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RESEARCH PAPER

Effects of Household Characteristics on Homegarden Characteristics in Kalaroa Upazila, Satkhira District, Bangladesh

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Abstract Tropical and subtropical homegardens often show variation in floristic and structure depending on household characteristics. This research investigated how the household characteristics could influence homegarden vegetation characteristics for 50 randomly selected households in Kalaroa Upazila of Satkhira District, Bangladesh. The central analytical tool to test the relationships between household and homegarden characteristics was multiple linear regression. The results revealed that household landholdings, income, homestead size, and time spent for homegardening were strong predictors of homegarden vegetation characteristics. Economic conditions of the household, experience of the household head, and homegarden investment explained 48 % of the total plant diversity. The combined effects of all significant variables explained about 57 % of the variability in species richness. If homegarden species composition and structure receive attention by concerned authorities, the development of economically viable and ecologically sustainable homegardens can be one aim of the policy guidelines with regard to natural resource conservation and sustainable management basis in Bangladesh could act as a principal source for employment of women in rural Bangladesh.

Keywords Agroforestry · Multiple linear regression · Principal components analysis

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Introduction

Densely populated Bangladesh is predominantly rural and is frequently impacted by natural disasters. Natural forest systems of Bangladesh have lost their ability to meet household needs and maintain environmental protection (FAO 2014). Bangladesh is now facing severe forest degradation from developmental pressures that have reduced the forest cover from 15 % in 1971 to 11 % in 2011 (FAO 2014) further limiting the supply of forest resources for both household consumption and commercial uses. Further increase in state owned forestland is not possible because the official forest boundaries have been demarcated. Thus, local needs for forest resources must be met by managed non-forest sources such as agroforestry homegardens (Kabir and Webb 2009). A homegarden is a mixture of deliberately planted vegetation with variable composition and structure in and around the homestead, often exhibiting multiple functions (Nair and Kumar 2006).

Species richness in tropical and subtropical homegardens can vary from less than five to more than 100 species with stand densities of less than 100 to more than several thousand stems per hectare, providing only a few to more than a hundred products (Fernandes and Nair 1986; Roshetko et al. 2002; Nair and Kumar 2006; Anami and Kingston 2010). In tropical America and in Africa, species composition, stand structure and product utilization are considered a function of land tenure, land fertility, livelihood requirements, local demand for tree based products, availability of planting materials, and planters' personal preferences (Bannister and Nair 2003; Aworinde and Erinoso 2013; Igwe et al. 2014; Ikyaagba et al. 2014). Homegardens provide household necessities such as food, timber, fuel wood, and medicine (Torquebiau 1992), biological conservation (Kabir and Webb 2008a; Webb and Kabir 2009) and environmental services such as shading, checking soil erosion, and conserving water (Nair and Kumar 2006).

Quantification of the relationships between homegarden biophysical conditions and household characteristics has been investigated in limited studies. A wide variety of household factors such as household landholdings, homestead size, household economic status, and household demography have been shown to be influential on homegarden vegetation characteristics (Mendez et al. 2001; Soini 2005; Peyre et al. 2006; Tangjang et al. 2011; Linger 2014; Sabastian et al. 2014). However, most of these studies used simple correlations rather than simultaneous investigation on multiple predictors.

More than 20 million households in Bangladesh maintain homegardens (Salam et al. 2000; Kabir and Webb 2008a, b) covering an area of 0.27 million ha equivalent to 2 % of the country's total land area and provide approximately 75 % of the nation's forest products (Kabir and Webb 2008a, b). Thus, understanding the factors influencing farmers' choices in homegarden investment is important to improve homegardening systems in Bangladesh (Kabir and Webb 2009; Bardhan et al. 2012; Roy et al. 2013). Most homegarden studies in Bangladesh provide only descriptions of floristic composition, product utilization and management (Kabir and Webb 2009). This study addresses the question of how homegarden vegetation characteristics are related to household characteristics in Kalaroa Upazila of

Satkhira District, Bangladesh. Findings from this study can provide a model for further investigations of the impact of household characteristics on aspects of homegardening systems such as species choice, use preferences, commercialization and carbon sequestration.

Study Area

The study area, Kalaroa Upazila, is located between latitudes 22°23′–22°42′N and longitudes 89°52′–90°03′E in Satkhira District, Bangladesh (Fig. 1), covering an area of 233 km^2. The physiography is primarily a low fertile deltaic plain experiencing seasonal flooding during the monsoon season (June–October) and severe drought during the dry season (March–May). Four main river tributaries are located in the study area. Alluvium, stream deposits, delta plain deposits, and flood plain deposits are the main topographic base forming calcareous to non-calcareous alluvium, with grey and dark grey soils and no or little effects from salinity (SRDI 1997). Tropical to sub-tropical monsoon climate characterizes the region. The mean annual temperature is 26 °C (range 10–36 °C). Seasonal rain is the result of tropical depressions in the Bay of Bengal. The monsoon season (June–October) receives more than 80 % of the total annual rainfall (average 1800 mm, range 1400–2600 mm). The annual average relative humidity of the region is 78 % and can go up to 85 % during the monsoon season and down to 60 % during dry season (Kabir and Webb 2009).

