost of paddy cultivation was worked at ₹17,113 per acre in case of large farmers followed by medium and small farm size categories i.e. ₹16,045 and ₹14,492 respectively. On an average the cost of paddy cultivation estimated at ₹15,883 per acre. Out of this, ₹5,941 were incurred on human labour, ₹3,972 on machine labour, ₹2,550 on irrigation, ₹1,443 on fertilizer and ₹1,275 on insecticides. The lowest amount ₹89 was incurred on manure, followed by ₹613 on seed. In the case of paddy cultivation the highest cost 37.40 per cent was incurred on human labour, 25.01 per cent on machine labour, 16.05 per cent on irrigation, 9.09 per cent on fertilizer, 8.03 per cent on insecticides, 3.86 per cent on seed and 0.56 per cent on manure respectively. Therefore, human labour emerged as the highest cost component and manures the lowest cost component of paddy production in case of all farm size categories i.e. small, medium and large.

Table 4.3.3: Cost of cultivation of paddy in Punjab, 2013-14

Particulars	Category-wise cost of cultivation of paddy (₹/acre)							
	Small	**%age**	**Medium**	**%age**	**Large**	**%age**	**Overall**	**%age**
Seed	593	4.09	611	3.81	635	3.71	613	3.86
Human labour	5622	38.79	5956	37.12	6245	36.49	5941	37.40
Machine labour	3705	25.57	3995	24.90	4216	24.64	3972	25.01
Fertilizer	1224	8.45	1495	9.31	1610	9.41	1443	9.09
Manure	67	0.46	89	0.55	111	0.65	89	0.56
Irrigation charges	2291	15.81	2555	15.93	2805	16.39	2550	16.05
Insecticides	990	6.83	1344	8.38	1491	8.71	1275	8.03
Total cost	**14492**	**100.00**	**16045**	**100.00**	**17113**	**100.00**	**15883**	**100.00**

Returns from paddy cultivation

Table 4.3.4 indicated that the yield of paddy crop was estimated at 28.56 quintal per acre with price ₹1,310 per acre per quintal in case of overall farms. The variable cost, gross returns and returns over variable cost were worked out at ₹15,883, ₹37,414 and ₹21,531 per acre respectively. The yield of paddy crop was estimated at 27.50, 28.75 and 29.45 quintals per acre for small, medium and large farmers respectively. The gross returns from paddy cultivation came to be ₹38,580 per acre in case of large farmers, followed by medium and small farm size categories i.e. ₹37,663 and ₹36,025 respectively. The variable cost was estimated at ₹14,492, ₹16,045 and ₹17,113 per acre of small, medium and large farmers respectively. The returns over variable cost were worked out at ₹21,618 per acre in case of medium farmers followed by small and large farm size categories i.e. ₹21,533 and ₹21,467 respectively. This indicated that returns from paddy cultivation were higher than that from wheat crop.

Table 4.3.4: Returns from paddy cultivation in Punjab, 2013-14

Particulars	Category-wise returns from paddy cultivation (₹/acre)			
	Small	**Medium**	**Large**	**Overall**
Gross returns	36025	37663	38580	37414
Variable cost	14492	16045	17113	15883
Yield (Qtls)	27.50	28.75	29.45	28.56
Price/Qtls	1310	1310	1310	1310
Returns over variable cost	21533	21618	21467	21531

Category-wise comparative economics of poplar vis-à-vis wheat-paddy cultivation

Table 4.3.5 shows the comparison of returns from poplar and wheat-paddy crop rotation. For the comparison purpose annuity value was estimated for poplar plantation according to age of harvesting using 12 per cent discount rate. The annuity value was worked out by dividing the net present value with the rate of annuity factor. The annuity values worked out at ₹43,386, ₹37,322 and ₹32,319 for AFS-I and ₹47,688, ₹40,829 and ₹35,350 for AFS-II in the 4th, 5th and 6th year of harvesting age on overall basis. The average net returns from wheat-paddy cultivation were estimated at ₹40,744 per annum. Therefore, the annual returns from poplar in both the systems i.e. AFS-I and AFS-II were found to be higher than the wheat and paddy crop rotation. Thus, the poplar plantation was more beneficial than wheat and paddy crop rotation during the study year at the estimated costs and price of poplar as well as intercrops.

