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Home Gardening for Biodiversity Conservation in Kalaroa Upazila of Satkhira District, Bangladesh

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Abstract Agroforestry homegardens are important repository of useful plants in most tropical and subtropical world. Home gardens, which are maintained by at least 20 million households, represent possible strategies for livelihood provision, environmental amelioration and perhaps more importantly biodiversity conservation in Bangladesh.Having no accessible natural forests, majority people of Satkhira District in Bangladesh are heavily depend on home gardens to meet their basic forest resources need. This study investigated the existing useful plant resources, its utilization and conservation importance of home gardens in Kalaroa *Upazila* of Satkhira District, Bangladesh. All useful plants were censused, totalling 270 species including four threatened from 50 randomly selected home gardens totalling 9.29 ha area. Of the 270 species, 108 trees, 53 shrubs, 67 herbs, and 42 woody and non-woody climbers. All the recorded plant species were classified into nine main usage categories where 36species were multipurpose. Home gardens accounted for about 18% of household's total annual income. Maintaining high species richness, home gardens in the study area are representing biodiversity hotspot through use in Bangladesh. Despite the high species richness majority species in the home gardens was rare.Thus, serious effort must be taken to increase the population density of most species to determine whether home gardens indeed act as long-term source to livelihood options, climate resilience, and biodiversity conservation in Bangladesh.

Key words: Agroforestry, Livelihood, Rare species, Species composition, Subsistence use

Introduction

Seventy percent of Bangladesh's total land area under agricultural use (0.2 ha per capita), making it the main source of livelihood for more than 80% people (FAO, 2014). Approximately 40% people are functionally landless, putting land the most valuable and scarce resource of the country. In addition, once heavily forested Bangladesh is now almost devoid of forest vegetation (cover <10% of the total land area, FAO, 2010). Forest land per capita in Bangladesh has reduced to half in last 50 years due to continued degradation and improper management of forests created major gaps between demand and supply of forest resources. Yet, possibility of forest land expansion is not possible in Bangladesh (Kabir and Webb, 2008a). In support of governmental efforts to help save the remaining forests, integrated land use technologies such as home gardening would be an important option for plants conservation and sustainable supply of forest products and services (Kabir and Webb, 2008b). Home garden is an agroforestry land use system immediately surrounding the dwelling house is cultivated with diverse mixture of useful plants and animals (Kumar and Nair, 2004; Nair and Kumar, 2006; Mattsson *et al.*, 2013; Mekonnen *et al.*, 2014). Yet, the extent of scientific studies on home garden systems are inadequate than what their various values would warrant (Nair, 2001). Therefore, home gardens required considerable research attention mainly due to their certain sustainable supply of socioeconomic products and environmental services for the gardeners (Jose and Shanmugaratnam, 1993).

About 20 million households in Bangladesh have been maintaining home garden covering 2% of the country's total land and 10% of total forest area (Kabir and Webb, 2008a;b). Home garden plants, play an important role for providing livelihoods to million people living in rural Bangladesh (Millat-e-Mustafa *et al.*, 1996; Ali, 2005; Kabir and Webb, 2008b; Akhter *et al.*, 2010; Mannan *et al.*, 2013; Islam *et al.*, 2014; Rahman and Rahman, 2014) and also show promise for biodiversity conservation (Kabir and Webb, 2008a; Muhammed *et al.*, 2011; Bardhan *et al.*, 2012; Roy *et al.*, 2013). In absence of accessible natural forests, majority people of Satkhira District in Bangladesh largely depend on home gardens to meet the basic forest resources needs. Approximately 80% of wood of all kinds and 73% bamboo come from home gardens in Bangladesh (Kabir and Webb, 2008b). Home garden productivity in Bangladesh

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is 7–8 folds higher than that of primary forests (Huda and Roy, 1999). This way home garden provided strong subsistence and economic incentives to the landowners to grow and maintain plants in and around their homestead.

Therefore, investigation of Bangladesh home gardens is important and understanding home garden vegetation could lead to important recommendations to further promote home gardens – perhaps improving rural livelihoods in the face of disappearing natural forests. Tropical home gardens have played important role in conserving plant biodiversity as well as environmental stability while providing substantial subsistence and commercial benefits to households. This research, thus, aimed to determine the biodiversity and distribution of useful plants to understand the use and contributions of home garden to rural livelihood. The study, therefore, has important implications to promote home gardening system to improve rural livelihoods in Bangladesh.

Materials and Methods

Study area

The study area, 'Kalaroa' *Upazila* is located (22°23' to 22°42' N latitudes and 89°52' to 90°03' E longitudes) in Satkhira District of Khulna Division, Bangladesh covering a total area of 233 km^2. The physiography of the study area is primarily a low fertile deltaic flood plain experiencing seasonal flood during monsoon (June–September) and severe draught during dry season (March–May). Calcareous to non-calcareous alluvium, grey and dark grey soils are reported with potential zinc deficiency and no or little effect of salinity (SRDI, 1997). Tropical to sub-tropical monsoon climate characterizes the region, marked with seasonal variations, moderately warm temperature, heavy rainfall, and excessive humidity. The mean annual temperature is 26° C (range: 16–32). Monsoon receives the most rains (80% of the total annual rainfall). The annual average rainfall is 1800 mm (range: 1400–2600). The annual average relative humidity of the region is 78%.