As of 2011, the human population in Kalaroa Upazila was 221,596 people (51 % male) with an annual average growth rate of 0.6 % (BBS 2013). Of the 35,475 households, the majority (84 %) is rural and spread over 142 villages in 12 unions

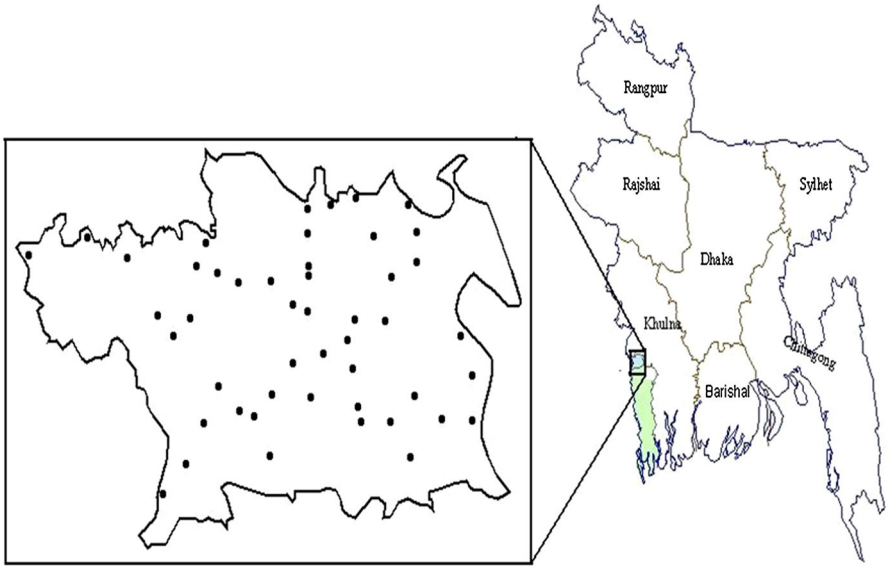

Fig. 1 Study area. Kalaroa Upazila of Satkhira District, Bangladesh. *Black dots* are the location of sample households

and one municipality. The average family size is four persons per household. Approximately 43 % of the total population lives below the poverty line (measured as 1963 kcal per person per day, BBS 2013). The majority (93 %) of people are Muslim followed by Hindu (6 %) and the rest are Christian and Buddhist. Agriculture is the main occupation of most people (73 %), and literacy is low 26 % (BBS 2013). The only public forest in the study area is the littoral Sundarbans Reserved Forests and is not accessible to people. The main exports are jute, betel leaf, oil and coconut. Cell phones are a newly emerging communication mode. Daily newspapers, radio and television are the main communication media.

Research Method

Sampling Design

The study area, Kalaroa Upazila (administrative unit) in Satkhira district, Bangladesh consists of 12 Unions (local administrative unit) and one Paurashava (local municipal administrative unit). A total of 50 households (four from each Union and two from the Paurashava) were selected using a snowball method (Fig. 1). Every day, a new local guide was selected to assist finding households and she/he was requested to stay away from the selected household in order to prevent bias in future household selection (Kabir and Webb 2008a). This way the sample bias was minimized.

Data Collection

Data on 21 biophysical, demographic, and socioeconomic characteristics (Table 1) were collected from each sampled household through personal interviews, mainly with the household heads (if the household head was absent another member of the household was interviewed, this occurred for 10 % of the households). In addition to the structured interviews, unstructured interviews were carried out with local informants, mainly elderly people, school teachers, local leaders and government and non-government workers. Additionally, three key informants selected by the village headman were interviewed. Two of them were elderly persons who had a thorough understanding of the area and the history of homegardening and settlements during the last few decades. The third key informant was an agriculture extension officer who was responsible for providing technical help related to crop selection, tending, curing, harvesting and sale of the products.