Table 4.3.5: Comparative economics of poplar vis-à-vis wheat-paddy cultivation in Punjab, 2013-14

Farm category	Annuity Values in different Agro-forestry systems at 12 per cent discount rate (₹/acre)	
	AFS-I	AFS-II
4th year of harvesting		
Small	40195	-
Medium	43089	46370
Large	46579	51388
Overall	43386	47688
5th year of harvesting		
Small	34601	-
Medium	37661	40265
Large	39454	43394
Overall	37322	40829
6th year of harvesting		
Small	30422	-
Medium	32503	34724
Large	33815	37212
Overall	32319	35350
Wheat + Paddy rotation		
Small	40935	
Medium	41409	
Large	39889	
Overall	40744	

4.4 Financial viability of poplar based agro-forestry systems

In order to examine the poplar plantation along with crops in terms of productivity of capital over time, the concepts of discounting was used. Cost benefit analysis was used for this purpose. The discount rate for costs and benefits was considered at 10, 12 and 15 per cent respectively. However, two efficiency measures used in this section were net present value and benefit-cost ratio.

Financial viability of poplar plantation under agro-forestry system-I

Small farmers

Considering the total cost and returns from the poplar plantation and agricultural crops in case of small farmers, the benefit-cost ratio and net present value were worked out by using the discount rate of 10, 12 and 15 per cent at 4th, 5th and 6th year of harvesting and presented in Table 4.4.1. It was found that the highest net present value was obtained when poplars were harvested at the age of 6th year amounting to ₹1,38,229, ₹1,25,068 and ₹1,08,078 per acre at 10, 12 and 15 per cent rate of discount respectively. The benefit cost ratio was found to be highest during 6th year being 2.71, 2.61 and 2.47 at the same rate of discount respectively.

Table 4.4.1: Financial viability of poplar plantation investment in case of small farmers under agro-forestry system-I, 2013-14

Year	Benefit-Cost Ratio (Per cent)			Net Present Value (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.70	2.64	2.57	130713	122072	110428
5	2.72	2.64	2.54	135685	124739	110298
6	2.71	2.61	2.47	138229	125068	108078

Medium farmers

Table 4.4.2 shows the results of net present value and benefit-cost ratio at 10, 12 and 15 per cent rate of discount in block plantation of poplar in case of medium farmers. The benefit-cost ratios were the highest at the 5th year of harvesting of poplar at 10, 12 and 15 per cent rate of discount. The net present value was also highest at the age of 5th year of harvesting of poplar in case of medium farmers. At 5th year of age of harvesting of poplar the benefit-cost ratio varied between 2.77 to 2.58 and net present value between ₹1,47,655 to ₹1,20,084 at various discount rates. For 4th year and 6th year the benefit-cost ratio and net present value were lower as compared to 5th year of harvesting.

Table 4.4.2: Financial viability of poplar plantation investment in case of medium farmers under agro-forestry system-I, 2013-14

Year	Benefit-Cost Ratio (Per cent)			Net Present Value (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.72	2.67	2.59	140106	130862	118405
5	2.77	2.70	2.58	147655	135768	120084
6	2.74	2.64	2.50	147610	133620	115554

Large farmers

All the economic parameters viz. benefit-cost ratio and net present value were worked out by using the discount rate of 10, 12, and 15 per cent at 4th, 5th and 6th year of harvesting of poplars and presented in Table 4.3.3. It was found that highest net present value was obtained when poplars were harvested at the age of 6th year amounting to ₹1,53,445, ₹1,39,014 and ₹1,20,371 per acre at 10, 12 and 15 per cent rate of discount respectively. The benefit cost ratio was found to be highest during 6th year being 2.80, 2.70 and 2.56 at the same rate of discount respectively.

Table 4.4.3: Financial viability of poplar plantation investment in case of large farmers under agro-forestry system-I, 2013-14

Year	Benefit-Cost Ratio (Per cent)			Net Present Value (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.85	2.79	2.72	151420	142462	128042
5	2.86	2.77	2.66	154605	142233	125907
6	2.80	2.70	2.56	153446	139014	120371

Overall farms

Table 4.4.4 presented the results of net present value and benefit-cost ratio were worked out at 10, 12 and 15 per cent rate of discount in block plantation of poplar in case of overall farms. All the efficiency measures i.e. benefit-cost ratio and net present value used to analyze the financial viability of poplar based agro-forestry system revealed that at different rates of discounts taken to be 10, 12 and 15 in block plantation, the increase in benefit-cost ratio was found to be highest during 6th year being 2.75, 2.65 and 2.51 respectively. The net present value at these discount rates turned out to be ₹1,46,733, ₹1,32,867 and ₹1,14,959 respectively which was again high in the 6th year.

