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Valuation of Tangible Benefits of a Homestead Agoforestry System: A Case Study from Bangladesh

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Introduction

Homegardens (*syn.* homestead agroforestry, homestead forest, village forest) are a longstanding landuse practice prevalent in rural areas throughout Bangladesh. They are characterized by multi-storied vegetation of trees, bamboos, palms, shrubs, and herbs, both spontaneous and cultivated around living quarters. The same or slightly modified forms of such landuse occur in many tropical and subtropical regions, such as Indonesia (Christanty *et al.* 1986), Tanzania (Soini 2005), and West Africa (Kumar and Nair 2004). Homegardens are established and maintained for household consumption, additional household income through the sale of produce, and environmental services (e.g., controlling the microclimate of the homestead). A number of accounts describe the structure, composition, and biodiversity of homegardens in various parts of the world (Millat-e-Mustafa *et al.* 1996; Abebe 2005; Acharya 2006; Peyre *et al.* 2006; Fernandes *et al.* 1984; Kabir and Webb 2008). But there is also a need for an inventory of the products and costs associated with these systems. Furthermore, the environmental, social, cultural and non-market benefits provided by homegardens such as biodiversity conservation, carbon sequestration, aesthetics, microclimate improvement, and wildlife habitat provision are assumed to be valuable outputs, but no quantified data are available to support this hypothesis (Mohan 2004). Although some studies[1] have addressed the subsistence income provided by the homegardens, very few attempts have been made to quantify detailed tangible benefits and environmental services provided by these systems. Mohan (2004), and Mohan *et al.* (2006) in their study on assessment of ecological and socioeconomic benefits provided by homegardens, attempted a financial analysis for a typical homegarden year in Kerala, India. Babulo *et al.* (2008) analyzed the role and significance of forest environmental products in rural household income and examined the impact on poverty and inequality estimates in the rural economy in northern Ethiopia. However, as noted by Mohan *et al.* (2006), the lack of studies quantifying the economic value of homegardens is due to three main reasons: first, these systems have high and variable levels of biodiversity that makes data collection time-intensive and error-prone; second, these systems provide some benefits that are designed to be of particular use to certain farmers only; and third, these are established systems, some of which have existed for many hundreds of years, and the benefits realized in the past may not be accurately quantified because of inadequate availability of data.

This study is a part of an ethnobotanical research project, the goal of which is to analyze and quantify the benefits and total financial worth of homegarden systems in Bangladesh. The total economic value (TEV) of homegardens is the

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[1] See, for example, Rahman *et al.'s* (2005) study of homestead forest resources and their role in household economy in Bangladesh which reported that the average annual value of gross production of homestead forest was US$228.2 per household, of which US$89.2 (39.1 %) was used by the household and US$138.9 (60.9 %) was sold and the overall contribution of homestead forest income to average household income was 11.8 %. Also in Indonesia Soemarwoto (1987) found that income from homestead forests ranged from 6.6–55.7 % of the total income from homesteads, with an average of 21.1 %, depending on the homestead size and species composition.

summation of the use and non-use values including direct use values (e.g., fruit, fuel, timber), indirect use values (e.g., soil conservation), option values (e.g., biodiversity), existence values (e.g., endangered species), and bequest values (e.g., habitat) (FEE 2002; Pagiola *et al.* 2004). However, here I attempt to quantify the tangible benefits derived from tree-based products. The study also investigated the factors influencing annual output and established relationships among variables related to input, output, and income.

Research Methods

The primary function of rural homegardens is production of multiple use products for subsistence. A second important function is generation of cash income and most of this income is derived from tree-based resources (Kehlenbeck 2007). Collection of a broad spectrum of products including fruits, spices, timber, construction materials, fodder, fuel, medicines, vegetables, and so on are reported in the literature. But here I hypothesize that households most frequently harvest four tree-based resources to meet these primary and secondary functions: fruit, fuel, timber, and bamboo. Though bamboo is not a tree-based product, it is included since it is consumed as a substitute of timber in rural areas throughout Bangladesh in large quantities. The financial value of fodder was not accounted for due to the difficulty determining the amount consumed by livestock and because it is not traded.

The estimation of monetary value of these tree-based products was complicated since they were both consumed by the household as well as sold in the market for cash income. The amounts the farmers received from selling the products in the market were noted. In cases where they were unable to recall the exact amount, the estimated units sold were multiplied by a predetermined market price. The values of the outputs consumed in the previous year were estimated by multiplying the units consumed by the existing market price of that product.