A vegetation survey was conducted to determine species composition and stand structure for each selected homegarden. Every individual plant, except small grasses (<25 cm height) and naturally growing herbs and climbers (woody and non woody), was identified and recorded by botanical name whenever possible or by local name. If the botanical name was not immediately known it was sent to the Bangladesh National Herbarium for identification. Each species recorded in the homegardens was classified by family, form (tree, shrub, herb or climber), and origin (planted or naturally grown) (Kabir and Webb 2008b). Every individual stem was counted only for trees and shrubs. Only herbs and climbers (woody and non woody) that were

Table 1 Biophysical, demographic and socioeconomic characteristics of household used as independent variables in Kalaroa Upazila of Satkhira District, Bangladesh

Biophysical	Demographic	Socioeconomic
Quality of road access to nearest market	Household age (years)	Household agricultural landholdings (ha)
Quality of road access to urban center	Household head's age (years)	Homestead size (ha)
Distance to nearest market (km)	Gender of the household head	Major source of family income
Distance to nearest urban center (km)	Household head's education (schooling years)	Household agricultural income (US$ year^{-1})
	Headship period (years)	Household off-farm income (US$ year^{-1})
	Family size (numbers)	Household homegarden income (US$ year^{-1})
	Adult male members in the family (numbers)	Occupation of the household head
	Earning members in the family (numbers)	Labor invested for homegardening (hour week^{-1})
	Literate members in the family (numbers)	

intentionally cultivated by the gardeners were identified but they were not enumerated. Geographical location and altitude of each sample homegarden was recorded using a handheld GPS unit. Normally the head of the family was asked the local name of each of the species, and its use.

Data Analysis

Multiple linear regression was used to test the relationships across household characteristics and homegarden vegetation conditions. Food species richness, commercial species richness, timber species richness, household income from homegarden, and the percent share of household income coming from homegarden were the dependent variables. Principal component analysis (PCA) was used to reduce the number of variables (Cooley and Lohnes 1971). The principal component scores were used to test for relationships with homegarden vegetation characteristics using backwards stepwise multiple linear regressions. Pearson's correlation coefficients (ρ) were calculated to see the relation between household characteristics whenever needed.

Results

Household Characteristics

The sample households have been in their current location from 1 to 80 years, with 50 % established in the last 20 years. The age of household heads vary from 30 to

75 years. About 60 % of the household heads are <50 years old. Most household heads are male (98 %), married (96 %), and residents (98 %). Eighteen percent of household heads are illiterate, with 52 % having primary and secondary educations (10 years or less of schooling). Households are composed of a median family size of five with two or three adults, one wage earning member (male for 92 % of households) and three literate members.

Sixty-six percent of households are connected to local markets by paved roads. About 50 % of households have road access within 1 km and 82 % within 2 km. Ninety-six percent of households are connected to the nearest urban center by paved road. Most households (90 %) are located within 9 km from the nearest urban center while only 30 % are within 5 km (Table 2). In rural areas, transportation facilities are mainly confined to tricycle, battery run tricycle, bicycle and bullock-cart. Houses are built with mud with straw roofing in the rural areas, but stouter buildings are common in the urban and periurban areas. The main source of drinking water is wells. Almost every rural household uses cow dung, dried leaves, fuel wood, and agricultural residues for cooking purposes.

Household Economic Conditions

The mean landholding size per household is 0.67 ha (range 0.01–2.41 ha), of which 65 % is for agriculture, and 20 % for homestead (average 0.13 ha, range 0.01–0.67 ha) occupied by the dwelling house and homegarden and the rest for other uses such as horticulture, woodlot, poultry, fisheries etc. Fourteen percent of the households have no agricultural lands and only 6 % have relatively larger agricultural lands (Table 2). Approximately 96 % of households have less than half a hectare of homestead land with a homegarden (Table 2). Household agricultural landholdings and homegarden size are positively correlated with household total landholdings ($r = 0.944$ and 0.464 respectively).

Agriculture is the main land use for 80 % of the cultivable land (0.11 ha per capita). The principal agricultural crops are rice, jute, wheat, betel leaf, potato, vegetables, spices, fruits, and nuts. The main fruit crops of the region are mango, jackfruit, banana, coconut, papaya, litchi and guava, mostly come from homegardens. Most households (90 %) manage their homegarden with family labor spending a median of 12 h per week (range 0–25 h). Sixty-five percent of the households spend <3 h of labor per day for homegardening (Table 2).

Agriculture is the main occupation and source of income for 75 % of the households (Table 2). The mean annual income per household is US$2341; 51 % from agriculture, 31 % from off-farm activities and 18 % from homegardens. About 36 % of households have a total income of less than or equal to US$1000 a year. Small to medium scale business (for 15 % of the households), day labor (for 40 % of the households), and civil service (for 4 % of the households) are other major sources of household income. Approximately 12 % of the households have no agricultural income and 36 % of the households have no off-farm income (Table 2).

