Economic Analysis of Agroforestry Options for Small Irrigated Farms in Punjab Province, Pakistan

Malik Mohammad Khan, *Conservator of Forests, Punjab Forest Service,*
David R. Betters, *Graduate Student and Professor, Dept. of Forest and Wood Sciences, Colorado State University, Ft. Collins, Co.*

Summray

Agroforestry on small irrigated farms may represent opportunities for solving Pakistan's wood supply problems. However, in order for such practices to be adopted small farms must realize economic benefits. An approach to determining economic benefits is illustrated in an application to a typical small irrigated farm in Punjab. The analysis first finds the most economically efficient single crop and joint poplar-wheat production possibilites then analyzes these possibilities under typical farm constraints and requirements. In the case study, the results show that applying agroforestry practices can increase overall farm production and income. Applying the economic analyses approach discussed here coupled with sound policy and extension activities should help promote the acceptance of agroforestry.

Introduction

Agroforestry systems represents practices where woody perennials and agricultural crops and/or animals are produced together on the same land area, either spatially or temporily. The goals of such systems are: to improve the quantity and quality of production, to generate a sustained agricultural base, to reduce environmental damage and to raise the living standard of the human population.

Expanding the application of agroforestry (AF) in Punjab Province is particularly important. The rising population and increase demand for wood and food products have made it imperative to examine new agricultural production options. Agroforestry for small land holdings is particularly significant as it is unlikely that land can be diverted to just produce forest plantations and the state forests alone cannot meet the wood needs. It has been shown that AF has the potential to improve overall agricultural production substantially (Ashraf & Hafeez , 1984; Sheikh et al., 1984).

Agroforestry, however, has not been readily accepted by farmers because of the perceived risks, length of investment for tree crops, capital scarcity, land ownership patterns, and possible complications trees cause in terms of grazing and agriculture crop protection (Sheikh, 1987). While the government has formulated many policies to create incentives for adopting agroforestry, systems to date, they have had limited success. In part, this is because of the lack of extensive experimentation of AF options, limited extension services and lack of proper economic analysis. In general, most agree that AF systems will be adopted if it can be demonstrated that the AF system improves and stabilizes farmer's income (Singh and Osman, 1987).

The purpose of this paper is to illustrate an economic analysis approach that may be applied to AF systems in small farm ownerships. This analysis can be used to compare AF systems to more traditional small farm crop production and develop more efficient farm management schemes to increased farm income.

Procedures and Data

The procedures followed here will follow those suggested by Betters (1988). In general, these procedures invlove the use of production economics, capital theory and operations research tools. The approach follows two steps. First, production economics and capital theory are used to determine the best AF production combination to produce from an economic standpoint. Subsequent to this analysis, operations research, in particular linear programming, is used to determine what mix of AF and traditional practices might be best considering additional farm-level constraints and requirements.

The details of the procedures are illustrated by analyzing a wheat-poplar AF practice applied in Punjab. The principal data and its sources are shown in Table 1. Yields and costs for poplar include that activities of site preparation, planting, restocking, weeding, pruning, irrigating and spraying over a period of 10 years. Yields and costs for wheat include site preparation, fertilizing/-

harvesting and threshing. In part, the costs are based on the number of man-days required to do each operation using a daily wage of Rs. 30.00. Yields for wheat and poplar at other spacings (2.5 m × 30m and 2.5 m × 50 m) were estimated using the data from Table 1. Since experimental data for AF systems in Pakistan is limited a significant amount of manipulation had to be made to derive certain figures. Details of these derivations are given by Khan (1989).

Table 1. Principal Data Sources

	Yield/ha		Annual Cost/ha (Rs)				Rev/m³ Poplar[4]	Rev/Kg[5] Wheat & Straw
	poplar with 10 yr rotation (m^3)	annual wheat (Kg)		Yr 1	Yr 2-3	Yr 4-10	(Rs)	(Rs)
Poplar Alone[1] 2.5 m x 2.5 m	456.8	—		6500	2500	500	700	
Wheat Alone[2]		2050		2762	2762	2762		2.20
Poplar and Wheat[3] 2.5 m x 10 m	122.6	1350	Poplar	2270	648	100	700	
			Wheat	2762	2762	2762		2.20

[1]Using Hussain and Sheikh (1981); [2]Using Jehangir (1986) and Sheikh et al. 1984; [3] Using Sheikh et al. (1984) [4]Using Ashraf and Akbar (1989); [5] Using Jehangir (1986).