Agriculture is the main land use of the study area totaling 15880 ha cultivable land (0.11 ha per capita) of which over 50% under double cropping system. The principal agricultural crops from the cultivable lands are paddy, jute, wheat, betel leaf, potato, vegetables, spices, fruits, and nuts. The only public forest of the study area is the mangrove Sundarbans is not accessible to people. Seven percent of the total study area under homestead (average size 0.07 ha) use. A typical homestead comprised of a dwelling house, animal pens, cow shade, a pond, a set of plants of annual and perennials. A set of plants in and around the homestead lands is traditionally called the home garden. Almost every household in the study area have been maintaining a home garden mainly for family subsistence use with subsequent commercial use from the sale of surplus home garden products plus appropriating many environmental, social, and religio-cultural benefits.

Sampling design

The study area, Kalaroa *Upazila* (administrative unit), were purposively selected from Satkhira district, Bangladesh. The *Upazila* 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 only *Paurashava*) were selected randomly (as described in Kabir and Webb, 2008a) from purposively selected Kalaroa *Upazila* of Satkhira District for primary data collection as shown in Fig. 1.

Data collection

A botanical inventory was conducted in each sample home garden continuously during May to June 2011, using a "Home garden Botanical Inventory Form". All trees and shrubs present in the home garden were identified and recorded to species level. Every individual of trees and shrubs was counted except those are growing in hedgerows due to difficulties in differentiating the stems. Only herbs and climbers those were intentionally cultivated by the gardeners were identified without individual counting. Individuals of the species of all life forms on the Bangladesh IUCN Red List were counted. Geographical location of each sample home garden was recorded using a GARMIN® GPS. The botanical inventory was conducted only once in each selected home garden and therefore, the seasonal variation in plant composition and structure was not assessed.

Data processing and analysis

Each species recorded in the home gardens was classified by family, habit according to the morphology of the plant in its full growth form (tree, shrub, herb or climber), origin (Kabir and Webb, 2008b), conservation status (Khan *et al.*, 2001), and use by the people.

Relative frequency, relative density and relative abundance (Cox, 1990) was calculated only for tree and shrub species (except those were planted in hedgerows). The average of the relative values of density and frequency for each species of tree and shrub (except those

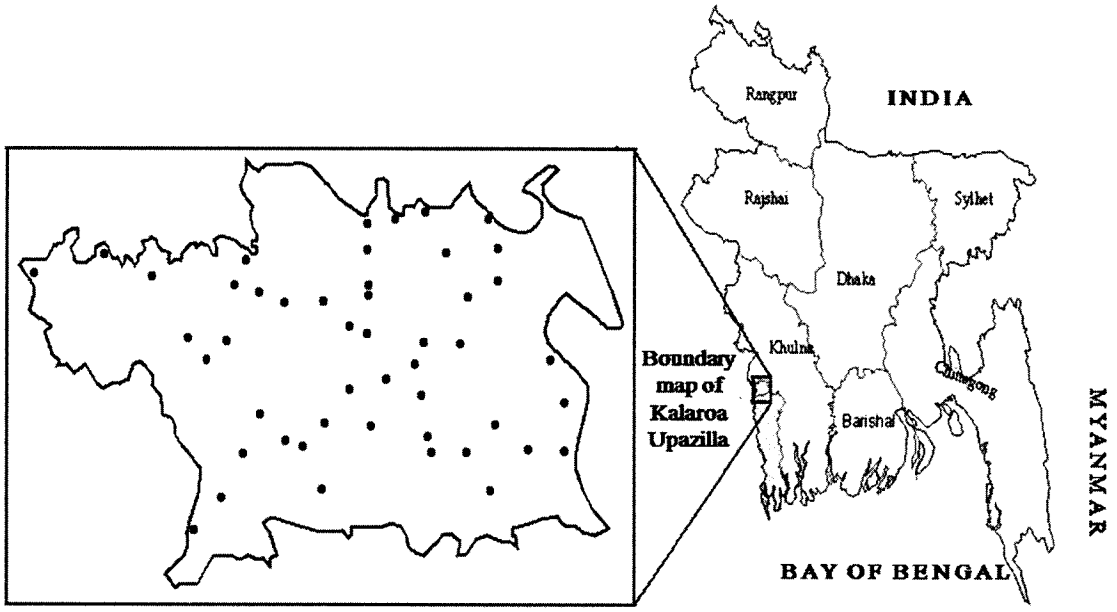

Fig. 1. Study area. Kalaroa *Upazila* of Satkhira District, Bangladesh. Black dots are showing the location of sample home garden.

were planted in hedgerows) was used in computing the ecological importance of a species in relation to the plant community in the study area (Kaya *et al.*, 2002; Das and Das, 2005). For trees and shrubs, relative importance value was then used to rank species per life form. For herbs and climbers (both woody and non-woody), relative frequency value was used to rank species per life form. The common species name in each stratum was determined from the relative importance and relative frequency value of each species in its respective life form.