Table 4.4.4: Financial viability of poplar plantation investment in case of overall farms under agro-forestry system-I, 2013-14

Year	Benefit-Cost Ratio (Per cent)			Net Present Value (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.76	2.71	2.63	141050	131764	119249
5	2.78	2.71	2.60	146286	134545	119054
6	2.75	2.65	2.51	146733	132867	114959

Financial analysis brought out that the agro-forestry system-I is more profitable for all the categories of farmers, if the harvesting of poplar is done at the age of 5th year and the cost of capital is less than or equal to 12 per cent. If the cost of capital increased to 15 per cent the poplar should be harvested at the age of 4th year indicating the returns with the increase in age of poplars are less than the increase in cost of capital.

Financial viability of poplar plantation under agro-forestry system-II

None of the small farmer followed agro-forestry system-II. Thus analyze has been presented for medium and large farmers.

Medium farmers

The results of net present value and benefit-cost ratio at 10, 12 and 15 per cent rate of discount in block plantation of poplar in case of medium farmers presented in Table 4.4.2. The benefit-cost ratios were the highest at the 5th year of harvesting of poplar at 10, 12 and 15 per cent rate of discount. The net present value was also highest at the age of 5th year of harvesting of poplar in case of medium farmers. At 5th year of age of harvesting of poplar the benefit-cost ratio varied between 2.43 to 2.28 and net present value between ₹1,57,284 to ₹1,29,138 at various discount rates. For 4th year and 6th year the benefit-cost ratio and net present value were lower as compared to 5th year of harvesting.

Table 4.4.5: Financial viability of poplar plantation investment in case of medium farmers under agro-forestry system-II, 2013-14

Year	BCR (Per cent)			NPV (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.40	2.36	2.29	150365	140828	129962
5	2.43	2.37	2.28	157284	145158	129138
6	2.40	2.32	2.21	156952	142753	124387

Large farmers

Considering the total cost and returns from the poplar plantation and agricultural crops in case of large farmers, the benefit-cost ratio and net present value were worked out

by using the discount rate of 10, 12 and 15 per cent at 4th, 5th and 6th year of harvesting and presented in Table 4.4.6. It was found that the highest benefit-cost ratio was obtained when poplars were harvested at the age of 4th year being 2.46, 2.42 and 2.35. Correspondingly the net present value at the age of 4th year was ₹1,69,504, ₹1,56,565 and ₹1,41,978 per acre at 10, 12 and 15 per cent discount rates respectively. For 5th year and 6th year the benefit-cost ratio and net present value were lower as compared to 4th year of harvesting.

Table 4.4.6: Financial viability of poplar plantation investment in case of large farmers under agro-forestry system-II, 2013-14

Year	BCR (Per cent)			NPV (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.46	2.42	2.35	169504	156565	141978
5	2.46	2.40	2.31	169251	156436	139491
6	2.43	2.34	2.23	167828	152980	133754

Overall farms

Table 4.4.7 shows the overall benefit-cost ratio in the 4th year at given rates of discount was 2.39, 2.35 and 2.28 respectively. The net present value on overall basis at 10, 12 and 15 per cent rate of discount was estimated at ₹1,59,553, ₹1,47,830 and ₹1,31,708 per acre respectively. Therefore, the comparative picture revealed that the benefit-cost ratio and net present value were more in 4th year of harvesting age as compared to 5th and 6th year respectively.

Table 4.4.7: Financial viability of poplar plantation investment in case of overall farms under agro-forestry system-II, 2013-14

Year	BCR (Per cent)			NPV (₹/acre)		
	10%	12%	15%	10%	12%	15%
4	2.39	2.35	2.28	159553	147830	131708
5	2.41	2.34	2.26	158329	147191	131145
6	2.39	2.31	2.20	159568	145326	126891

In case of agro-forestry system-II the benefit-cost ratio and net present value is again highest at the 5th year age of harvesting at 12 per cent discount rate. If the discount rate increased to 15 per cent then it is beneficial to harvest the poplar at the age of 4th year. Though the undiscounted returns increased with the increase in the age of poplar but using discounting criteria it is indicated that the returns are highest at the age of 4th year if cost of capital is 15 per cent and above.