To calculate the net tangible benefit (NTB)[2] per annum, production costs in the form of various farm inputs including labor, planting materials, fencing, fertilizer and pesticide application, transportation, and contingencies, were also taken into account. Labor inputs were provided both from the household and hired labor. Hired labor cost was easy to calculate. However, household labor cost was more difficult to estimate because there was no organized labor market and alternative opportunities were also limited. We thus calculate total incurred cost both with- and without including household labor.

A number of methodological challenges were identified that limited a full analysis of the production potential of homegardens:

- Parts of some garden lands are fallowed; hence in the calculation of per hectare production the potential is underestimated.
- Trees are felled and sold as "whole tree," so the amount harvested and sold was not calculated in standard units (e.g. cubic feet).
- The amount of fruits (in kilograms) consumed in the last year could not be calculated since they are not weighed before they are eaten. In addition, some fruits (e.g., coconuts) are sold individually, making conversion into kilograms difficult.
- It is difficult to assess the market value of some "direct use value" products harvested from homegardens, e.g., fodder, medicinal plants, and fuel wood.
- It is difficult to recall and estimate the labor input (which is further divided into family and hired labor) for the application of fertilizers, pesticides, and fungicides, although the amounts used can be easily calculated. Some inputs, e.g., fencing and cowdung, are provided from homestead sources and it is difficult to estimate the cost involved.

The study area is Porsha *thana* (sub-district) in Naogaon district situated in the northwestern region of Bangladesh and located between 24°54′ and 25°06′ north latitudes and between 88°24′ and 88°39′ east longitudes. Agroecologically, it belongs to High Barind Tract (Agroecological Zone-26) (FAO 1988), which is the largest Pleistocene physiographic unit of the Bengal Basin covering an area of about 7,770 sq km. It has long been recognized as a unit of old alluvium, which differs from the surrounding flood plains.

To collect survey data, three villages were selected randomly from the sub-district. Using the holding tax registers and information gathered during an exploratory phase, 32 households were selected from each of the three villages. Households were classified, following the criteria of BBS (2003), into four landholding size classes, namely marginal (<0.4 ha), small (0.41–1.01 ha), medium (1.02–3.03 ha), and large (3.03 ha). A structured questionnaire was supplied to the respondents which included questions related to socioeconomic characteristics of the respondents as well as other household members, land-use characteristics and species composition in the homestead agroforestry systems. For financial analysis both farm input and output data were solicited. Respondents were asked to give an estimate of the products that are both consumed within family and sold in the market. Prices of all products including a wide range of fruit varieties were obtained

[2] Net Tangible Benefits (NTB) here refers to provisioning services (use values) within the framework of the concept of TEV mentioned above.

Table 1 Socio-economic and landuse profile of sample households in the northwest Bangladesh

LSC	Total farm size (ha)	Homestead area (ha)	Land available for homegarden		Family Schooling (yr)	HH head schooling (yr)	Annual family income (US$)	Family member		
			Area (ha)	%				Total	Male	Female
Marginal	0.15	0.05	0.02	40	14.29	2.54	533.93	5.04	2.71	2.33
Small	0.85	0.15	0.08	53	20.63	7.04	1173.21	4.50	2.29	2.21
Medium	2.70	0.41	0.13	32	28.13	8.75	1464.16	5.29	3.00	2.33
Large	28.04	0.85	0.25	29	37.96	9.21	2786.92	6.75	3.88	2.83
Overall	7.94	0.37	0.12	32	25.25	6.89	1489.56	5.4	2.97	2.43

LSC landholding size class, *HH* household

through market survey. Family labor as farm input was obtained through amount of time in a day spent in agro-forestry farming. The collected survey data were fed into statistical packages for analysis. The analyzed results were presented as descriptive statistics in tables and diagrams. Pearson's correlation coefficients were calculated to establish relationships among variables related to production.

Results

Socioeconomic and Landuse Characteristics

Landuse profile of the sample households of four landholding size classes (LSC) is presented in Table 1. Average farm size, including agricultural land, for all sample households was 7.94 ha, although this high average value did not reflect the real landowning situation since large LSC had average farm size of over 28 ha. In contrast, marginal, small and medium LSCs had average farm sizes of 0.15 ha, 0.85 ha and 2.70 ha respectively. Homestead land area, which includes the living quarters and homegarden resources, was smallest (0.05 ha) for marginal LSCs and largest (0.85 ha) for large LSCs. Existing as well as potential land available in the homesteads to be allocated for homegardens in marginal, small, medium and large farm categories were 0.02 ha, 0.08 ha, 0.13 ha and 0.25 ha respectively and these were 40 %, 53 %, 32 % and 29 % of the total homestead land areas respectively.

