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A Comparative Assessment of Economics of Common Agri-Silviculture Models from Haridwar Region of Northern India

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ABSTRACT
The present study was carried out to estimate the economic viability (BCR, NPV and IRR) of selected agrisilviculture models by using discounting factor technique. Here, values of discounted cash flow were generated at 10% rate of interest for a rotation period of six years for Poplar and eight years for Eucalyptus based models. The discounting factor was developed for all costs applied and benefits obtained that were calculated from initial establishment to final rotation period. In results, among studied economic indicators, Poplar-wheat-paddy generated higher values than Eucalyptus-paddy-wheat agri-silviculture model. Total costs were reported more in Eucalyptus-paddy-wheat (Rs. 5.07 Lakh/ha),when compared to Poplar-wheat-paddy (Rs. 4.42 Lakh/ha). Total benefits were reported more from Poplar-wheat-paddy (Rs. 9.96 Lakh/ha) compared to Eucalyptus-paddy-wheat (Rs. 9.51 Lakh/ha). The Wheat intercrop yielded higher returns (3.70 Lakh/ha) under Poplar trees while returns from Paddy were accounted maximum under Eucalyptus trees (3.79 Lakh/ha). Values of discounted Cash flow and economic analysis confirmed higher BCR, NPV and IRR as 2.15:1, 3.75 Lakh/ha and 120.6% for Poplar-wheat-paddy and 1.80:1, 2.66 Lakh/ha and 75.51% for Eucalyptus-paddy-wheat boundary plantation. It is concluded that in agri-silviculture system, wheat-paddy rotation is economically more profitable and viable under Poplar than Eucalyptus based agri-silviculture models.
Keywords: *Agri-silviculture, Benefit, Cost, Discounting, Economics, Model*

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INTRODUCTION

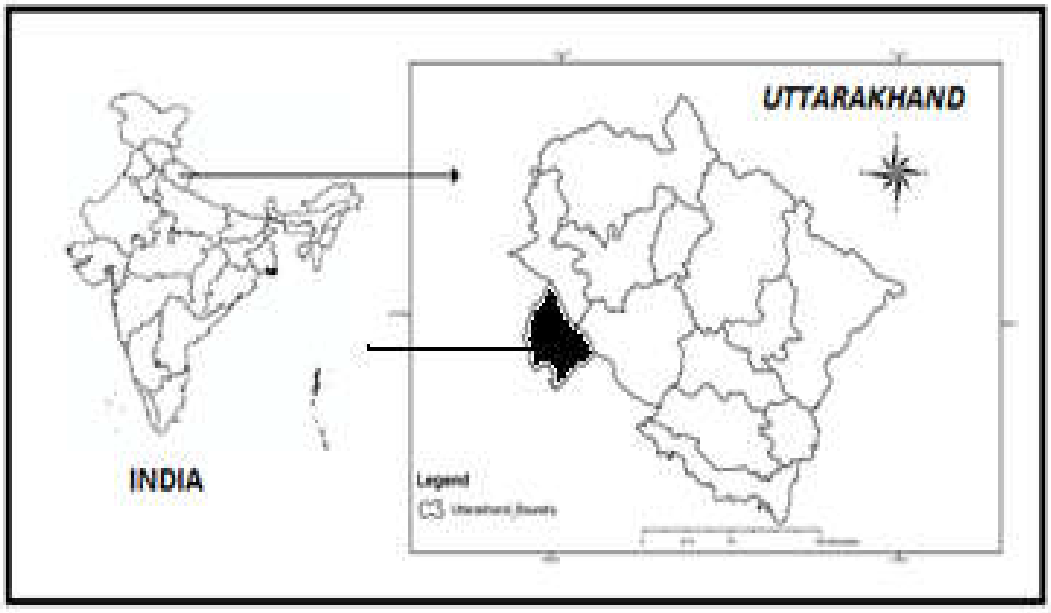
The presence of agroforestry systems in land management today has many concerns about major objectives like estimation of costs, benefits while achieving overall economic development and at the same time, what economic changes or aspects one can expect while practicing agroforestry. Various economists have shown the application of economic theory in the study of agroforestry [6].Economic studies of agroforestry have shown that financial benefits are a consequence of increasing the diversity and productivity of the systems which are influenced by market and price fluctuations of timber, livestock and crops.The role of economic benefits provided by agroforestry is considered by various scholars and scientists like [5] and later by Fregene (2007). Economics of agroforestry practice includes many terms like economic analysis, financial analysis etc. Evaluation of economic aspects in agroforestry helps in providing a baseto estimate financial requirements while highlighting cash flows from multiple benefits and costs.Economics is concerned with the analysis of choice of decisions like what goods can be produced with available resources, and how much of these resources can be used in order to achieve certain objectives such as an increased income to the farmers. In recent years, consideration from various agencies has been directly given to agroforestry systems such as agri-silviculture. As a system under agroforestry, agri-silviculture provides income from trees and agricultural crop management. It may help in increasing farm profitability as it generates new products which add to the financial diversity and flexibility of the farming enterprise and the total output per unit area of tree/crop/livestock combinations (6). In tropical regions, agri-silviculture models are widely adopted by the farming communities to fulfill the demand of grains, timber, fuelwood and other produces at the same time. Therefore, it is understood that there must be more studies to examine the full range of potential of agri-silviculture models, and the economics is not apart from that. Wheat-paddy rotation is an integral part of farming systems in India and