Economic Analysis Application

As a *first step* economic analysis can be used to determine the best production option to apply to a hectare of land. Joint production economics has been suggested for analyzing agroforestry systems (Arnold, 1982; Hoekstra, 1985). In our case five possibilities exist: produce wheat alone, produce poplar alone or produce wheat and poplar together at popular avenue spacings of either 10 m, 30 m, or 50 m. Figure 1 shows these single and joint production possibilities. The net present values (NPV) shown in the figure were derived using a LOTUS 1-2-3 computer package. The planning horizon is 10 years, thus all revenue and cost values over the ten-year period were discounted using a single payment discounting formula. In this case 6% annual discount rate was used.[1]

As shown in Figure 1, the results indicate that the best present net value alternative for a single product would be producing poplar alone and the best joint production alternative would be to produce wheat and poplar together with a 10 m × 2.5 m spacing.

While these are the most efficient economic alternatives on a hectare basis selecting the best alternative(s) to apply to a typical farm situation requires consideration of additional constraints and requirements. For example, one must consider constraints dealing with family labor, budget and irrigation water and requirements for wheat and vegetables for family food, fodder for livestock and a minimum net annual income. Table 2 shows some of these constraints and requirements for a typical traditional small farm in Punjab Province.

The *second step* in the economic analysis involves determining what combination of the best alternatives selected in the first step are optimal considering these farm-level constraints and requirements. Linear programming (LP) is an appropriate economic analysis technique to use in agroforestry cases such as these (Verinumbe, Knipsheer & Enabor, 1984; Dykstra, 1984).

The linear programming formulation for this problem is shown in Table 3. The formulation was solved using the LINDO (1982) computer package to determine the best alternatives to use to maximize present net income while considering the additional constraints and requirments. In this case the optimal solution is: use 1/3 ha to produce wheat alone for food, use 2 ½ ha to produce wheat and poplar together for sale using a 2.5 m × 10 m spacing, use 1/10 ha for fodder and vegetables

[1]For example, using the values in Table 1 the present value for the revenue from producing poplar alone would be:

$$\frac{456.8\text{m}^3/\text{ha} \times 700 \text{ Rs/m}^3}{(1.06)^{10}} = \text{Rs. } 165,206/\text{ha}$$

and use the remaining land, approximately 2 ha, to produce poplar for sale. This allocation results in a total NPV of Rs. 443,265 over the ten year period.[2] Thus a combination of alternatives involving agricultural crops only, agroforestry, and forestry alone is best for the small farms.

Table 2, Typical Constraints and Requirements for a Small Irrigated Farm.

Constraints and Requirements	Amount of resources used or products produced (per ha): wheat only for sale	wheat only for food	wheat & polpar for sale	wheat & poplar for food	poplar only	fodder & vegetables	Total amount available or required
Irrigated Land [1] (ha)	1	1	1	1		1	3
Non-Irrigated Land (ha)					1		2
Budget [2] (Rs)	2762	2762	3159	3159		1409	25000
Family Labour [3] (man days)	37	37	41	41	2	40	624
Fodder and Veg.[4] (ha)						1	0.1
Family food, wheat [5] (kg)		2050		1350			800
Family net income [6] NPV (RS)	19178	23091	47180	23091	165206		150842

1. The farm totals 5ha, however there is only enough irrigation water using gravity flow to irrigate 3 ha.
2. These are the amounts required each year. A maximum of Rs. 25000 is available annually, in part from interest free government loans.
3. These values assume a family size of five with two members devoting 6 days a week, 52 weeks a year or a total of 624 man days per year.
4. Besides wheat and poplar the family is expected to grow vegetables for food and devote some land for fodder for feeding farm animals.
5. At least 800 Kg of wheat must be grown for food each year; any additional wheat will be sold to generate income.
6. Income is generated by selling wheat and/or poplar. At least Rs 1500 per month or Rs 18000 per year is necessary. The value, Rs 150842 represents the total amount in present value for a 10 year period. All present values were derived using a 6% discount rate.
7. The figures were derived using the references cited in Table 1 and the experience of the senior author working with small farmers in Punjab province.

