More details/abstract: Agroforestry is an important category of agriculture that provides potential benefit to farmers, communities and society at large with a wide array of forest-related goods and services. In this study, we evaluated the selected multistrata agroforestry model in Northern Bangladesh, comparing to traditional monoculture. Research data were collected by the means of Focus Group Discussion (FGD), household structured interviews and indepth case study. Data were analyzed through quantitative economic methods and models. The results of present research indicate that multistrata agroforestry gives positive and much higher Net Present Value (NPV) than traditional monoculture in both scenarios with and without the inclusion of family labor costs (Tk. 1, 620, 331.73 and Tk. 1, 666, 425.79) and it is more profitable as well as less risky compared to other agricultural options.

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An Economic Evaluation of the Multistrata Agroforestry System in Northern Bangladesh

[1]S.A. Rahman, [2]K.M. Farhana, [3]A.H.M.M. Rahman and [4]A. Imtiaj

[1]Department of Sociology, [2]Institute of Bangladesh Studies,
[3]Department of Sociology, [4]Department of Botany,
University of Rajshahi, Rajshahi-6205, Bangladesh

Abstract: Agroforestry is an important category of agriculture that provides potential benefit to farmers, communities and society at large with a wide array of forest-related goods and services. In this study, we evaluated the selected multistrata agroforestry model in Northern Bangladesh, comparing to traditional monoculture. Research data were collected by the means of Focus Group Discussion (FGD), household structured interviews and indepth case study. Data were analyzed through quantitative economic methods and models. The results of present research indicate that multistrata agroforestry gives positive and much higher Net Present Value (NPV) than traditional monoculture in both scenarios with and without the inclusion of family labor costs (Tk. 1, 620, 331.73 and Tk. 1, 666, 425.79) and it is more profitable as well as less risky compared to other agricultural options.

Key words: Traditional monoculture · multistrata agroforestry · net present value

INTRODUCTION

Unsustainable exploitation of forest resources and deforestation, decreasing productivity and environmental degradation in the agricultural lands with multiple natural resource management problems are the major environmental challenges for Bangladesh. In recent years one of the most common proposed strategies for addressing environmental degradation in rural areas of the tropics is agroforestry. It is an agricultural practice that spans centuries, one that has been used by many indigenous peoples as a traditional land use option, providing sustainability for early agriculturists while preserving forest resources and biodiversity. These early forms of agroforestry have since evolved to be a dynamic ecologically based, institutionalized natural resources management system, broadly defined as the integration of trees on farms or agricultural landscapes. Agroforestry diversifies and intensifies production; both for subsistence and cash, while maintaining forest cover and associated biodiversity [1].

The local farmers in northern Bangladesh have practiced traditional monoculture for decades and depend on it for their livelihood. Regardless of opinions on the merits or demerits of traditional cultivation, some farmers have recognized the need for modifying the traditional farming practices and the value of conserving soil resources for economic growth and poverty reduction. Some alternative farming technologies (e.g., fruit gardening, alley cropping, multipurpose home gardens) have been introduced in northern Bangladesh. Multistrata agroforestry system is one of the most important and modern cultivation practices of these farming technologies. Because, it can potentially deliver a sequence of environmental, economic and social benefits and this system is taken as the point of concentration of the present study.

MATERIALS AND METHODS

This research focused on Capasia village of Paba Upazila (Upazila is a small administrative unit) under Rajshahi District in Northern Bangladesh. More exactly study area is lies between 24°25″ to 24°20″ north latitudes and between 88°40″ to 88°45″ east longitudes. More information about study area is presented in Table 1.