other south-East Countries. When combined with tree species like Poplar (*Populus deltoides*) and Eucalyptus (*Eucalyptus tereticornis*), this combination is widely adopted by the farmers. The present study has focused on assessment of economic viability of widely adopted crop rotation (wheat-paddy) under two agroforestry tree species i.e. Poplar and Eucalyptus in boundary plantation under agrisilviculture system. The study also compares their economic feasibility and profitability for different economic indicators like Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR).

MATERIAL AND METHODS

1. Study area

Uttarakhand is one of the Northern states of India. District Haridwar lies in this state covering an area about 2,360 km^{-1} is in the South-West part of Uttarakhand State. Its latitude and longitude are 29.96° N and 78.16° E respectively. Haridwar is situated at height of 314 m (1,030 ft) msl. It lies in West Himalayan hill region (its agro-climatic zone). The study area falls under most fertile alluvial belt in North India. On a seasonal basis, farmers cultivate a variety of field crops with Poplar and Eucalyptus, the dominant species in agroforestry in the region.



Map: Location of study area (District Haridwar) in Uttarakhand state, India

2. Data collection criteria

The information upon costs incurred and benefits received was explored for both summer (kharif) and winter (rabi) crops for the whole plantation period. Though data pertaining to the economics of agroforestry models (pertaining to final and all previous year of tree–combination) were collected from agroforestry farmers, data to be analyzed were received only from 48 farmers' families who provided data for all cost and benefits occurred during that period (initial to final year of rotation) while practicing models on sixth (Poplar) and eighth year of tree rotation (Eucalyptus) with wheat and paddy as seasonal intercrops. For studied agri-silviculture models, data on expenditure and returns were collected as suggested by [3]. Farmers' records of labour, materials and operations required for planting, management and harvesting of trees and seasonal agricultural/fodder crop combinations. Similarly, total amount received in Rupees/ha as benefits/returns collected from sale value of trees, pruned wood, grains, straw, husk, dry/green fodder were recorded and compared with prevalent market/social rate for the produces of that particular crop. All records were computed in monetary terms considering local market /social rates/charges. Wage rate for agricultural laborers were taken in man-days which varied between Rs. 180-200 to Rs. 350/ man-day during 6-8 years time period. Quantitative data containing monetary values of all investments and returns were entered in spreadsheet and calculated by using specific excel functions.

3. Data analysis

Discounting factor technique [1] was applied to evaluate money value during project period. Discounted values of costs on the presumption that entire cost is invested in the beginning of the first year of model plantation. This has been done so, as the most of the expenditure on trees occurs at the time of sowing as

previously explained by [3]. Discounted cash flow was calculated with this premise that money in the initial (base) year had worthless value than money in the final year of model rotation. Using discount factor for time, costs and benefits of selected agroforestry models were discounted to obtain market values.

