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The ecology and management of traditional homegardens in Bangladesh.

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THE ECOLOGY AND MANAGEMENT OF TRADITIONAL HOMEGARDENS IN BANGLADESH

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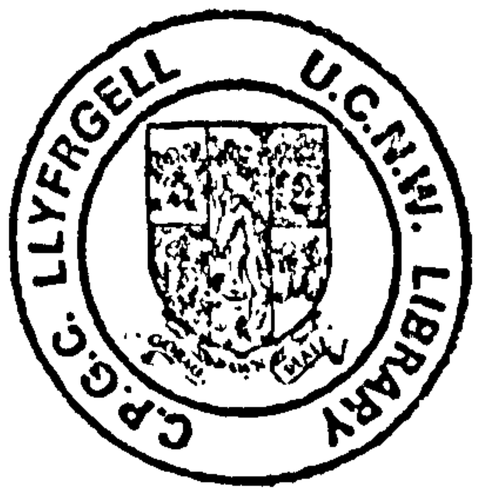

Dedicated to my parents

LATE HABIB ULLAH
&
MRS. AYESHA HABIB

who have raised me to the standard of being capable of completing this work

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ABSTRACT

A vegetation survey in four regions (Deltaic, Dry, Hilly and Plain) in Bangladesh was conducted with reference to marginal (> 0.02 - 0.08 ha), small (> 0.08 - 0.14 ha), medium (>0.14 - 0.20 ha) and large (> 0.20 ha) farm categories. Eighty homegardens (five from each farm category in each of the four regions) were assessed in terms of structure, species composition and diversity of the perennial species. Ordination of floristic data from the 80 homegardens showed a distinction between the Dry and the other regions due to a combination of lower species richness in the Dry region homegardens and several species exclusive to the regions. Floristic differences led to less marked but nevertheless important differences among the other regions, also.

Most species were planted in the border of the homegardens irrespective of farm size and region. Food and fruit producing species dominated near the living quarter and working areas and small plots of annual vegetables and crops separated this part of the garden from the more distant parts favoured for timber species. Six vertical strata were recognised with higher plant density and species richness recorded in the lower three (<7 m). In total ninety two perennial species were recorded for the set of 80 homegardens surveyed. From gardens in the Deltaic region 67 species were recorded. Corresponding figures were 56 for the Plain region, 54 for the Hilly region and 46 for the Dry region. Diversity was highest among food and fruit producing species, followed by the timber species.

Indigenous management techniques in homegardens were investigated using different PRA methods. Farmers' used all sorts of planting materials to regenerate homegardens plants. Homegarden provided more than three quarters of the required planting materials. Mother trees were selected for fruit species only. Farmers practised simple cultural operations (weeding and pruning) which were rarely intensive. The fertility of homegardens was maintained naturally from leaf litter, faeces of animals, kitchen waste and the mud of fish ponds. There was a clear separation of tasks between men and women for homegarden management. Farmers spent only 5 - 12 % of their labour and 4 - 7.5% of their active time in homegarden management.

Farmers have considerable knowledge about mother tree selection, silvicultural protection, as well as about positive and negative interactions. Farmers' had more knowledge about above-ground interaction than below-ground interactions. Women are more knowledgeable than men in many management aspects of homegardens, but their access to various resources is limited. Farmers are very much aware of different functional aspects of homegardens, but due to the lack of good planting materials, funds and extension supports do not utilise their full awareness and knowledge of these matters for homegarden development.

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Chapter 1

INTRODUCTION

Bangladesh is a densely populated country with 755 persons per km^2. About 80% of this population live in rural areas in 13.8 million households spread over 68,000 villages with an average family size of 5.48 persons per household (BBS, 1994). According to the last census, the estimated growth rate of population is 2.17.

Two parallel systems of production forestry exist in Bangladesh: government forest land managed by the Forest Department and privately owned homegardens. Of the country's total land area, only about 2.24 million hectares are designated as government forest land (both natural and plantation forests). Homegardens constitute 0.27 million hectares and are scattered all over the country.

Government forest land and homegardens together make up 17% (2.5 million hectares) of the potential tree growing area of the country the lowest figure of any South Asian country (Forestry Master Plan, 1992). The ever-increasing population of Bangladesh is imparting pressure on existing forests for more food, fuelwood, timber, fodder and other forest products and is resulting in the over-exploitation of government managed forest resources. About 70% of the plain land sal forests are encroached (Forestry Master Plan, 1992). Other forest lands are also degraded and as a result their productivity is unacceptably low. ODA (1985) estimated that the productivity of mangrove forest has declined by 25% over a period of 25 years. Similarly, the yield of hill forests has declined at the same rate. Present productivity of forests has declined to a range of 1.5-2.5 m^3 per hectare per annum from 7-8 m^3 twenty years ago (Forestry Master Plan, 1992).

The recuperative capacity of the natural growth of plants has failed to keep pace with the increasing level of demand. In 1984, the estimated per capita consumption of fuelwood and timber was only 0.08 m^3 and 0.008 m^3, respectively (FAO, 1986). It was perhaps the lowest level of consumption in the world. Even if the consumption level would remain the same, the projected supply would be able to satisfy only 26% of fuelwood and 41% of timber requirement in the year 1995, and 20% of the projected demand of fuelwood and 33% of timber respectively of the year 2000 (Davidson, 1984). The rate at which destruction of forest resources has been taking place has been much faster than the contemporary attempts of rehabilitation programme and as such restoration to even original status is largely in default because of the increasing population and consequent increase in demand. The dismal forestry situation of the country is further exacerbated by the eccentric spatial distribution of the existing government forest areas. Almost 48% of the government forests are located in the eastern region of the country along the international frontiers (hill forests). Another 23% is on the south-western corner along the Bay of Bengal (mangrove forests). The vast flat countryside where almost the whole population live has only 0.12 million hectares (5.44% of the total forest area) of plain land Sal (*Shorea robusta*) forests. While major portions of the natural hill forests are inaccessible and hence either under-utilised or un-utilised, the accessible forests have been over-utilised or denuded and in parts encroached. Consequently the benefit ordinarily derivable even from these meagre forest areas with appropriate management and development are not available to the people at present.

It is the homegardens, although small in coverage, that supply the major part of fuelwood, timber and other forest products requirements of the country. Farmers intensively manage this system for their subsistence using their own resources of land, labour and know-how. It is estimated that the average rate of

increment of homegardens is 5 m^3 per hectare per annum that is more than double that of the government forests (Forestry Master Plan, 1992).

Homegardens are well-established traditional land use systems. For Bangladesh, Dalmacio (1989) points that homegardens are a particularly appropriate form of agroforestry, being operational units for subsistence in which different crops including trees are grown in mixture with livestock. Fish culture is also quite common in the homegardens. Most of the homegardens are rectangular in shape. They are usually built on mounds to raise dwellings above the water level during annual flood (Leuschner and Khaleque, 1987). The extra earth for raising these mounds is generally obtained by digging ponds within the homegarden. The homegarden is usually fenced by trees or shrubs. A typical homegarden serves several houses of related families in a cluster, and has space for vegetable gardens and yard for threshing ground and communal activities, cattle shed, ponds, trees, shrubs and bamboo (Khaleque, 1987). The most frequently used plants are generally grown in the back yard, at the pond side and around the cow shed areas for the provision of fruit/food, fuelwood, timber and fodder both for domestic use as well as for cash.

Homegardens are more reliable from the physical and socio-economic points of view than crop fields for growing trees and agricultural crops, and are important sources of income for the farmers of Bangladesh. The farmers sell crop land to fight against pauperisation but retain the homegarden unless absolutely unavoidable. Even functionally landless farmers have their own homegardens where they grow the essential commodities for subsistence (Abedin and Quddus, 1990). Davidson (1984) observed that over half of the fruits, vegetables and spices grown in the homegardens are sold to meet family expenses. Income from homegardens ranges from 26% to 47% of the total family expenses. During the last 40-50 years, the relative importance has shifted from the traditional forestry

(government forests) to homegardens in such a way that today about 55% of requirement of timber, fuelwood and bamboo are met from the homegarden source (Forestry Master Plan, 1992).

A wide variety of trees, shrubs and vegetables is grown in the Bangladesh homegardens. The common trees and shrubs are coconut (*Cocos nucifera)*, betel nut *(Areca catechu)*, mango *(Mangifera indica)*, jack fruit *(Artocarpus heterophyllus)*, litchi *(Litchi chinensis)*, guava *(Psidium guajava)*, lemon *(Citrus limon)*, jujube *(Zizyphus jujuba)*, papaya *(Carica papaya)*, banana *(Musa* spp.*)*, koroi *(Albizia procera)*, rain tree *(Samanea saman)*, mahogany *(Swietenia macrophylla)*, neem *(Azadirachta indica)*, kadam *(Anthocephalus chinensis)*, and bamboo *(Bambusa* spp.*)*. The commonly grown vegetables are aroid (*Colocacia indica*), egg plant (*Solanum melongena)*, okra (*Hibiscus esculantus)*, bitter gourd (*Momordica charantia)*, snake gourd (*Trichosanthes anguina)*, and different varieties of beans. Among cereal crops, pulses like lentil (*Lens esculanta)*, cow pea (*Vigna sinensis)*, black gram (*Phaseolus mungo)*, oil seeds, ground nuts and castor beans are common. Farmers also rear a variety of animals in their homegardens such as cows, goats, buffaloes, sheep and poultry (Baten, 1991).

The Bangladesh Agricultural Research Institute (BARI) has taken the lead in recognising the importance of homegardens in Bangladesh and has undertaken exploratory surveys through its On-Farm Research Division in different Farming Systems Research (FSR) sites. Under the auspices of BARI, Alam *et al.* (1990) conducted a survey on homestead trees and household fuel uses in and around the Farming Systems Research sites of Jessore and Mymensingh districts. The objectives of this research were to identify what was planted at the homesteads and how the species were used, types of fuel used at household level and the constraints of homestead production. Similar surveys were also conducted by Akhtar *et al.* (1989), also for BARI, at Damurhuda thana of Chuadanga district,

Momin *et al.* (1990) at the flood plain Tangail district, Kar *et al.* (1990) in the Barind tracts of Rajshahi district, Khan *et al.* (1990) in non-saline tidal flood plain area in the southern part of Bangladesh, Dasgupta *et al.* (1990) in Kishorgonj district, Islam *et al.* (1990) in the high lands of Tista flood plain areas and Islam and Ahmed (1987) in Kalikapur. Lack of good planting materials, extension support, lack of land and money were identified as major constraints to production but it was nevertheless concluded that there was much scope for improvement.

Besides BARI, socio-economic studies pertaining to homegarden production systems were carried out by Leuchner and Khaleque (1987) and Hossain *et al.* (1988). Leuchner and Khaleque (1987) concluded that homegardens are the major source of income for rural poor and that there exists ample potential to improve the production system. Hossain *et al.* (1988) studied the role of gender in homegarden plantations and observed that women play the vital role in the homegardens production system.

Even though homegardens are well-established traditional agroforestry systems in Bangladesh, relevant documentation is very limited. Most studies of homegardens have been carried out on an *ad-hoc* basis and are fragmentary in nature. A more comprehensive holistic approach to understanding homegarden production systems in different regions of Bangladesh and more synthesis of the farmers indigenous knowledge for achieving the sustainability of such systems is needed. The sustainability and environmental compatibility of homegardens depend on the composition, diversity and spatial arrangement of species. These, in turn, are dictated by the management objectives. Consequently, the species composition and diversity and structure of homegardens differ from one Asian region to another (Chacko, 1991; Padock and de Jong, 1987). Established patterns of spatial arrangement help give homegardens uniformity of production against the variabilities of soil resources and climate. Species composition and diversity help

give homegardens efficiency in nutrient recycling and flexibility in outputs. Appreciation of how these systems operate in a particular region demands knowledge of the composition, diversity and spatial arrangement of species. No systematic study has so far been conducted to examine in any detail the pattern of composition, diversity, and spatial arrangement of species in the traditional homegardens of Bangladesh.

The management of the traditional homegarden systems has evolved as a response to many factors, cultural, economic, and environmental as well as personal preferences (Southern, 1994). Since farmers live in intimate contact with their homegarden production systems, it is reasonable to assume that they have detailed knowledge of the components that they manage in their homegardens and the interactions between them and the local environment. But no work has so far been conducted to acknowledge farmers' indigenous knowledge in managing such complex systems. Thus, it is reasonable to suppose that a broader understanding of the system could be reached by examining the indigenous management techniques which can complement and supplement existing scientific knowledge.

The present project is to provide some of the background needed to improve understanding of the foregoing issues, combining a systematic survey of the patterns of species composition, diversity, structure of traditional homegardens of different regions of Bangladesh, with an evaluation of management strategies adopted by the farmers to maintain such patterns. The intention has been to generate information on vegetation patterns and indigenous management techniques that can be related and which will serve as a tool for development planners, extension agents and researchers in designing appropriate research and development activities in homegardens of Bangladesh. The present project was, therefore, carried out to achieve four objectives:

— to assess the pattern of the species composition, diversity and vegetation structure through a systematic vegetation survey,

— to assess farmers' knowledge about homegarden systems and their management strategies in maintaining such patterns,

— to characterise and describe the traditional homegarden systems practised in different regions of Bangladesh on the basis of the present study

— to recommend strategies for the improvement of the traditional homegardens production systems.

Chapter 2
Literature review

Chapter 2

LITERATURE REVIEW

This chapter is in four sections. Section One (2.1) provides a general description of Bangladesh and is divided into six sub-sections presenting, in brief, the geographical location (2.1.1), biophysical environment (2.1.2), climate (2.1.3), soil (2.1.4), land use system (2.1.5) and forest resources of Bangladesh (2.1.6). Section Two (2.2) gives general background to homegardens and section Three (2.3) presents a detail review of literature concerning homegardens.

2.1 General description of Bangladesh

2.1.1 Geographical location

The People's Republic of Bangladesh lies 20°34' - 26°38' N and 88°01' - 92°41' E. It is bounded on the west, north and east by India, on the south-east by Myanmar and on the south by the Bay of Bengal.

2.1.2 Biophysical Environment

The country is mostly low and flat with hilly areas restricted to the north-east and south-east and scattered higher land in the north and north-east (FAO, 1988[b]). The floodplains of the Ganges, Brahmaputra, Meghna and smaller rivers account for about 80% of the land, hills account for 12% and terraces occupy 8% of the country (Brammer, 1990). Four general physiographic regions are recognised: the Hilly, Deltaic, Plain and the Dry land regions (BBS, 1994). The Hilly regions are an extension of the Assam and Myanmar hill ranges and occupy the north eastern (Sylhet district) and south eastern parts (greater Chittagong and Chittagong Hill

Tracts districts) of the country (FAO, 1981). The Deltaic region is located in the southern part (greater Barisal and Khulna districts) of the country. This region is mostly formed by the deltaic action of the Ganges, the Brahmaputra, the Meghna rivers and their feeders (FAO, 1981). The Dry region is located in the north western part of the country. This area was developed under marine conditions but later uplifted, block faulted and eroded, resulting in the present day surface topography (Das, 1990). The Plain region occupies the remainder of Bangladesh.

2.1.3 Climate

The country enjoys a sub-tropical monsoon climate with a distinct dry season. Although there are six seasons in a year, three seasons viz. winter, summer and monsoon are prominent (BBS, 1994). In the winter (November-February) the temperature varies from 5° - 23°C (FAO, 1988[a]). In the summer (March-June) the maximum temperature shoots up to 40°C (FAO, 1988[a]). Monsoon starts in July and persists until October. This period accounts for 80% of the total rain fall (FAO, 1988[a]). An analysis of the isohyet map of the country indicates that mean annual rainfall varies from 1250 mm in the extreme west to 6000 mm in the north east corner of the country, although mean annual rainfall over much of the country is in the range of 1500-3000 mm (FAO, 1988[a]). The potential evapo-transpiration rate during summer is 5-8 mm/day; during the monsoon it is 3-4 mm/day and in the winter 2-3 mm/day (FAO, 1988[a]). A high wind velocity is common during summer and monsoon season in the country. Storms of wind speed of 18 to 24 m second^{-1} occur more than once every year. The direction of the storm depends on the movement of the depression in the Bay of Bengal and the direction of the spin of the cyclonic storm caused by the depression. Generally, the northerly storms occur during the April-May period and the southerly storms during the September-October period (Brammer, 1990).