Research methods used were (1) structured interviews of 60 households and 6 in-depth case study

Corresponding Author: Dr. S.A. Rahman, Research Fellow, Department of Sociology, University of Rajshahi, Rajshahi-6205, Bangladesh

Table 1: Hydrometeorological characteristics of the study site

Climate	Tropical monsoon
Mean temperature	Maximum 32°C~36°C
	Minimum 07°C~16°C
Average humidity	Dry season 45~71 percent
	Rainy season-84~92 percent
Average rainfall	1,448 mm
Topography	Flood plain
Soil condition	Loamy
Average elevation	60 ft

focused especially on experiences and capacities; actual and envisaged costs and benefits of Multistrata Agroforestry (MA) and traditional monoculture/ traditional agriculture (TM/TA), (2) Focus Group Discussion (FGD) and observation were also carried out in order to determine actual species combinations and envisaged costs and benefits of both types of land use. Other data were gathered by way of interviews with key informants (Government, non-government and public organizations) and market prospecting. The secondary data are used from statistical yearbooks, local administrative and various related sources. Research data were collected from the period of May to October, 2006.

For many elements of the study (the model of MA, actual and envisaged cost and benefit etc.), semi-quantitative analysis was carried out by the use of econometric techniques, especially cost-benefit analysis of MA and TM at the household level. The Net Present Value (NPV), Internal Rate of Return (IRR), benefit-cost ratio (B/C) and pay back period of MA and TM were calculated and compared. The NPV determines the present value of net benefits by discounting the streams of benefits and costs back to the beginning of the base year.

The NPV is calculated by the following formula:

$$NPV=\sum_{t=1}^{n}\frac{(B_t-C_t)}{(1+r)^t}$$

Where,

B_t: Benefits of production by a cultivation practice

C_t: Costs of production by a cultivation practice

t: Year time

r: Discount rate

The IRR is equal to the discount rate (r) that brings the NPV down to zero. An investment is considered financially attractive if the IRR is higher than the opportunity cost of project finance (i.e. what one would pay to the bank for borrowing the investment capital). Following the definition, IRR is obtained by solving the equation:

$$\sum_{t=0}^{n}\frac{B_t-C_t}{(1+r)^t}=0$$

The B/C compares the discounted benefits to discounted costs. A B/C of greater than 1 means the project is profitable, whilst a B/C of less than 1 means the project generates losses. The B/C is calculated as follows:

$$\frac{B}{C}=\frac{\sum_{t=0}^{n}\frac{B}{(1+r)}}{\sum_{t=0}^{n}\frac{C_t}{(1+r)^t}}$$

The pay back period measures the number of years it will take for the undiscounted net benefits to repay the investment. An investment can be acceptable only if its benefits can offset all investment costs within a limited arbitrary period.

The sensitivity analysis was also carried out to study the effects of the change in mutable factors such as input and output prices, yields of products and discount rate on farmers' benefit. In sensitivity analysis the results of economic analysis are checked by considering the effects of changes in the value of key variables.

Multistrata Agroforestry Systems (MAS): The term “multistrata” describes Agroforestry Systems (AS) that incorporate combinations of woody plants, such as timber and/or fruit trees, along Common Agricultural Crops (CAC), in a same area and at the same time, so that multiple layers of vegetation form. Crops are usually the dominant product while the trees get established and grow [2]. MAS can be very labor and knowledge intensive and thus can require both commitment on the part of the farmer and good initial training and technical support. Table 2 adds further description of Multistrata Systems (MS) along with other common AS.

Thus, with reference to Table 2, the AS examined in this paper correspond to the last two multistrata categories, multi-purpose trees of croplands and plantation crop combinations.

Table 2: Attributes of select agroforestry systems (adapted from Nair, 1989)

Agroforestry system	Description	Components (W and H)	Primary role of woody components	Agro-ecological adaptability
Improved or enriched fallow	W planted and left to grow during the "fallow phase"	W: fast growing and preferable leguminous H: CAC	Pt: soil fertility and stability Pd: wood products	In shifting cultivation areas
Taungya	Combined stand of W and A during early stages of establishment of plantations	W: usually F plantation, i.e. (*Swietenia* sp.) H: CAC	Pd: additional income from F	In most ecological regions; several improvements possible
Multi-layer tree gardens (multi-strata)	Areas with fertile soils, dense plant associations	Multi-species, multi-layer, form H: usually absent	W: different W of varying efficient nutrient cycling Pd: various	Pt: soil conservation; good availability of labour, and high human population pressure
Multi-purpose trees of crop lands (multi-strata)	Trees scattered or arranged according to some pattern within boundaries	W: multi-purpose trees and other fruit trees H: CAC	Pt: fencing, social values, plot demarcation Pd: various tree products	In all ecological regions, especially in subsistence farming. Sometimes integrated with animals
Plantation crop combinations (multi-strata)	Integrated multi-story mixtures of plantation crops, arranged in some pattern, with possibly some shade trees and other crops	W: combined crops (coffee, coconut or other fruit trees or F) H: CAC present, especially with intercropping arrangements	Pt: shade, windbreak, soil protection Pd: large number of products	In humid, sub-humid regions (depending on adaptability of plantation crops); usually in smallholder subsistence system