Table 2 Biophysical, demographic, and socioeconomic characteristics of the households in Kalaroa Upazila of Satkhira District, Bangladesh

Household characteristics	Min	Median	Max	Remarks
Biophysical				
Quality of road access to nearest market	–	–	–	56 % Paved and 44 % mud
Quality of road access to urban center	–	–	–	96 % Paved and 4 % mud
Distance to nearest market (km)	0	2	8	50 % (<1 km) and 82 % (<2 km)
Distance to nearest urban center (km)	0	7	30	90 % (<9 km) and 30 % (<5 km)
Demographic				
Household age (years)	1	20	80	50 % (1–20), 20 % (21–40), 18 % (41–60), 10 % (61–80), and 2 % (>80 years)
Household head's age (years)	30	45	75	24 % (22–40), 62 % (41–60), 13 % (61–80), and 1 % (>80 years)
Gender of the household head	–	–	–	98 % Male and 2 % female
Household head's education (years of schooling)	0	5	16	18 % Illiterate, 25 % elementary, 52 % secondary, and 5 % higher
Headship period (years)	1	18	70	70 % (1–20), 25 % (21–40), 4 % (41–60), and 1 % (>60 years)
Family size (numbers)	1	5	25	70 % (1–6), 22 % (7–10), 7 % (11–15), and 1 % (>15 members)
Adult male members in the family (numbers)	0	2	11	59 % (1–2), 36 % (3–4), and 5 % (>5 members)
Earning members in the family (numbers)	0	1	5	85 % (1–2), 14 % (3–5), and 1 % (>5 members)
Literate members in the family (numbers)	0	3	14	5 % Illiterate, 70 % primary, 20 % secondary, and 5 % higher
Socioeconomic				
Household agricultural landholdings (ha)	0	0.32	24.45	14 % (0), 45 % (<0.27), 32 % (0.27–1), 6 % (>1 to 3), and 3 % (>3 ha)
Homestead size (ha)	0.01	0.13	1.50	96 % (<0.05 ha)
Major source of family income	–	–	–	74 % Agriculture and 26 % other than agriculture
Household agricultural income (US$ year^{-1})	0	1194	48,526	12 % (0), 45 % (<415), 33 % (4150–1000), and 10 % (>1000 US$)
Household off-farm income (US$ year^{-1})	0	726	5690	36 % (0), 25 % (<365), 32 % (365–1000), and 7 % (>1000 US$)
Household homegarden income (US$ year^{-1})	0	421	1232	2 % (0), 4 % (>300), and 94 % (<1000 US$)
Occupation of the household head	–	–	–	75 % Agriculture and 25 % other than agriculture
Labor invested for homegardening (hour week^{-1})	0	12	25	65 % (<3), 28 % (5–15), and 7 % (>15 h)

Income from the sale of surplus homegarden products after own consumption is a secondary objective for 94 % of the households. For 44 % of the households, homegardens contribute ≤15 % of their total income. Only 8 % of the households have higher income (>40 % of the household total) from homegardens.

Homegarden Characteristics

An average (area 1300 m^2; range 100–15,000 m^2) homegarden is comprised of a set of annual and perennials plants mainly for subsistence use along with many other reported environmental, social, and religio-cultural benefits. A total of 271 plant species in 79 families were recorded from a total of 9.29 ha area across the 50 homegardens surveyed. A set of 15 species (*Areca catechu*, *Cocos nucifera*, *Mangifera indica*, *Musa* spp., *Alocasia indica*, *Artocarpus heterophyllus*, *Phoenix sylvestris*, *Citrus limon*, *Citrus grandis*, *Manilkara zapota*, *Moringa oleifera*, *Carica papaya*, *Sygygium cumini*, and *Curcuma longa*) are present among all sampled homegardens. Of the 271 recorded species, 40 % are trees, 20 % are shrubs, 25 % are herbs, and 15 % are woody and non-woody climbers. A typical homegarden is composed of 44 species (range 28–54), of which 48 % are trees, 16 % are shrubs, 23 % are herbs, and 13 % are woody and non-woody climbers. Fifty-six percent of homegardens have <45 species and 6 % of homegardens have more than 50 species each (Fig. 2). The average tree and shrub density is 1003 ha^{-1} (range 0–18,000). Tree and shrub stem density is up to 1000 ha^{-1} for 42 % of the homegardens, 1000–5000 ha^{-1} for 53 % of the homegardens and over 5000 ha^{-1} for 5 % of the homegardens (Fig. 2).

All the species recorded are reported to be useful for several purposes. The 271 recorded plants can be divided into three use categories: (1) self consumption (64 %), (2) commercial (9 %) and (3) self consumption and commercial (27 %) (see Kabir et al. 2015). Of the recorded species, 36 (13 %) have multiple uses, 90 (33 %) double uses and 145 (54 %) single use, most commonly for food.