The overall average family size of the sample households was 5.40 (Table 1). The average family size of marginal and small landholding classes were 5.04 and 4.50 while that of medium and large classes were 5.29 and 6.75. The average amount of education for the household heads was 6.8 years, while the average family schooling was 25.2 years. The average annual family income was US$1489 - highest in the large homesteads (US$ 2786) and lowest in the marginal homesteads (US$ 533).

Quantified Benefits and Costs

Table 2 shows the monetary value of production, consumption and sale of four tree-based products across the farm

Table 2 Market value (in US$) of various homegardens products harvested in one year

		Marginal	Small	Medium	Large	Overall
Fruit	HC	18.9	13.2	38.6	25.6	24.1
	CS	36.3	27.0	75.8	99.0	59.5
	Total	55.2	40.2	114.4	124.6	83.6
Timber	HC	5.0	5.4	10.6	15.5	9.1
	CS	14.9	27.0	26.5	40.3	27.2
	Total	19.8	32.4	37.1	55.8	36.3
Fuel	HC	35.3	60.9	62.4	67.3	56.4
	CS	8.0	18.1	12.9	22.7	15.4
	Total	43.2	79.0	75.3	90.0	71.9
Bamboo	HC	10.6	24.9	32.4	38.8	26.6
	CS	27.7	28.0	26.0	25.6	26.8
	Total	38.2	52.9	58.4	64.4	53.5

HC homestead consumption, *CS*, sold for cash; (1 US$=68.5 TK)

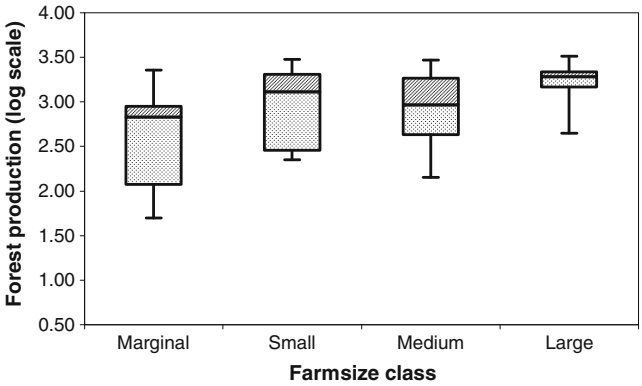

Fig. 1 Box and whisker plot for homegarden production across farm size classes (log scale)

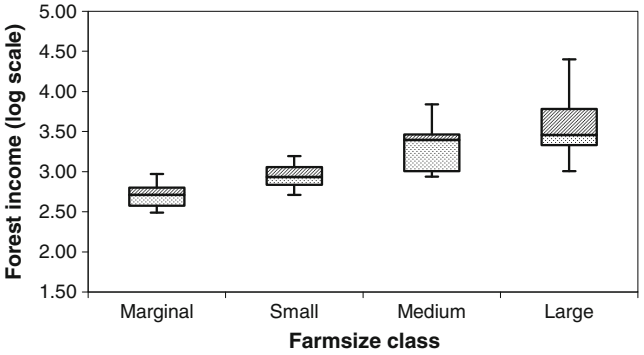

Fig. 2 Box and whisker plot for homegardens income across farm size classes (log scale)

classes. The market price of all products (i.e., timber, fruit, fuel, and bamboo) produced over a year in the homegardens of the study area was US$285.2. This amount included the price of the products sold in the market plus market price of family consumption. The greatest amount of products was harvested on large farms (US$334.8 farm^{-1} year^{-1}) while the lowest on marginal farms (US$156.4 farm^{-1} year^{-1}). Itemized annual production per homestead, converted to existing market price per homestead for timber, fruit, fuel, and bamboo, were US$36.3, US$83.6, US$71.9, and US$53.5 respectively.

