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Economic Evaluation of Different Land Use Systems in North Western Region of Punjab, India

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Abstract

The present study is the outcome of socio-economic diagnosis of traditional as well as commercial agroforestry practices followed by farmers in north western region of Punjab state, India. Tree species like *P. deltoides*, *E. tereticornis* and *T. grandis* are the main species of commercial agroforestry system, whereas, agricultural crops are grown traditionally. Simultaneously economics of *P. pyrifolia* based orchid was also included for evaluation. Results showed that tree based land use systems are economically viable and more profitable than pure agricultural crops. Highest B:C ratio was recorded in pure *E. tereticornis* plantations (3.30) after 5 years. Simultaneously higher B:C ratio (2.02) was recorded in *P. deltoides*+*T. aestivum* crop based land use system followed by *T. grandis* plantations (2.06), *T. aestivum*+*O. sativa* (1.89), *T. aestivum*+*P. glaucum*+fruit crop (1.72), *B. napus*+fruit crop (1.56) and *B. napus*+*O. sativa* (1.27) during period of study. *E. tereticornis* and *P. deltoids* based land use systems are economically viable and more profitable than other land use systems in this study area of Punjab. These land-use systems have also provided additional revenue and generated on farm employment opportunities.

Keywords: Agricultural interventions; B:C ratio; Economic evaluation; Timber tree species

Introduction

Due to increased pressure of population, need for food and wood is increasing enormously. Large forest area has been diverted to non-forestry activities like agriculture, industries, urbanization, roads, etc. This caused great difficulty in meeting firewood, fodder and timber requirements. As such agroforestry has received considerable attention during past years in the states of Punjab, Uttar Pradesh, Haryana, Gujarat and Karnataka with the object of integrating land use for agriculture and forestry to meet multifarious needs of society and provide additional employment and income to rural population.

In Punjab, Poplar based agroforestry system adopted on large scale by the farmers because of high rate of growth, short rotation and without hampering much the growth of intercrops in general and specially of rabi crops. This system provides various products, which contribute to commercial and subsistence agricultural productivity as well as to farm family livelihood. Intercropping of poplar with compatible seasonal crops is essential not only for generating continuous supplementary income but also for creating on-farm employment [1]. Punjab, being an agrarian state, practically, it is not possible to divert the fertile agricultural land to plantations in view of prevailing socio-economic and agro-climate conditions favorable for agriculture. There is loss of agricultural production arising from the transfer of land to tree plantations but poplar being deciduous in nature has little effect on the winter crops. Diversification in agriculture in general and rice-wheat rotation in particular has strongly been advocated in irrigated agro-ecosystem. The traditional crop rotation though profitable has not remained sustainable and rice cultivation is draining the water extensively and contributes methane (a green house gas) GHG in the atmosphere.

Agroforestry is a land use option and one of the important alternatives for diversification is gaining importance in irrigated agro-ecosystem for production through diverse food production, natural resource conservation, improving nutrition, health and increasing economic income of farmers. Agroforestry systems play an important role in country's food security [2-4]. A different tree based land use system offers an economical and ecologically viable option for large scale diversification in agriculture on one hand and environmental amelioration on the other. Hence to save forests and meet the growing demands of wood, there is need for large scale plantations of fast growing tree species outside forests to make country self-reliant in its timber requirements. On-farm timber tree plantations can also benefit from the global environmental facilities like carbon trading [5-7]. Therefore, there is a great need to identify the fast growing tree species, suitable agricultural and horticultural crops, which are compatible with tree species with minimum compromise in crop productivity and higher overall economic returns.

The farm industry linkages have also helped the different tree based land use systems to be more sustainable than the traditional cropping systems [8]. So economic evaluation of different tree based land use systems provides a basis for estimating financial viability and feasibility of the system, highlights trade-offs between multiple benefits and monitors economics efficiency. In north western region of Indian Punjab, agri-silviculture, agri-horticulture and pure *Eucalyptus* plantations based land use systems are being experimented by select

farmers, which seem economically more profitable than traditional crop rotation and sustainable in terms of saving natural resources. However, values on profitability of these practices were not available to substantiate the claims and scientifically scale up the practices. Thus, without a systematic study, the economic benefits generated by practices may remain unknown. Therefore, the present study was conducted to find out the most profitable tree based land use system for the farmers in Indian Punjab State. The economic yield of agricultural crops, fruit crop and trees were subjected to economic analysis by calculating the cost of cultivation, gross and net returns per hectare and benefit-cost ratio. These parameters were calculated on the basis of prevailing market prices at the time of the study. All intercultural operations and management practices were done throughout the growing season.