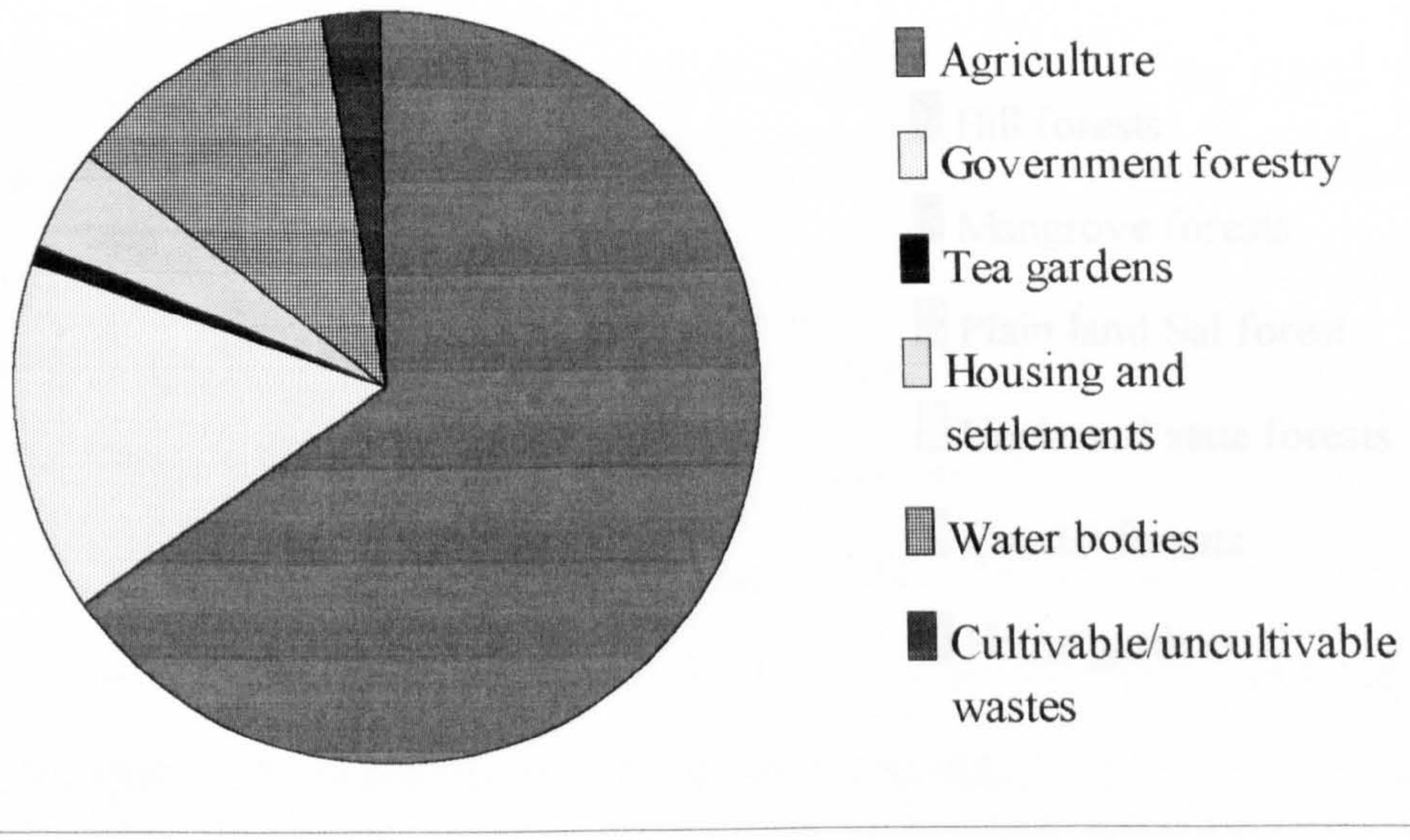
2.1.4 Soils

Bangladesh comprises three major soil physiographic units. These are flood plain soil, hill soil and terrace soil. The flood plain soil covers 79%, hill soil covers 13% and terrace soil covers 8% of the land, respectively (FAO, 1988[b]). Most of the soils have been formed and developed in seasonally flooded and non-flooded with wet or moist and dry conditions under geological sedimentary of tertiary and quaternary age (Morgan and Mcintere, 1959). In the Deltaic region the soil contains river borne silt, a very fine mud, being loamy where water is fresh and stiff clay where it is saline. Also some sands occur locally (Das, 1990). In the Dry region the soils are eutric gleysols and these soils are coarse to fine textured (UNESCO, 1977). The soils are silty loam to silty clay loam. The hilly soils are generally coarse, acidic and non-saline, varying in depth and texture (FAO, 1981). The soils are clayey to clay loamy on the flat valley and sandy on the hill slopes. The sandy soil is often reddish or yellowish due to the presence of iron compounds. Laterization appears on the hill tops as a result of denundation and repeated fires. In the Plain the soils are clayey and clay loam with sand and sandy loam near rivers over a thousand metre deep (FAO, 1981).

2.1.5 Land use systems in Bangladesh

The proportions of land area under different uses in Bangladesh are shown in Fig. 2.1. The total land area of the country is about 14.75 million hectares of which 12.98 million hectares (88%) are land surface (agricultural land 65.3%, government forest land 15.19%, tea garden 0.76%, housing and settlement 4.38%, cultivable and uncultivable wastes 2.37%) and 1.77 million hectares (12%) are covered by the rivers and inland water bodies (BBS, 1994).

Fig. 2.1: Land use systems (%) in Bangladesh

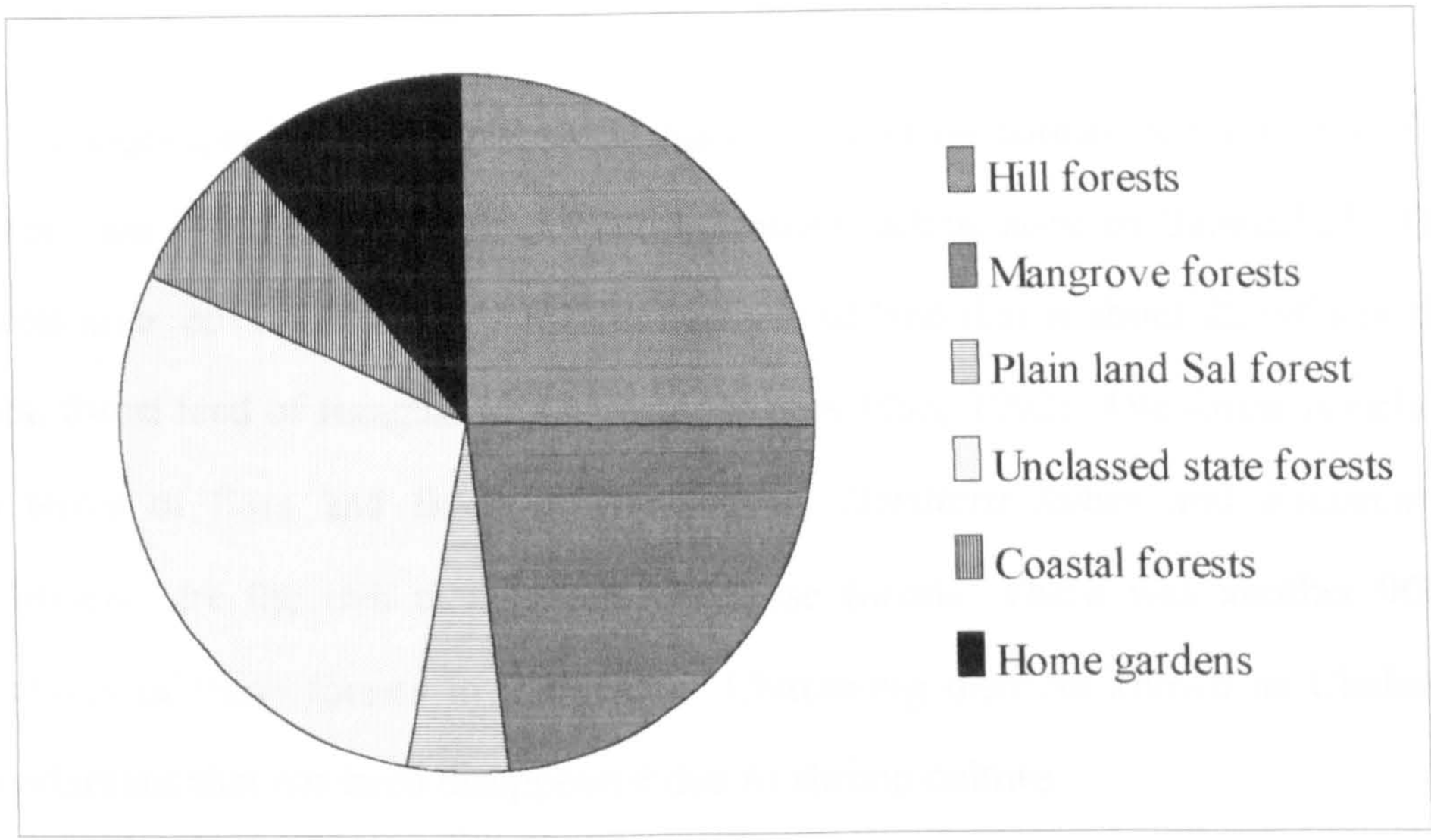


With the increasing population level, persons per hectare is calculated to be 9.6 for all cropped land including forest and plantation crops and 12.4 for land under agricultural crops. In other words per capita land is about 0.08 hectare (BBS, 1994). More than 60 million people are functionally landless possessing less than 0.02 ha of agricultural land (BBS, 1994). The country is essentially an agrarian society wherein the present work force absorbed by this sector is up to 60% and had already reached its saturation with only 0.2% growth (FAO, 1989). This sector directly contributes around 37% of the GDP (BBS, 1994). The country is marginally deficit in food grains. Per capita income is US$ 210 (BBS, 1994).

2.1.6 Forest resources of Bangladesh

On the basis of geographical location, climate, topography and management principles, the forests of Bangladesh can broadly be classified into: Hill forests, Mangrove forests, Plain land sal forests, Unclassed state forests, Coastal forests and Homegardens as shown in Fig. 2.2 (Forestry Master Plan, 1992).

Fig. 2.2: Distribution of different forest types (%) in Bangladesh



2.1.6.1 Hill forests

The Hill forests of Bangladesh are located in the hilly areas of the greater Chittagong, Chittagong Hill Tracts and Sylhet districts. This forest area covers about 0.64 million hectares of land that is about 25.49% of the total forest land of Bangladesh (Forestry Master Plan, 1992). The forests consist of a mixture of many tropical evergreen and tropical deciduous species occurring in association with each other and with bamboo. *Tectona grandis*, *Dipterocarpus* spp., *Gmelina arborea*, *Artocarpus chaplasha* are some of the important timber species.

Although these forests are classed as closed multi-storeyed high forests, large areas are heavily encroached by local tribal people for shifting cultivation that is a major cause of destruction of these forests. Encroachment of forest land for agriculture and homestead, pilferage of forest produce for local consumption and trade and attack of *Gmelina arborea* and *Tectona grandis* by *Loranthus* are some of the major problems of the hill forests.

2.1.6.2 Mangrove forests

Bangladesh has the largest single tract of mangrove forests of the world. The forests are found in the south and south-western deltaic zone of Bangladesh. The forest area covers about 0.57 million hectares of land that is about 22.98% of the total forest land of Bangladesh (Forestry Master Plan, 1992). The forest is richest in terms of flora and fauna in Bangladesh. *Heritiera fomes* and *Excoecaria agallocha* are the two main species of these forests. There was another 9000 hectares of these forests in the greater Chittagong districts known as Chakaria Sundarbans that has been disappeared due to shrimp culture.

The mangrove forests are important sources of timber and fuelwood as well as minor forest products and are an essential component of the coastal ecosystem. The yields from these forests are being reduced due to great change in biotic and edaphic factors, over-exploitation and diseases especially top dying of sundri trees.

2.1.6.3 Plain land Sal forest

The Plain land sal (*Shorea robusta*) forest covers about 0.12 million ha of land that is about 4.86% of the total forest area of the country (Forestry Master Plan, 1992). The forests are located mostly in patches in the greater districts of Dhaka, Mymensing, Comilla, Tangail, Rajshahi, Rangpur and Dinajpur. The main species of the forest is *Shorea robusta*. The area under tree cover has been estimated to 32% (Forestry Master Plan, 1992). This is the only forest type available to the greater majority population of the country. But due to encroachment, over exploitation, conversion of forest lands into agricultural land, fire and grazing the productivity of the forests has been reduced to an alarmingly low level.

2.1.6.4 Coastal plantation

These forests are found in the coastal areas of Bangladesh. The forest area covers about 0.18 million hectares of land that is about 7.20% of the total forest land of Bangladesh (Forestry Master Plan, 1992). Coastal afforestation was first initiated in 1961 to provide protection against natural calamities and later on accelerated from 1966 for stabilisation of coastal land, for accelerating further accretion and stabilisation of the same for agriculture and meeting the demands for fuelwood and industrial raw materials. The main species are *Sonneratia apetala, Avicennia officinalis* and *Nypa fruticans.* Shrimp culture, salt manufacturing, grazing, fishing, erosion and stem borer infection are the major types of problems in this forest.

2.1.6.5 Unclassed State Forest

These forests are found in the greater districts of Chittagong Hill Tracts of Bangladesh. The forest area covers about 0.72 million hectares of land that is about 28.72% of the total forest land of Bangladesh (Forestry Master Plan, 1992). This forest is jointly controlled by the Revenue Department and the Forest Department. The species composition and the problems are the same as those of the hill forests.

2.1.6.6 Homegardens

Homegardens are an age old agroforestry practice prevalent throughout Bangladesh. A brief description of Bangladesh homegardens has been presented in Chapter One.

2.2 General background to homegardens

Homegarden can be defined as the land surrounding a house, on which a mixture of annual and perennial plants are grown together with/without animals largely managed by the household members for own use or commercial purposes. Brownrigg (1985) defines the term as "a supplementary food production system by and for members of a group of people with rights to the land, who eat meals together regularly". Fernandes and Nair (1986) state that the term homegarden can mean anything from growing vegetables behind houses to complex multistoried systems. They defined the term as "land use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and, invariably, livestock, within the compounds of individual houses, the whole crop-tree-animal unit being intensively managed by family labour".

Homegardens are an ancient and wide spread agroforestry system. While the focus on the system as a development strategy is relatively recent, its existence as a traditional land-use practice spans centuries, even millennia in some cases (Lai, 1989). According to Hutterer (1984), the system may have developed in prehistoric times when hunters and gatherers deliberately or accidentally dispersed seeds of highly valued fruit trees in the vicinity of their camp sites. Brownrigg (1985) in his literature review (cited in Soemarwoto, 1987) mentioned that homegardens in the Near Eastern Region were documented in paintings, papyrus illustration and texts dating to the third millennium BC. The systems have survived throughout centuries as the result of long term adaptation of cultivated plants and cultural techniques to local ecological conditions and they have in many cases reached a noticeable degree of harmonisation with the natural environment (Michon, 1983). Farmers who practise the systems are guided, perhaps in the absence of a unified set of expert recommendations, by their own perceptions and

convictions about species selection, admixture and management, so that each farm unit is a specialised entity in itself (Fernandes and Nair, 1986).

Homegardens are fundamental to peasant's lives, because they are not only units of production but are also part of the habitation unit of the peasant family (Buylla Roces *et al.* 1989). Although there are many variations in homegarden design and pattern, the basic features remain the same (Christanty, 1985). A homegarden usually contains a house, a bare space and a cultivated space. Usually the cultivated space (the garden) is located surrounding the house, in front of the house as front yard or behind the house as back yard. The bare space is used for various social and ceremonial activities. Intensive uses of cultivated space, the multiple functions of farm yard plantings, predominance of root, tuber and tree crops are some of the characteristic traits of traditional homegardens in many parts of the world (Ninez, 1987). The gardens often feature low capital input and simple technology and are intensively managed by family labour. Yields are generally low but stable and sustainable (Fernandes and Nair, 1986; Ninez, 1987; Soemarwoto, 1987). Personal preferences and attitudes, socio-economic status and culture often reflect the appearance, structure and function of the homegardens (Christanty, 1985).

Numerous terms have been used by various authors to denote these practices. These include, for example, mixed-garden horticulture (Terra, 1954), mixed garden or house garden (Stoler, 1978), homegarden (Ramsay and Wiresum, 1976), Javanese homegarden (Soemarwoto *et al.* 1985), compound farm (Lagemann, 1977; Okafor and Fernandes, 1987), kitchen garden (Brierley, 1985), household garden (Vasey, 1985), tropical mixed garden (Price, 1982), quintal (Posey, 1985), calmil (Palerm, 1967), pekarangan (Soemarwoto *et al.* 1985), kandyan garden (Jacob and Alleys, 1987), and homestead agroforestry (Leuschner and Khaleque, 1987). The term 'homegarden' is adopted in this thesis.