4.5 Factors influencing adoption behaviour of agro-forestry systems

To identify the factors affecting adoption behavior of farmers for agro-forestry, logit model was used in which adoption of agro-forestry was regressed with independent variables namely age of the farmer, education level of the farmer, size of farm holding, working members in agriculture, extension contacts of the farmer, source of motivation and off-farm income of the farm family. A functional analysis using Logit Model was carried out to identify the probability of dependence of adoption of agro-forestry system on various socio-economic parameters of the selected farmers and the estimated coefficients of the logistic regression model were presented in Table 4.5.1.

Table 4.5.1: Parameter estimates for Logistic regression model

Variables	**Coefficients**	**Antilog of Coefficients**	**95% wald Confidence Limits**		**Probabilities**
Intercept					
Age	0.0675*	1.0698	1.001	1.155	0.0604
Education	0.3973**	1.4878	1.095	2.102	0.0158
Farm size	-0.0456	0.9554	0.901	1.008	0.1027
Working members in Agril.	-0.4556**	0.6340	0.403	0.951	0.0353
Extension contacts	1.4839**	4.4101	1.311	16.338	0.0197
Source of motivation	-0.3674	0.6925	0.193	2.330	0.5577
Off-farm income	-1.6724**	0.1877	0.031	0.899	0.0475
Log likelihood ratio test		Chi-square = 34.0820		Pr >chi sq.	<0.0001

* and **significant at 10 and 5 percent level of significance respectively
Pi <0.05: significant at 5% level of significance

All variables together have highly significant effect on adoption of agro-forestry as likelihood ratio statistic is 34.0820 with a p value of about 0.0001 which is very small. The variables such as age, education and farmers having extension contacts enhance significantly adoption of the agro-forestry system. The adoption of agro-forestry system improves by 4.41 times with extension contacts, 1.49 times with education and 1.07 times with age of the farmers. The variables working members in agriculture and income from other sources other than crop income had significantly negative impact on adoption of agro-forestry system. Source of motivation by agriculture department has negative impact on adoption of agro-forestry so there is more need to popularize. Thus, extension contacts, education and age of the farmer have significant impact on adoption of agro-forestry system.

CHAPTER V

SUMMARY

The rice-wheat cropping system over time has caused serious problems in agriculture in terms of depletion of water resources, degradation of soil health, multiplicity of pests and diseases and environment pollution etc. As an alternative to rice-wheat system and without jeopardizing food and nutritional security of nation, the Government of India identified agro-forestry system as a mean of diversification of agricultural for optimum utilization of natural resources. Poplar is an agro-forestry tree introduced in the state by International Poplar Commission for diversification of agriculture and increasing the income of farmers. In this backdrop present study was planned to analyze the poplar based agro-forestry system in Punjab with the following specific objectives:

i. to examine costs and returns in agro-forestry system vis-à-vis crop farming in Punjab,
ii. to analysis financial viability of agro-forestry system; and
iii. to determine factors influencing adoption behaviour of agro-forestry system.

In order to accomplish the objectives of the study, the primary data were collected. Multi-stage random sampling technique was used for the selection of the sample farmers. The study was mainly confined to Central and Sub-mountainous Zone of Punjab state. One district namely Ludhiana from cental zone and Ropar from sub-mountainous zone was selected. At the second stage of sampling, two clusters of villages from each selected district were selected. At the third and final stage, four/five villages from each of these four clusters were randomly chosen. By using simple random sampling technique, 15 adopters and 8 non-adopters of agro-forestry system from each cluster were taken for the study. Therefore, a total sample of 92 farmers (60 adopters plus 32 non-adopters) covering four clusters and two districts of Punjab state was finally chosen for the ultimate analysis.

The information regarding various socio-economic parameters, input detail of poplar plantation, intercropping and wheat paddy cultivation was collected from the sample farmers. The data pertaining to the year 2013-14 were taken for the present study.

Averages and percentages were used to analyse cost returns detail in poplar, intercropping and wheat paddy cultivation. Benefit-cost ratio, Net present value and Annuity value were used for the financial viability of agro-forestry. Further, binary logistic regression was applied to identify the factors responsible for the adoption of a particular technology, using socio-economic characteristics of adopters and non-adopters.

The analysis of socio-economic characteristics such as age, education, farm size, agricultural working members and extension contacts etc. revealed that about 40 per cent of the adopters were below 40 years of age whereas only 34 per cent of non-adopters were below 40 years; about 10 per cent of adopter farmers were graduates and above and only 6 per cent non-adopters were graduate and post graduates; size of holding of adopter farmers was

large as compared to non-adopters and finally the adopter farmers have better extension contacts than the non-adopters.