Materials and Methods

The present experiment on yield performance of agricultural crops, tree species and fruit crop *(Pyrus pyrifolia)* under different land use systems and their economics were carried out at Chabal Kalan village, under Taran-Taran district, north western side of the Punjab state, India. The experimental site was selected where diversified systems including tradition cropping system was practiced by the single farmer. The experimental sites lie between 31°05', and 31°30' 05" North latitude and 74°30' and 75°15' 05" East longitudes. Mean annual precipitation received in the region is 472 mm, most of it is received from July to September [9]. Temperature ranges between a maximum of 40.5°C and minimum of 4.5°C in the study area. For economic evaluation different tree species *(Populus deltoides*, *Eucalyptus tereticornis* and *Tectona grandis*), agricultural crops *(Triticum aestivum*, *Oryza sativa*, *Brassica napus* and *Pennisetum glaucum)* and one fruit crop *(Pyrus pyrifolia)* under different land use systems were selected. Input data were collected for seeds or seedlings, human labour, tractor labour, pesticides, farmyard manure, fertilizers, irrigation, etc. used in the cultivation of different tree species, fruit crop, sole crops and intercrops grown with *Populus deltoides* and *Pyrus pyrifolia*. The opportunity cost of tractor hours and irrigation were considered equivalent to their hiring charges prevailing in the local area. Market prices prevailing were used to price other inputs and outputs. The following different models were evaluated in the study:

P. deltoides (Clone G-48, 5 year) under *T. aestivum*: In this situation, trees were grown at the spacing of 4 × 3.5 m, with 714 plants per hectare.

E. tereticornis (Clone C-413, 5 year) plantation: In this situation, pure eucalyptus trees were grown at the spacing of 1.5 × 1.5 m, with 4,444 plants per hectare.

T. grandis (10 year) plantation: In this situation, trees were grown at the spacing of 4 × 4 m, with 625 plants per hectare.

P. pyrifolia fruit based orchid (Patharnakh, 30 year): In this situation, orchid establishment cost was calculated, 400 trees per hectare grown at the spacing of 5 × 5 m.

Agricultural crops *(Teriticum aestivum*, *Oryza sativa*, *Brassica napus* and *Pennisetum glaucum)* inter-cultivated with trees: Under *P. deltoides* based agroforestry land use system, *T. aestivum* was grown in rabi season for five years. Whereas, under *P. pyrifolia* based land use system, *T. aestivum*, *B. napus* and *P. glaucum* were grown alternatively during study period. Simultaneously these agricultural crops were also carried out in open conditions for making comparison. Recommended agronomic practices were followed during study period.

Analytical tools and concepts

Gross returns: These are the total returns (in Euro and INR. ha^{-1}) at current prices through the sale of different tree species, fruit crop *(P. pyrifolia)* and agricultural crops.

Total variable cost: These include total (establishment and variable) costs (in Euro and INR. ha^{-1}) at current prices for tree and agricultural crops.

Net returns: These are the returns got after paying all the expenses incurred for carrying on an enterprise. Net returns (in Euro and INR. ha^{-1}) are taken at current prices and can be calculated by using the following formula:

Net return=[Gross Return]-[Total (Variable) Cost]

Present net worth (PNW): This is the present net worth of an investment based on a discount rate and a series of future payments and income. PNW (in Euro and INR. ha^{-1}) is calculated at 10 percent discount rate. It can be calculated by using the following formula [10].

$$PNW=\Sigma[(Bi-Ci/(1+r)i]$$

Where Bi=Gross Returns for the i^{th} year, Ci=Total (Variable) Costs for the i^{th} year, r=Discount rate, I=Number of years of rotation (i=1 to 5)

Annuity value (AV): This is the discounted return got (in Euro and INR. ha^{-1}) annually. It can be calculated using the following formula: $AV=PNW/\Sigma[1/1+r)i]$ Where; all the notations remain same as before.

Benefit-Cost ratio (BCR): This is the ratio of discounted net returns and discounted total (variable) costs.