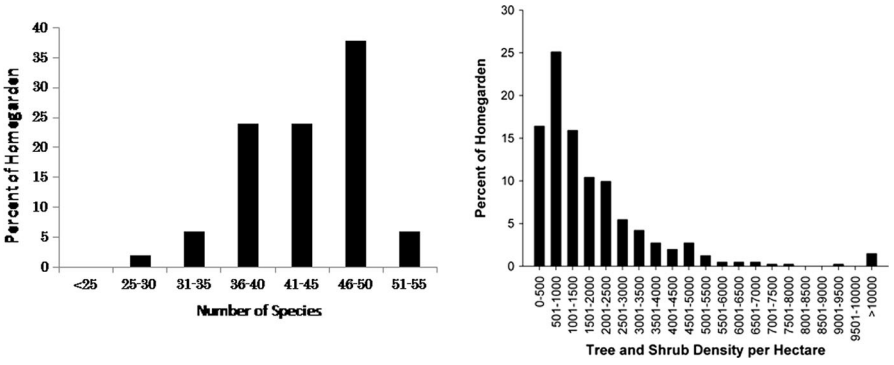

Fig. 2 Species richness per homegarden and stem density per hectare in Kalaroa Upazila of Satkhira District, Bangladesh

PCA to Reduce Household Characteristics into Component Variables

A correlation matrix exhibited several correlations among the 21 independent variables. The 21 independent household variables were reduced to seven principal component (PC) variables which explained 77 % of the total variance (Table 3). At least two variables dominated each PC. PC1 is related to economic condition, PC2 to demographic conditions, PC3 to income source, PC4 to experience of the household head, PC5 to homegarden investment, PC6 to road access, and PC7 to market distance (Table 3).

Homegarden Investment and Market Access

Multiple linear regression analyses show, species richness in homegarden to be positively associated with household economic condition (PC1), homegarden investment (PC5), and experience of the household head (PC4; Table 4). Total species and timber species richness in homegardens are influenced by the economic condition of the household and homegarden investment in the form of area allocated and time spend for homegardening (Table 4). Only commercial species richness in homegardens is influenced by road access to local market and nearest urban center (PC6). Income from homegardens is positively associated with the economic condition of the household (PC1), experience of the household head (PC4), homegarden investment (PC5), road access to local market and nearest urban center (PC6), and market distance from the household (PC7; Table 5). Household income sources (PC3) have a highly significant, negative effect on the share of household income from homegardens while a significant positive impact on homegarden investment.

Discussion

Household Characteristics

In general, homegardens in Bangladesh have maintaining inherited traditions, which have evolved over centuries of experience, observation, and trial-and-error (Millat-e-Mustafa et al. 1996; Alam et al. 2010; Bardhan et al. 2012; Islam et al. 2015). The experience of the household head is a significant determinant of homegarden species richness in this study. Similarly, the experience of household heads is positively correlated with timber tree planting in Central Java, Indonesia (Sabastian et al. 2014). We did not find any significant impacts of family size and types of family members (gender, age) on the homegarden composition. We found additional schooling of the household head may increase species richness in the homegardens, all else being held constant. Better education may help farmers to adopt more agroforestry innovations (Franzel and Scherr 2002; Linger 2014). In addition, older household heads and longer headship tenure may help increasing the species richness in the homegardens. In contrast, Abebe (2005) reported that the age, education and gender of the household heads do not have any significant effect on

Table 3 Results of a principal component analysis with Varimax Rotation and Kaiser normalization, on 21 contextual variables collected from 50 randomly selected households in Kalaroa Upazila of Satkhira District, Bangladesh

Household characteristics	Principal component (PC)						
	Economic condition (PC1)	Demographic conditions (PC2)	Income source (PC3)	Experience of the household head (PC4)	Homegarden investment (PC5)	Road access (PC6)	Market distance (PC7)
Total land holding (ha)	**0.903**	0.201	−0.146	0.057	0.135	−0.122	−0.014
Agriculture income (US$)	**0.880**	0.066	−0.081	0.000	0.071	0.121	0.069
Agriculture land holding (ha)	**0.877**	0.251	−0.167	−0.015	−0.079	−0.196	−0.022
Off-farm income (US$)	**0.810**	0.080	−0.220	0.194	0.075	−0.133	0.149
Number of adult member	0.165	**0.864**	−0.133	0.140	0.081	−0.128	−0.146
Family size	0.271	**0.832**	−0.113	0.218	0.058	0.047	−0.111
Number of earning member	0.034	**0.720**	0.168	0.330	−0.162	−0.202	0.011
Number of the literate member	0.195	**0.631**	0.287	−0.179	0.355	−0.056	0.442
Major source of family income	−0.044	0.006	**0.949**	−0.144	−0.051	0.091	−0.038
Occupation of the household head	−0.085	−0.031	**0.895**	−0.172	−0.107	0.153	−0.140
Headship period (year)	0.004	0.157	0.006	**0.901**	−0.019	−0.128	0.057
Age of the household head (year)	0.011	0.222	−0.149	**0.880**	0.075	−0.047	−0.034