The total establishment cost of poplar plantation among sample households was worked at ₹8,034 per acre in case of small farmers, followed by large and medium farm categories i.e. ₹7,849 and ₹7,731 respectively. On overall basis, the highest cost i.e. ₹4,967 (63.10%) was incurred on purchase of plants followed by planting operation, transportation cost, plant protection chemicals and fertilizers with ₹1,260, ₹748, ₹509 and ₹387 respectively. Majority of sample household cultivated either wheat in rabi season followed by fodder in kharif season (referred as agro-forestry system-I) or sugarcane during 1st and 2nd year of poplar and wheat in 3rd and 4th year of age of poplar (referred as agro-forestry system-II) as intercrops. In case of agro-forestry system-I (AFS-I), the operational cost on per acre basis for the 1-4 years varied between ₹4,093 to ₹3,518; 5-6 years between ₹3,158 to ₹2,717 among different farm size categories. On an overall basis the operational cost came to be ₹3,724 for the 1-4 years and ₹2,919 during 5-6 years of poplar plantation. In case of agro-forestry system-II (AFS-II), the operational cost for 1-2 years varied between ₹1,944 to ₹1,863; 3-4 years between ₹5,094 to ₹5,047 and ₹3,641 to ₹3,619 for 5th to 6th years of poplar plantation among different farm size categories. On an average basis, the operational cost was found to be ₹1,904 in the 1-2 years, ₹5,071 in the 3-4 years and ₹3,630 during 5-6 years of poplar plantation in AFS-II. The highest cost component came to be pruning during 1-4 years; manure and fertilizer during 5-6 years followed by irrigations and plant protection chemicals in AFS-I respectively. In case of AFS-II, the highest cost component found to be pruning during 1-2 years; manure and fertilizer during 3-4 and 5-6 years of poplar plantation followed by irrigations and plant protection chemicals respectively and there was no pruning of plants during 5-6 years in both the systems i.e. AFS-I and AFS-II.

Gross and net returns from poplar cultivation increased with increase in the age of harvesting among all the farm size categories. On overall basis the net returns from poplar cultivation was estimated at ₹1,53,716, ₹1,79,597 and ₹2,01,115 at 4th, 5th and 6th year of harvesting in AFS-I. The cost and returns from intercropping in AFS-I declined with age of the poplar in all the categories of farm. The net returns from intercropping of wheat during rabi season and fodder during kharif season were estimated at ₹19,183 during 1st year and declined to ₹6,510 during fourth year. There was no intercropping during 5th and 6th year of poplar cultivation. The gross and net returns from AFS-I (Poplar + intercropping) increased with the increase in farm size as well as increased with the increase in age of poplar. There was direct relationship between farm size and age of poplar with returns from poplar cultivation. On overall basis the net returns from AFS-I were ₹2,02,463, ₹2,05,283 and ₹2,29,720 in 4th, 5th and 6th year of harvesting. Gross and net returns from poplar cultivation

increased with increase in the age of harvesting among all the farm size categories. The net returns in AFS-II on overall basis from poplar cultivation was worked out at ₹1,54,662, ₹1,79,832 and ₹2,00,639 at 4th, 5th and 6th year of harvesting. The cost and returns from intercropping in AFS-II declined with age of the poplar in all the farm size categories. The net returns from intercropping of sugarcane during 1st two years and wheat during third and fourth years were estimated at ₹25,292 during 1st year and declined to ₹10,707 during fourth year of poplar age. There was no intercropping during 5th and 6th year of poplar cultivation due to more girth of plants. The gross and net returns from AFS-II (Poplar + intercropping) increased with the increase in farm size as well as increased with the increase in age of poplar. There was direct relationship between farm size and age of poplar with returns from poplar cultivation. On overall basis the net returns from AFS-II were ₹2,19,015, ₹1,78,832 and ₹2,00,639 in 4th, 5th and 6th year of harvesting.

The annual returns (Annuity value at 12 per cent discount factor) for poplar cultivation on overall basis worked out at ₹43,386, ₹37,322 and ₹32,319 for AFS-I and ₹47,688, ₹40,829 and ₹35,350 for AFS-II in the 4th, 5th and 6th year of harvesting age respectively and ₹40,744 from wheat-paddy crop rotation. The returns from poplar plantation were higher than that from wheat-paddy combined. Therefore, it was concluded that both the agro-forestry systems AFS-I and AFS-II were more beneficial as compared to the wheat-paddy cropping pattern during the study year.