Discount Factor=$1/ (1+r)^n$

Where, r=discount rate, n=time

The Benefit-Cost Ratio (BCR) of agroforestry models was calculated using formula:

BCR= $\sum_{t=0}^{t} Bt/(1+i)t / \sum_{t=0}^{t} Ct/(1+i)t$

Where, ∑Bt = total occurred benefits for a period of t years,

∑Ct=total occurred cost for a period of t years

i= discount rate

t=time period

The Benefit-Cost Analysis (BCA) had compared the benefits or revenues to the costs or investments done for studied models. The decision rule for BCR is that for any project to be economically viable, the ratio must be greater than 1.The Net Present value (NPV) of agroforestry models was calculated using following formula:

$$NPV= \sum_{t=0}^{t} \frac{Bt}{(1+i)t} - \sum_{t=0}^{t} \frac{Ct}{(1+i)t}$$

The NPV of agroforestry models was used to compare to see which practice is economic more profitable. The Internal Rate of Return (IRR) of agroforestry models was calculated using following formula:

$$C0 = \sum_{t=1}^{t} \frac{Nt}{(1+i)t}$$

If the farmer's acceptable rate of return is smaller than IRR or equal to IRR, the alternative should be accepted. Or if the minimum acceptable rate of return is greater than the IRR, the alternative should be rejected. This is because the minimum acceptable rate of return which is higher than IRR will result in a negative NPV, and a financial loss for the agroforestry alternative [2].

RESULTS

The discounted cash flows covering the 6 year old Poplar-wheat-paddy model and 8 years old Eucalyptus-paddy-wheat agri-silviculture models had positively accumulated balances at the end of their rotation periods. The result of comparative economic analysis of agrisilviculture models is evaluated in the following sections.

1. Economics of Poplar-wheat-paddy agri-silviculture model

In Poplar-wheat-paddy plantation, 400 ETPs were planted on the farm boundaries with 1.5-2.0-meter spacing. After 90.75% survival rate, remained 363 trees were harvested at their rotation age. Cost of tree planting was around Rs. 15792/ha. The overall cost of this agri-silviculture model occurred as Rs. 4.42 Lakh/ha in which, maximum amount was invested upon paddy as Rs 2.56 Lakh/ha for six years. Major collected returns were from the auction of trees as 2.90 Lakh/ha followed by sale value of wheat grains as Rs 2.29 Lakh/ha and Paddy grains Rs 2.89 Lakh/ha respectively (Table 01).The Wheat intercrop yielded higher returns as Rs 3.70 Lakh/ha while paddy intercrop had shown lesser yield as Rs 3.54 Lakh/ha. Ineconomic analysis, results had confirmed high NPV as Rs 3.75 Lakh/ha and positive BCR as 2.15:1. This has proven the possibility of very high income from this model as compared to other studied model. IRR worked out at 120.6% rate for Poplar-wheat-paddy boundary plantation model (Table 02).

2. Economics of Eucalyptus-paddy-wheat agri-silviculture model

In Eucalyptus-paddy-wheat model, 325 Eucalyptus saplings were planted during December- January. These after 89.23% survival rate, remained 290 trees at the time of harvesting. The overall cost of the model was Rs. 5.07 Lakh/ha while all returns were accounted as Rs. 9.50 Lakh/ha (Table 03). Since self-pruning occurs in Eucalyptus, no labour was reported to be applied for this purpose. However, farmers collect fallen branches and use them as firewood. Trees were sold out at a maximum price of Rs. 750/tree. Maximum returns were collected from paddy as Rs 3.79 Lakh/ha followed by wheat as Rs 3.54 Lakh/ha and auction of trees as Rs 2.15 Lakh/ha. The obtained economic indicators' value were NPV as Rs 2.66 Lakh/ha, BCR as 1.80:1 and IRR as 75.51%, when all investment and returns were recorded for a period of eight years for this model (Table 04).Total costs were reported more for Eucalyptus-paddy-wheat as Rs. 5.07 Lakh/ha, when compared to Poplar-wheat-paddy (Rs. 4.42 Lakh/ha) while total benefits were reported more from Poplar-wheat-paddy as Rs. 9.96 Lakh/ha, when compared to Eucalyptus-paddy-wheat (Rs. 9.51 Lakh/ha). Apart from this, values for economic indicators were also reported greater in economic analysis of Poplar-wheat-paddy agrisilviculture model. This proved the possibility of huge

income from this model as compared to the second studied model. It is further confirmed by even highest IRR as 120.6%.