2.3 Homegarden characterisation

Despite their potentials, homegardens are often ignored by scientist and development agents as an important part of traditional farming systems largely because of their small size and apparent insignificance (Bunderson *et al.* 1990). They are often looked at as an example of primitive, underdeveloped agriculture compared to modern high-yielding technological agrosystems (Michon *et al.* 1983). Many studies have reported the existence of homegardens in various regions of the world (Table 2.1), but very few studies have adequately analysed the structure, species composition, diversity and the management aspects of the homegardens (Table 2.2 & 2.3).

Table 2.1: Literature on qualitative description of homegardens from across the world

a) Asia and the Pacific region

Country	Specific homegardens	References
Bangladesh	Bangladesh homegardens	Chowdhury, 1993
	Bangladesh homegardens	Hocking & Islam, 1994
	Bangladesh homegardens	Leuchner & Khaleque, 1987
India	Kerala homegardens	Nair & Sreedharan, 1986
	Kerala homegardens	Salam & SreeKumar, 1991
Indonesia	Javanese homegardens	Abdoellah & Marten, 1986
	Javanese homegardens	Ahmad *et al.* 1980
	Sudanese homegardens	Christanty *et al.* 1986
	Javanese homegardens	Raintree, 1978
	Pekarangan	Soemarwoto & Soemarwoto, 1984
	Javanese homegardens	Soemarwoto *et al.* 1985
Sri Lanka	Sri Lankan homegardens	Wickramasinghe, 1992
Regional homegardens	South East Asia	Anderson, 1979
	Asia	Ninez, 1987
	Indian Subcontinent	Singh, 1987
	Tropical	Soemarwoto, 1987
	Asia and the Pacific	Tejwani & Lai, 1992
	Tropical	Torquebiau, 1992
	Tropical	Wojtkowski, 1993

Contd. Table 2.1

b) American region

Country	Specific homegardens	References
Regional homegardens	Tropical American homegardens	Budowaski, 1985
	American homegardens	Ninez, 1987

c) African region

Country	Specific homegardens	References
Swaziland	Swazi homegardens	Allen, 1990
Tanzania	Tanzanian homegardens	Rugalema *et al.* 1994
Zimbabwe	Zimbabwe homegardens	Campbell *et al.* 1991
Regional homegardens	Sub-Sahara	Cook & Grut, 1989
	Africa	Mergen, 1987
	Africa	Ninez, 1987
	Tropical Africa	Okigbo, 1987

2.3.1 Homegarden structure

Many authors from tropical regions describe homegardens on first sight as haphazard, random, even anarchic and, rather poetically, "order in disorder" (Table 2.2). Within Kandy homegardens of Sri Lanka, Jacob and Alles, (1987) and Nanayakkara (1990) failed to find any spatial pattern of species distribution. Similar observation is also made by Tuladhar (1990) for the homegardens of Nepal and Kumar *et al.* (1994) for the Kerala homegardens of India.

Opposite view is also expressed by a number of authors for the horizontal arrangement of plants in tropical homegardens. Fernandes and Nair (1986) claim that the Pacific homegardens present a more clearly defined spatial arrangement of plants following the orientation and relief characteristics of the watershed and each species perfectly occupies the available space in the homegardens. According to Nair and Krishnankutty (1984), a certain general pattern in arrangement of plants seems to exist in the homegardens of Kerala. However, Christanty *et al.* (1986),

Ahmad *et al.* (1980), Sommers, (1978) and Wickramasinghe, (1992) mention that the spatial arrangement of plants in a homegarden is always determined by various factors such as light, water and fertility requirements, security and crop protection, health, aesthetic and efficiency of space utilisation.

Table 2.2: Literature on structure of homegardens from across the world

Asia and the Pacific region

Country	Horizontal structure	Vertical structure	References
India	RA*	4 strata	Jose & Shanmugaratnam, 1993
	HA*	*	Kumar *et al.* 1994
		4 strata	Nair, 1979
	RA		Nair & Krishnankutty, 1984
Indonesia	HA		Christanty, 1985
		4 strata	Christanty et al. 1980
		4 strata	Jensen, 1993
	RA		Mergen, 1987
		3-5 strata, species richness & density higher in lower stratum	Michon, 1983
	HA	3-5 strata	Soemarwoto, 1987
Nepal	HA		Tuladhar, 1990
Pacific		4 strata	Barrau, 1961
Philippines		4 strata	Sommers, 1978
Sri Lanka	HA		Jacob & Alles, 1987
		3 strata	McConnell & Dharmapala, 1973
	HA		Nanayakkara, 1990
		4 strata, vertical dominance of species on the basis of RIV	Perera & Rajapaksa, 1991

American region

Country	Horizontal structure	Vertical structure	References
Grenada		4 strata	Brierley, 1985
Mexico		4 strata	Gliessman *et al.* 1981

Contd. Table 2.2

African region

Country	Horizontal structure	Vertical structure	References
Nigeria	HA	4 strata	Okafor & Fernandes, 1987
		4 strata	Okigbo, 1987
Tanzania		4 strata	Alriksson & Ohlsson, 1990
	HA	4 strata	Fernandes *et al.* 1984
Uganda	HA	4 strata	Oduol & Aluma, 1990

* Blank cell indicates "no information is available"
RA = Regular arrangement, HA = Haphazard and irregular arrangement

In homegarden, the vertical stratification of vegetation has been long recognised as one of its characteristic features, though the variation of height within any one stratum has led to some arguments as to the distinctness of the various strata recognised by various authors. Barrau (1961), Michon (1983), Altieri and Farrel (1984), Fernandes *et al.* (1984), Okafor and Fernandes (1987), Oduol and Aluma (1990) from various geographical regions give schematic presentations of vertical structure and observe that the canopies of most homegardens consist of 2-5 layers. Fernandes and Nair (1986) provide a useful general summary of layers:

<1 m	Vegetables, medicinal plants, tubers, roots
1-3 m	Food plants e.g. cassava, banana, papaya, yams
3-5 m	Saplings of fruit/timber trees all growing taller
5-10 m	Fruit/timber trees, some growing taller
>10 m	Fruit/timber tree

They stress that these layers are dynamic and there is constant recruitment from one layer to another. Soemarwoto (1987) first analysed layers in Javanese homegardens as above, then gave the percentages of number of species and number of plants contained in each layer, showing that it was highest in the lowest

layer and lowest in the upper layer, thus adding an element to the picture of vegetation distribution over the garden as a whole.

2.3.2: Homegarden floristics

Homegardens are a highly efficient form of land use, incorporating a variety of crops with different growth habits. Almost every author who describes a homegarden of a particular country gives a list of the important species found in the garden. There are a variety of methods in cataloguing plant species. Some authors take individual gardens. For example Mergen (1987) reported 191 species in one garden in Java (the upper limit for number of species in one garden found in the literature). Other authors look at a village as a whole. For example in Java, 500 species were enumerated in a village by Michon (1983).

Although no quantitative information regarding species composition in the homegardens is available in the literature (Table 2.3), the studies of Barrau (1961) in the Pacific, McConnell and Dharmapala (1973) in Sri Lanka, Sommers (1978) in Philippines, Michon *et al.* (1983) in Java, Boonkird *et al.* (1984) in Thailand have acknowledged the predominance of fruit and food producing species in the homegardens of the respective countries. Similar observations were also made by Islam and Ahmed (1987), Khaleque (1987), Akhtar *et al.* (1989), Alam *et al.* (1990), Dasgupta *et al.* (1990), Islam *et al.* (1990), Kar *et al.* (1990), Khan *et al.* (1990), Miah *et al.* (1990) and Momin *et al.* (1990) at different agro-ecological zones of Bangladesh. Food production is thus the primary function and role of most of the homegardens.

Species composition of the homegardens has been mentioned by several authors from different parts of the world, but less attention has been paid to analyse the similarity of species composition of the tropical homegardens.

Table 2.3: Literature on homegarden floristics from around the world

Asia and the Pacific region

Country	Total species	Species composition	Species similarity	Species diversity	References
Bangladesh	52	*			Abedin & Quddus, 1990
	21	+			Akhtar *et al.* 1989
	28	+			Alam *et al.* 1990
		+			Dasgupta *et al.* 1990
	20	+			Islam & Ahmed, 1987
		+			Islam *et al.* 1990
	28	+			Kar *et al.* 1990
		+			Khaleque, 1987
		+			Khan *et al.* 1990
	34	+			Miah *et al.* 1990
	52	+			Momin *et al.* 1990
Fiji	61				Thaman, 1990
India	127		28.57 - 81.08 %	H' = 1.13-3.02, E = 0.37-0.54	Kumar *et al.* 1994
	30				Nair & Sreedharan, 1986
	36				Babu *et al.* 1992
Indonesia	196			H' = 2.79	Abdoellah & Isnawan, 1980
	60				Jensen, 1993
	607			H' = 2.73 - 2.99	Karyono *et al.* 1978
	191				Mergen, 1987
	500	+			Michon, 1983
	600				Soemarwoto, 1987
Nepal	180				Sollart, 1986
	129				Thapa, 1994
Philippines	74	+			Sommers, 1978
	41				UNICEF, 1982
PNG	114				Thaman, 1990
Sri Lanka		+			McConnell & Dharmapala, 1973
	65				Perera & Rajapaksa, 1991
	170				Southern, 1994
Thailand		+			Boonkird *et al.* 1984
	100				Kamtuo *et al.* 1985
Tonga	65				Thaman, 1990

Contd. Table 2.3

American region

Country	Total species	Species composition	Species similarity	Species diversity	References
Grenada	31	+		H' = 0.24	Brierley, 1985
Martinique	67				Kimber, 1966
Mexico	338				Buylla Roces *et al.* 1989
		+			Gliessman *et al.* 1981
	135		49-59%	H' = 1.6	Rico-Gray *et al.* 1990
Peru	29				Padoch & De Jong, 1987
	168				Padoch & De Jong, 1991

African region

Country	Total species	Species composition	Species similarity	Species diversity	References
Nigeria	60				Bittenbender, 1985
		+			Okafor & Fernandes, 1987
Tanzania	111				O'kting'ati *et al.* 1984

* Blank cell indicates "no information is available"
+ indicates more food and fruit producing species

There is a general agreement among authors on the complexity of homegardens displayed in diversity. But most articles seem to reach their conclusions by observation followed by inference based on current theories and only a few quantitative information are available in the literature. Kumar *et al.* (1994) found a diversity index of 1.129 to 3.016 in different parts of Kerala, India. They concluded that the species diversity of the small gardens was significantly greater than the medium and large holdings. Christanty (1985) has found a diversity index of 2.79 for Javanese homegardens and 3.71 for Sudanese homegardens. Kumar *et al.* (1994) found equitability index of 0.542, 0.368 and 0.428, respectively for small, medium and large holdings of the Kerala homegardens.

2.3.3 Indigenous management techniques

The management of the traditional homegarden systems has evolved as a response to many factors, cultural, economic, and environmental as well as personal preferences (Southern, 1994). Since farmers live in intimate contact with their homegarden production systems, it is reasonable to assume that they have detailed knowledge of the components that they manage in their homegardens and the interactions between them and the local environment. Farmers' indigenous knowledge is often characterised as highly specific and context-bound, with knowledge emerging simply from localised, practical experience (Scoones and Thompson, 1994). Local communities in many areas benefit from generations of experience of the management of complex land use systems that take advantage of the benefits of stability and sustainability associated with complexity. They continuously conduct their own trials, particularly adopt and adapt technologies to their specific circumstances and spread innovations through their networks (Cornwall *et al.* 1994). Their experimentation is quicker and more able to accommodate changing circumstances and diversity than those of research scientists.

Over the past two decades, the importance of farmers' indigenous knowledge in managing their natural resources has gained increasing recognition from the scientific community (Rocheleau, 1987; Altier, 1990; Rist, 1991) and rural development planners are paying particular attention to the usage of the local knowledge (Chambers *et al.* 1989). An increasing number of literature exists that document indigenous systems for the management of the natural resources by local people and illustrate how such knowledge could be usefully applied in the development context (Mathias-Mundy *et al.* 1990; Warren, 1991; Kilahama, 1994; Southern, 1994; Thapa, 1994; Jinadasa, 1995).

Exploration of indigenous management techniques of the homegardens is always a complex exercise and the use of a multi-method approach using a combination of techniques (Kilahama, 1994; Southern, 1994) are often advantageous. Participatory Rural Appraisal (PRA) is one of the most effective multi-method approach which encourages the local people to express knowledge in their own terms by minimising the influences of the researchers (Chambers, 1990). The various participatory methods that were used to sought indigenous management techniques of the homegardens are outlined below.

(i) Tree use matrix

Tree use matrix is a powerful technique that can be used to understand farmers' decision-making process in recognising the uses of different species of plants through interactions among the farmers/family members (Freudenberger, 1994). The scoring technique which is an output of the tree use matrix exercise is a useful tool to rank species according to their multiple uses.

(ii) Paired ranking techniques

This technique can be used to compare preferences for different species of plants between farm categories and regions. The ranking highlights the differences in priorities and differences in decision criteria used as expressed by good and bad properties of each species.

(iii) Semi-structured interview

This is guided interviewing and listening in which only some of the questions and topics are predetermined and questions arises during the interview (Freudenberger, 1994). Formal interviews generally use pre-established

questionnaires. In contrast, the semi-structured interview starts off with a checklist of issues that the interviewer wishes to address and new avenues of questioning are pursued as the interview develops.

(iv) Calendars

Calendars are tools that help to explore changes taking place over the period of a year. They can be useful in counteracting time biases because they are used to find out what happens in different seasons. Knowledge of local calendars and classification systems often provides important information about gender roles in different farming activities (Molnar, 1989).

(v) Sketch mapping

A sketch map is a simple diagram which informants can use to present the physical aspect of their homegarden. It is a simple, schematic device which presents information in a readily understandable visual form (Conway, 1989). Sketch maps can be used to show, roughly to scale, the spatial relationships of living houses, cattle and poultry sheds, ponds, yards, vegetable gardens, planting area, specific locations of species on the ground etc.. Another use of sketch maps is for gaining insight into people's perceptions of their environment. Sketch maps create new avenues for discussion about different management aspects of the homegardens.

2.3.4 Research on indigenous management techniques of homegardens

Many authors acknowledged the management skills of farmers in dealing with the complex homegardens that they acquired empirically over generations. For example Michon *et al.* (1983) claimed that Javanese farmers have such a

thorough knowledge of ecology that they can often choose the correct niche for each plant depending on the gradient of light and humidity and this seems to correspond to its ecological niche in the natural forest. In fact, the diversified structure of homegarden provides knowledge of a broad range of plant species and systems to the farmers. Farmers utilise this knowledge to manage plant species with different means of propagation, life form and origins with a variety of uses. However, literature provides a little basis for the management of homegardens across the world. Management activities of homegardens available from the literature include: planting materials used to regenerate the homegarden plants, cultural operations such as weeding and pruning, watering and fertilising, products and services of the homegardens, labour forces required for homegarden management and the constraints of the present management systems.

2.3.4.1 Planting materials used for regeneration

Both seeds and vegetative methods are used to propagate plants in the homegardens. Indeed fruit trees may spring up wherever people eat fruits and leave the seeds behind. The farmers also scatter the seeds or nuts in suitable places. Sometimes bats, squirrels, birds also act as vector. Seedlings of valuable species are also used to propagate the plants whenever available. Some authors (e.g. Fernandes *et al.* 1984 in Chagga homegarden) report that the farmers also encourage naturally coming seedlings of valuable species to grow.

The farmers collect their planting materials from different sources. Leuchner and Khaleque (1987) report that the farmers of Bangladesh obtain different planting materials from own homegardens, relatives and neighbours, market and occasionally from government nursery. Wickramasinghe (1992) reports that in Sri Lanka most planting materials are obtained freely from neighbours and the farmers also occasionally buy the seedlings of valuable species from the market.

2.3.4.2 Cultural operations

Weeding

Removal and/or partly uprooting of undesirable species from the homegardens through weeding is a common cultural practice reported by Sollart (1986) and Bompard *et al.* (1980) from Javanese homegardens. The practice of farmers in west Java of partly uprooting weeds under trees and leaving them to decompose illustrates how weeding is an integral part of skilful management of traditional systems: the soil is covered, nutrients recycled and unnecessary work avoided (Bompard *et al.* 1980). Weeding may follow a schedule or be done from time to time as required. Sollart (1986) mentions that the farmers of Javanese homegardens weed when time is available but they do it at least once every (two) month(s).

Pruning

Pruning is another important cultural operation practised by the farmers for various reasons. Buylla Roces *et al.* (1989) mention that in Mexico, the farmers prune trees to increase fruit production, to facilitate harvesting of fruits, to avoid conflicts with the neighbours due to excessive lateral growth of plants and to prolong the life spans of some shrubs and herbs. The farmers of Jessore district of Bangladesh pruned their homegarden plants mainly for four reasons which in accordance of preference were: to get more fruits, to get more quality fruits, to get fuel wood and to ensure more space for sunlight (Alam *et al.* 1990).