Results and Discussion

Species composition

The species-sample size curve indicated the sampling effort was adequate. A total of 271 useful plant species in 79 families were recorded from a total 9.29 ha area in 50 randomly sampled home gardens as in Table 1. Not many studies documented a high absolute species richness of useful plants from a smaller total area (<10 ha) and/or a sample size (<50 home gardens) surveyed globally (Kabir and Webb, 2008a). Our findings of 271 species represented significantly higher among the documented total useful plant species richness in South and Southeast Asian home gardens. The number of plant species may increase if surveys included plants of all life forms and can be conducted across seasons. Kabir and Webb (2008b) documented 419 species of all life forms from 45.2 ha sampled area (402 home gardens) – perhaps represents the most species rich home gardens in Bangladesh. High total species richness in the tropical and subtropical home gardens have presented in few studies globally (Kabir and Webb, 2008a;b; Kumar 2011; Saikia *et al.* 2012) – otherwise, total species richness less than 200 in most other home garden studies. After Webb and Kabir's (2009) intensive review on home garden total species richness in terms of total sample size or area surveyed from tropical and subtropical world, we found most home garden studies yet have total botanical richness considering varied levels of taxonomic treatments (e.g., only useful plants or only trees). Many of the other studies did not mention the number and/or total area of home gardens surveyed.

Leguminosae sub-families accounted for approximately 12% of the total accounted species. Of the 271 species, 109 (40%) trees, 53 (20%) shrubs, 67 (25%) herbs, and 42 (15%) woody and non-woody climber species were recorded as in Table 2. Trees and herbs accounted for about 65% of all identified species which is consistent with the subsistence requirements of timber and food (mainly fruits and vegetable) in rural Bangladesh. Species native to the Indian Subcontinent was accounted for 58%.According to Table 2, of all the recorded species, trees, herbs, and climbers are accounted more native than exotic species. However, home gardens in rural Bangladesh are experiencing an increasing trend in exotic species introduction (presence of 42% exotic) due to manifold reasons such as quick and quantity returns of various products and services. Results of this study documented a fair mixture of both native and exotic

Table 1. Complete list of useful plant species recorded from the homegardens of Kalaroa *Upazila*, Satkhira District, Bangladesh.

Botanical Name	Uses	Botanical Name	Uses
Trees			
Acacia auriculiformis A. Cunn. *ex* Benth.	3	*Ficus benghalensis* L.	1
Acacia mangium Willd.	3	*Ficus hispida* L.f.	1
Acacia nilotica Karst.	3	*Flacourtia indica* (Burm.f.) Merr.	1
Aegialitis rotundifolia Roxb.	2	*Flacourtia jangomas* (Lour) Reech.	1
Aegle marmelos (L.) Correa	3	*Garcinia cowa* Roxb.	3
Albizia chinensis (Osb.) Merr.	2	*Garcinia pedunculata* Roxb	3
Albizia lebbeck (L.) Benth.	2	*Gmelina arborea* Roxb.	3
Albizia procera (Roxb.) Benth.	2	*Grewia asistica* L.	1
Albizia richardiana King & Prain	2	*Hibiscus tiliaceus* Linn	1
Alstonia scholaris (L.) R. Br.	1	*Holarrhena pubescens* (B.-H.) Wall. & G.Don	1
Annona reticulata L.	3	*Lagerstroemia speciosa* (L.) Pers.	1
Annona squamosa L.	3	*Lannea coromandelica* (Houtt.) Merr.**	1
Anthocephalus chinensis (Lmk.) A. Rich. *ex* Walp.	1	*Leucaena leucocephala* (Lam.) de Wit	1
Aphanamixis polystachya (Wall.) R.N.Parker	3	*Limonia acidissima* L.	3
Aquilaria agalocha Rocb	2	*Litchi chinensis* Sonn.	3
Araucaria cookii R. Br. *ex* D. Don	1	*Madhuca indica* J.F.Gmel.	3
Areca catechu L.	2	*Mangifera indica* L.	3
Areca triandra Roxb.	2	*Mangifera sylvatica* Roxb.	1
Artocarpus heterophyllus Lam.	3	*Manilkara zapota* (L.) P. Royen	3
Artocarpus lakoocha Roxb.	3	*Melia azedarach* L.	1
Averrhoa bilimbi Linn	1	*Microcos paniculata* L.	1
Averrhoa carambola L.	1	*Mimusops elengi* L.	1
Azadirachta indica A.Juss.	1	*Morinda citrifolia* L.	3
Baceaura ramiflora Lour	1	*Moringa oleifera* Lam.	3
Barringtonia acutangula (L.) Gaertn.	1	*Nyctanthes arbor-tristis* L.	1
Barringtonia racemosa Roxb.	1	*Peltophorum pterocarpum* (DC.) Back.	1
Bauhinia acuminata L.	1	*Phoenix sylvestris* Roxb.	3
Bombax ceiba L.	3	*Phyllanthus emblica* L.	3
Borassus flabellifer L.	3	*Pithecellobium dulce* (Roxb.) Benth.	3
Butea monosperma (Lmk.) Taub.	1	*Plumeria rubra* L.	3
Caesalpinia pulcherrima (L.) Swz.	1	*Polyalthia longifolia* (Sonn.) Hook.f. & Thomson	1
Carissa carandas L.	1	*Psidium guajava* L.	3
Caryota urens L.	1	*Punica granatum* L.	1
Cassia fistula L.	1	*Samanea saman* (Jacq.)Merr.	2
Ceiba pentandra (L.) Gaertn.	1	*Senna siamea* (Lam.) Irw. & Barneby	1
Cinnamomum verum J. Presl	1	*Sesbania grandiflora* (L.) Pers.	1
Cinnamomum tamala (B.-H.) F. Nees *ex* T. Nees & Eberm.	3	*Spondias pinnata* (L.f.) Kurz	3
Citrus grandis (L.) Osbeck	3	*Sterculia villosa* Roxb. *ex* G.Don	2
Cocos nucifera L.	3	*Streblus asper* Lour.	1
Crocus sativus L.	1	*Swietenia macrophylla* King	2
Croton tiglium L.	3	*Swietenia macrophylla* King X *Putranjiva roxburghii* Wall.	2
Dalbergia sissoo Roxb.	3	*Syzygium cumini* (L.) Skeels	3
Delonix regia (Boj. *ex* HK.) Raf.	1	*Syzygium fruticosum* DC.	3
Dillenia indica L.	3	*Syzygium syzygioides* (Miq.) Merr. & L.M. Perry.	1
Dimocarpus longan Lour.	1	*Syzygium samarangense* (Blume) Merr. & L.M.Perry	3
Diospyros peregrina Gurke	3	*Tamarindus indica* L.	3
Diospyros phillipensis (Desr.) M.R. Almeida	3	*Tectona grandis* L.f.	2
Elaeocarpus floribundus Blume	3	*Terminalia bellirica* (Gaertn.) Roxb.	2
Erioglossum edule Blume	1	*Terminalia catappa* L.	2
Erythrina variegata L.	1	*Terminalia chebula* Retz.	2