Method of economic benefit analysis

The inputs/output analysis was applied in economic benefits analysis. One hectare of experiment field was the basic unit for analysis. The economic input of these systems included: costs on plant material, labour for planting, transportation, irrigation, farmyard manure and fertilizers inputs were taken for the first year i.e., the year of plantation. Similarly operational cost i.e., cost on irrigation labour, insecticide, watch and ward were considered at the end of the rotation period. While calculating marketing costs (per hectare), harvesting, freight, commission and miscellaneous charges were considered for the fifth or the year of harvest of tree species. Enterprise budgets of different tree species and agricultural crops have been prepared. These included input-output information both in physical and financial terms. Market prices were considered for converting the physical values into monetary terms. While calculating economic returns from different tree species *(P. deltoides*, *E. tereticornis* and *T. grandis)*, 5% mortality was presumed, which was generally observed on account of damage by wind, insects/pests, etc. [11]. Similarly economics of fruit crop *(P. pyrifolia)* and agricultural crops *(T. aestivum*, *O. sativa*, *P. glaucum* and *B. napus)* were also calculated on the current prevailing market price.

Results

The data for gross returns, total expenses, net profit, present net worth, annuity value and benefit cost ratio, which were realized from different land use systems are presented in Tables 1-4.

Inputs/outputs	*Populus deltoides*	*Eucalyptus tereticornis*	*Tectona grandis*	*Pyrus pyrifolia*
Tree planted (no)	714	4444	625	400
Average survival at 5% mortality(no.)	677	4,221	593	-
Rotation (years)	5	5	10	(30 yrs fruit orchard)
A. Total establishment cost	624.85 € (=48,438 INR)	2,719.42 € (2,10,807.5)	629.75 € (48,818)	1,604.37 € (1,24,370)
B. Total operational cost for remaining years	1,383.92 € (1,07,281)	1,806 € (1,40,000)	2,619.86 € (2,03,090)	-
C. Cultivation cost (A+B)	2,008.77 € (1,55,719)	4,525.42 € (3,50,807.5)	3,249.61 € (2,51,908)	-
D. Total marketing costs	3,636.72 € (2,81,916)	15,802.18 € (12,24,975)	2,520.61 € (1,95,396)	-
E. Total (variable cost)	5,645.49 € (4,37,635)	20,327.59 € (15,75,783)	5,770.22 € (4,47,304)	1689.42 € (1,30,963)
Wood yield	Wood yield (q)	Wood yield (q)	Wood yield (cubic feet)	Average fruit yield (per ha)
Timber 10-24"girth	2,392	10,417.5	1,328.32	441.575 carts
Fuel wood <10" girth	195.4	6,593	265.66	-
F. Gross Returns	18,892.18 € (14,64,510)	86,669.62 € (67,18,575)	17,649.33 € (13,68,165)	4,727.95 € (3,66,507.5)
G. Net Returns after 5 years	13,246.69€ (10,26,875)	66,342.03€ (51,42,793)	11,879.11€ (9,20,861)	3,038.53€ (2,35,545)
H. Benefit-cost ratio	2.35	3.3	2.06	1.80

Table 1: Enterprise budget (values in Indian rupee in parentheses) of timber tree species and fruit orchard (per hectare). *Market rate of *P. deltoides* wood and fuel wood 2014-7.74 € and 1.93 € (Rs. 600 and 150 per quintal), **Market rate of *E. tereticornis* wood and fuel wood 2014-7.10 € and 1.93 € (Rs.550 and 150 per quintal), ***Market rate of *T. grandis* wood and fuel wood 2014-12.9 € and 1.93 € (Rs. 1000 and 150 per cubic feet), ****Market rate of *P. pyrifoila* fruit in 2014-10.71 € (Rs. 830 per cart). Note 1: INR=0.0129 € during December month of 2014.