2.3.4.3 Fertilising and Irrigation

Several authors (e.g. Bompard *et al.* 1980 from Java; Fernandes *et al.* 1984 from Chagga homegardens; Nair and Sreedharan, 1986 and Dadhwall *et al.* 1989

from India; Hossain *et al.* 1988 and Alam *et al.* 1990; and Miah *et al.* 1990 from Bangladesh and Thaman, 1990 from the Pacific) report that the farmers generally use farm yard manure and organic manure/compost for the soil fertility management of their homegardens and application of chemical fertiliser is very rare and limited to valuable species only during early stage of development and/or during fruiting. Irrigation is done in a very limited scale for high valued trees during dry season and/or early stage of establishment of seedlings in different agroecological zones of Bangladesh (Hossain *et al.* 1988; Alam *et al.* 1990 and Miah *et al.* 1990).

2.3.4.4 Products and services of homegardens

Several authors agree on the wide ranging uses of products from homegardens. The multipurpose tree crops can provide shade, living fences, fodder and mulch, fuelwood, fruit, timber and poles. Other components provide food both for home consumption and for sale if a surplus remains, protection against pests, cash crops, medicines, spices, mushrooms, fibres for ropes and mats and even simply ornament.

One of the most striking features of homegardens, observed on all three continents (e.g. Anderson, 1950 in Guatemala; Kendaragama, 1983 in Sri Lanka; Michon, 1983; Brierly, 1985 in Grenada; Christanty *et al.* 1986 in Java; Okafor and Fernandes, 1987 in Nigeria; Buylla Roces *et al.* 1989 in Mexico) is that, due to great diversity of species and their varied biological cycles, having the effect of staggering production of food crops, small daily harvests can be made year round for immediate home consumption.

2.3.4.5 Labour force required for homegarden management

Several authors mentioned the low labour demand for homegardens from different countries, e.g. half hour to two hours daily in a 500 m^2 homegardens of Philippines (Sommers, 1978). Similar range is reported in Indonesia [Haryadi (1975), cited in Christanty (1985)]; 50 minute per day in a 200 m^2 homegardens in Lima (Ninez, 1985); 35-45 days of family labour per year during the year of homegardens establishment and 17-22 days during subsequent years in Mexico (Buylla Roces *et al.* 1989).

Several authors (e.g. Stoler, 1978; Ahmad *et al.* 1980; Hossain *et al.* 1988) mention that there is a clear share of tasks between women and men for the management of homegardens. According to Stoler (1978), homegarden cultivation occupies only 8% of the total working time of men and an insignificant amount of time for women, but Ahmad *et al.* (1980) found that most women spent 9.4% of their productive activities for working in the homegarden while men spent only 2.3% of their productive activities in west Java. Hossain *et al.* (1988) reported that in Bangladesh, women are mostly involved in the pre- and post- harvest work of vegetable production while men play key role in timber and fruit tree growing activities.

2.3.4.6 Constraints of the present management system

Many sources (e.g. Liyanage *et al.* 1984; Hossain *et al.* 1988; Alam *et al.* 1990; Miah *et al.* 1990;) mentioned a number of constraints faced by the farmers in managing their homegardens. Some of the common constraints are: lack of fund, land, planting materials, technical know-how, and natural calamities such as drought, flood. Almost all homegardens face at least three of the constraints mentioned above.

Summary

The above review of literature indicated that in Asia Javanese, Kandyan and Kerala homegardens are reasonably well studied and documented. Studies on the homegardens of Bangladesh are limited to species composition, density and some aspects of management in few farming systems research sites only indicating that in-depth studies on different aspects of traditional homegardens of Bangladesh are still needed.

Chapter 3
Materials and methods

Chapter 3

MATERIALS AND METHODS

This chapter has three sections. The first section (3.1) deals with the sampling framework and is divided into three sub-sections (3.1.1 - 3.1.3) following the selection of respondents through multistage random sampling. Section 3.2 deals with the data collection procedure and this is divided into two sub-sections: primary data collection (3.2.1) and secondary data collection (3.2.2). Primary data collection procedure is sub-divided into two sub-sections: vegetation survey procedure (3.2.1.1) and interviews and participatory approaches. Section Three (3.3) explains data processing and analysis procedures.

3.1 Sampling framework

A systematic vegetation survey of the traditional homegardens of Bangladesh and an exploratory survey of the farmers' indigenous knowledge on the management of the system were carried out over a period of 15 months in two phases. The first phase of field work was from July 1992 to April 1993 and covered the vegetation survey. The second phase of field work (from April 1995 to August 1995) focused on the indigenous management techniques used in the homegardens as revealed by different participatory techniques. A multistage random sampling method was applied to locate representative areas and households for the studies. Sampling was done at four levels: district, sub-district (thana), village and household (respondents).

3.1.1 Districts

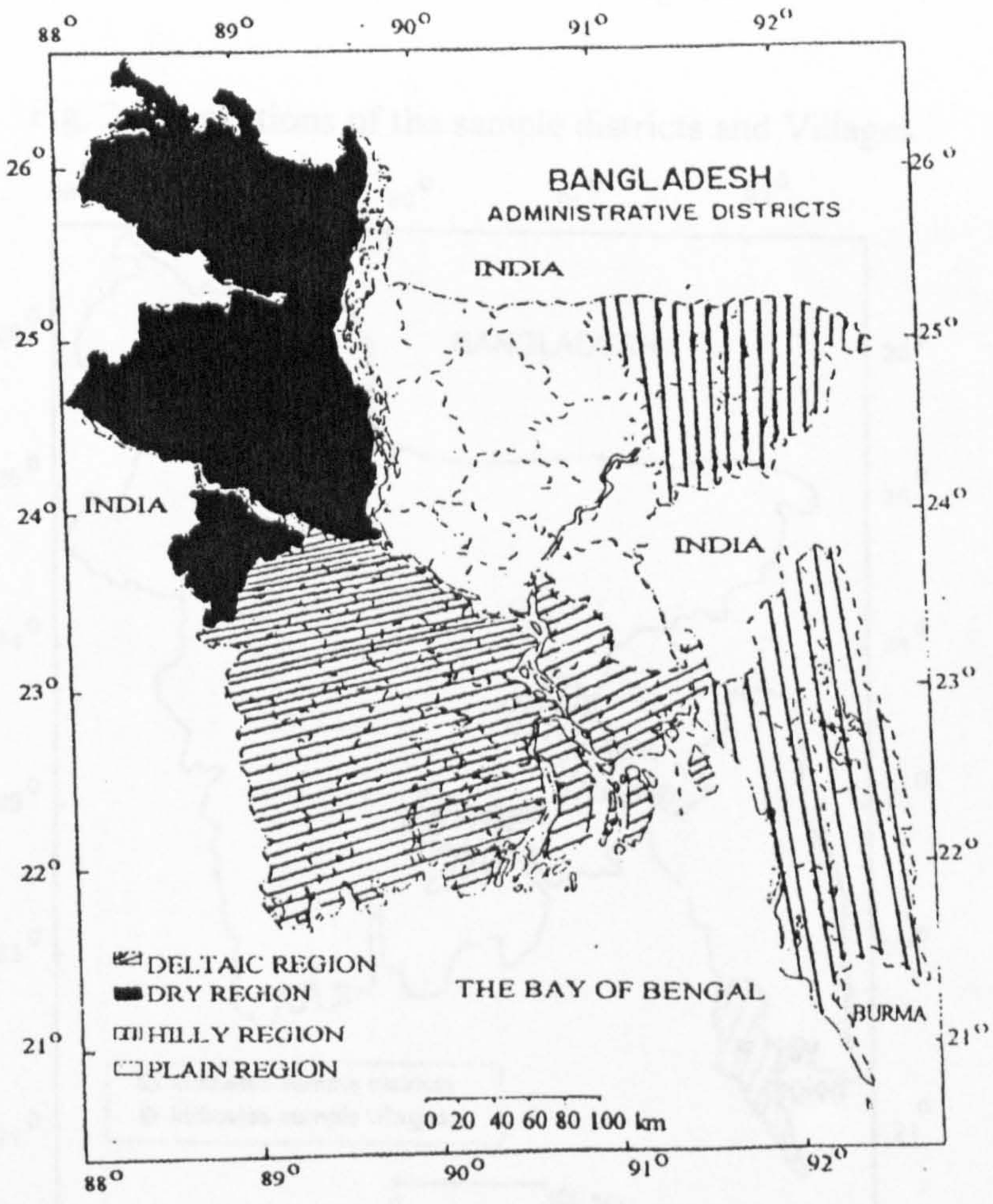
According to the Bangladesh Bureau of Statistics, Bangladesh is divided into Deltaic, Dry, Hilly and Plain regions on the basis of physiographic conditions

(Bangladesh Bureau of Statistics, 1994). There are sixty four administrative districts in Bangladesh of which 22 belong to the Deltaic region, 19 to the Dry, 9 to the Hilly region and 14 to the Plain regions (Fig 3.1). Districts were listed alphabetically under each physiographic region and one from each region sampled randomly:

- Deltaic region: Barisal district
- Dry region: Dinajpur district
- Hilly region: Cox's Bazar district
- Plain region: Comilla district

Background information on these study areas is appended (Appendix 3.1).

Fig. 3.1: Map showing different regions in Bangladesh



3.1.2 Sub-districts and villages

A list of sub-districts (thanas) in each sample district was provided by the Bangladesh Bureau of Statistics (BBS). One sub-district (thana) was sampled randomly in each district. A list of the villages of this sub-district (thana) was provided by the respective Thana Statistics Officer (TSO). The representative village was sampled at random, giving:

- Deltaic region, Barisal district: Ruiya village
- Dry region, Dinajpur district: North Vobanipur village
- Hilly region, Cox's Bazar district: Jinonza village
- Plain region, Comilla district: Perul village.

Locations of the sample districts and villages are shown in Fig 3.2. Climatic diagrams of the study areas are shown in Fig. 3.3.

Fig. 3.2: Locations of the sample districts and Villages

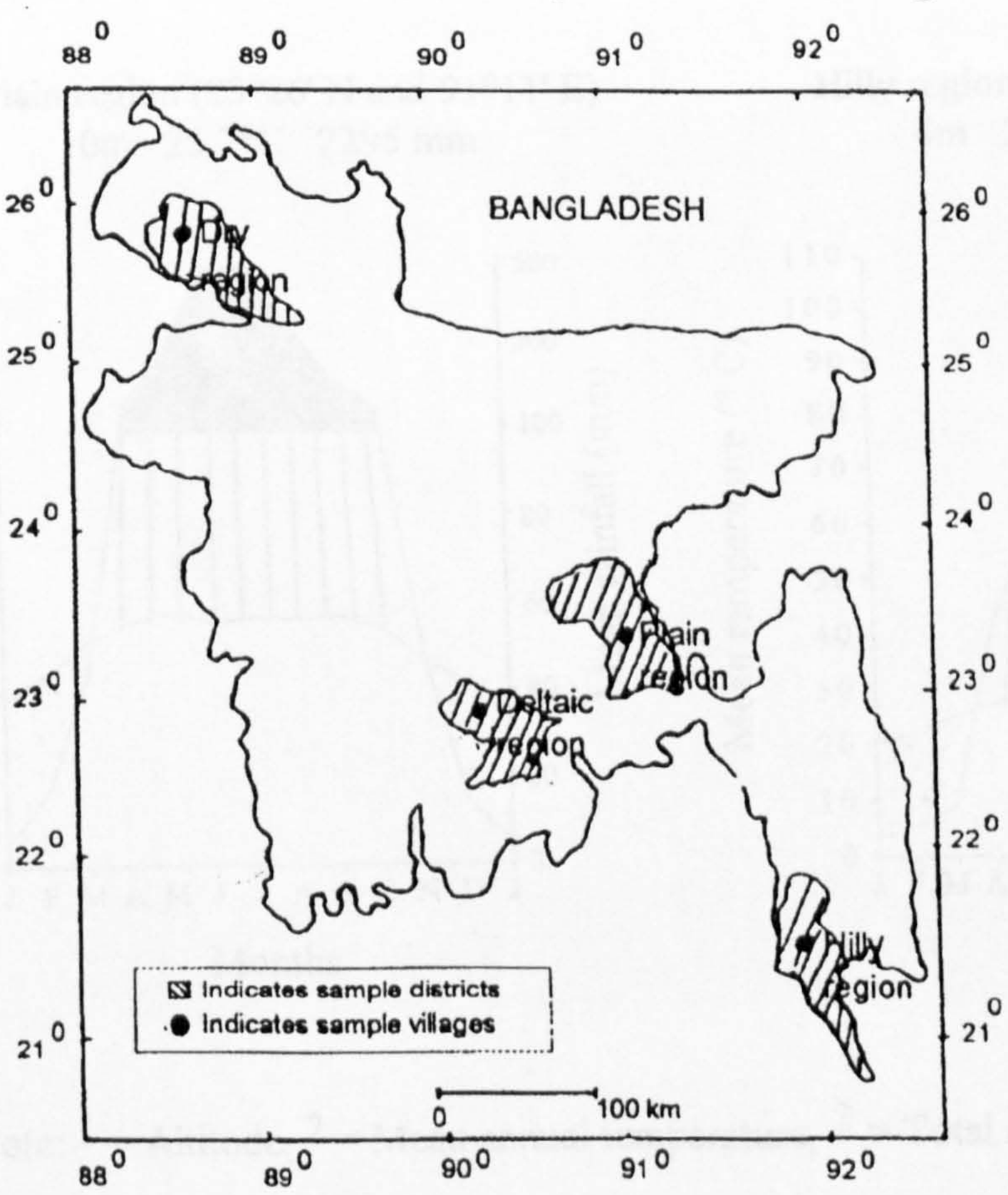
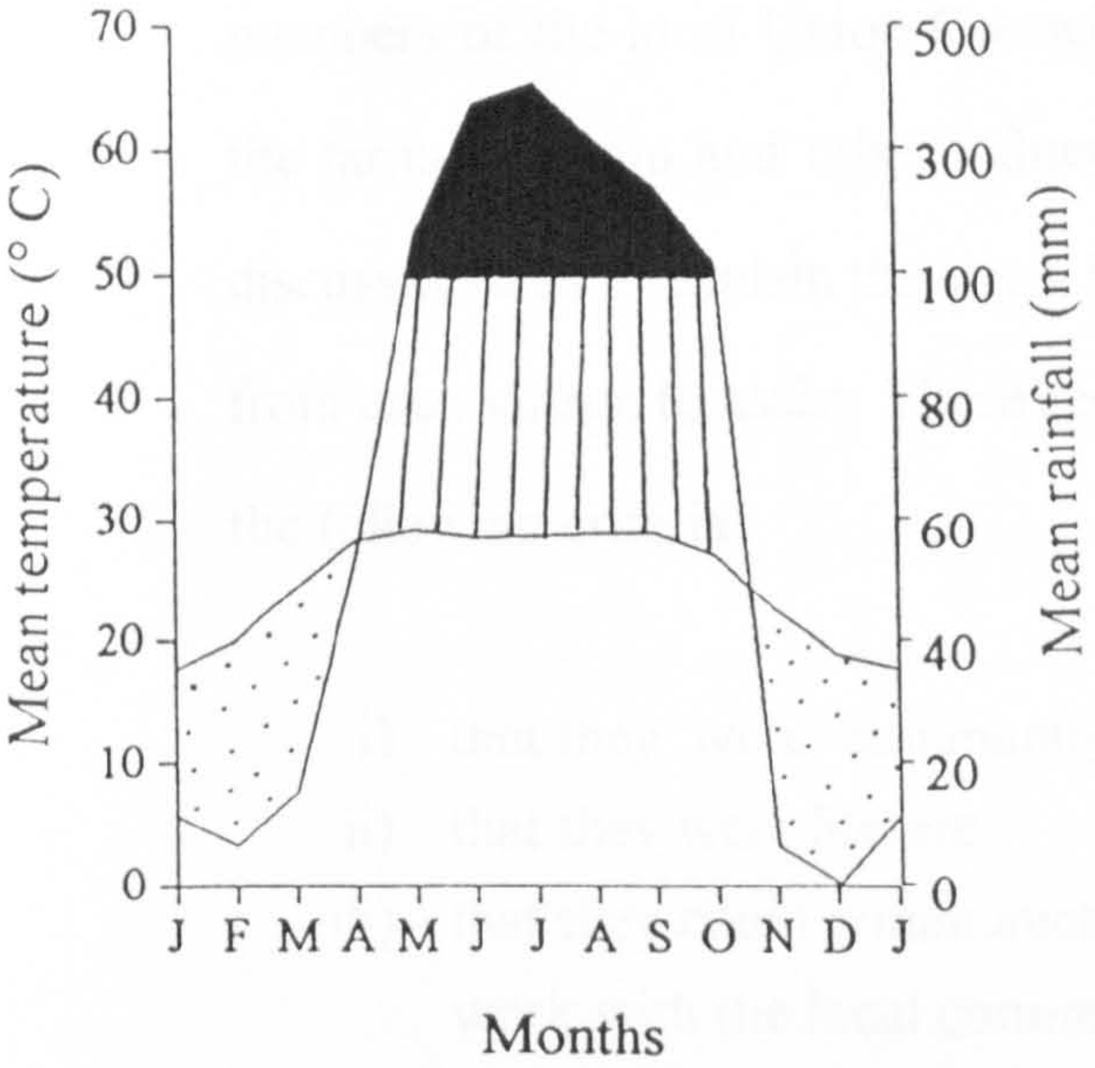
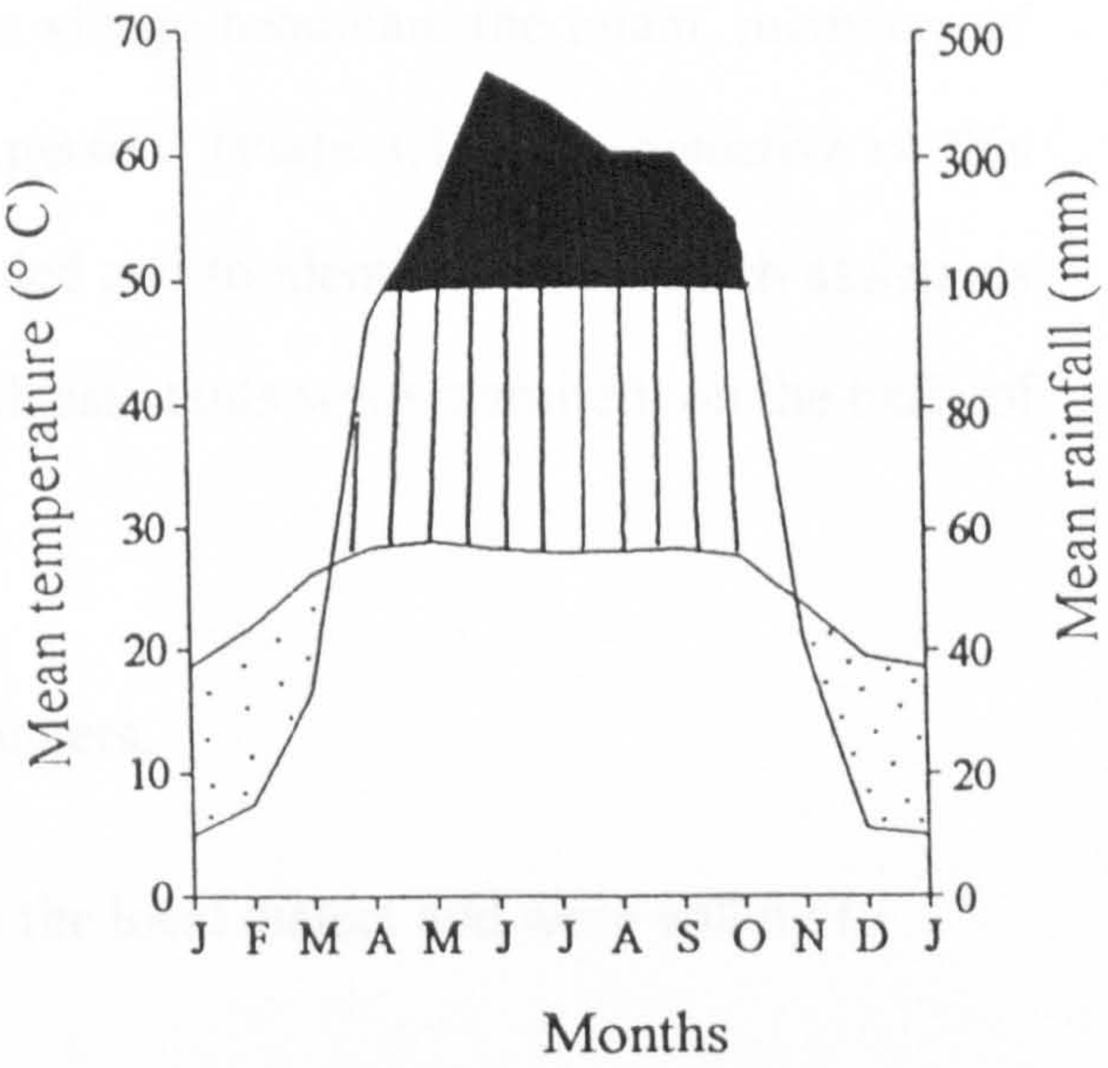