A: Agricultural species, F: Forest species, H:herbaceous species, W: woody species, Pt: Protective, Pd: Productive CAC: Common agricultural crops,

Selected agroforestry model in the study site: The MAS in the study area is chosen since it is an important agroforestry model that is appropriate for the cultivation fields and mostly popular and widely accepted by traditional cultivators. The litchi (*Litchi chinensis)* is planted as a multipurpose tree species in this model. Crop species, i.e., ginger (*Zingiber officinales*), turmeric (*Curcuma domestica*), brinjal (*Solanum melongena),* lemon (*Citrus limonum*), papaya (*Carica papaya)* and banana (*Musa* sp.) are intercropped with litchi as crop species. In spite of the very small average size of the management units, MAS is characterized by high species diversity and usually 3-4 vertical canopy strata, which result in intimate plant associations. The lower strata is usually be partitioned into two, with the lowermost (less than 1 m height) dominated by brinjal, ginger and turmeric; the second strata (1-3 m height) is composed by banana, papaya and lemon. The upper stratum is dominated by litchi, which is continuing to grow taller. The layered structure is never static; the pool of replacement species results in a productive structure, which is always dynamic while the overall structure and function of the system are maintained. Brinjal, papaya and banana are intercropped in the beginning years (first 4 years). Lemon is cultivated for the first 6 years. After that time the shade-tolerant ginger and turmeric are commonly planted under litchi trees with the purpose of income generation and rational utilization of sunlight and improvement of soil protection and erosion control.

Economic analysis of MA and TA: The analysis of collected data is to estimate the costs and benefits from MA and TA. The actual estimation of MA and TA vary widely and depend upon site conditions as well as on many factors such as tree spacing, maintenance techniques and the rate of growth of trees. For the analysis, all values are based on August 2006 prices, which are held constant throughout the term of the analysis. Analysis is given consistently on a taka/acre basis where US$ 1 = 68 taka.

Table 3: Assumptions of Multistrata Agroforestry (MA) and Traditional Monoculture (TM)

Operation	Year	Approximate worth (Taka/acre) MA	TM	Comments
Establishment cost	-	40,000.00	30,000.00	This cost is required at the 1st year of MA and TM
Labor cost	1-10	4,000.00	1,500.00	Average yearly labor costs including weeding, thinning, pruning, harvesting, protection etc.
	11-30	5,000.00	1,500.00	For A, year 11 to 30 litchi gives high yields, which required high protection and harvesting cost
Pesticide cost	1-30	-	300.00	Pesticide is only used for M and it is a common picture of study area
Fertilizer cost	1-6	6,000.00	3,000.00	For A: during the time period tree species growing up, it
	7-10	5,000.00	3,000.00	provides nutrients so fertilizer is gradually less used Irrigation
	11-30	3,000.00	3,000.00	Irrigation cost of A is high because of on farm species
	1-30	15,000.00	3,500.00	diversity and shortening fallow period
Yields				
Rice and wheat	1-30	-	45,000.00	All costs are calculated average yearly basis
Brinjal	1-4	8,000.00		
Papaya	1-4	50,000.00		
Banana	1-4	30,000.00		
Lemon	1st	15,000.00		
	2nd	45,000.00		
	3-6	1,00,000.00	-	
Ginger and turmeric	7-30	60,000.00		
Litchi	4-6	30,000.00		
	7-10	50,000.00		
	11-30	2,50,000.00		