The study findings showed that 0.14 m^3 timber was collected annually per farm out of which 0.04 m^3 was consumed and the rest was sold in the local market. Average revenue generated from selling homestead timber was US $27.2 (@ unit price US$258.75/m^3). Highest revenue was generated in the large farms (US$40.3) with the lowest in the marginal farms (US$14.9). Small and medium landholdings generated similar revenue of US$27 and US$26.5 respectively. Furthermore, 386.7 kg fruit was collected per year per farm, out of which 125.9 kg was consumed by the household and relatives and the rest was sold in the market for cash. Most frequently harvested fruits included mango, jackfruit, coconut and jujube. Both production and sales increased with the increase of landholding size. Average revenue generated form selling fruits was US$59.5 at average selling price of US$0.19/kg. Revenue generated in marginal, small, medium and large farms were US$36.3, US$27.0, US$75.8, and US$99.0 respectively. Annual collection of fuel per farm from homegardens was 71.8 *mounds* (1 mound=approx. 35 kg), out of which 54.0 *mounds* were consumed and the rest was sold. Unit price of sold fuelwood was US$0.84 and annual revenue generated from selling fuelwood per household was US$14.8. Fifty-three bamboos, on average, were collected annually per farm out of which about half was consumed and the rest was sold for cash. The market price of bamboos sold highly depended on the maturity, height, and girth and ranged between US$0.75 and US $1.2 per piece; average revenue earned by selling bamboos was US$6.8 per farm annually, which was highest in small farms (US$28.0) and lowest in large farms (US$25.6).

Table 3 presents the results of analysis of costs, benefits and per hectare net tangible benefits produced by homegardens. The annual production cost per homestead was US $35.5 without incorporating family labor as cost item; otherwise the cost would be more than doubled. The annual net tangible benefit (NTB) per homestead with- and without considering family labor was US$198.0 and US$249.7 respectively. The calculated value of annual tangible production per hectare was US$535.2 with and US$674.9 without family labor cost.

Table 3 Quantified benefits and costs of homegardens across the LSCs

LSC	Benefit (US$)	Cost (US$)		NTB (US$)		NTB/ha (US$)	
		With FL	Without FL	With FL	Without FL	With FL	Without FL
Marginal	156.4	48.2	13.2	108.2	143.2	2164.0	2864.8
Small	204.5	77.9	21.8	126.6	182.7	844.1	1217.8
Medium	285.2	90.9	41.8	194.3	243.4	474.0	593.7
Large	334.8	132.7	66.1	202.1	268.7	237.8	316.1
Overall	285.2	87.2	35.5	198.0	249.7	535.2	674.9

Field survey 2008; *NTB* net tangible benefit, *FL* family labor

The annual homegardens production and income were compared across different farm size categories. Figures 1 and 2 show vertical Box and Whisker plots for log transformed values of production and income per farm respectively. The figures indicate that both mean and median values of income increased with the increase of farm size classes and a similar trend was found in the case of forest production, except in medium farm category. However, standard deviation decreased with increasing farm size. These results suggest that both production and income per farm increase with the increase of farm size in the sampled households.

Factors Influencing Production

Results of paired correlation analysis (Pearson's coefficients) to investigate the direction and strength of the relationships between variables related to homegardens and its outputs are presented in Table 4. Annual production was relatively strongly correlated to the size of the homegardens (r=0.42). This correlation was statistically significant at the 0.01 level. Other statistically significant correlations were observed between production and introduction of new species (r=0.21, $p<0.05$), forest production and family education (r=0.31, $p<0.05$), size of forest land and new species introduction (r=0.27, $p<0.01$), family education and forest size (r=0.31, $p<0.05$), and number of male family members and forest size (r=0.26, $p<0.05$). According to Fowler *et al.* (2001) such correlations, though they seem weak, are significant.

Discussion and Conclusions

A homegarden is typically situated on slightly raised land and consists of living quarters, a separate kitchen, cattle shed, small vegetable garden, inner and outer courtyards and a pond. Presence or absence of any component in a particular homestead under consideration depends on the available homestead space and household wealth. Spatial distribution of these components varies from one homestead to another, but it is common practice that a vegetable garden is planted around the kitchen and tended by female household members. Sometimes vegetables are grown on a relatively larger scale in the outer courtyard also. The cattle shed is usually situated near the living quarters so that household members can watch them at night. The analysis of land allocation for homegardens showed a tendency of decreasing the percentage of existing and potential land for homegardens with increasing farm size. Thus smaller farms allocated a larger portion of their homestead land for forestry practices than the larger farms in order to maximize the utilization of the limited land they owned. The wealthier large farmers, in contrast, kept more vacant spaces in their inner and outer yards for the purposes of aesthetics, recreation, free movement, and post-harvest agricultural tasks.