Input/outputs	*Triticum aestivum*	*Oryza sativa*	*Brassica napus*	*Pennisetum glaucum*
A. Total variable cost	344.38 € (26,905)	440.02 € (34,377)	272.19 € (21,265)	227.42 € (17,767.5)
B. Interest on variable cost (12% p.a. for 6 months)	20.66 € (1,614.3)	26.41 € (2,063)	16.32 € (1,275)	13.64 € (1,066)
C. Total variable Cost (A+B)	365.06 € (28,520)	466.43 € (36,440)	288.51 € (22,540)	241.07 € (18,834)
D. Quantity of product	*main and by product	**main product	***main and by product	****fodder yield
2012 2013 2014	130 123.38 125	- - 70	- - 30	- - 448.35
E. Gross returns				

2012 2013 2014	1,125.98 € (82,188) 1,075.62 € (91,933) 1,338.37 € (1,03,750)	- - 1,228.08 € (95,200)	- - 501.16 € (38,850)	- - 1,156.74 € (89,670)
F. Net returns				
2012 2013 2014	735.25 € (53,668) 741.93 € (63,413) 970.47 € (75,230)	- - 758.00 €(58,760)	- - 210.40 € (16,310)	- - 913.78 € (70,836)
G. Benefit cost ratio				
2012 2013 2014	1.88 2.22 2.64	- - 1.61	- - 0.72	- - 3.76

Table 2: Enterprise budget for agricultural crops (quintal per hectare) crop in open condition (values in Indian rupee in parentheses). *Minimum support price of main and by product 2012-17.60 € and 2.60 € (Rs. 1285 and 190), 2013-15.80 € and 4.10 € (Rs. 1350 and 350), 2014-18.06 € and 5.80 € (Rs.1400 and 450 q/ha). **Minimum support price of main product 2014-17.54 € (Rs.1360 q/ha). ***Minimum support price of main and by product 2014-32.25 € and 1.20 € (Rs. 2500 and 90 q/ha). ****Minimum support price of fodder 2014-2.58 € (Rs.200 q/ha). **Note:** 1 INR=0.0137 € (2012), 1 INR=0.0117 € (2013), 1 INR=0.0129 € (2014). **Note:** A, B and C cost calculated by taking average values of all years (2012, 2013, 2014).

Years	***T. aestivum* under *P. deltoides***						
	Grain		**Straw**		**Returns**		
	Yield (q)	**Returns (Rs ha^{-1})**	**Yield (q ha^{-1})**	**Returns (Rs ha^{-1})**	**Gross returns (Rs ha^{-1})**	**Net returns (Rs ha^{-1})**	**B:C**
2010 (1*)	45.00	831.60 € (49,500)	63.75	144.04 € (8,574)	975.64 € (58,074)	496.51 € (29,554)	1.04
2011 (2**)	40.00	678.60 € (46,800)	58.25	118.25 € (8,155)	796.85 € (54,955)	383.31 € (26,435)	0.93
2012 (3)	35.00	616.16 € (44,975)	47.00	70.83 € (5,170)	686.99 € (50,145)	296.26 € (21,625)	0.76
2013 (4)	32.50	513.34 € (43,875)	46.25	189.40 € (16,188)	702.74 € (60,063)	369.05 € (31,543)	1.11
2014 (5)	30.75	555.34 € (43,050)	49.25	285.90 € (22,163)	841.25 € (65,213)	473.34 € (36,693)	1.30
T. aestivum under *P. pyrifolia*							
2012	34.86	613.96 € (44,815)	47.5	123.64 € (9,025)	737.61€ (53,840)	346.88 € (25,320)	0.89
2013	34.25	540.98 € (46,238)	46.25	72.40 € (6,188)	730.37 € (62,425)	396.69 € (33,905)	1.19
2014	36.25	654.67 € (50,750)	50.00	290.25 € (22,500)	944.92 € (73,250)	577.02 € (44,730)	1.57
B. napus under *P. pyrifolia*							
2014	10.25	330.56 € (25,625)	9.88	11.48 € (890)	342.04 € (26,515)	51.28 € (3,975)	0.20
P. glaucum (fodder crop) under *P. pyrifolia*							

2014	-	-	275	709.50 € (55,000)	-	466.54 € (36,166)	1.92

Table 3: Yield and gross returns (per hectare) of agricultural crops under tree based land use systems (values in Indian rupee in parentheses). 1*, 2** data collected from farmer, in parenthesis with year in first column-Age of *P. deltoides* trees.