Fig. 3.3: Climatic diagrams of the study areas in Bangladesh

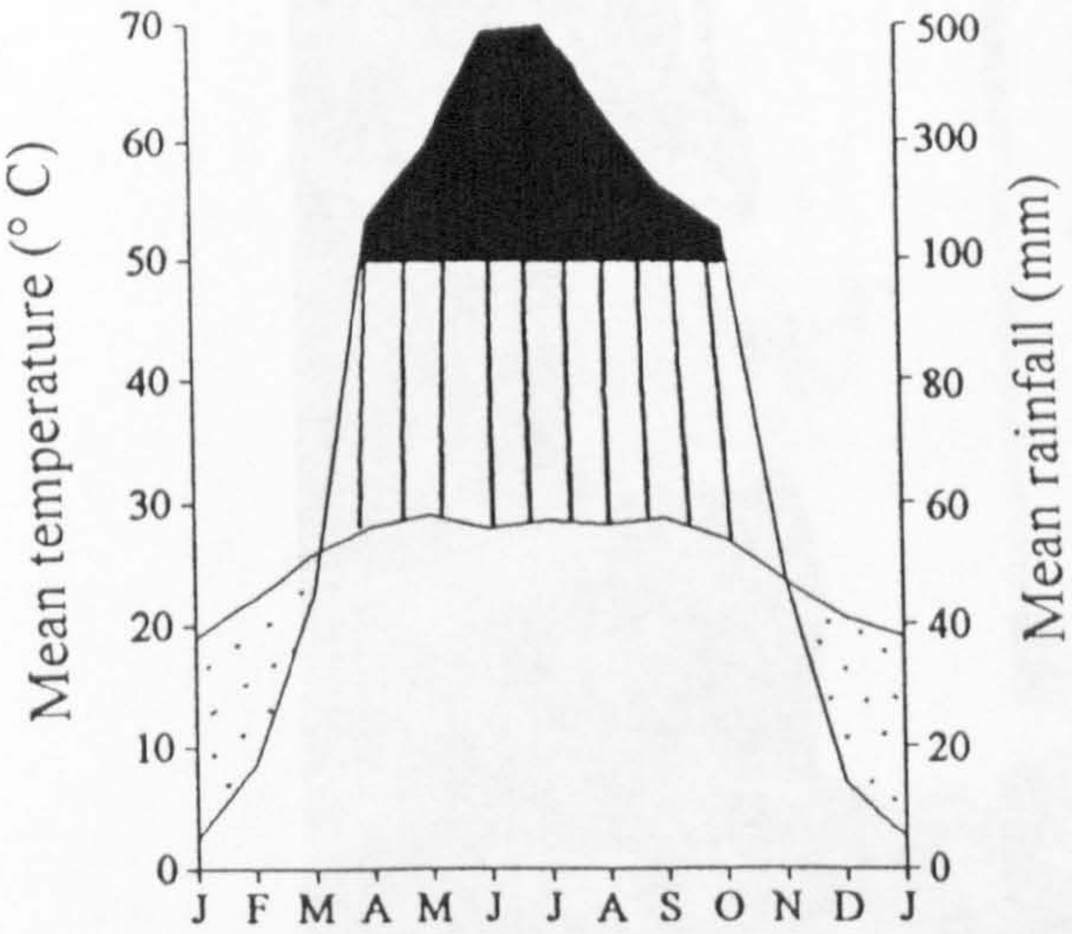
Dry region (25°39' N and 88°41' E)
37m[1] 25.3°C[2] 1695 mm[3]



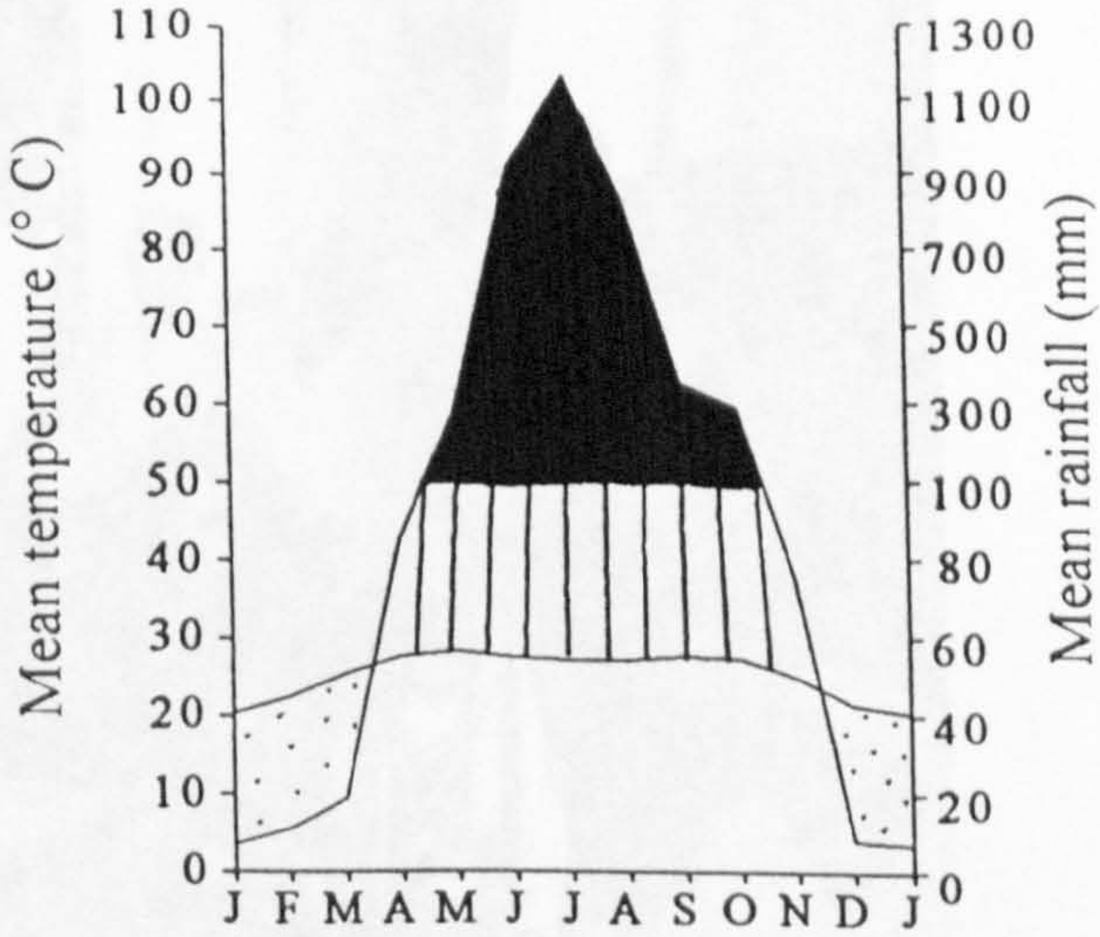
Deltaic region (22°45' N and 90°22' E)
4m 25.7°C 2037 mm



Plain region (23°26' N and 91°11' E)
10m 25.7°C 2295 mm



Hilly region (21°26' N and 91°58' E)
4m 25.5°C 4037 mm



Note: [1] = Altitude, [2] = Mean annual temperature, [3] = Total annual rainfall

3.1.3 Households

Before households were sampled, a formal discussion was held at the local Union Council office in each region with local representatives: the chairman and members of the local Union Council, the village headman, the imam, members of the farmers' group and other influential persons (Plate 3.1). The objective of this discussion was to explain the work intended and to identify two research assistants from each village to assist. These research assistants were recruited on the basis of the following criteria:

i) that they were community members,
ii) that they were literate,
iii) that they could communicate in the local dialect and were willing to work with the local community.

Plate 3.1: A group discussion with the local representative held in the local union council office before starting work in a village

After recruitment, the research assistants undertook a one day training session at the local Union Council which ensured a comprehensive briefing about the research work and methods of data collection. At the beginning of the session the purpose and aim of the research project and survey were discussed. This was followed by reading the preliminary socio-economic questionnaire and discussing each question at length. The preliminary socio-economic questionnaire was designed to gather background information to use as a basis for household sampling. A pre-sampling socio-economic survey was then carried out on five households to practise administering the survey. The questionnaire proved satisfactory and did not require modification for the formal survey (Appendix 3.2).

The formal preliminary socio-economic survey of each village was carried out using the pre-tested questionnaire by the author with the help of the two research assistants. The whole village was surveyed at this stage (excluding the first five pre-sampled households interviewed for questionnaire testing). The total number of households in the village was obtained from the district/village census published by the Bangladesh Bureau of Statistics. This list was cross checked and corrected through consultation with the member of the local Union Council, village headman and the research assistants. Heads of the households (in most cases the household-level decision makers) were the respondents for this survey. Help from other members of the households was sought when felt necessary. During the 1995 field work a more detailed wealth ranking exercise was carried out, separating this aspect from other elements of the preliminary discussions with farmers.

At the end of each day a brief discussion was held with the research assistants to discuss the day's work and plan for the next day. A summary of the day's findings was also made every evening.

After the preliminary socio-economic survey, socio-economic parameters of potential value for the study were reviewed (Appendix 3.3). In the wealth ranking exercise farmers were categorized into different groups on the basis of their economic well-being. Interested farmers (male and female) of different socio-economic status were invited to the local union council for this exercise. The name of each household head was written on a card. A discussion about the concept of wealth (or well-being) was held with the group. After the discussion, the farmers were asked to sort the cards into five wealth groups based on their perceptions. For cross-checking, starting from one pile, a research assistant was asked to read aloud the name on a card for all present to hear and then make changes if necessary by transferring the cards from one pile to another. After the review the farmers were asked to give principal features of the livelihood of each category. The findings of the wealth ranking exercise are shown in Table 3.1.

From the table it is evident that the definition of wealth varied with region. Therefore, to maintain more uniformity of criteria in categorising the farmers into common size classes across all regions, only homestead size was considered. Farmers were categorised into the five groups by homestead size:

Landless,	homestead areas < 0.02 ha
Marginal,	homestead areas $> 0.02 — 0.08$ ha
Small,	homestead areas $> 0.08 — 0.14$ ha
Medium,	homestead areas $> 0.14 — 0.20$ ha
Large,	homestead areas > 0.20 ha.

The landless farmers were excluded from further consideration as they do not practise agroforestry in their homesteads due to land scarcity: the homestead is totally occupied by their houses. Marginal, small, medium and large categories of farmers were retained. Five homegardens were sampled randomly from each homestead size category. The total number of homegardens surveyed was 80.