Table 1.Cost and benefit structure in Rs/ha^{-1} from initial to 6 year old Poplar-Wheat-Paddy agri-silviculture model

I. Cost of the model							
A. Labour cost in Poplar wheat paddy boundary plantation model (Rs. 180-Rs. 350/day)							
Detail of costs in Rs./ha	Ist year	IIndyear	IIIrdyear	IVthyear	Vthyear	VIthyear	Total
Labour cost for tree management							
Labour cost for wheat cultivation	0	680	850	800	1000	1150	4480
Labour cost for paddy cultivation	7990	8926	9673	9738	9806	10300	56433
	12816	13035	15202	15953	17319	20250	94575
B. Operation and management cost of Poplar trees							
Initial planting cost	15792	-	-	-	-	-	15792
Fertilizers/insecticides/pesticides	0	2425	3002	0	0	0	5427
Transportation charges	0	180	200	250	280	300	1210
Total (including labour cost from A)	15792	3285	4052	1050	1280	1450	26909
C. Operation and management cost of wheat							
Seed (Rs. 25- 35/kg 90-100 Kg/ha)							
Tillage/furrow/plow Harrow	2625	2701	2807	2902	3157	3510	17702
Irrigation (2-3, @ 100-220/hr.	3375	3464	4172	4218	4894	5325	25448
Fertilizers/insecticides/pesticides	2223	2353	2479	2566	2765	3005	15391
Transportation @ 200-400	2379	3248	4860	5544	5955	6110	28096
/trolley	892	1086	1225	1333	1472	1525	7533
Thrashing rate @ 25- 45 for 75 kg	1263	1356	1461	1535	1569	1771	8955
Total (including labour cost from A)	20,747	23,134	26,677	27,836	29,618	31,546	159,558
D. Operation and management cost of paddy							
Seeds(@ 35- 60 /kg ; 50-60 kg/ha)							
Tillage/furrow/plow	2263	2312	2534	2673	2768	2816	15366
Irrigation	7715	8492	9546	10109	10164	12550	58576
Fertilizers/insecticides/pesticides	5121	5603	6401	6496	7593	7952	39166
Transportation (@200-400/trolley)	4242	4441	4934	5364	5425	6120	30526
	985	1119	1461	1495	1536	1801	8397
Thrashing (@. 45-100/ for 75 kg)	1402	1033	1342	1503	1890	1972	9142
Total (including labour cost from A)	34544	36,035	41,420	43,593	46,695	53,461	255,748
Sum of cost of model (A+B+C)	**71083**	**62454**	**72149**	**72479**	**77593**	**86457**	**4,42,215**
II. Benefits received from the model							
A. Benefits from the Poplar trees							
Detail of benefits in Rs./ha	Istyear	IIndyear	IIIrdyr	IVthyear	Vth year	VIthyear	Total
Prune wood (@Rs. 200-350)	0	0	0	1050	1280	1450	3780
Auction @Rs. 800(363 trees)	0	0	0	0	0	290400	290400
Total	0	0	0	1050	1280	291850	294180
B. Benefits from wheat							
Sale of grains	30927	3420	38156	43934	41703	40150	229070
Sale of straw @ 350-800/qntl	13232	14666	15861	20756	19540	19000	103055
Total	44,159	48866	54017	64690	61,243	59,150	332125
C. Benefits from paddy							
Sale of grain@. 1400-2200/qntl	43877	45519	48219	51000	51943	48850	289408
Sale of husk@. 400-1000/cart	12600	14159	15080	13715	14955	10155	80664
Total	56,477	59,678	63,299	64715	66,898	59,005	370072
Sum of all benefits (A+B+C)	**1,00936**	**1,08544**	**1,17316**	**130455**	**1,29421**	**410005**	**996377**

Table 2. Detail Cost-Benefit analysis and values of economic indicators (NPV, BCR, IRR) in Rs/ha^{-1} for Poplar-wheat-paddy agri-silviculture model