Parameters	Land Use Systems						
	LUS-1	LUS-2	LUS-3	LUS-4	LUS-5	LUS-6	LUS-7
Gross returns	86,669.62 € (67,18,575)	17,649.33 € (13,68,165)	12,114.6€ (9,39,119)	22,895.65 € (17,52,960)	25,349.96 € (19,65,113)	31,261.81 € (24,23,396)	8,646.22 € (6,70,250)
Total (variable cost)	20,327.59 € (15,75,783)	5,770.22 € (4,47,304)	4,189.92€ (3,24,800)	7,470.16€ (5,80,235)	9,901 € (7,67,520)	11,496.20 € (8,91,178)	3,804.21 € (2,94,900)
Net returns	66,342.03 € (51,42,793)	11,879.11 € (9,20,861)	7,924.71€ (6,14,319)	15,265.16 € (11,72,725)	15,484.71 € (12,00,365)	19,765.68 € (15,32,223)	4,842.01 € (3,75,350)
PNW	41,206.22 € (31,94,281)	4,752.68 € (3,68,425)	4,922.19€ (3,81,565)	9,481.46€ (7,28,401)	9,617.83€ (7,45,568)	12,276.81 € (9,51,691)	3,007.47 € (2,33,137)
AV	10,872.35 € (8,42,818)	782.98 € (60,696)	1,298.73€ (1,00,677)	2,501.71€ (1,92,190)	2,537.69€ (1,96,720)	3,239.27€ (2,51,106)	810.64€ (62,840)
BCR	3.3	2.06	1.89	2.02	1.56	1.72	1.27

Table 4: Comparative economics (values in Indian rupee in parentheses) of different land use systems (per hectare). LUS-1: Pure *eucalyptus* plantation (5 yrs), LUS-2: *T. grandis* plantation (10 yrs), LUS-3: *T. aestivum* and *O. sativa*, LUS-4: *T. aestivum+P. deltoides* (5 yrs), LUS-5: *B. napus+P. pyrifolia* (fruit crop), LUS-6: *T. aestivum+P. glaucum+P. pyrifolia* (fruit crop), LUS-7: *B. napus+O. sativa.* *For *T. grandis* all returns calculated at the age of 10 yrs and rest at 5 yrs, Figures in Rs. ha^{-1} at 10% discount rate.

Cost-benefit analysis of *Populus deltoides*

Enterprise budget of *P. deltoides* for a rotation of five years is shown in Table 1. Out of 714 plants planted per hectare, about 677 survived assuming 95 percent survival rates. Establishment cost came out to be 624.85 € (Rs. 48,438) per hectare. Whereas, total operational cost of 1,383.92 € (Rs. 1,07,281) per hectare was calculated for five years. Total cost of cultivation came out to be 2,008.77 € (Rs. 1,55,719). Calculated marketing costs were 3,636.72 € (Rs. 2,81,916) per hectare, whereas the total (variable) costs were 5,645.492 € (Rs. 4,37,635). Gross returns included the returns from timber and fuel wood. From *P. deltoides*, gross and net returns were 18,892.18 € and 13,246.69 € (Rs. 14,64,510 and Rs. 10,26,875) per hectare under agroforestry based land use system.

Cost-benefit analysis of Eucalyptus pure plantations

Table 1 shows the costs and returns from *Eucalyptus* plantations. Establishment cost was estimated to be 2,719.42 € (Rs. 2,10,807.5) per hectare. Total operational cost was 1,806 € (Rs. 1,40,000) for the five years. Total cost of cultivation after five years was 4,525.42 € (Rs. 3,50,807.5) per hectare, and marketing costs were 15,802.18 € (Rs. 12,24,975) and total (variable) costs 20,327.59 € (Rs. 15,75,782.5). Gross returns included the returns from timber and it was 86,669.62 € (Rs. 67,18,575). The net returns after five years from *Eucalyptus* plantations (66,342.03 € or Rs. 51,42,793) was considerably higher and thus it appeared that these plantations can compare favorably with any alternative land use system.

Cost-benefit analysis of *Tectona grandis*

Financial calculations were made for a *T. grandis* plantation for a rotation of ten years (Table 1). Out of 625 plants initially raised, about 593 survived. Establishment cost was worked out to be 629.75 € (Rs. 48,818) per hectare. Total operational cost were calculated 2,619.86 € (Rs. 2,03,090) for ten years. Whereas, marketing costs were 2,520.61 € (Rs.1,95,396) and total (variable) costs 5,770.22 € (Rs. 4,47,304) per hectare. Gross returns included the returns from timber (17,649.33 € or Rs. 13,68,165) with net returns of 11,20,861 € (Rs. 9,20,861) per hectare.