Erythrina fusca Lour.**	1	*Terminalia arjuna* Wight & Arn.	2
Eucalyptus camaldulensis Dehnh.	3	*Trema orientalis* (L.) Blume	1
Ficus lacor Buch.-Ham.	1	*Trewia polycarpa* Benth. & Hook.f.	1
Ficus racemosa L.	1	*Ziziphus nummularia* (Burm.f.) W. & A.	2
Ficus religiosa L.	1		
Shrubs			
Acacia suma Kurz *ex* Brandis	2	*Jasminum angustifolium* Vahl	1
Allamanda cathartica L.	1	*Jasminum auriculatum* Vahl	1
Ambroma augusta (L.) L.f.	1	*Jasminum grandiflorum* L.	1
Caesalpinia bonduc (L.) Roxb.	1	*Jasminum sambac* (L.) W.A.T.	1
Cajanus cajan (L.) Millsp.	3	*Justicia adhatoda* L. Nees	1
Calotropis gigantea (Willd.) Dryand. *Ex* W.T.A.T.	1	*Lantana camara* L.	1
Calotropis procera R. Br.	1	*Lawsonia inermis* L.	1
Capsicum annuum L.	3	*Manihot esculenta* Crantz	1
Carissa carandas L.	1	*Mimosa pudica* L.	1
Centratherum anthelminticum (willd) Kuntze	1	*Murraya paniculata* (L.) Jack	1
Cestrumnocturnum L.	1	*Mussaenda glabrata* Hutchinson *ex* Gamble	1
Citrus aurantium L.	1	*Mussaenda erythrophylla* Schumach. & Thonn.	1
Citrus limon (L.) Burm.f.	3	*Origanum majoranum* L.	1
Citrus aurantifolia (Christm.) Swingle	1	*Pedilanthus tithymaloides* (L.) Poit.**	1
Clerodendron indicum (L.) O.K.	1	*Rauvolfia serpentina* (L.) Bth. *ex* Kurz *	1
Clerodendrum inerme (L.) Gaertn.	1	*Ricinus communis* L.	1
Codiaeum variegatum (L.) Blume	1	*Rosa damascena* Mill.	1
Duranta erecta L.	1	*Sennaalata* (L.) Roxb.	1
Eupatorium odoratum L.	1	*Senna occidentalis* (L.) Irw. & Barneby	1
Gardenia jasminoides Ellis	1	*Sesbania sesban* (L.) Merr.	1
Glycosmis pentaphylla (Retz.) DC.	1	*Solanum indicum* L.	1
Gossypium herbaceum L.	1	*Solanum melongena* L.	1
Hibiscus rosa-sinensis L.	1	*Solanum torvum* Sw.	1
Hibiscus schizopetalus (Most.) Hook.f.	1	*Tabernaemontana divaricata* (L.) R. Br. *ex* Roem & Schult.	1
Hibiscus syriacus L.	1	*Thuja orientalis* L.	1
Ixora arborea Roxb. *ex* Sm.	2	*Vitex negundo* L.	1
Ixora coccinea L.	1		
Herbs			
Abelmoschus esculentus (L.) Moench.	3	*Glinusoppo sitifolius* (L.) DC.	3
Achyranthes aspera L.	1	*Gloriosa superba* L.	1
Aclypha indica L.	1	*Gomphrena globosa* L.	1
Allium cepa L.	3	*Hedychium coronarium* Koen.	1
Allium sativum L.	3	*Helianthus annuus* L.	2
Alocasia indica (Lour) Koch	3	*Heliconia metallica* Planch. & Linden	1
Aloe indica Royle	1	*Heliotropium indicum* L.	2
Alternanthera philoxeroides (Mart.) Griseb.	1	*Lasia spinosa* Thwaites	1
Alternanthera sessilis (L.) DC.	1	*Lycopersicon esculentum* P. Miller	1
Amaranthus oleraceus L.	3	*Mirabilis jalapa* L.	1
Amaranthus gangeticus L.	1	*Musa spp.*	3
Amaranthus viridis L.	1	*Nigella sativa* L.	1
Amorphophallus campanulatus Blume	1	*Ocimum americanum* L.	3
Amorphophallus paeoniifolius (Denn.) Nicol.	3	*Ocimum basilicum* L.	3
Ananas comosus (L.) Merr. var. *sativus* (Schult.f.) Mez	1	*Opuntia dillenii* Haw.	1
Andrographis paniculata Nees *	3	*Oxalis corniculata* L.	1
Argemone mexicana L.	1	*Pachyrhizus tuberosus* Spreng.	1
Bacopa monniera (L.) Wettst.	1	*Plumbago indica* L.	1
Bambusa spp.	1	*Polianthes tuberosa* L.	1