Year	Components	Actual cost (X)	Discounting period (yr)	Discount factor	Discounted 10% (X1)	Actual benefit (Y)	Discounted 10% (Y1)	Net benefit (Y-X)	Discounted At 10% (Y1-X1)
	Poplar	15792	0	1.0000	15792	0	0	-15792	-15792
	Wheat	20747	0.5	0.9950	20643	44159	43938	23412	23295
0-1	Paddy	34544	1	0.9091	31404	56477	51343	21933	19939
	Poplar	3285	1	0.9091	2986	0	0	-3285	-2986
	Wheat	23134	1.5	0.8668	20053	48866	42357	25732	22304
1-2	Paddy	36035	2	0.8264	29779	59678	49318	23643	19539
	Poplar	4052	2	0.8264	3349	0	0	-4052	-3349
	Wheat	26677	2.5	0.7880	21021	54017	42565	27340	21544
2-3	Paddy	41420	3	0.7513	31119	63299	47557	21879	16438
	Poplar	1050	3	0.7513	789	1050	789	0	0
	Wheat	27836	3.5	0.7163	19939	64690	46337	36854	26399
3-4	Paddy	43593	4	0.6830	29774	64715	44200	21122	14426
	Poplar	1280	4	0.6830	874	1280	874	0	0
	Wheat	29618	4.5	0.6512	19287	61243	39881	31625	20594
4-5	Paddy	46695	5	0.6209	28993	66898	41537	20203	12544
	Poplar	1450	5	0.6209	900	291850	181210	290400	180309
	Wheat	31546	5.5	0.5920	18675	59150	35017	27604	16342
5-6	Paddy	53461	6	0.5645	30179	59005	33308	5544	3130
Investment-returns/ha		442215 (4.42)	Discounted costs-benefits		325557 (3.23)	996377 (9.96)	700232 (7.00)	554162 (5.54)	374675 (3.75)
Net Present Value (NPV) when discounted at 10% interest rate ∑ (Y1-X1)								**3.75 Lakh/ha**	
Benefit-Cost Ratio (BCR) when discounted at 10% interest rate (Y1/X1)								**2.15:1**	
Internal Rate of Return (IRR)								**120.6%**	

Table 3. Cost and benefit structure in Rs/ha^{-1} from initial to 8 year old Eucalyptus-wheat-paddy agri-silviculture model

I. Costs for the model									
A. Labour cost for Eucalyptus paddy wheat boundary plantation model (Rs. 150-Rs. 350/day)									
Detail of all cost in Rs/ha	Ist yr	IInd yr	IIIrd yr	IVthyr	Vth yr	VIthyr	VIIthyr	VIIIthyr	Total
Labour cost for paddy	6950	7940	10170	12000	12790	14680	15720	16990	97240
Labour cost for wheat	4600	4950	5550	6010	7490	8220	9450	10680	56950
B. Operation and management cost of trees (Rs./ha)									
Planting cost	10460	-	-	-	-	-	-	-	10460
C. Operation and management cost of paddy (Rs./ha)									
Seeds @25-50/kg, 60-75Kg/ha.)	1864	1980	2157	2345	2510	2715	2844	2910	19325
Tillage/plow/furrow	1480	5940	6880	8000	9200	12100	14200	15600	73400
Irrigation	3910	4450	5268	5790	6210	6600	7340	7850	47418
Fertilizers/insecticides/pesticides	2510	3420	3975	4220	4504	5282	5926	6605	36442
Transportation@150-400 /trolley	545	680	900	1000	1250	1400	1550	1720	9045
Thrashing @20- 45 for 75 kg)	700	950	1100	1320	1570	1684	1880	2000	11204
Total (including cost from A)	17,959	25,360	30,450	34,675	38,034	44,461	49,460	53,675	2,94,074
D. Operation and management cost of wheat (Rs./ha)									
Seed purchase	2080	2300	2400	2625	2800	3000	3250	3690	22145
Tillage/plow/furrow	3400	3750	4200	4550	4700	5400	6200	6950	39150
Irrigation thrice @ 100-220/hr.	1280	1572	1945	2210	2580	2755	3010	3350	18702
Fertilizers/insecticides/pesticides	2400	2950	3250	3800	4400	4820	5572	5948	33140
Transportation @150-400/trolley	500	600	750	1050	1225	1450	1500	1600	8675
Thrashing @25-45/kg; 75 kg/ha)	1550	1900	2150	1800	1950	2340	200	2380	14270
Total (including cost from A)	15,810	18,022	20,245	22,245	25,145	27,985	29,182	34,598	193,032
All costs of model (A+B+C)	**54,199**	**46,382**	**50,695**	**56,720**	**63,179**	**72,446**	**78,642**	**88,273**	**5,07,486**
II. Benefits from the model									
A. Benefits from Eucalyptus trees (Sale/sale value)									
Benefits in Rs./ha	Ist year	IIndyear	IIIrdyear	IVthyear	Vthyear	VIthyear	VIIthyear	VIIthyear	Total
Rs.750/tree290 trees	0	0	0	0	0	0	0	217500	217500
B. Benefits from paddy									
Grains	30000	31000	33000	35200	37150	38600	39000	40500	284450
Husk @300-1000/cart	9450	10100	10800	12000	12800	13000	13500	13000	94650
Total benefit	39,450	41,100	43800	47200	49950	51600	52500	53500	379100
C. Benefits from wheat									
Grains	24000	26500	28000	32500	33180	35000	35900	35500	254580
Straw	10000	10500	12000	13200	14300	14500	14650	14400	103550
Total	34000	37,000	40,000	45700	47480	49,500	50,550	49,900	354130
All benefits (A+B+C)	73,450	78,100	83,800	92,900	97,430	1,01100	1,03050	3,20,900	9,50730