US$ 1= Taka 68.00 as of August 2006, MA: Multistrata agroforestry and TM: Traditional monoculture

Assumptions

Land: The real estate market is underdeveloped in the study area, especially for land under traditional cultivation. Therefore, the price of land is difficult to identify. However, as mentioned in [3], there is no need to value the land if farmers want to change existing land use to agroforestry because it would be canceled out in a "with" and "without" comparison. Thus, for simplicity and with the assumption that the value of land is the same and does not change over time for both cultivation practices, it is neglected from the calculation.

Establishment cost: Establishment cost involves land preparation, seedlings, planting etc. Costs for preparation vary greatly depending on the condition of the site. The farmers in the study area purchased seeds and seedlings from private or state sources and price ranges vary depending on species and quantity grown. The average establishment cost is tk. 40,000.00 for MA and tk. 30,000.00 for TM per acre (Table 3).

Labor: Family labor is mainly used for farm work in the study site. Yet, hired laborers are also accepted in the area. However, family labor is not cash expenditure from the farmer's perspective. Therefore, all calculations will be carried out for two variants: with and without inclusion of family labor in the production costs. The scenarios with the exclusion of family labor costs seem more meaningful for poor farmers. The labor cost in the study area is tk. 100/workday, which is the common price in this region.

Pesticide and fertilizer: Pesticide and fertilizer are often used for enhance the farm production. The average cost of pesticide and fertilizer of TM is same from beginning to last year. But, for MA the fertilizer is gradually less used, because the tree species can provide nutrients for understory crops. On the other hand the usually pesticide is not used for MA and it is common picture of the study area.

Irrigation: Irrigation is essential during the dry season. In the study area average yearly irrigation cost is calculated 15,000.00 for MA and 3,500.00 for TM.

Discount rate: The analysis is carried out from the farmer's perspective, thus the discount rate applied here is not social, but individual. It can be referred to as the opportunity cost of capital for farmers, which is closely related to the financial interest rate. Therefore, the real discount rate of 10% can be obtained by deducting the inflation rate of 4% from the average nominal interest rate of the loans for agricultural production (14%) in the banking system. However, to have a better look at the problem, a Sensitivity Analysis (SA) will be carried out for a range of different discount rates.

Yields: For calculation of yields, two common and popular cash earning crops (rice and wheat) are considered for TA and for MA litchi, ginger, turmeric, brinjal, lemon, papaya and banana are considered. Yields of litchi are calculated under three categories, 1) fourth to sixth year low yields, 2) seventh to tenth year medium yields, 3) eleventh to thirtieth year high yields.

Time horizon for analysis: Once forest trees are included in the AS, its life can be considered infinite. However, the productive life of the model is 30 years and it is also taken as the time horizon for present analysis.

RESULTS

Research data indicates that MA is more beneficial than TM. The financial picture of the two options shows that, from initial year, the return from MA gradually increases but the average return of TM is constant (Fig. 1). The average yearly income of MA is tk. 2, 27, 300.00 substantially higher than TA (Table 4).

The calculations of NPV, IRR, B/C and payback period of TM and MA systems are illustrated in Table 5. In both scenarios with and without the inclusion of family labor costs, the MAS gives positive and much higher NPVs than TM. The B/C of MA is more than twice that of TM in the both scenario with and without the inclusion of family labor costs. Moreover, the IRR of MA is also high, so the calculation clearly shows that MA is more attractive, as it provides a higher yearly net cash flow than TM.

Sensitivity Analysis (SA): Prices can fluctuate significantly over a long time period, especially if overall output increases due to increases in TA or MA adoption, thus reducing the farmer's benefits. Farmer's benefits are also reduced if the opportunity costs of resource use increases. Therefore, SA is considered for the reduction of yields and increase in discount rate. All SA is shown in Table 6 and 7.