Table 3.1: Criteria for wealth grouping within village communities in four regions of Bangladesh

Wealth category	Regions			
	Deltaic	Dry	Hilly	Plain
Rich	• Houses made of bricks • Having > 2 acres of land • Surplus farm produce • Owns > 8 cattle • Employs labourer	• Houses made of bricks • Having > 4 acres of land • Having 3 or more mango orchards • Owns > 10 ploughs • Money lenders	• Houses made of bricks • Having >5 betel nut orchards • Having 2 or more fishing trawler • Owns 2 salt fields • employs 10 or more labours permanently	• Houses made of bricks • Having >2 acres of land • Surplus farm produce • Having permanent government job • Receiving remittance from abroad • Owns >5 cattle
Well-off	• Houses made of bricks with CI sheets roofing • Having 1-1.5 acres of land • Self sufficient in farm produce, sometimes surplus food grain • Owns 4-5 cattle • Employs labourer	• Houses made of bricks • Having 2-3 acres of land • Having 1-2 mango orchards • Owns 5-8 ploughs • Money lenders but in smaller scale	• Houses made of bricks • Having 2-4 betel nut orchards • Having 1-2 fishing trawler • Owns 1 salt field • employs 5-7 labours permanently	• Houses made of bricks with CI sheet roofing • Having 1-2 acres of land • Surplus farm produce • Having permanent government job • Owns 2-4 cattle
Medium	• Houses made of CI sheets walling and roofing • Having 0.5-1 acres of land • 3-6 months food grain from farm • Owns 1-2 cattle • Employs labourer occasionally	• Houses with mud walling and CI sheet roofing • Having 1-2 acres of land • 1 mango orchard • Owns 2-3 ploughs • Lends money occasionally from rich farmers	• Houses made of wood walling and CI sheet roofing • Having 1 betel nut orchard • Having 1 or no fishing trawler • employs 2 or more labours permanently	• Houses made of bricks/CI sheet walling and roofing with CI sheet • Having 0.5-1 acres of land • 6-8 months food grain from farm • Share cropper • Owns 1-2 cattle
Poor	• Houses made of bamboo walling thatched with grasses • Having 0.2-0.4 acres of land • 1-2 months food grain from farm • No cattle • Goes outside for labour work besides own work	• Houses with mud walling thatched with grasses • Having <1 acres of land • Having 1 plough • Lends money from well-off farmers and give labour in exchange whenever needed by well-off farmers	• Houses made of bamboo walling thatched with grasses • 1 or no betel nut orchard • petty businessmen • Occasionally sales labour outside	• Houses made of bamboo walling and roofing with CI sheet/ grasses • Having <0.5 acres of land • 1-2 months food grain from farm • Occasionally sales labour outside
Very poor	• Houses made of bamboo walling thatched with grasses and with bad repairing condition • No farm land • Always sales own labour to outside	• Houses with bamboo walling thatched with grasses and with bad repairing condition • No farm land • Always sales own labour to outside	• Houses with bamboo walling thatched with grasses and with bad repairing condition • Gives permanent labour to rich, well-off or medium farmers	• Houses made of bamboo walling thatched with grasses and with bad repairing condition • No farm land • Always sales own labour to outside

3.2 Data collection procedure

3.2.1 Primary Data

3.2.1.1 Vegetation survey procedure

A systematic vegetation survey was conducted at each homegarden to ascertain floristics, diversity and structure. For every survey a north-south base line was established to divide the homegardens into two roughly equal parts. Sample centre points were demarcated on this line at 10 m intervals until the boundary was reached. From the centre points additional lines perpendicular to the base line, were demarcated towards the east and west as far as the homegarden limit. By creating further points at 10 m intervals on these east-west lines, a 10 m x 10 m sample grid was generated. In each grid, the individuals of all perennial species with their location co-ordinates, total height, crown diameter and crown height were recorded. In the case of banana and bamboo, each clump was counted as one individual. After measuring a plant, it was marked with chalk to avoid double counting. Since it was not possible to conduct the study during the same season in all regions, seasonal crops including vegetables and weeds grown in the homegardens were excluded. Standard instruments (Haga altimeter, diameter tape, distance measuring tape) were used to take measurements.

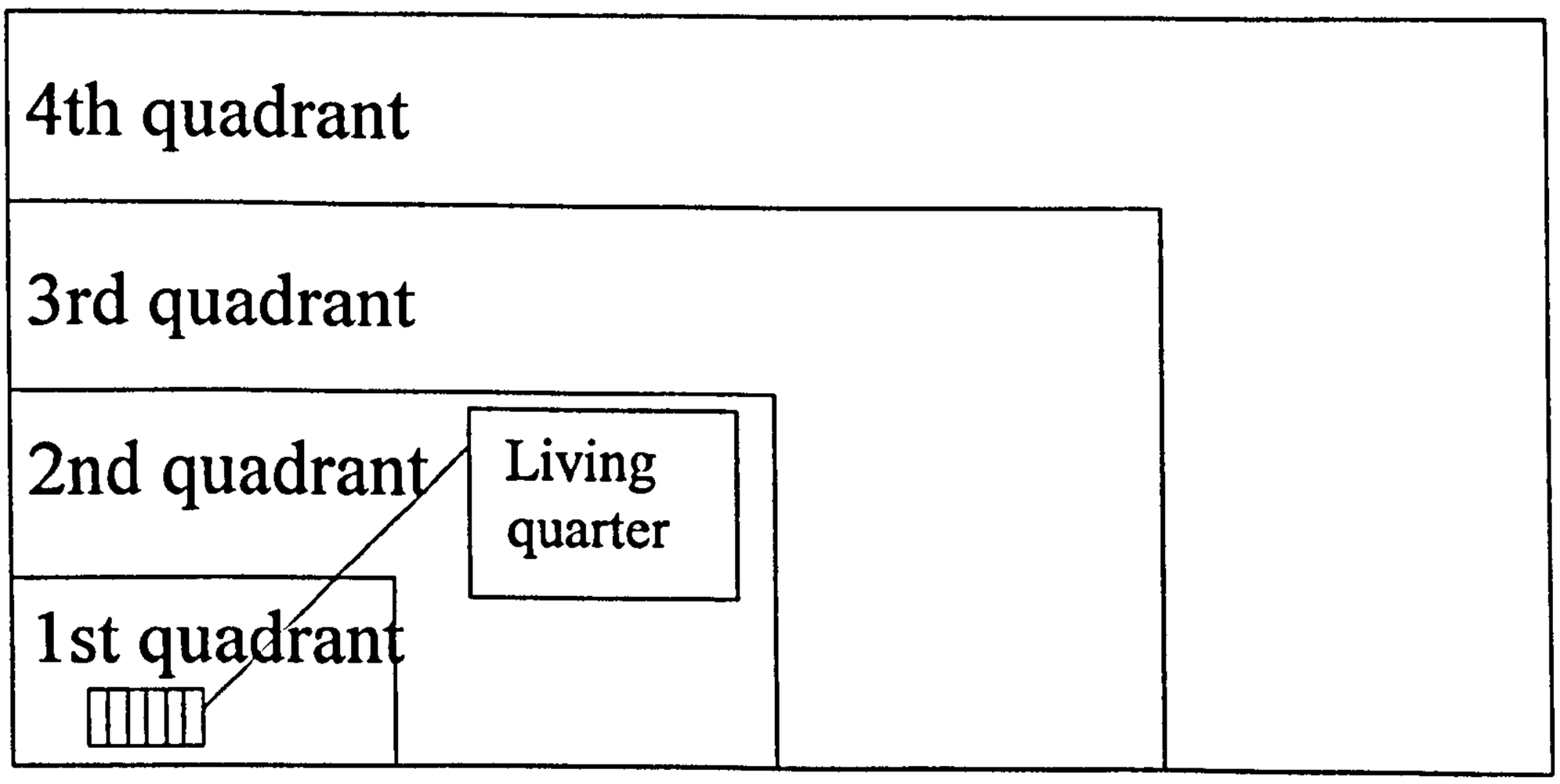
3.2.1.2 Structure of Vegetation

Horizontal structure

The horizontal structure of vegetation was assessed in terms of species locations within the homegardens. Species locations within the homegardens were assessed in relation to distance from the living quarter. Four quadrants were

distinguished. The quadrant containing the living quarter was taken as the first quadrant (Fig 3.4). The next nearest quadrant to the middle of the living quarter was taken as second quadrant and that beyond the third quadrant. The fourth quadrant was that most distant from the living quarter. The species present, grouped according to function, were assessed by quadrant. Each function group was also assessed as the percentage of the number of different species present in each quadrant. Species location within the homegardens was also considered with respect to major locations: only border, only interior part and both border and interior parts.

Fig. 3.4: Location of different quadrants within a homegarden



Vertical structure

The recognition of more or less continuous layers of vegetation on the basis of height classes/differences is a structural approach to vegetation structure (Goldsmith *et al.*, 1986). A structural approach can be used to simplify the organisation of complex vegetation types. The vertical structure of the homegardens was summarised by referring individuals to vertical strata:

S_0, plants ≤ 1 m high
S_1, plants 1 — 3 m high
S_2, plants 3 — 5 m high
S_3, plants 5 — 7 m high
S_4, plants 7 — 9 m high
S_5, plants > 9m high.

In addition, a profile diagram for each farm category of all regions was drawn. The profile diagram was constructed to scale by using the field measurements of the position, total height, height of first branch, crown depth and crown diameter of all plants on this belt.

3.2.1.3 Interviews and participatory approaches

The following interviews and participatory approaches were adopted to explore indigenous management of homegardens.

Tree use matrix

When the vegetation survey was completed at one homegarden, a list of the species present was made. A tree use matrix exercise (Plate 3.2) was then conducted with the farmer and his/her family members to determine the uses of

different species, preferences between species and preferred combinations of different species in the homegardens. Before starting the exercise, the farmer was asked to collect the leaves/twigs of each species present in his/her homegarden to allow cross checking of species with the list made from vegetation survey. If any species was missing, the farmer was asked to provide it. To begin the exercise, leaves/ twigs of all species present in the homegarden were placed in line away from the observer to represent rows of a table marked on the ground. Columns representing uses were then marked out. In the cells the farmers placed a number of beans proportional to the importance of each species for each use (4 for very good, 3 for good, 2 for fair, 1 for not good). After the matrix was completed, the beans against each species were counted. A preference list of species was then made putting the species with highest score first. Cross checking preferences of species was then made by asking the farmers to order the species according to their preference. How the farmers arranged the species, was checked with the score of the species. Inconsistencies were resolved by consulting further with the farmers.

Plate 3.2: A tree use matrix exercise in the Plain region

A paired ranking exercise was then carried out to find the preferred combination of five most preferred species. There were ten pairwise combinations in all (Table 3.2). The interaction between the species of each preferred combination were then explored by semi-structured interviews.

Table 3.2: Possible pair wise combinations of species

Species	A	B	C	D	E
A		AB	AC	AD	AE
B			BC	BD	BE
C				CD	CE
D					DE

Semi-structured interviews

After the tree use matrix exercise, an interview was organised with the family members of that homegarden using a semi-structured questionnaire. This was a guided interview and started off with checking the different management issues for which farmers opinions were wanted. The questionnaire addressed eight broad topics:

Question 1: "what planting materials do you use for your homegarden plants?" This was to elicit farmers' knowledge about regeneration procedures with different homegarden plants. The relative advantages and disadvantages of various types of planting material for different species were ascertained through further questions (2 questions).

Question 2: "what are the sources of different planting materials?" This was to establish the relative contribution of different sources of planting materials in the homegardens (1 question).

Question 3: "Do you follow any criteria to select mother trees to collect planting materials?" This retrieves farmers' knowledge about the introduction of improved varieties of species in the homegardens. If the farmers said 'yes', then details of the criteria for mother tree selection and the types of species for which mother trees were sought with more questions (3 questions).

Question 4: "What sizes of seedling are available to plant and which one do you prefer and why?" This was to explore farmers' silvicultural knowledge about different sizes of seedling. (3 questions)

Question 5: "Do you adopt any spacing at the time of planting?" This question was to gather information about any horizontal arrangements of species in the homegardens. If the response was 'yes', further questions were asked to ascertain the planting spacing and the reasons for its use (3 questions).

Question 6: "Do you carry out weeding, lopping, pruning, thinning, coppicing, pollarding in your homegarden?" Weeding and thinning determine the horizontal structure of the homegardens while pruning determines how the farmers regulate sunlight in the homegarden. In the case of 'yes' answers, subsequent further questions were posed to find out why, and at what the operations were applied (16 questions).

Question 7: "Do you water and manure your homegarden plants?" This question was to device an idea of the effort given to managing the homegarden. If the reply was 'yes', the frequency and quantity of watering and manuring, and the name of the species to which these

were applied, were determined with further questions (6 questions).

Question 8: "Why do you prefer this specific combination of plants?" sought the farmers' perception of plant-plant interactions with respect to shade, nutrient requirements, symbiotic relationships and allelopathic effects. (7 questions).

On each key topic the farmer was free to express his own views. New avenues of questioning were pursued as the interview developed. The interview was guided to cover the key topics on the checklist, while leaving room to pursue any relevant subjects brought up by the farmer. The farmer was assisted by his/her family members in answering some of the questions.

Gender roles

Daily activity and seasonal calendars were used to assess gender role in the homegarden. The farmers preferred to use an aggregate period of three or four months, which corresponds to a local calendar and agricultural season. Daily activity and seasonal labour calendars were thereafter drawn for the each of the three principal seasons: summer, monsoon and winter.

Seasonal labour calendar

Seasonal labour calendars were used to find out the seasonality of household labour for homegarden and crop land management and were done separately for the four gender/age categories. Hiring-in labour for homegarden management activities in different seasons was also recorded. In all cases beans were used to indicate the number of days engaged in different activities.

Daily activity calendar

A daily activity calendar was used to find out day-to-day gender roles in homegarden activities. The calendar was drawn on the ground, putting different sections of day (morning, late morning, afternoon, late afternoon, evening and night) against adult male, adult female, male child and female child.

Sketch mapping

Farmers were asked to represent their homegardens on the ground with a stick, drawing in diagrammatic form. Then they were asked to show the existing positions of their living house, the boundary and paths, ponds, cowstalls and other features and to detail the major plants/crops in the garden according to the way that they perceive things and decide among themselves. The whole family was involved in this exercise. This sketch map indicated the arrangement of the gardens and formed the basis for discussion in the subsequent stages about definite agroforestry practices, factors affecting the location of different species, role of the family members in different homegarden management activities, farmers' awareness about different functional aspects and the problems and the potential of the homegarden.

3.2.2 Collection of secondary data

General background information regarding population, land use pattern, meteorological data, and the map of the selected districts were collated from published sources and archives accessible in the respective district council library and the Bangladesh Agriculture Research Council library.

3.3 Data processing and analysis

3.3.1 Vegetation characterisation

3.3.1.1 Homegarden floristic composition

All perennial plant species in the homegardens were recorded. Specimens were taken of plants that could not be identified in the field. These were later identified at the Bangladesh Forest Research Institute. To structure the data set, plants were broadly grouped according to functions - into food and fruit producing species, timber species, spices and miscellaneous. Those species that could not be grouped under the first three categories were the ones classified as miscellaneous and include: *Lawsonia inermis*, *Piper longum*, *Ocimum sanctum*, *Achyranthes aspera*, *Pongamia glabra*, *Morus alba*, *Gossypium herbaceum*, *Ricinus communis*, *Hibiscus rosa-sinensis* and *Schumannianthus dichotoma*.

3.3.1.2 Species ordination

Broad floristic trends within and among regions were sought through Detrended Correspondence Analysis, DECORANA (Hill and Gauch 1980). The standard (default) version was used, on presence/absence data for all perennial species in each homegarden. An initial ordination included the homegardens of all four regions (full ordination), but a second ordination was restricted to the Deltaic, Hilly and the Plain regions homegardens. In both the cases the two main axes (Axis 1 and Axis 2) were extracted for the ordination.

3.3.1.3 Species dominance

To determine species dominance in each region, Relative Importance Values

(RIV) were calculated according to the formula of Myres and Shelton (1980) as follows:

RIV = Relative frequency + Relative density + Relative cover

where:

$$\text{Relative frequency} = \frac{\text{Percentage frequency of species A}}{\text{Sum of all species percentage frequencies}} \times 100$$

$$\text{Relative density} = \frac{\text{Density of species A}}{\text{Density of all species}} \times 100$$

$$\text{Relative cover} = \frac{\text{Crown area of species A}}{\text{Crown area of all species}} \times 100$$

RIV is a unitless score that combines the three measures, giving each equal weight, and can be used as a ranking of the dominance of each species in the community. The maximum relative importance value of a species is 300. In the present study, to find the dominant species of the traditional homegardens, the Relative Importance Value of each species was calculated and then ranked regionally, considering each region as a single unit. Finally the dominant species of the homegardens of Bangladesh were determined by comparing the mean ranking of each species across the regions.

3.3.1.4 Similarity of species

To find the species similarity between the regions Sϕrenson's coefficient of similarity, expressed as a percentage (Muller-Dombis and Ellenberg, 1974), was calculated using the formula:

$$\text{Similarity coefficient} = \frac{2c}{a+b} \times 100$$

where:

a = number of species present in community A

b = number of species present in community B

c = number of species common to both communities

3.3.1.5 Species diversity

Species diversity was determined as Shannon's index (Fowler and Cohen, 1992):

$$H' = - \sum P_i \ln P_i$$

Where:

H' = Shannon's index

P_i = proportion of a particular species in a sample

From Shannon's index, evenness was estimated as (Zar, 1984):

$$E = \frac{H'}{H_{max}}$$

Where:

E = Evenness index

H' = Shannon's index of diversity

H_{max}= ln S, where S = Number of species.

Shannon's diversity and evenness indices were calculated separately for each farm category of all the regions.