Table 4.Detail cost-Benefit analysis and values of economic indicators (NPV, BCR, IRR)inRs/ha^{-1}for Eucalyptus-paddy-wheat agri-silviculture model

Year	Components of model	Actual cost (X)	Discounting period	Discount factor	Discounted (X1)	Actual benefit (Y)	Discounted (Y1)	Actual (Y-X)	Discounted (Y1-X1)
	Eucalyptus	20380	0	1.0000	20380	0	0	-20380	-20380
	Paddy	17959	0.5	0.9950	17869	39450	39253	21491	21386
0-1	Wheat	15810	1	0.9091	143723	34000	30909	18190	16536
	Eucalyptus	0	1	0.9091	0	0	0	0	0
	Paddy	25360	1.5	0.8668	21982	41100	35625	15740	13643
1-2	Wheat	18022	2	0.8264	14893	37000	30577	18978	15684
	Eucalyptus	0	2	0.8264	0	0	0	0	0
	Paddy	30450	2.5	0.7880	23994	43800	34514	13350	10520
2-3	Wheat	20245	3	0.7513	15210	40000	30052	19755	14842
	Eucalyptus	0	3	0.7513	0	0	0	0	0
	Paddy	34675	3.5	0.7163	24837	47200	33809	12525	85972
3-4	Wheat	22045	4	0.6830	15056	45700	31213	23655	16156
	Eucalyptus	0	4	0.6830	0	0	0	0	0
	Paddy	38034	4.5	0.6512	24767	49950	32527	11916	7760
4-5	Wheat	25145	5	0.6209	15612	47480	29480	22335	13867
	Eucalyptus	0	5	0.6209	0	0	0	0	0
	Paddy	44461	5.5	0.5920	29280	51600	32547	7139	4226
5-6	Wheat	27985	6	0.5645	15797	49500	27943	21515	12145
	Eucalyptus	0	6	0.5645	0	0	0	0	0
	Paddy	49460	6.5	0.5381	26614	52500	28250	3040	1636
6-7	Wheat	29182	7	0.5132	14976	50550	25942	21368	10966
	Eucalyptus	0	7	0.5132	0	217500	111621	217500	111621
	Paddy	53675	7.5	0. 4914	25823	53500	25738	-175	-85
7-8	Wheat	34598	8	0.4665	16140	49900	23278	15302	7138
Investment -returns/ha		507486 (5.07)	Discounted costs & benefits		334649 (3.35)	950730 (9.51)	601281 (6.01)	443244 (4.43)	266632 (2.66)