In relation to discount rate, the NPV of AS are positive and higher than NPV of TM with the rate up to 100% for both scenarios with and without the

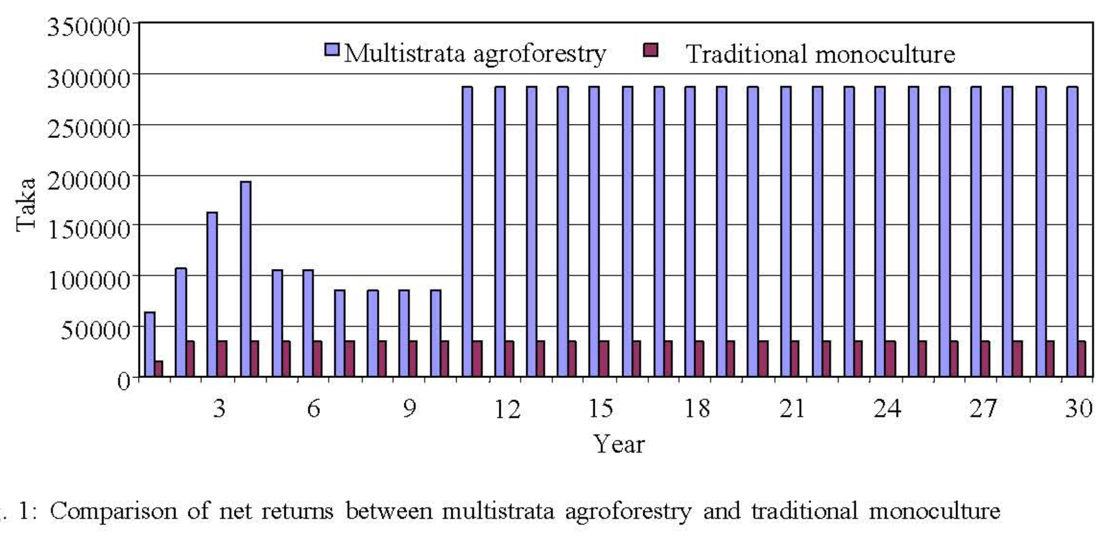

Fig. 1: Comparison of net returns between multistrata agroforestry and traditional monoculture

Table 4: Income of multistrata agroforestry (MA) and Traditional Monoculture (TM)

Indicators	MA	TM
Mean	2,27,300.00	34,333.33
Median	2,87,000.00	35,000.00
Std. Deviation	88,622.08	3,651.48
Minimum	63,000	15,000
Maximum	2,87,000	35,000

Taka/acre

Table 5: Financial results of Multistrata Agroforestry (MA) and Traditional Monoculture (TM)

	Costs including family labor		Costs excluding family labor	
Method	MA	TM	MA	TM
NPV (at 10%) (taka)	1,620,331.73	311,760.19	1,666,425.79	331,809.65
IRR (at 10%)	208%	86%	289%	131%
B/C	7.70	3.77	9.51	4.59
Payback period	1 year	2 years	1 year	1 year

Taka/acre

Table 6: Sensitivity analysis of traditional monoculture

Sensitivity to yield decrease		Sensitivity to change in discount rate	
Decrease in yields	NPV	Discount rate	NPV
Including family labor costs			
0%	311,760.19	5%	518,988.17
1%	308,642.59	10%	311,760.19
2%	305,524.98	20%	157,596.11
3%	302,407.38	30%	101,237.52
4%	299,289.78	40%	73,210.67
5%	296,172.18	50%	56,666.30
6%	293,054.58	60%	45,833.29
7%	289,936.97	70%	38,235.29
8%	286,819.37	80%	32,638.89
9%	283,701.77	90%	28,362.57
10%	280,584.17	100%	25,000.00
Excluding family labor costs			
0%	331,809.65	5%	548,237.32
1%	328,491.55	10%	331,809.65
2%	325,173.46	20%	170,481.18
3%	321,855.36	30%	111,235.61
4%	318,537.26	40%	81,603.37
5%	315,219.17	50%	63,999.62
6%	311,901.07	60%	52,395.79
7%	308,582.98	70%	44,201.67
8%	305,264.88	80%	38,125.00
9%	301,946.78	90%	33,450.29
10%	298,628.69	100%	29,750.00