The field data showed that a large amount of homegarden revenue (US$71.9) came from fuel wood harvesting. The reason was that wood fuel is the only source of energy for cooking food three times a day. This was the only homegarden product that was collected throughout the year. Similar findings have been reported from northern Ethiopia where a major share of homegarden income is accounted for by the domestic use value of firewood (45 % of the total homegarden products' value) (Babulo *et al.* 2008). Consumption of fuelwood is directly related to the number of members in the household and this is why larger farms with large households collected and consumed a greater amount of fuelwood. Because of the energy crisis in rural Bangladesh, households usually consume almost all of the fuelwood they collect and a very small amount is sold in the market (Alam 2011). The annual production of homestead timber gradually increased

Table 4 Results of Pearson coefficients (r) from the paired correlation analysis between variables

	Annual forest production	Homegarden size	Introduction of new species	Education of the farmholder	Total family education	Female family members	Male family members
Annual homegarden production	-	0.424** (0.000)	0.214* (0.036)	0.191 (0.062)	0.311** (0.002)	0.108 (0.294)	0.14 (0.173)
Homegarden size	0.424** (0.000)	-	0.258* (0.011)	0.049 (0.638)	0.276** (0.006)	0.106 -0.304	0.261* (0.010)
Introduction of new species	0.214* (0.036)	0.258* (0.011)	-	0.091 (0.375)	0.089 (0.390)	-0.034 (0.745)	0.077 (0.457)
Education of the farmholder	0.191 (0.062)	0.049 (0.638)	0.091 (0.375)	-	NI	NI	NI
Total family education	0.311** (0.002)	0.276** (0.006)	0.089 (0.390)	NI	-	NI	NI
Female family member	0.108 (0.294)	0.106 (0.304)	-0.034 (0.745)	NI	NI	-	NI
Male family member	0.14 (0.173)	0.261* (0.010)	0.077 (0.457)	NI	NI	NI	-

** Correlation is significant at the .01 level (2-tailed); * Correlation is significant at the .05 level (2-tailed);

Sig. values are within parenthesis; *NI* not investigated

from marginal to large farm size categories, and the amount of timber sold in the local market also followed the same trend. Bamboos are widely used as construction material in the rural areas throughout Bangladesh. This is why it is called 'poor man's timber' (FAO 1994) and it is produced in clumps in most homesteads, almost like money in the bank.

The overall monetary value of tangible benefits per homestead was US$285.2. The total production cost substantially depended on whether family labor input was taken into account or not. NTB per hectare was calculated by dividing the NTB by average homestead land area, not by area of homegarden. It is notable that on a per hectare basis annual NTB was highest in small farms and lowest in large farms by nearly one-third.

The productivity of homegardens is associated with a number of factors including species composition and diversity, quality of planting stock, climatic parameters, management intensity. Climatic parameters - temperature, aspect, precipitation and soil density - of an area influence the growth and development of species cultivated in homegardens and this ultimately determines the quality of growing stock of the forest (Yang *et al.* 2006). Clearly, healthy and vigorous vegetation gives higher production. Greater species richness helps efficient utilization of land potential by improving ecosystem stability and optimizing ecosystem productivity (Loreau *et al.* 2001, cited in Rahman 2006). Hence, composition and type of species planted in homegardens greatly influence annual production. Farmers usually plant those species that are favored for household consumption but have market value as well. In the study area mango is highly preferred since it grows well, and farmers generally tend to grow mango to sell commercially.

The growth, development, and production of fruit trees are usually high in homegardens because the farmers select seeds from trees known to bear sweeter and bigger fruits Regarding timber species, the farmers tend to depend on the market-produced seedlings. The quality of produced timber is also dependent, among many other factors, on the quality of the planting stock.

The results presented here all indicate that the allocated amount of land is a good predictor of annual production of homegardens. The regression analysis (results not shown) indicates that the NTBs from homegardens increase with the increase in the area of land allocated to such landuse practices. However, it is important to be cautious in using such models where high degree of accuracy is required since there are many other factors directly or indirectly impacting annual outputs. Furthermore, agroecological variations also determine the structure, composition, and diversity of homegardens that ultimately result in variation in outputs. The most notable limitation of the current study is the fact that there remained high variability of year-to-year farm inputs and outputs. This limitation could be overcome if data were gathered over a longer period, and for perennial components over their entire life cycle, which was, of course, beyond the scope of this small research project. Nevertheless, for government policy formulation long-term monitoring of farm inputs and outputs is essential to increase the effectiveness of interventions.

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