Bryophyllum calycinum K.D.Koenig & Sims	1	*Polygonum hydropiper* L.	1
Carica papaya L.	1	*Polygonum glabrum* Willd.	1
Celosia argentea L.	1	*Ravenala madagascariensis* J.F.Gmel.	1
Centella asiatica (L.) Urban	1	*Saccharum spontaneum* L.	1
Chenopodium album L.	1	*Tagetes patula* L.	1
Chrysanthemum segetum L.	3	*Tagetes signata* Bartl.	1
Clerodendron viscosum Vent.	1	*Thunbergia erecta* (Bth.) T. Anders.	1
Colocasia esculenta (L.) Schott	1	*Trapa bispinosa* Roxb.	1
Colocasia esculenta (L.) Schott	1	*Tridax procumbens* L.	1
Colocasia nymphaeifolia Kunth	3	*Typhonium trilobatum* (L.) Schott	1
Curcuma longa L.	1	*Xanthosoma atrovirens* K.Koch & Bouche	1
Curcuma zedoaria (Berq.) Rosc.	3	*Xanthosoma nigrum* (Vell.) Mans.	3
Dahlia rosea Cav.	3	*Zea mays* L.	2
Datura metel L.	1	*Zingiber officinale* Rosc.	3
Datura starmonium L.	1		
Climber (woody and non-woody)			
Abrus precatorius L.	1	*Ipomoea hederacea* (L.) Jacq.	1
Antigonon leptopus Hook. & Arn.	1	*Iponoca fistulosa* Mart. *ex* Choisy	1
Artabotrys hexapetalus (L.f.) Bhandari	1	*Lablab perennans* DC.	2
Asparagus racemosus Willd.	1	*Lagenaria siceraria* (Md.) Standl.	3
Basella alba L.	3	*Luffa acutangula* (L.) Roxb.	3
Benincasa hispida (Thunb.) Cogn.	3	*Luffa amara* Roxb	1
Bougainvillea glabra Heimerl	1	*Luffa cylindrica* M.Roem.	3
Calamus guruba (Mart.) Kunth *	2	*Lygodium flexuosum* (L.) Sw.	1
Cissus quadrangularis L.	1	*Momordica charantia* L.	3
Citrullus colocynthis (L.) Schrad.	1	*Mucuna pruriens* (L.) DC.	1
Clitoria ternatea L.	1	*Passiflora foetida* L.	1
Coccinia cordifolia (L.) Cogn.	1	*Petrea volubilis* L.	1
Cucumis sativus L.	3	*Piper abbreviatum* Opiz	1
Cucurbita maxima Duchesne *ex* Lmk.	3	*Piper betle* L.	1
Cuscuta reflexa Roxb.	1	*Piper longum* L.	3
Dioscorea alata L.	3	*Scindapsus aureus* Engl.	1
Dioscorea bulbifera L.	1	*Tinospora cordifolia* Miers	1
Dioscorea esculenta (Lour.) Burkill	1	*Trachyspermum ammi* L.	1
Hiptage bengalensis (L.) Kurz	1	*Trichosanthes anguina* L.	1
Hoya verticillata (Vahl.) G. Don	1	*Vigna unguiculata* (L.) Walp.	3
Ipomoea aquatica Forssk.	3	*Vitis setosa* (Roxb.) Wall. *ex* Wight	1

A total of 271 species (109 trees, 53 shrubs, 67 herbs and 42 woody and non-woody climbers) in 3 different use categories were recorded. For uses, 1 for self consumption, 2 for commercial, and 3 for both (self consumption and commercial) uses. * indicates IUCN red listed species for Bangladesh. ** indicates the species planted as hedgerow.

Table 2. Species composition of homegardens in Kalaroa *Upazila* of Satkhira District, Bangladesh.

Plant Life Form	All Home gardens (total area surveyed 9.29 ha)					Per Home garden (average size 1340 m^2)			
	Number of Species			No of Family	Percent of all species	Number of Species			Percent of total species
	Exotic	Native	Total			Exotic	Native	Total	
Trees	35 (32)	74 (68)	109	39	40	19 (43)	25 (57)	21	48
Shrubs	31 (58)	22 (42)	53	17	20			7	16
Herbs	30 (45)	37 (55)	67	32	25			10	23
Climbers	17 (33)	25 (67)	42	20	15			6	13
Total	113 (42)	158 (58)	271	79	100	19 (43)	25 (57)	44	100
IUCN Red Listed- 0		4	4	4	1.48				

Total number of homegarden sampled 50 totalling 9.29 ha area. Native plants were determined according to the Indian Subcontinent Floristic (Kabir and Webb, 2008b). Figure in the parenthesis showing the percent of total. Plants that had been declared under any level of threat by the IUCN were defined as the IUCN Red Listed species for Bangladesh (Khan *et al.*, 2001).

species across the study area – maintained the central livelihood function for vast majority rural people – while providing biodiversity conservation services.