Establishment cost of *Pyrus pyrifolia*

Enterprise budget of fruit crop is also shown in Table 1. Financial analysis showed that establishment cost came out to be 1,604.37 € (Rs. 1,24,370), whereas, gross and net returns were 4,727.95 € (Rs. 3,66,507.5) and 3,038.53 € (Rs. 2,35,545) per hectare, respectively.

Enterprise budget of agricultural crops in open and under tree species

Agroforestry models were compared economically with mono-cropping systems. For pure *wheat (T. aestivum)*, total variable costs for

the enterprise were worked out to be 365.06 € (Rs. 28,520). Gross and net returns from the sale of *T. aestivum* came out to be 1,125.98 €, 1,075.62 €, 1,338.37 € and 735.25 €, 741.93 €, 970.47 € (Rs. 82,188, Rs. 91,933, Rs. 1,03,750 and Rs. 53,668, Rs. 63,413, Rs. 75,230) per hectare, respectively during three years of study period in open conditions.

Yield and gross returns from *T. aestivum* and *B. napus* under *P. deltoides* and *P. pyrifolia*, respectively are depicted in Table 3. There was a gradual decline in the yield of *T. aestivum* crop over the years under *P. deltoides*. Similarly under *P. pyrifolia*, lower yield was recorded during the study period. Gross and net returns of *T.* aestivum over the years varied from 975.64 € and 496.51 € (Rs. 58,074 and Rs. 29,554) under one year old *P. deltoides* to 841.25 € and 473.34 € (Rs. 65,213 and Rs. 36,693) under five year old *P. deltoides*. On the other hand, gross returns of *T. aestivum* were 737.61 €, 730.37 €, 944.92 € (Rs. 53,840/ha, Rs. 62,425/ha and Rs. 73,250/ha) and net returns were 346.88€, 396.69 € and 577.02 € (Rs. 25,320/ha, Rs. 33,905/ha and Rs. 44,730/ha) during the period of study under in fruit crop. Whereas, gross and net returns of *B. napus* (oil seed crop) were 330.56 € (Rs. 26,515/ha) and 51.28 € (Rs. 3,975/ha). For *P. glaucum* (fodder crop), gross and net returns of 709.50 € and 466.54 € (Rs. 55,000 and Rs. 36,166/ha) were recorded during period of study.

Cost-benefit analysis of *Oryza sativa*

Financial calculation for *Oryza sativa* mono-cropping land use system in open conditions is presented in Table 2. Total variable costs for the enterprise was worked out to be 466.43 € (Rs. 36,440) on a hectare scale. Gross and net returns from the sale of *Oryza sativa* (paddy) came out to be 1,228.08 € and 758.00 € (Rs. 95,200/ha and Rs. 58,760/ha) during period of study.

Cost-benefit analysis of *Brassica napus* crop

Economics of oil seed crop in open is presented in Table 2. Total variable costs, gross and net returns were assessed as 288.5 €, 501.16 € and 210.40 € (Rs. 22,540, Rs. 38,850 and Rs. 16,310) per hectare.

Cost benefit analysis of *Pennisetum glaucum*

In this study, enterprise budget of fodder crop (Table 2) in open conditions was prepared. Total variable costs per hectare for the enterprise came out to be 241.07 € (Rs. 18,834). Gross and net returns from the sale of fodder crop came out to be 1,156.74 € and 913.78 € (Rs. 89,670 and Rs. 70,836) during the period of study.

The estimates of the benefit-cost ratio of *T. aestivum* crop under different land use systems are presented in the Table 3. B:C ratio of *T. aestivum* crop ranged from 0.76 to 1.30 under *P. deltoides*, whereas, *T. aestivum* crop under *P. pyrifolia* ranged from 0.89 to 1.57 and in *B. napus* the ratio is 0.20. B:C ratio of *T. aestivum* crop in mono-cropping system ranged from 1.88 to 2.64, *O. sativa* (1.61), *P. glaucum* (3.76) and in *B. napus* ratio is 0.72. B:C ratio of *T. aestivum* under pure agricultural land use system is (2.64) against (1.30) under poplar canopy during 2014, which is higher than previous year 2013 (2.22 in pure wheat and 1.11 under poplar canopy). The future returns derived by discounting both costs and benefits at 5% and 10% rate of interest are presented in Table 4. Gross returns, total (variable) costs, net returns, present net worth values (PNW), annuity value (AV) and benefit cost ratio have been worked out for different land use systems. Gross return varied markedly with respect to land use system.