Table 3 continued

Household characteristics	Principal component (PC)						
	Economic condition (PC1)	Demographic conditions (PC2)	Income source (PC3)	Experience of the household head (PC4)	Homegarden investment (PC5)	Road access (PC6)	Market distance (PC7)
Education of the household head	0.014	−0.363	0.409	**0.539**	0.086	0.045	0.232
Gender of household head	0.209	0.119	−0.262	**−0.557**	0.274	−0.356	−0.228
Time spent for homegardening	0.382	0.225	−0.214	0.130	**0.713**	−0.147	−0.031
Homestead size (ha)	0.414	−0.115	0.011	0.248	**0.508**	0.230	−0.025
Age of the household (year)	0.258	0.207	−0.079	0.376	**−0.558**	0.018	0.347
Road access to local market	0.069	−0.027	0.068	−0.065	0.151	**0.781**	0.180
Road access to urban center	−0.298	−0.080	0.087	−0.258	0.210	**0.636**	0.185
Distance to local market (km)	−0.023	−0.134	−0.258	0.073	−0.247	0.322	**0.614**
Distance to urban center (km)	−0.069	0.011	−0.076	−0.001	−0.173	0.012	**−0.748**
Percent total variation explained	23.24	14.33	13.37	8.33	7.02	5.68	5.00

Bold values are highly correlated variables

Table 4 Results of a multivariate linear model of total, food, commercial, and timber species richness with household characteristics in Kalaroa Upazila of Satkhira District, Bangladesh

Dependent variables → Independent variables ↓	Total species richness β	Food species richness β	Commercial species richness β	Timber species richness β
Constant	43.500	22.54	8.32	10.1
Economic condition (PC1)	0.479***	0.373**	0.446***	0.475***
Demographic conditions (PC2)	Ns	Ns	Ns	Ns
Income source (PC3)	Ns		Ns	Ns
Household head's experience (PC4)	0.263*	0.254*	0.220*	0.288**
Homegarden investment (PC5)	0.387***	0.336**	0.455***	0.538***
Road access (PC6)	Ns	Ns	0.294**	Ns
Market distance (PC7)	Ns	Ns	Ns	Ns
Model R^2	0.478	0.363	0.569	0.624

Ns not significant

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 5 Results of a multivariate linear model of household income from homegardens and share of household income from homegardens with household characteristics in Kalaroa Upazila of Satkhira District, Bangladesh

Dependent variables → Independent variables ↓	Household income from homegardens β	Share of household income from homegardens β
Constant	413.96	19.92
Economic condition (PC1)	0.533***	Ns
Demographic conditions (PC2)	Ns	Ns
Income source (PC3)	Ns	−0.414**
Household head's experience (PC4)	0.367***	Ns
Home garden investment (PC5)	0.430***	0.270*
Road access (PC6)	0.269**	Ns
Market distance (PC7)	0.166*	Ns
Model R^2	0.726	0.362

Ns not significant

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

homegarden plant diversity. This may be due to, at least in part, to the lack of variation in age, education and gender among the household heads in their study.

In our study area, the household characteristics are not strong predictors of homegarden composition. This may be due to the fact that not all possible relevant independent variables were collected, and there may be a strong random component

in the decision making of households towards homegardening investment or there are non-linear relationships between household and homegarden characteristics. It is important to identify and collect other relevant variables, such as religio-cultural, wildlife and environmental uses for inclusion in future analyses. A strong random component would arise because of the unpredictable nature of species choice for planting, or historical factors such as the rate at which land converted to agriculture and technological development adoption which were not captured by the analysis (Kabir and Webb 2009).

Household Economic Conditions

The second most important source for subsistence of many Bangladeshi households, after agriculture, is homegardens. Species richness in homegardens has significant positive correlation with the economic condition of the household. Households' economic statuses and patterns are often reflected in the diversity of homegarden plants (Yongneng et al. 2006; Kabir and Webb 2009; Aworinde and Erinoso 2013; Riu-Bosoms et al. 2014), although the exact nature of the relationship is unknown. The relationship between species composition and household income is hypothesized to be positive as with richer households expected to grow more crop varieties than poorer households (Abebe 2005; Winters et al. 2006; Linger 2014). The availability of income increases the likelihood that farmers will adopt quality planting material of diverse species. Farmers who have more land (Kabir and Webb 2009; Kumari 2009; Igwe et al. 2014), income (Byron 2001; Sabastian et al. 2014) and spare family labor (Salam et al. 2000; Abebe 2005) can afford more trees for homegarden production (Linger 2014). Our results revealed that the plant species richness in homegardens would be increased with increasing landholdings and income of the household.