To analyze the financial viability of poplar based agro-forestry system, Benefit-cost ratio and net present value were estimated using 10, 12 and 15 per cent discount rate. The benefit-cost ratio of AFS-I varied between 2.47 to 2.72 in case of small farmers; 2.50 to 2.77 in case of medium farmers; 2.56 to 2.85 in case of large farmers for different discount factors and at different age of harvesting of poplar. The benefit-cost ratio was the highest at 5th year of harvesting among all the farm size categories in AFS-I indicating the highest returns from the harvesting of poplar at 5th year of age. The benefit-cost ratio of AFS-II varied between 2.21 to 2.43 in case of medium farmers and 2.23 to 2.46 in case of large farmers for different discount factors and at different age of harvesting of poplar. The benefit-cost ratio was the highest at 5th year of harvesting among all the farm size categories in AFS-II indicating the highest returns from the harvesting of poplar at 5th year of age of poplar.

To identify the factors affecting adoption behaviour of farmers for poplar cultivation, logistic model was used in which adoption of agro-forestry system by sample farmers was regressed with independent variables namely age of the farmer, education, farm size, working members in agriculture, extension contacts, source of motivation and off-farm income of the farmer. Age, education and extension contacts of the sample farmers was positively correlated with the adoption behavior, whereas agricultural working members and off-farm income was negatively correlated with the adoption behavior of poplar cultivation.

It is concluded from above analyze that the AFS-I is more profitable for all the categories of farmers, if the harvesting of poplar is done at the age of 5th year and the cost of capital is less than or equal to 12 per cent. If the cost of capital increased to 15 per cent the poplar should be harvested at the age of 4th year indicating the returns with the increase in age of poplars are less than the increase in cost of capital. In case of AFS-II the benefit-cost ratio and net present value is again highest at the 5th year age of harvesting at 12 per cent discount rate. If the discount rate increased to 15 per cent then it is beneficial to harvest the poplar at the age of 4th year. Though the undiscounted returns increased with the increase in the age of poplar but using discounting criteria it is indicated that the returns are highest at the age of 4th year if cost of capital is 15 per cent and above. The returns from poplar plantation were the highest in case of large farmers at 4th, 5th and 6th years of harvesting followed by medium farmers and the lowest in case of small farmers in AFS-I. The large farmers also earned little more than the medium farmers in AFS-II. The annuity values worked out at ₹43,386, ₹37,322 and ₹32,319 for AFS-I and ₹47,688, ₹40,829 and ₹35,350 for AFS-II in the 4th, 5th and 6th year of harvesting age on overall basis. The average net returns from wheat-paddy cultivation were estimated at ₹40,744 per annum. Thus, the annual returns from poplar in both the systems i.e. AFS-I and AFS-II were found to be higher than the wheat and paddy crop rotation. Thus, the poplar plantation was more beneficial than wheat and paddy crop rotation during the study year at the estimated costs and price of poplar as well as intercrops. Age, education and extension contacts of the sample farmers was positively correlated with the adoption behaviour, whereas agricultural working members and off-farm income was negatively correlated with the adoption behaviour of poplar cultivation.

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APPENDIX-I

Age-wise average operational cost of poplar cultivation in AFS-I in Punjab

(₹/acre/annum)

Cost items	**Age in years**						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Small							
Manure & Fertilizer	1020	850	788	910	1467	1729	**6764**
Irrigations	693	625	610	760	1016	1148	**4852**
Pruning	1359	1399	1704	1634	-	-	**6096**
Plant protection chemicals	705	782	824	493	283	251	**3338**
Misc.	173	289	265	489	224	198	**1638**
Total cost	**3950**	**3945**	**4191**	**4286**	**2990**	**3326**	**22688**
Medium							
Manure & Fertilizer	1011	789	783	913	1399	1671	**6566**
Irrigations	661	603	587	733	930	1048	**4562**
Pruning	962	984	1306	1232	-	-	**4484**
Plant protection chemicals	649	730	778	451	224	198	**3030**
Misc.	147	251	233	445	160	132	**1368**
Total cost	**3430**	**3357**	**3687**	**3774**	**2713**	**3049**	**20010**
Large							
Manure & Fertilizer	975	760	753	884	1272	1544	**6188**
Irrigations	651	595	536	722	894	1012	**4410**
Pruning	937	943	1282	1198	-	-	**4360**
Plant protection chemicals	688	765	793	478	215	183	**3122**
Misc.	151	262	244	455	169	145	**1426**
Total cost	**3402**	**3325**	**3608**	**3737**	**2550**	**2884**	**19506**
Overall							
Manure & Fertilizer	1002	780	775	903	1379	1648	**6487**
Irrigations	668	608	578	738	947	1069	**4608**
Pruning	1086	1109	1431	1355	-	-	**4981**
Plant protection chemicals	681	759	798	474	241	211	**3164**
Misc.	157	267	248	463	185	158	**1478**
Total cost	**3594**	**3523**	**3830**	**3933**	**2752**	**3086**	**20718**