Gross returns as achieved from pure *eucalyptus* plantations, agri-silviculture and agri-horticulture based land use system is markedly higher than in the annual cropping systems. Maximum gross returns 86,669.62 € (Rs. 67,18,575 ha^{-1}), total expenses 20,327.59 € (Rs. 15,75,783 ha^{-1}) and net profit 66,342.03 € (Rs. 51,42,793 ha^{-1}) were recorded in the pure eucalyptus plantations followed by agri-silviculture 22,895.65 €, 7,470.16 €, 15,265.16 € (17,52,960, 5,80,235 and Rs. 11,72,725 ha^{-1}) and agri-horticulture 31,261.81 €, 11,496.20 €, and 19,765.68 € (24,23,396, 8,91,178 and 15,32,223 Rs. ha^{-1}) land use systems. The analysis of this data revealed that highest discounted present net worth value (PNW) and annuity value (AV) values from one hectare of *eucalyptus* plantations were 41,206.22 € and 10,872.35 € (Rs. 31,94,281 and Rs. 8,42,818) followed by *P. deltoides*+ *T. aestivum* 9,481.46 € and 2,501.71 € (7,28,401 and 1,92,190) and *T. aestivum* +*P. glaucum*+fruit crop 12,276.81 € and 3,239.27 € (9, 51,691 and 2,51,106) with benefit cost ratios of 3.3, 2.02 and 1.72, respectively. The highest benefit-cost ratio of 3.30 in pure eucalyptus based land use system was due to minimum inputs and maximum number of trees.

Discussion

Poplar *(P. deltoides)* based agroforesrty system is economically more viable and more profitable than any of the crop rotations [8,10,12,13]. Gradual crop yield reduction under tree canopy with age is usual phenomenon due to shade effect on the inter-cultivated crops [14,15]. The reduction in yield of agricultural crops under fruit trees was recorded by Bijalwan [16] but this reduction is supplemented by fruit production, which compensates the crop reduction losses. Dhillon et al. [17] reported annual net return of 1,312.74 € and 1,737.92 € (Rs. 55,390 and Rs. 73,330) per hectare without intercropping and with intercropping, respectively, over the entire rotation period under poplar cultivation. Some progressive farmers of the Punjab state with intensive management of poplar have earned 1,125 € to 1,305 € (Rs. 75,000 to 87,000) $ha^{-1}yr^{-1}$ from poplar-based agroforestry against approximately 450 € to 555 € (INR 30,000 to 37,000) $ha^{-1}yr^{-1}$ from rice-wheat rotation [18]. Much higher output of flower seeds than wheat crop was reported by Rani et al. [12]. Flowers for seed production are relatively remunerative enterprise as compared to the traditional rabi crop i.e., *Triticum aestivum* (wheat). Chauhan et al. [13] reported higher economics benefits in block and boundary plantation than pure cropping of rice-wheat (B:C ratio of 3.30, 1.90 and 1.61, respectively). Although oilseed crops prices are higher but their yields are not equivalent to other crops in the system [19,20] thus moderating the benefit cost ratio. The economics of fruit tree based agroforestry is better than the traditional crops [21]. Getahun [22] also reported net profit from fruit based land use system was nearly about two times higher than the net profit of mono-cropping system in Wondo district, Ethiopia. Shode and Amanuel [23] reported about Moringa, tree based agroforestry practice is highly profitable than mono-cropping system in Konso district (Woreda), Southern Ethiopia. Similar study was carried out in Pakistan on economic comparison of agriculture with tree based land use system, showing that the net benefits of tree based sugarcane system were eighty-six per cent more than tree-less sugarcane land use system.

Conclusion

Gross income from intercrops declined over the years, however, costs remained same. Therefore, under tree based land use systems, safely selective shade tolerant crops can be grown for optimum utilization of land with enhanced the economic returns. There is

reduction of grain and straw yield of *Triticum aestivum* and *Brassica napus* (wheat and oil seed) crops under fruit trees but this reduction is supplemented by fruit production income. Tree based land use systems had more productivity resulting in higher benefit cost ratio in comparison to the land under mono-cropping systems. The contribution of the trees under different land use systems certainly added to the diversity dimension by way of income and employment to the farm households besides fulfilling the requirement of wood and safe environment. Due to fast rate of growth of *eucalyptus* and poplar and better market acceptability, these two fast growing trees have emerged a viable alternative land use system.

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