An average total of 44 (range: 28–54, 25 native and 19 exotic) species were recorded from 1340 m^2 (range: 170–6700) mean home garden size, which corroborates with the global range of other tropical home garden's size and species content (Fernandes and Nair, 1986).Of the 44 species, 21 (48%) trees, 7 (16%) shrubs, 10 (23%) herbs, and 6 (13%) woody and non-woody climbers. A set of common 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*) were reportedly present among all sampled homegardens across study area. Four plant species of different families, *Andrographis paniculata*, *Calamus guruba*, *Mangifera sylvatica*, and *Rauvolfia serpentina*, were on the Bangladesh IUCN Red List. Plant species of Bangladesh IUCN Red List accounted for about 1.5% of all identified species.

The ten most important species of each life form were represented by 57% native and 43% exotic. Relative frequency value of each species recorded from the homegarden was used to rank the importance value of the respective species. Kabir and Webb (2008a) reported this figure 45% and 55% respectively from south-western Bangladesh home gardens. The difference may be due to the fact that this study conducted in a significantly smaller area and sample size than that of Kabir and Webb (2008a). Ten most important tree species showed relatively similar evenness among them in all surveyed home gardens as in Table 3, and also shrubs, except *Lawsonia inermis*. *Musa* spp., *Carica papaya* and *Alocasia indica* dominated herb synuse while woody and non-woody climber's was dominated by *Cuscuta reflexa*, *Tinospora cordifolia*, *Iponoca fistulosa*, and *Basella alba*.

Species use

The species those provide quick production of edible crops, multiple use options and income generating opportunities are attractive globally (Kabir and Webb, 2008b). Farmers used all plant species recorded from the home gardens in Kalaroa *Upazila*. We categorize all the useful plants into three main uses as in Table 4. Of the total 271 species, 173 (64% of all recorded species) were used for self consumption, 25 (9%) for commercial and 73 (27%) for both self consumption and commercial use. Majority species (64%) utilization for self consumption represented the subsistence nature of most home garden in the study area. This result is consistent with other home garden studies in Bangladesh (Millat-e-Mustafa *et al.*, 2002; Kabir and Webb, 2008b; Roy *et al.*, 2013). Of the 173 self consumption species, 51 (46) were from tree, 48(90%) from shrub, 47 (70%) from herb and 28 (66%) from climber category. Plants of all life form were significantly used for self consumption. Seventy-two percent of all the species used for commercial purposes exclusively were trees.

Twenty percent of the ten most important species (tree 60%, and herbs 20%) in the home garden were multipurpose (i.e., having at least 2 uses). The multiple use option in our study is an indication of how the rural residents in Bangladesh value plants as an important component for livelihoods. Species planted for multiple use are common in rural home gardens as the financial means do not prevalent to replace plant resources (High and Shackleton, 2000) such as hedges with concrete wall (Molebatsi *et al.*, 2010). The value of multipurpose trees is much higher in rural areas where plants can be conserved in the home gardens through uses. A total of 198 (73% of all recorded) species had only use in the study area. As most species in the home garden are planted by the farmers, functional diversity of species was low (i.e., multiple use of species is low, only 27% of all recorded species) than a specific target oriented use of species. This is true for all commercial plus subsistence oriented forestry and agroforestry practices across the tropical and subtropical region (Nair, 2001; Peyre *et al.*, 2006).

Home gardens are a vital source for subsistence economy and self-sufficiency of many Bangladeshi households, owing to their diverse products (Leuschner and Khaleque, 1987; Millat-e-Mustafa *et al.*, 2002; Ahmed and Rahman, 2004; Kabir and Webb, 2008b; Kabir *et al.*, 2010; Roy *et al.*, 2013; Rahman and Rahman, 2014). This also is true for many other tropical home gardens (Lamont *et al.*, 1999; Kumar and Nair, 2004; Molebatsi *et al.*, 2010; Saikia *et al.*, 2012; Maroyi, 2013; Amberber *et al.*, 2014; Sharma *et al.*, 2014). Of all recorded species, 73 (27%) used for cash income from the sale of surplus home garden products after subsistence consumption to supplement family income as shown in Table 4. Though, cash income from the sale of home garden products was not vividly the reason of planting those trees in the gardens. This represented a good mix of subsistence and commercial use of home garden products by the farmers. Farmers actively maintain and/or modify home garden composition to suit their particular livelihood needs (Kabir and Webb, 2008b; Roy *et al.*, 2013).

In general, native plant species were more com-

Table 3. Ten most important useful plant species in each life form based on relative frequency from the home gardens in Kalaroa *Upazila* of Satkhira District, Bangladesh.