APPENDIX-II

Age-wise average operational cost of poplar cultivation in AFS-II in Punjab

(₹/acre/annum)

Cost items	**Age in years**						
	1	**2**	**3**	**4**	**5**	**6**	**Total**
Medium							
Manure & Fertilizer	-	-	1819	1789	1741	1829	**7178**
Irrigations	-	-	1096	1084	1556	1406	**5142**
Pruning	930	1064	1495	1049	-	-	**4538**
Plant protection chemicals	526	846	1026	278	232	228	**3136**
Misc.	103	421	175	377	166	124	**1366**
Total cost	**1559**	**2331**	**5611**	**4577**	**3695**	**3587**	**21360**
Large							
Manure & Fertilizer	-	-	1805	1773	1732	1812	**7122**
Irrigations	-	-	1083	1065	1547	1427	**5122**
Pruning	912	960	1478	1052	-	-	**4402**
Plant protection chemicals	510	836	1022	272	217	225	**3082**
Misc.	98	410	164	380	158	120	**1330**
Total cost	**1520**	**2206**	**5552**	**4542**	**3654**	**3584**	**21058**
Overall							
Manure & Fertilizer	-	-	1812	1781	1736	1820	**7149**
Irrigations	-	-	1089	1074	1552	1416	**5131**
Pruning	921	1012	1487	1051	-	-	**4471**
Plant protection chemicals	518	841	1024	275	225	227	**3110**
Misc.	101	415	170	379	162	122	**1349**
Total cost	**1540**	**2268**	**5582**	**4560**	**3675**	**3585**	**21210**

APPENDIX-III

Returns from Intercrop (Wheat) in Agro-forestry System-I & II in Punjab

(₹/acre)

Age of Poplar (Years)	Yield of Wheat (Qtls)	Price of Wheat (₹\Qtls)	Total Returns
Small			
1	18.33	1400	25662
2	15.48	1400	21672
3	14.05	1400	19670
4	15.974	1400	22364
Medium			
1	19.40	1400	27160
2	17.24	1400	24136
3	15.61	1400	21854
4	17.554	1400	24575
Large			
1	19.56	1400	27384
2	17.61	1400	24654
3	15.88	1400	22232
4	18.384	1400	25738
Overall			
1	19.09	1400	26726
2	16.77	1400	23478
3	15.17	1400	21238
4	17.304	1400	24225

Note: Cost of byproduct of wheat is included in above operations.

APPENDIX-IV

Returns from Intercrop (Kharif fodder) in Agro-forestry System-I in Punjab

(₹/acre)

Age of Poplar (Years)	Yield of Kharif fodder (Qtls)	Price of Kharif fodder (₹\Qtls)	Total Returns
Small			
1	109.21	110	12013
2	67.58	125	8448
3	56.06	132	7400
Medium			
1	101.65	115	11690
2	69.06	128	8839
3	57.01	135	7696
Large			
1	119.71	107	12809
2	74.55	120	8946
3	61.625	128	7788
Overall			
1	112.73	111	12513
2	70.59	124	8753
3	57.90	132	7642

APPENDIX-V

Returns from Intercrop (Sugarcane) in Agro-forestry System-II in Punjab

(₹/acre)

Age of Poplar (Years)	Yield of Sugarcane (Qtls)	Price of Sugarcane (₹\Qtls)	Total Returns
Medium			
1	327.38	210	68750
2	250.00	210	52500
Large			
1	350.24	210	73550
2	274.87	210	57723
Overall			
1	338.81	210	71150
2	262.43	210	55111

VITA

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