NPV: Net present value

Table 7: Sensitivity analysis of multistrata agroforestry

Sensitivity to yield decrease		Sensitivity to change in discount rate	
Decrease in yields	NPV	Discount rate	NPV
Including family labor costs			
0%	1,620,331.73	5%	3,040,189.00
1%	1,604,128.41	10%	1,620,331.73
2%	1,587,925.09	20%	692,125.30
3%	1,571,721.78	30%	411,577.43
4%	1,555,518.46	40%	288,989.30
5%	1,539,315.14	50%	221,463.37
6%	1,523,111.82	60%	178,625.80
7%	1,506,908.51	70%	148,946.35
8%	1,490,705.19	80%	127,158.10
9%	1,474,501.87	90%	110,504.51
10%	1,458,298.56	100%	97,391.11
Excluding family labor costs			
0%	1,666,425.79	5%	3,114,459.13
1%	1,649,761.53	10%	1,666,425.79
2%	1,633,097.27	20%	717,692.92
3%	1,616,433.01	30%	429,705.78
4%	1,599,768.75	40%	303,336.23
5%	1,583,104.50	50%	233,486.44
6%	1,566,440.24	60%	189,051.93
7%	1,549,775.98	70%	158,194.21
8%	1,533,111.72	80%	135,493.38
9%	1,516,447.46	90%	118,107.81
10%	1,499,783.21	100%	104,391.60

NPV: Net present value

inclusion of family labor costs. Normally, the discount rate is not likely to go up this high and hence, MAS are generally more profitable than TM. In the case of decrease in yields of annual crops, the NPV of AS are also found to always be positive and higher than TM. The diversification of planted species contributes to the reduction of the risk of output losses for AS.

DISCUSSION

Derived from above results, it is clear that MA is financially more benefited than TM. Experimental evidence supporting claims of beneficial effects of MA is provided by a number of studies. Research [4] conducted in Dinajpur, Bangladesh indicated the NPV of agroforestry is positive under all three situations i.e., forest department situation, participant situation and whole situation of AS. The B/C ratios stand at 1.43, 2.21 and 1.95, respectively in all situations. The IRR under the above three situations are 21%, 250% and 42%, respectively. Cashew plantations established at central Tamil Nadu, India under an AS also showed comparable financial results giving B/C ratio of 1.65 and IRR of 40.83% [5]. The cost and benefit of AS in

Hawaii is financially viable and less risky than TA and forestry [6].

Agroforestry is not only economically promising but also environmentally sound. Inside agroforestry both tree and crop species play a critical role for agroclimate. It can improve soil fertility by providing nutrients, conserve water, improve soil moisture and protect from erosion as well as improving biodiversity [7]. AS is most extensive in developing countries where approximately 1.2 billion poor people depend directly on a variety of agroforestry products and services [8]. In the five sub-Sahara African case studies in [9], agroforestry is shown to have potential to increase farm incomes and solve difficult environmental problems. It is financially more profitable to local farmers in comparison with traditional cultivation, beside its other economic and social benefits. Thus, it can be a potential alternative cultivation practice that helps to enhance poverty reduction and transition to permanent cultivation [10].

CONCLUSION

MA exemplify many agroforestry characteristics, i.e., the intimate mix of diversified agricultural crops and multipurpose trees fulfill most of the basic needs of traditional cultivators and local population while the multistoried configuration and high species diversity help to produce sustained yields in a most resource-efficient way. Some traditional farmers in Northern Bangladesh are practicing MA that is well organized, ecologically sound and could provide high yields. In the farmer's own perspective, the cost-benefit analysis shows that MAS is more profitable and less risky than TM. On the other hand, TM becomes increasingly unsustainable due to the population growth and the loss of environmental conservation methods, which drives farmers into a vicious cycle of poverty and may deteriorate the social and economic life as well. However MAS requires comparatively higher investment in the beginning years. Whilst, the assessment of MAS is underestimated since some of environmental benefits are not quantifiable due to the lack of available technical data.

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