3.3.2 Data summarisation and analysis

Simple description	Parameters considered	Formal analysis
Horizontal structure	Spatial arrangement with respect to major location	
	Spatial arrangement with respect to quadrants	
Vertical structure	Stratification of vegetation	
	Profile diagram	
	Vertical plant density	
	Vertical species richness	
Vegetation composition	DECORANA ordination	
	Species richness	ANOVA
	Species dominance	
	Species similarity	
	Species diversity	ANOVA
	Species evenness	ANOVA
	Functional species groups	Correlation co-efficient
Homegarden silviculture	Planting materials	• Chi Sq. • ANOVA (Arc Sine)
	Sources of planting materials	• Chi Sq. • ANOVA (Arc Sine)
	Mother tree selection	
	Size of seedlings	
	Spacing	
	Cultural operations	
	Watering and fertilising	
Plant interactions	Sunlight/shade	
	Water and nutrients	
	Soil	
	Pests and diseases	
Gender roles	Division of labour	
	Homegarden management	
	Decision making	
	Access to resources	
Roles of homegarden	Uses of the species	
Farmers' awareness	Functions of homegardens	
Management constraints	Problems of management	

Chapter 4
Results - Vegetation study

Chapter 4

RESULTS - VEGETATION STUDY

This chapter presents the results of vegetation study and is organised in two sections: vegetation structure (4.1) and vegetation composition (4.2). Vegetation structure is considered in terms of horizontal features (4.1.1) and vertical features (4.1.2). Vegetation composition is divided into four sub-sections: compositional variation with region - DECORANA ordination (4.2.1), species richness (4.2.2), species dominance and diversity (4.2.3) and functional species groups (4.2.4).

4.1 Homegarden vegetation structure

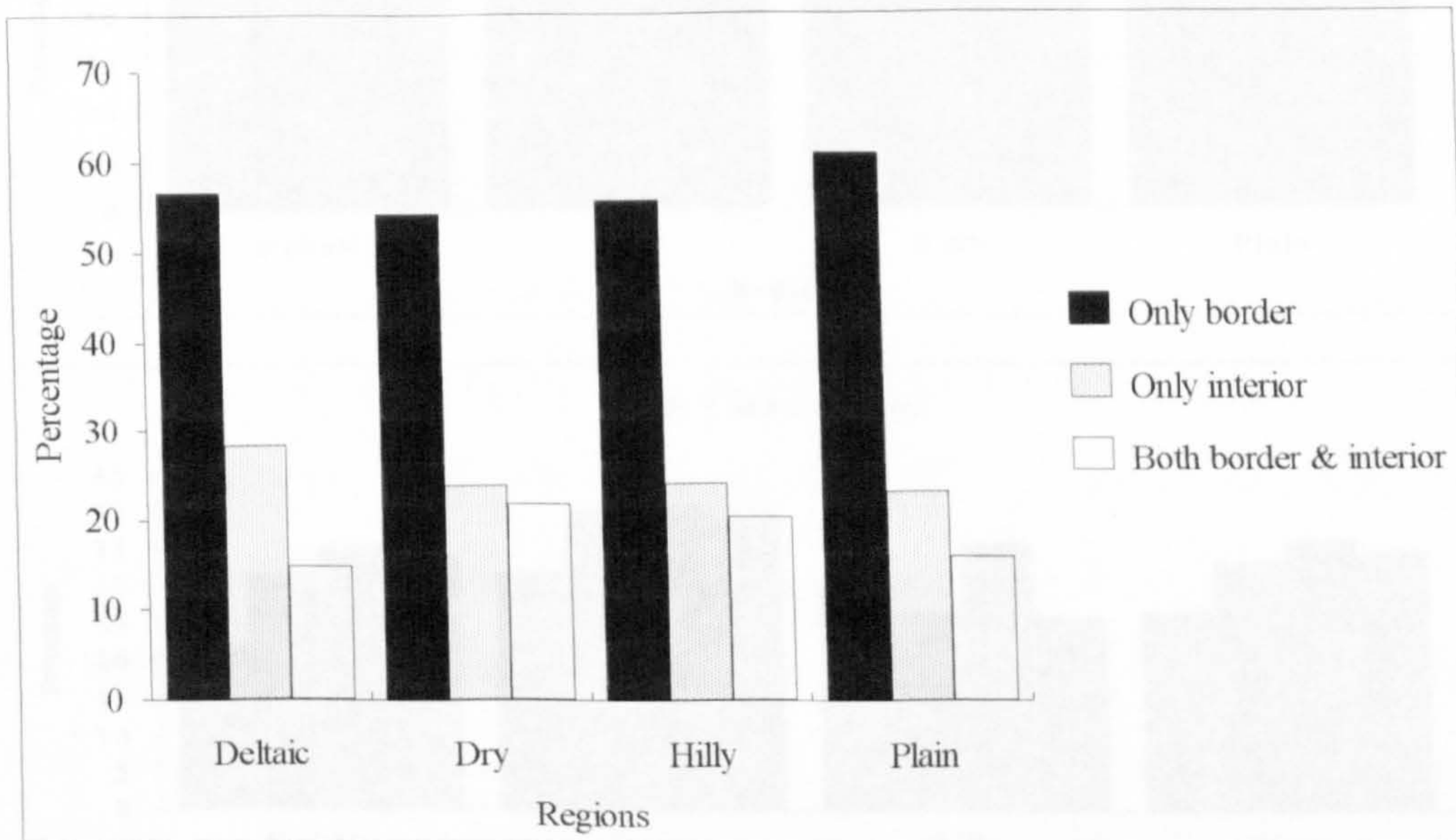
4.1.1 Horizontal structure

4.1.1.1 Spatial arrangements of plants with respect to major locations within the homegardens

On the basis of planting locations within the homegarden, species can be divided into three categories: species for the border only; species for the interior only; species for both the border and the interior. Out of the all-species totals for each region farmers plant most species only in the border of the homegardens (Fig. 4.1). These include all timber trees and selected tall fruit trees such as *Syzygium* spp., *Cocos nucifera* and *Tamarindus indica*. About half as many species including *Citrus limon, Punica granatum, Carica papaya, Ziziphus jujuba* and *Cinnamomum tamala* are planted only in the interior part of the homegardens. The remaining species are grown both in the border and the interior parts of the homegardens. Many medium- and small- crowned fruit trees (such as *Mangifera indica, Artocarpus heterophyllus* and *Areca catechu), Musa* spp. and herbaceous

(non-seasonal) perennials such as *Curcuma longa* and *Zingiber officinale* are in this group.

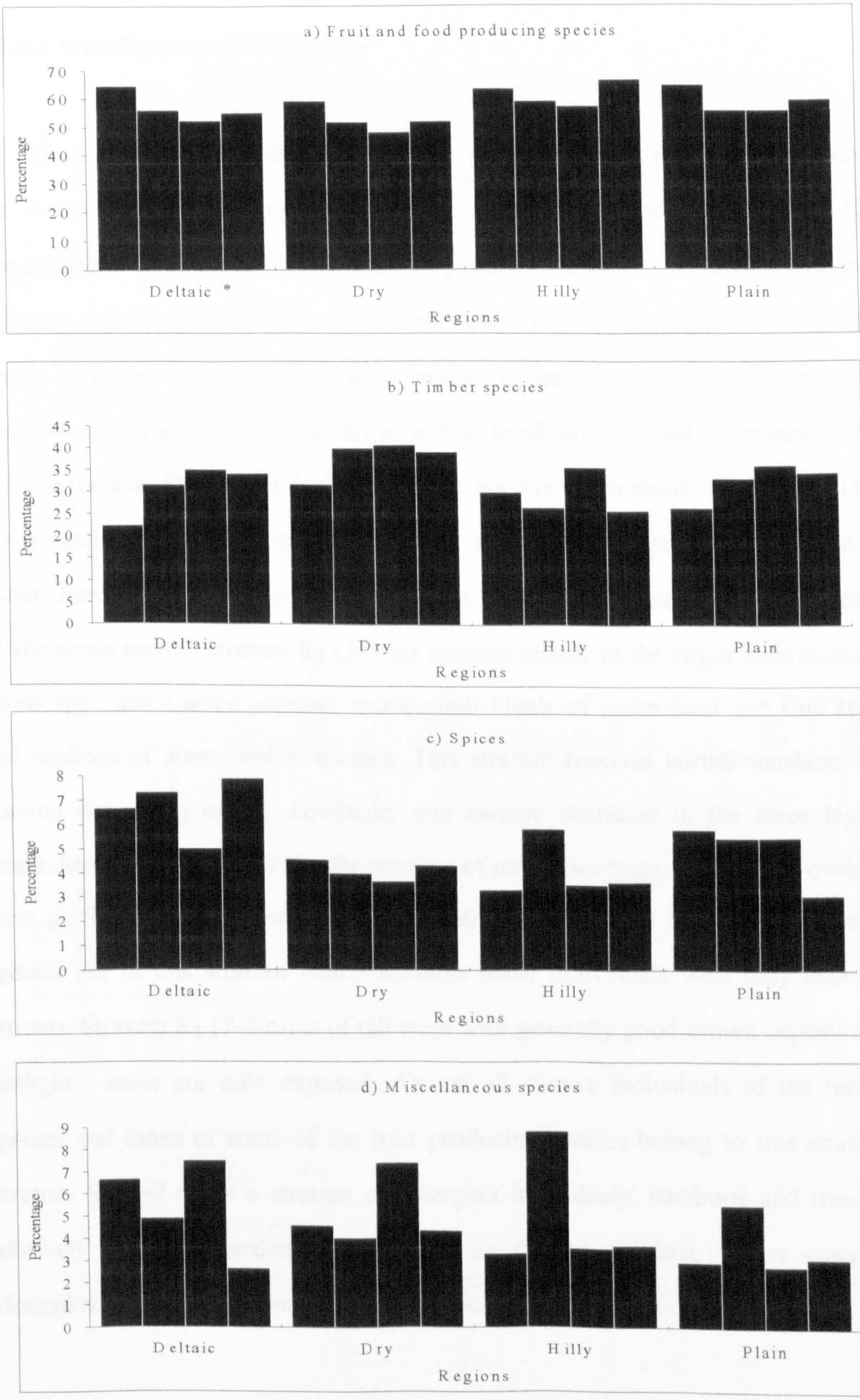
Fig. 4.1: Species arrangements with respect to major locations within homegardens by regions



4.1.1.2 Spatial arrangements of plants with respect to different quadrants within the homegardens

In all quadrants, food and fruit producing species contributed more than the other functional groups to the species richness. However, this group was particularly dominant in the 1st quadrant (Fig. 4.2). Timber species ranked second in terms of species richness in all quadrants and this was consistently the group best represented in the 3rd quadrants. No pattern was apparent in the location of spices and miscellaneous species within the homegardens: the use of these was very variable.

Fig 4.2 : Species distribution by quadrants in traditional homegardens in Bangladesh



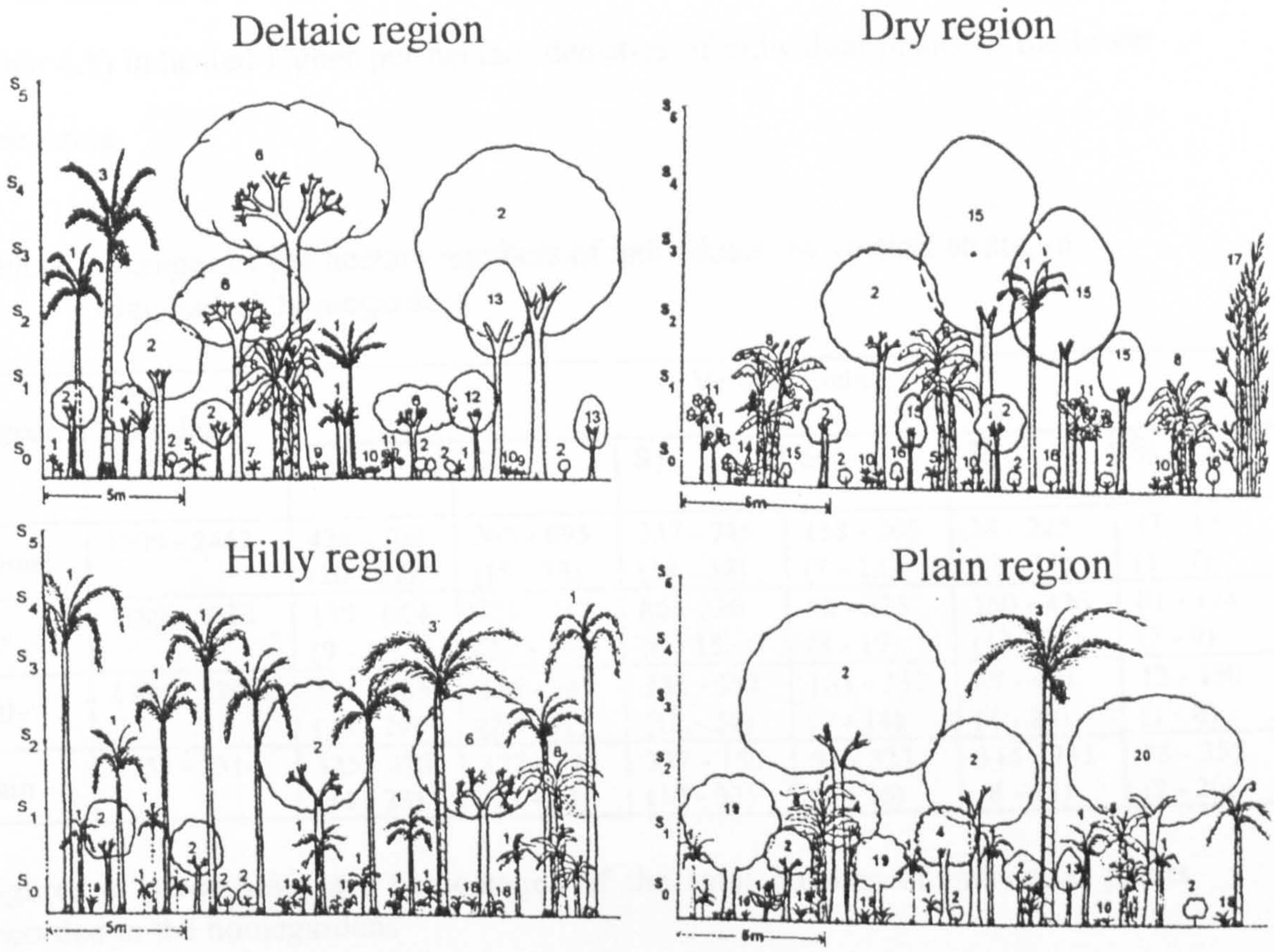
* Bars indicate quadrant sequence 1-4, from the left

4.1.2 Vertical structure

4.1.2.1 Stratification of vegetation

The homegardens displayed a broadly consistent vertical structure throughout the country and many important species are typical in all the regions. The homegardens have a multistoried canopy configuration. It is convenient and relatively feasible to distinguish six vertical strata (Fig. 4.3 and Appendix 4.1). The lowest stratum, S_0 (<1 m), consists mainly of herbaceous perennials such as *Curcuma longa* and *Ananus sativus* as well as seedlings of woody perennials. This stratum receives little direct sunlight as there are five strata above. Stratum S_1 (1-3 m) typically consists of a mixture of *Musa* spp., *Carica papaya,* shrubs such as *Citrus limon,* and large seedlings of various trees. This stratum is heavily shaded by the strata above. Stratum S_2 (3-5 m) consists mainly of the larger individuals of *Musa* spp., and *Carica papaya,* mature individuals of some food and fruit trees and saplings of some timber species. This stratum receives partial sunshine, the amount depending on the continuity and canopy character in the three higher strata. Stratum S_3 (5-7 m) usually consists of numerous trees with their crowns at least partly exposed. Most productive individuals of food and fruit producing species are in this stratum which includes some individuals with fully exposed crowns. Stratum S_4 (7-9 m) is of tall trees with generally good crown exposure to sunlight - most are fully exposed. Almost all mature individuals of the timber species and those of some of the fruit producing species belong to this stratum. Stratum S_5 (>9 m) is a stratum of emergent individuals: bamboos and trees of relatively tall homegarden species such as *Cocos nucifera, Areca catechu, Mangifera indica* and *Samanea saman,* all with fully exposed crowns.

Fig. 4.3: Profile diagrams of the traditional homegardens in Bangladesh



Note: 1 = *Areca catechu*, 2 = *Mangifera indica*, 3 = *Cocos nucifera*, 4 = *Swietenia macrophylla*, 5 = *Phoenix sylvestris*, 6 = *Samanea saman*, 7 = *Ocimum sanctum*, 8 = *Musa* spp., 9 = *Glycine max*, 10 = *Curcuma longa*, 11 = *Carica papaya*, 12 = *Spondias pinnata*, 13 = *Diospyros embryopteris*, 14 = *Colocacia indica*, 15 = *Melia azedarach*, 16 = *Azadirachta indica*, 17 = *Bambusa* spp., 18 = *Ananus sativus*, 19 = *Artocarpus heterophyllus*, 20 = *Albizia* spp.