SL. No	Botanical name	Local name	Family	Origin	Uses	RF
Trees						
1	*Mangifera indica*	Am	Anacardiaceae	N	3	3.88
2	*Lannea coromandelica*	Ziol kacha	Anacardiaceae	N	1	3.59
3	*Cocos nucifera*	Narikel	Palmae	N	3	3.49
4	*Psidium guajava*	Peara	Myrtaceae	E	3	3.29
5	*Swietenia macrophylla*	Mehogony	Meliaceae	E	3	3.20
6	*Phoenix sylvestris*	Khejur	Palmae	N	3	3.00
7	*Samanea saman*	Rain Tree	Mimosoideae	E	3	2.81
8	*Artocarpus heterophyllus*	Kanthal	Moraceae	E	3	2.71
9	*Borassus flabellifer*	Tal	Palmae	N	3	2.71
10	*Ficus hispida*	Dumur	Moraceae	N	1	2.71
Shrubs						
1	*Lawsonia inermis*	Mendi	Lythraceae	E	1	8.10
2	*Citrus limon*	Kagojee Lebu	Rutaceae	E	3	6.70
3	*Ricinus communis*	Venna	Euphorbiaceae	E	1	6.42
4	*Codiaeum variegatum*	Pata Bahar	Euphorbiaceae	E	1	4.75
5	*Pedilanthus tithymaloides*	Bera Chita	Euphorbiaceae	E	1	4.47
6	*Calotropis procera*	Choto Akondo	Asclepiadaceae	N	1	4.19
7	*Glycosmis pentaphylla*	Daton Gach	Rutaceae	N	1	3.63
8	*Rauvolfia serpentina*	Sharpogondha	Apocynaceae	N	1	3.35
9	*Solanum torvum*	Tit Begun	Solanaceae	E	1	3.35
10	*Caesalpinia bonduc*	Natam	Caesalpinioideae	E	1	3.07
Herbs						
1	*Musa spp.*	Kola	Musaceae	E	3	8.47
2	*Carica papaya*	Pepe	Caricaceae	E	3	5.30
3	*Alocasia indica*	Man Kachu	Araceae	N	3	5.08
4	*Centella asiatica*	Thankuni	Apiaceae	N	1	4.45
5	*Xanthosoma nigrum*	Dosta Kachu	Araceae	E	1	4.45
6	*Bambusa spp.*	Bans	Gramineae	N	3	4.03
7	*Datura metel*	Kalo Dhutura	Solanaceae	E	1	3.81
8	*Abelmoschus esculentus*	Vendi	Malvaceae	N	2	3.18
9	*Amaranthus oleraceus*	Data Shak	Amaranthaceae	N	3	2.97
10	*Colocasia nymphaeifolia*	Buno Kachu	Araceae	N	1	2.97
Climbers (woody and non-woody)						
1	*Cuscuta reflexa*	Swarna Lata	Convolvulaceae	N	1	14.54
2	*Tinospora cordifolia*	Guloncha	Menispermaceae	N	1	8.87
3	*Iponoca fistulosa*	Dhol kolmi	Convolvulaceae	N	1	8.51
4	Basella alba	Pui Shak	Basellaceae	E	3	8.16
5	*Coccinia cordifolia*	Tela Kucha	Cucurbitaceae	N	1	5.67
6	*Piper abbreviatum*	Chui	Piperaceae	N	1	5.32
7	*Hoya verticillata*	Pargacha	Asclepiadaceae	N	1	4.26
8	*Mucuna pruriens*	Chutra	Papilionoideae	N	1	4.26
9	*Abrus precatorius*	Kunch	Papilionoideae	N	1	2.84
10	*Benincasa hispida*	Chal Kumra	Cucurbitaceae	E	1	2.84

N native and E exotic species. For uses, 1 for self consumption, 2 for commercial, and 3 for both (self consumption and commercial) uses. RF is relative frequency of the species used to rank species in their respective life form.

Table 4. Functional diversity of plants in the home gardens of Kalaroa *Upazila* of Satkhira District, Bangladesh.

Life forms	Uses Category			Total number of recorded species
	Self consumption	Commercial	Both	
Tree	51 (46)	18 (17)	40 (37)	109 (40)
Shrub	48 (90)	2 (4)	3 (6)	53 (20)
Herb	47 (70)	3 (5)	17 (25)	67 (25)
Climber	28 (66)	2 (5)	12 (29)	42 (15)
Total number of species in each use category	173 (64)	25 (9)	73 (27)	271

Total percent for species and individuals in nine different use categories exceeded 100 because many of the recorded species were multipurpose. Figures in the parenthesis are the percent of the total number of species recorded in each life form.

monly used for all purposes except commercial and fibre because exotic species were alleged to produce those valuable products more rapidly than native species which correspond with the findings of Kabir and Webb (2008b) for the same region of Bangladesh. Exotic species reportedly provided high volume and value in their products with the sale of surplus providing increased income. As the ratio of species used for various purposes differ depending on the needs of the gardeners (Saikia *et al.*, 2012), many tropical home gardens are turning to commercial orientation from subsistence use over time. We found a shifting trend of planting more cash crops in home gardens due to increasing access to market. Owner choice to earn and/or maximize cash income for family may be the reason for more exotic introduction in home gardens which correspond with Roy *et al.* (2013). Roy *et al.* (2013) suggested to create better market access to home gardeners with strong doubt of negative influence of market access to home garden biodiversity – can be considered as a question for future research.

In calculating total annual contribution of home gardens to households, a few assumptions were made. Even though food, medicines and other uses consumed by households did not represent direct income to households, it was assumed that home garden products (both used and sold) contributed to household's income. Our results represented the total annual average household income accounted 51% from agriculture, 31% from off-farm and the rest 18% (range: 3–50) from home garden as in Table 5. Mean annual income from home gardens may vary depending on the component products and nature of the products utilization. Household income from home garden may vary from 6% (Kabir and Webb, 2008b) to 54% (Trinh *et al.*, 2003) in South and Southeast Asia. Home garden's contribution to household annual income of this study does not corroborate with many other studies documented for Bangladesh. In addition, home garden's contribution to household income in Bangladesh was at the lower extreme compared to other results in South and Southeast Asian home gardens (Kabir and Webb, 2008b). Nevertheless, such contribution is substantial for the households in such a resources poor (0.16 ha per capita land) and income (829 US$ per capita) holding country like Bangladesh. Contribution of home gardens to the family income was calculated based on the yearly gross benefit earned from subsistence consumption and from the sale of surplus products by the households. However, there is aesthetics, ecological, social, and religious-cultural shadow benefits associated with home gardening systems. Future research can be conducted using more systematic evaluation of the costs incurred and benefits earned from all aspects such as subsistence, cash, ecological, social, aesthetics, and religious-culture of home gardening systems.