NPV calculated when discounted on 10% rate of interest ∑(Y1-X1)	**2.66 Lakh/ha**
BCR when discounted on 10% rate of interest (Y1/X1)	**1.80:1**
Internal Rate of Return (IRR)	**75.51%**

DISCUSSION

In economic analysis, time is an important factor of investment, production, and returns. Since the profitability of studied agroforestry models was evaluated for 6 and 8 year period, results have confirmed the adoption of studied agri-silviculture models as a good investment option. The discounting factor technique was utilized in interpretation of data, involving suitable economic indicators to answer certain specific questions regarding their profitability and viability in terms of BCR, NPV and IRR. The findings are especially important because agroforestry is being used as a developmental tool in the tropics and economic tool in the temperate regions [4]. Economics of Poplar-wheat-paddy model had generated positive results. This finding has supported [3] who studied the model and recorded IRR at 389%, BCR ration as 2.42:1 and NPV as Rs. 1.78 Lakh/ha, when calculated at 9% discount rate. [3] had also estimated economics of this model and accounted BCR as 2.84 at 10% discounted rate. Although in this study, the results for economic indicators for both agri-silviculture models had generated excellent values (positive NPV and BCR more than 1 and highest IRR), the viability of this model was not reported up to that level as mentioned by(3) and (2). Also, in Eucalyptus-paddy-wheat model, due to less number of harvestable trees (290 trees /ha), this model had provided average profitability when compared to Poplar-wheat-paddy (363 trees /ha). The calculated value of IRR further confirmed that as to Poplar-wheat-paddy model, the pace of economic returns from Eucalyptus-paddy-wheat was slow. NPV from Poplar-wheat-paddy was reported higher over NPV of Eucalyptus –paddy-wheat from all feasible alternatives which showed it as potentially more adoptable. A greater BCR as indicated in economics of Poplar-wheat-paddy model showed it preferably good to be followed in farm fields. It was further proven by higher IRR, a function which compared profitability for both agri-silviculture models. It is interesting to note that Eucalyptus-paddy-wheat model provided less NPV and BCR as compare to Poplar-wheat-paddy agri-silviculture model, IRR was also accounted at much lower discount rate showing less profitability from this model, the reason behind this was long rotation period of Eucalyptus-paddy-wheat model i.e. eight years, which

is six years for Poplar based models. Another possible reason was low market demand and supply of Eucalyptus timber as compared to Poplar timber in the region. However, the impact of number of trees/ha and timber price value cannot be ignored in both models under agri-silviculture system as the market price of Poplar wood was reported higher then Eucalyptus wood. Overall, the values NPV and BCR and IRR had confirmed adoption of both agri-silviculture models as good investment in terms of their profitability and viability since all three studied economic parameters had measured the economic worthiness of these two models. Also, in-appropriate price making for trees on farm has also reduced total profitability of this model.

CONCLUSIONS

The results obtained in this study lead to the conclusion that among studied agri-silviculture models in boundary plantation, total costs were accounted maximum for Eucalyptus-paddy-wheat model while benefits were recorded maximum from Poplar-wheat-paddy model. In economic evaluation and comparison, the result has proven that Poplar-wheat-paddy boundary plantation generated higher values for BCR, NPV and IRR than Eucalyptus-wheat-paddy. It is due to more number of trees/ha (Poplar), more economic opportunities from collected prune wood, auction opportunities for Poplar trees/wood and less rotation age of species as compared to Eucalyptus in Eucalyptus-wheat-paddy boundary plantation model. As far as agriculture crops were concerned, Wheat crop had generated more economic returns under Poplar while Paddy crop generated more economic returns under Eucalyptus. Overall for both tree species and agriculture crops, the studied models had fulfilled criteria of good economic profitability i.e. a positive NPV, BCR more than 1 and IRR higher than accepted rate of interest (10%). On basis of economic performance, the cultivation of Poplar-wheat-paddy is recommended over Eucalyptus-paddy-wheat in boundary plantation. Since, the profitability generated is largely dependent upon sale value of timber, application of farm level grading system and rise in timber price will be helpful in increasing the economic viability of these agri-silviculture models.

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