We found household demographic condition had no predictive power on household income from homegardens. This is largely because income generation was not the primary reason for homegardening in the study area. The economic condition of the household had more influence on species richness than homegarden investment, while the experience of the household head had a minimum influence. Conversely, homegarden investment followed by economic condition of the household had the highest effects on plant diversity, while road condition followed by experience of the household head had moderate effects on species richness.

Share of household income from homegardens was negatively related to household income sources. This negative relationship indicates that as more family income was coming from sources other than the homegarden and occupations other than agriculture, the share of household income from homegardens was reduced. This may be due to an increased share of family income coming from off-farm activities. These findings closely corroborate with studies in Central Java, Indonesia (Sabastian et al. 2014) and Abia Sates, Nigeria (Igwe et al. 2014). Homegarden investment in the form of homestead size, labor invested and the age of the household had significant, positive relationships with the share of household income from homegardens. One hour of additional labor investment plus 1300 m^2 of increased homestead size can provide more than 3 % increased share of household

income from homegardens. Similar findings have been reported by Igwe et al. (2014) from Abia States, Nigeria. The moderate R^2 value (0.362) shows the weak explanatory power of household income sources and homegarden investment on the share of homegarden income. This is mainly due to the fact that the household economic and demographic conditions, experiences of the household head, and market access are not strongly associated with the model.

Homegarden Investment

Land, labor and capital investment are considered important factors in determining farming strategies. The total land holding (Kabir and Webb 2009; Amberber et al. 2014), capital input (Igwe et al. 2014), quality labor input (Salam et al. 2000; Abebe 2005; Ali 2005) and secure land tenure (Roshetko et al. 2008; Mulugeta and Admassu 2014) can be considered as the determining factors for homegarden investment and as positive determinants of homegarden species richness.

The general hypothesis is that for subsistence oriented homegardens, there is a positive correlation between homestead size and homegarden species richness (Salam et al. 2000; Kindt et al. 2004; Igwe et al. 2014; Sabastian et al. 2014). Many other studies documented a lack of relationship between homegarden species diversity and homestead size (Wiersum 1982; Okafor and Fernandes 1987; Rico-Gray et al. 1990; Blanckaert et al. 2004; Albuquerque et al. 2005; Saikia et al. 2012; Aworinde and Erinoso 2013). The positive relationship between homestead size and species richness in the majority of homegardens in southwestern Bangladesh (Kabir and Webb 2009) supports the general hypothesis of subsistence oriented homegardens. For our study area, both plant richness and evenness increases with the increase in homestead size, then reaches to a maximum and finally declines. We found an increase of 1000 m^2 (75 % of an average size homestead) in homestead area may increases homegarden species richness by 11 species given all other household characteristics being held constant. But the opposite relationship has been reported in many other studies (Wiersum 1982; Jacob and Alles 1987; Rico-Gray et al. 1990; Blanckaert et al. 2004; Abebe 2005). Homegarden commercialization may be one of the reasons for such discrepancies.

Plant species exclusively used for subsistence may reduce in commercial homegardens. In general, homegarden owners allocate a larger extent of their homegardens to cash crops and lower the plant richness and evenness in the gardens. Unlike subsistence homegardens, commercial homegardens generally experienced reduced species richness regardless of the homestead size, as large homegardens tend to promote only a few market-oriented species (Kumar et al. 1994; Kindt et al. 2004; Kabir and Webb 2009; Saikia et al. 2012). This is likely due to the fact that farmers with a commercial orientation make conscious efforts to increase the density of market oriented species in their homegarden to increase their earnings. The larger land extents available in the homestead allowing farmers from adopting mono cropping to enhance their earnings is another potential reason for reduced plant diversity in commercial homegardens in some areas. However, this effect could be simply due to more affluent people focusing more on income generating

(e.g., *Technotona grandis*) and hobby or luxury (e.g., *Ficus* spp.) plant species in their homegarden.

Studies documented variable ranges of labor input for homegardening depending on the homestead area and family size and these may influence species diversity and stem density (Mendez et al. 2001; Abebe 2005; Ali 2005; Kabir and Webb 2009; Igwe et al. 2014). Quantity and quality of labor investment (Jose and Shanmugaratnam 1993) either from within the household or hired (Salam et al. 2000; Kabir and Webb 2009; Igwe et al. 2014) is of foremost importance for homegarden establishment and management. Our findings demonstrate that quantity (person hours per week) of labor input increases homegarden species richness and income. Results of this study reveal that for an additional 4 h per week additional labor investment, all else being held constant, there is an increase of nine species. Salam et al. (2000) reported that labor shortage may negatively influence species richness in homegardens primarily managed by hired labor and consequently reduced income from homegardens (Igwe et al. 2014). This is not relevant in our study area, as households primarily manage gardens with family resources. In southwestern Bangladesh, 98 % of the households managed their homegardens using family labor and the amount of labor spent was not a function of family size (Kabir and Webb 2009). Given the family labor source, it is unlikely that the outside labor source and family size would negatively impact homegarden biophysical conditions in Bangladesh.