Table 5. Household average annual income from various sources in Kalaroa *Upazila* of Satkhira District, Bangladesh.

Source of income	Average income per household	
	Amount, US$	% Total
Off-farm	727	31
Agriculture	1199	51
Home garden	414	18
Total	2340	100

1 US$ = 74.79 BDT as on August 08, 2011

Species Rarity

Although the species richness and similarity across home gardens were high, majority species could be considered rare (i.e., low frequency and abundance). Of all the recorded species, 55% were in 10 or fewer percent of all home gardens sampled. A total of 87 (32% of all recorded species) species represented by 34 trees, 11 shrubs, 24 herbs and 18 climbers were found only in one or two home gardens as shown in Fig. 2. Only 2% of all recorded species were common (found in more than 75%

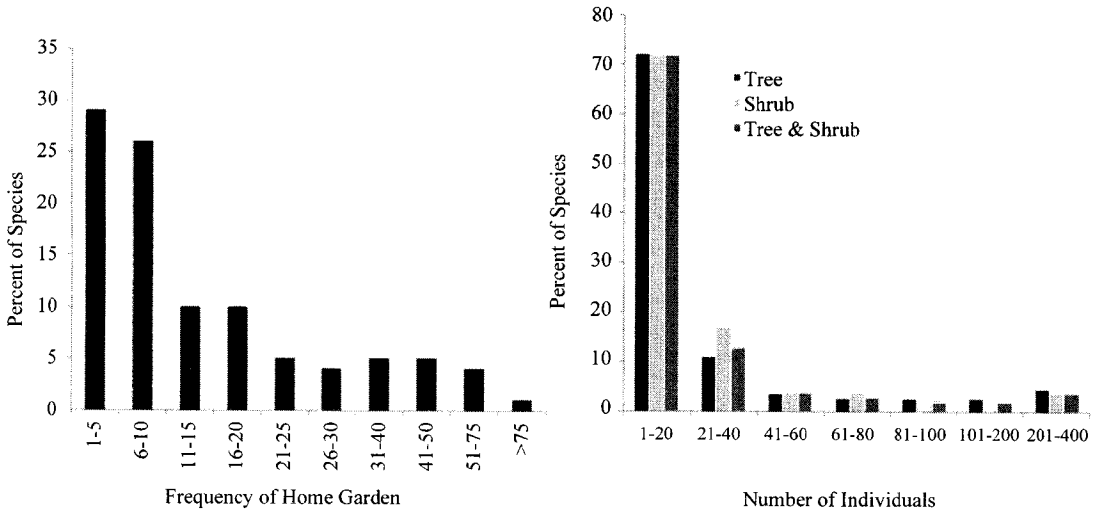

Fig. 2. Frequency and abundance of species distributed in the home gardens of Kalaroa *Upazila*, Satkhira District, Bangladesh.

of sample home gardens). About 72% of all species of trees and shrubs had 20 or fewer individuals each and 85% had 40 or fewer individuals each. Only five of 109 recorded tree and two of 53 recorded shrub species (i.e., only 4% of all recorded trees and shrubs species) had more than 200 individuals each as shown in Fig. 2. We found all four IUCN Red listed species for Bangladesh were planted in a total of 19 home gardens having only one species each. A total of 34 individuals of *Rauvolfia serpentina* were recorded in 12 home gardens. *Andrographis paniculata*, *Calamus guruba* and *Mangifera sylvatica* were found in two, four and one home garden and recorded with four, six, and one individual respectively. Thus, there was a low prevalence of threatened species into home gardens. Home gardens showed the capability of preserving these valuable species while the owners are using them. Sincere efforts may require to increase the number of population of those threaten species for conservation in Bangladesh home gardens.

Conclusion

Bangladesh is a transitional zone of flora and fauna because of its strategic geographical location. However the biodiversity loss is rapid due to escalated deforestation. The numerous direct and indirect human causes of deforestation must be curtailed with the implementation of effective nature resources management policy. In these circumstances, traditional land use pattern should be carried over which will permit maintenance of productivity combined with conservation of the resources on which, that production depends. Results of this study showed that home garden investment and subsequent practices largely depends on the farmer's economic, cultural, and environmental understanding of home gardening. Under the homestead practices farmers are mainly concerned with growing food producing species, especially fruit and vegetables plants. Food, timber, fuel wood, medicinal, and fodder were the five most preferred products from the home gardens. Efficient management of limited space can ensure a more reliable and sustainable supply of rural livelihood commodities and wide range of services. Whatsoever, in absence of supply of resources from natural forests, species rich home gardening system in Bangladesh exhibit clear scope of livelihoods to million people and perhaps conserve biodiversity outside natural and/or protected area systems. However, strategies such as (1) propagation, (2) protection (3) provision and (4) popularity building for conservation of threatened species in Bangladesh home gardens can be taken by all responsible to save help useful plants from any levels of threat.

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