Table 3. Linear Programming Formulation.

X_1 = ha of wheat only for sale
X_2 = ha of wheat only for family food
X_3 = ha of wheat and poplar (10 x 2.5 m) for sale
X_4 = ha of wheat and poplar (10 x 2.5 m) for food (wheat)
X_5 = ha of poplar only
X_6 = ha of fodder and vegetables

$$\max NPV = 19178\,x_1 - 23091\,x_2 + 47180\,x_3 - 23091\,x_4 + 165206\,x_5$$

Subject to:

$X_1 + X_2 + X_3 + X_4 + X_6 < 3$ ha of irrigated land
$X_5 < 2$ ha of non-irrigated land
$X_6 > .1$ ha of fodder and vegetables
$2050\,X_2 + 1350\,X_4 > 800$ Kg of wheat per year.
$19178\,X_1 - 23091\,X_2 + 47180\,X_3 - 23091\,X_4 + 165206\,X_5 > 150842$ Rs present value net income 10 yr.
$37X_1 + 37X_2 + 41X_3 + 41X_4 + 2X_5 + 40X_6 < 624$ man days of labor per year
$2762X_1 + 2762X_2 + 3159X_3 + 3159X_4 + 1409X_5 < 25000$ Rs annual budget

[2] Even if one ignores the NPV of the additional two ha in poplar plantations, the 3 irrigated ha involving wheat alone (⅓ ha) and wheat-poplar combination (2½ ha) has a present net value of Rs 112,694 compared to a NPV of Rs 40,323 for 3 ha in wheat alone. Thus, AF is still best from an economic standpoint even using only irrigated hectares.

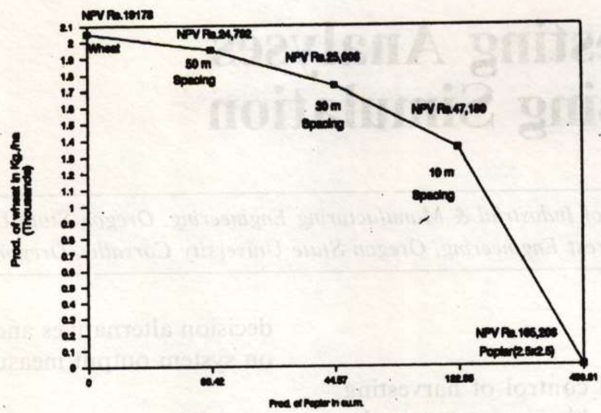

Figure 1. Single and joint production combinations for wheat and poplar.

Beyond the optimal allocation LP provides other information important to analyzing the problem. For example, everything else being the same, budget and labor are not constraining the solution (there is some amount unused), thus the farmer might consider using the unused amounts elsewhere. On the other hand, all the irrigated land is used.

Water which would allow an additional hectare to be irrigated is worth Rs 47,180 (present value) under this agricultural production scheme. Finally, the sensitivity analysis indicates a Rs. 28, 002 decrease in NPV/ha for wheat - poplar (2.5 m X 10 m) for sale might change the optimal solution. Thus, if the economic value or production figures are significantly lower than those used here the LP sensitivity analysis indicates we should reanalyze the problem with the new estimates. Additional economic information of this type is available from the LP sensitivity analysis.

Conclusions

The preliminary economic analysis here shows agroforestry practices should be part of a typical small farm operation in order for it to be most efficient from and economic perspective. This type of economic analysis is useful in demonstrating the potential of agroforestry systems and should be applied in other possibly more complex cases where additional tree species and agriculture crops are involved.

The economic analysis approach coupled with sound policy and extension activities should help promote acceptance of agroforestry options. The preliminary analysis here demonstrates the economic value of such practices and their potential to increase farm production and income.

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