The more family members available, the greater the family labor allocated to homegardening activities and this may significantly affect the diversity of agroforestry adoption (Sood 2006; Igwe et al. 2014). Families with more adult male members could contribute more labor for homegardening – perhaps maintaining more species and generating more income (Salam et al. 2000; Sood 2006; Kabir and Webb 2009; Igwe et al. 2014). Our findings of more adult male members and male heads for 98 % of the household corroborate the findings of Salam et al. (2000) and Kabir and Webb (2009). If labor becomes unavailable, farmers may respond by increasing the cultivation of agricultural crops (Scherr 1995).

Usually homegardens which are maintained by women tend to have higher plant diversity (Perrault-Archambault and Coomes 2008; Akther et al. 2010). The role of women in traditional management practices has increasingly been recognized as a strong incentive for biodiversity conservation (Akther et al. 2010; Amberber et al. 2014). That role has potential in enhancing conservation and sustainable use of natural resources, including homegardens, and therefore as a remedy for numerous forest conservation problems. Reduction of gender disparity in division of labor for homegardening may allow male members to use their full time for non-homegardening activities and maximize household income from all possible sources. This way a homegarden could act as a principal source for employment of women in rural Bangladesh.

Market Access

Market influences on species richness and stem density in homegardens heavily depends on management objective (Abdoellah et al. 2006; Aworinde and Erinoso

2013; Igwe et al. 2014; Ikyaagba et al. 2014). The impact of market access on the farmers' knowledge-base for species choice and use patterns are not well documented. Studies revealed both negative (Nair and Kumar 2006; Kabir and Webb 2009; Linger 2014) and positive (Nair 1993; Peyre et al. 2006) influences of market access on the homegarden species composition and structure. With the proliferation of market economies, mixed species tropical homegardens are being transformed into single species dominated homegardens (Nair and Kumar 2006). The general hypothesis is that the impact of market economy lowers species richness (Nair 1993; Peyre et al. 2006).

Commercialization of homegardens has enabled households to increase their incomes, although the same phenomenon has contributed towards reducing plant diversity. Species richness has not been significantly influenced by the market orientation of farmers in the study area. Farmers with low market orientation possess homegardens with high plant diversities compared to farmers with high market orientation who usually maintain increased dominance of highly marketable species (Major et al. 2005; Bernholt et al. 2009; Riu-Bosoms et al. 2014). However, the combined commercial-subsistence gardens in the study area did not reinforce the general fears of a gradual decline in species richness. The association between plant diversity and the degree of commercialization cannot be utilized to infer to what extent market proliferation explains plant diversity in homegardens.

Quality and proximity of roads to market are generally considered important factors of homegarden species composition and structure. Better road access (Kabir and Webb 2009) and closer proximity (Abebe 2005; Kumari 2009) to markets may lead to increasing commercial species richness and perhaps subsequent introduction of more exotic species in homegardens. When farmers have easy access to markets they tend to grow more of a limited number of cash crops (Nair and Kumar 2006). Commercialization of homegardening systems with species intensification for gaining monetary benefits has become popular (Riu-Bosoms et al. 2014). It has been argued that such intensification of species may have eroded the plant diversity in homegardens. We found 1 km closer proximity to market can generate US$50 per year of more income from homegarden in rural Bangladesh. This situation may lead homegardeners to establish commercial gardens of reduced diversity with more highly marketable introduced species.

Conclusion

In terms of understanding the influences of key household attributes on the homegarden vegetation conditions, a number of conclusions can be drawn from this study. Household economic condition, followed by homegarden investment, has the strongest affect on homegarden composition and income. Sizes of garden and labor investment are the most significant factors influencing homegarden production systems. Market access has low impacts on homegarden composition due to the primary objective of maintaining homegardens being subsistence utilization. Homegardens offer clear responses to wise use of small homestead land areas, livelihood support, soil and water conservation, biodiversity conservation, rural

energy supply, deforestation and afforestation, carbon sequestration, landscaping and environmental improvement. Reduction of gender disparity in division of labor for homegardening may act as a principal source for employment of women in rural Bangladesh. Thus, the development of economically viable and ecologically sustainable homegardens should be one aim of the policy guidelines with regard to natural resource conservation and management on a sustainable basis in Bangladesh and elsewhere in tropical and subtropical regions.

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