Strata:

S_0 = ≤ 1m, S_1 = 1 - 3 m,

S_2 = 3 - 5 m, S_3 = 5 - 7 m,

S_4 = 7 - 9 m, S_5 = > 9 m

4.1.2.2 Vertical distribution of plant density

In terms of the density of individuals in each stratum, the range of values (Table 4.1) indicated higher per hectare densities of individual plants in the lower three strata.

Table 4.1: Ranges of per hectare numbers of individuals, by vertical strata, in Bangladesh homegardens

Regions	Total individuals ha^{-1}	Vertical strata					
		S_0	S_1	S_2	S_3	S_4	S_5
Deltaic	1909 - 2462	424 - 704 (20 - 37)	368 - 693 (19 - 33)	337 - 719 (18 - 34)	158 - 265 (7 - 12)	38 - 225 (2 - 11)	17 - 136 (1 - 7)
Dry	1189 - 2078	139 - 614 (9 - 30)	325 - 742 (27 - 37)	86 - 230 (6 - 15)	52 - 225 (3 - 19)	150 - 426 (13 - 28)	81 - 128 (5 - 9)
Hilly	1389 - 2380	271 - 583 (20 - 29)	435 - 742 (29 - 31)	233 - 384 (12 - 24)	163 - 231 (9 - 14)	69 - 471 (4 - 20)	12 - 150 (1 - 8)
Plain	1754 - 2314	325 - 478 (14 - 23)	377 - 793 (21 - 34)	337 - 756 (19 - 33)	91 - 323 (5 - 16)	145 - 231 (8 - 11)	35 - 355 (2 - 20)

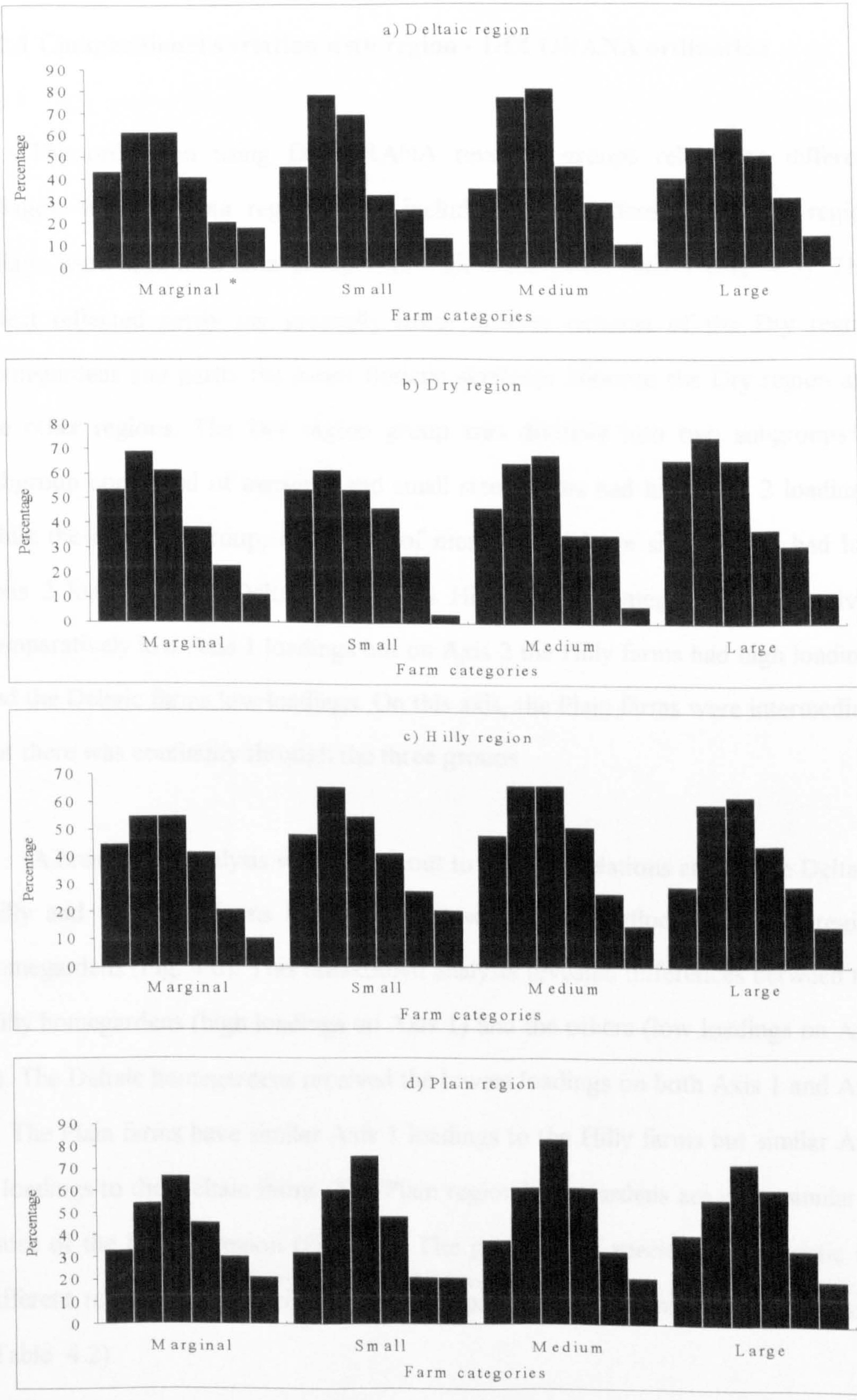
Figures in parentheses are percentages of the total number of individual plants recorded in the homegardens

[Ranges are minimum to maximum values for farm categories].

4.1.2.3: Vertical distribution of species richness

The distribution of species richness varied with regions (Fig. 4.4). In the Dry region the highest species richness was recorded from the lower three strata (S_0, S_1 and S_2) of the homegardens regardless of farm category. The same situation arose in the smaller farms (marginal and small) of the Deltaic and Hilly regions. In the larger farms (medium and large) of the Deltaic and Hilly regions stratum S_3 was also rich in species compared with stratum S_0 and this was consistently the case (i.e. for all farm size) in the plain region.

Fig. 4.4: Vertical distribution of species richness by farm categories in traditional homegardens in Bangladesh



* Bars indicate strata sequence S_0 - S_5, from the left

4.2 Vegetation composition

4.2.1 Compositional variation with region - DECORANA ordination

The ordination using DECORANA revealed groups related to different villages. When all four regions were included, homegardens in the Dry region village were separated as a group with high loadings on Axis 1 (Fig. 4.5). This effect reflected partly the generally lower species richness of the Dry region homegardens and partly the lower floristic similarity between the Dry region and the other regions. The Dry region group was divisible into two subgroups: a subgroup composed of marginal and small sized farms had high Axis 2 loadings, while the other subgroup, composed of medium and large sized farms, had low Axis 2 loadings. The Deltaic, Plain and Hilly group homegardens all received comparatively low Axis 1 loadings but on Axis 2 the Hilly farms had high loadings and the Deltaic farms low loadings. On this axis, the Plain farms were intermediate but there was continuity through the three groups.

A breakdown analysis was carried out to examine relations among the Deltaic, Hilly and the Plain farms in more detail without the influence of Dry region homegardens (Fig. 4.6). This breakdown analysis revealed differences between the Hilly homegardens (high loadings on Axis 1) and the others (low loadings on Axis 1). The Deltaic homegardens received the lowest loadings on both Axis 1 and Axis 2. The Plain farms have similar Axis 1 loadings to the Hilly farms but similar Axis 2 loadings to the Deltaic farms. The Plain region homegardens are more similar to those of the Deltaic region (Fig. 4.6). The presence of species characteristic for different regions also contributed to the separation of regions in the ordinations (Table 4.2).

The difference between the Dry region subgroups arises from differences in the number of species present in individual homegardens. Larger farms have more species. Fruit trees such as *Moringa oleifera*, *Citrus acida*, *Borassus flabellifer* and *Aegle marmelos* and timber trees such as *Dalbergia sissoo*, *Anthocephalus chinensis* and *Bombax ceiba* were not found in the smaller farm categories.

Table 4.2: Characteristic species of Bangladesh homegardens, by region

Regions			
Deltaic	Dry	Hilly	Plain
Achyranthes aspera	*Azadirachta indica*	*Averrhoa bilimbi*	*Terminalia arjuna*
Annona squamosa	*Dalbergia sissoo*	*Casuarina equisetifolia*	
Caesalpinia crista	*Gossypium herbaceum*	*Citrus grandis*	
Cassia siamea	*Leucaena leucocephala*	*Delonix regia*	
Cinnamomum zeylanicum	*Melia azedarach*	*Dipterocarpus turbinatus*	
Feronia limonia	*Morus alba*	*Gmelina arborea*	
Glycine max	*Moringa oleifera*	*Hibiscus rosa-sinensis*	
Polyalthia longifolia	*Odina wodier*	*Michelia champaca*	
Pongamia glabra			
Sesbania sesban			
Piper longum			
Zingiber officinale			

Fig. 4.5: DECORANA ordination of eighty homegardens of Bangladesh in relation to moisture regimes: dry zone (* = marginal and small homegardens; x = medium and large homegardens) and wetter zones (+)

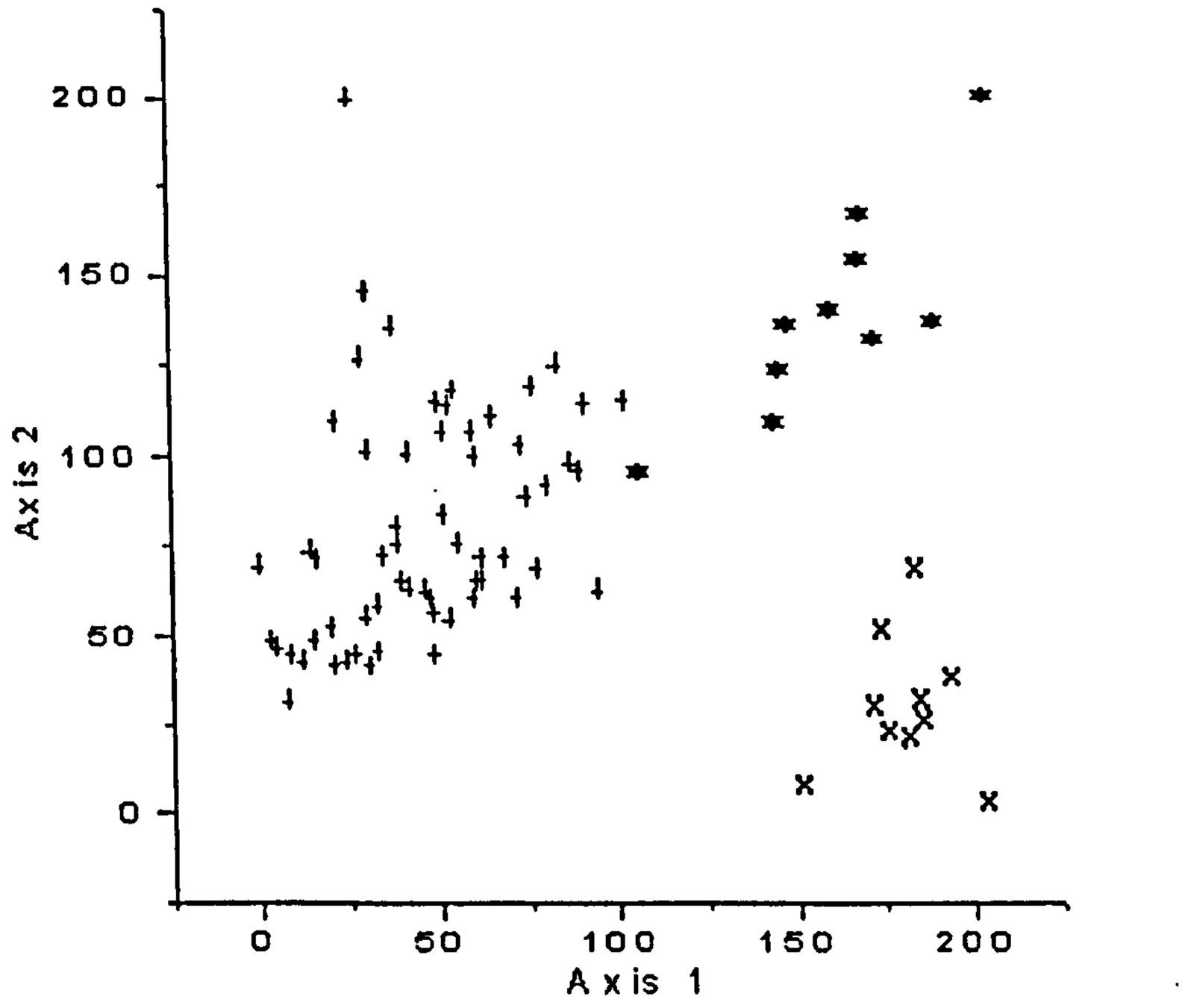
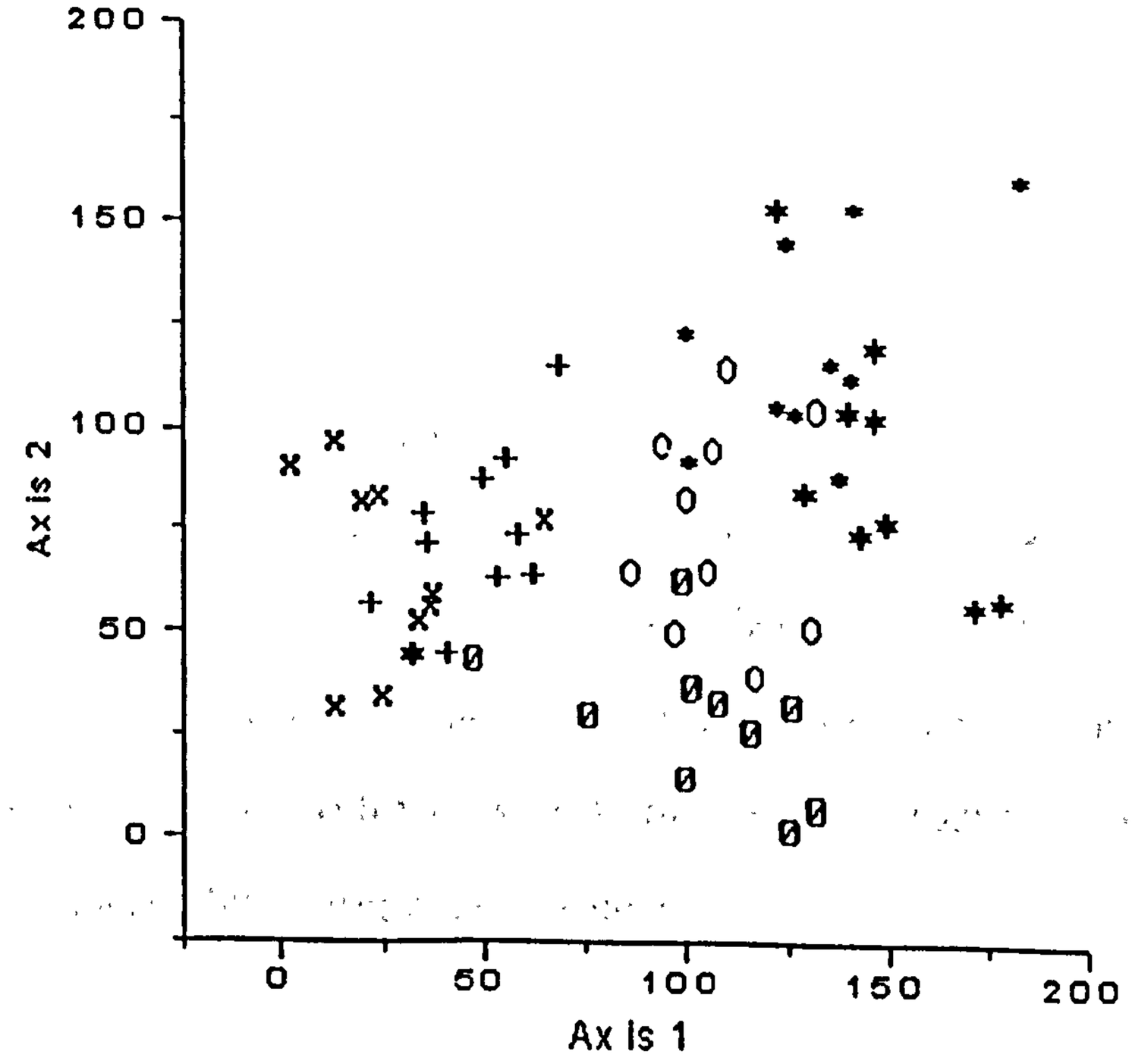


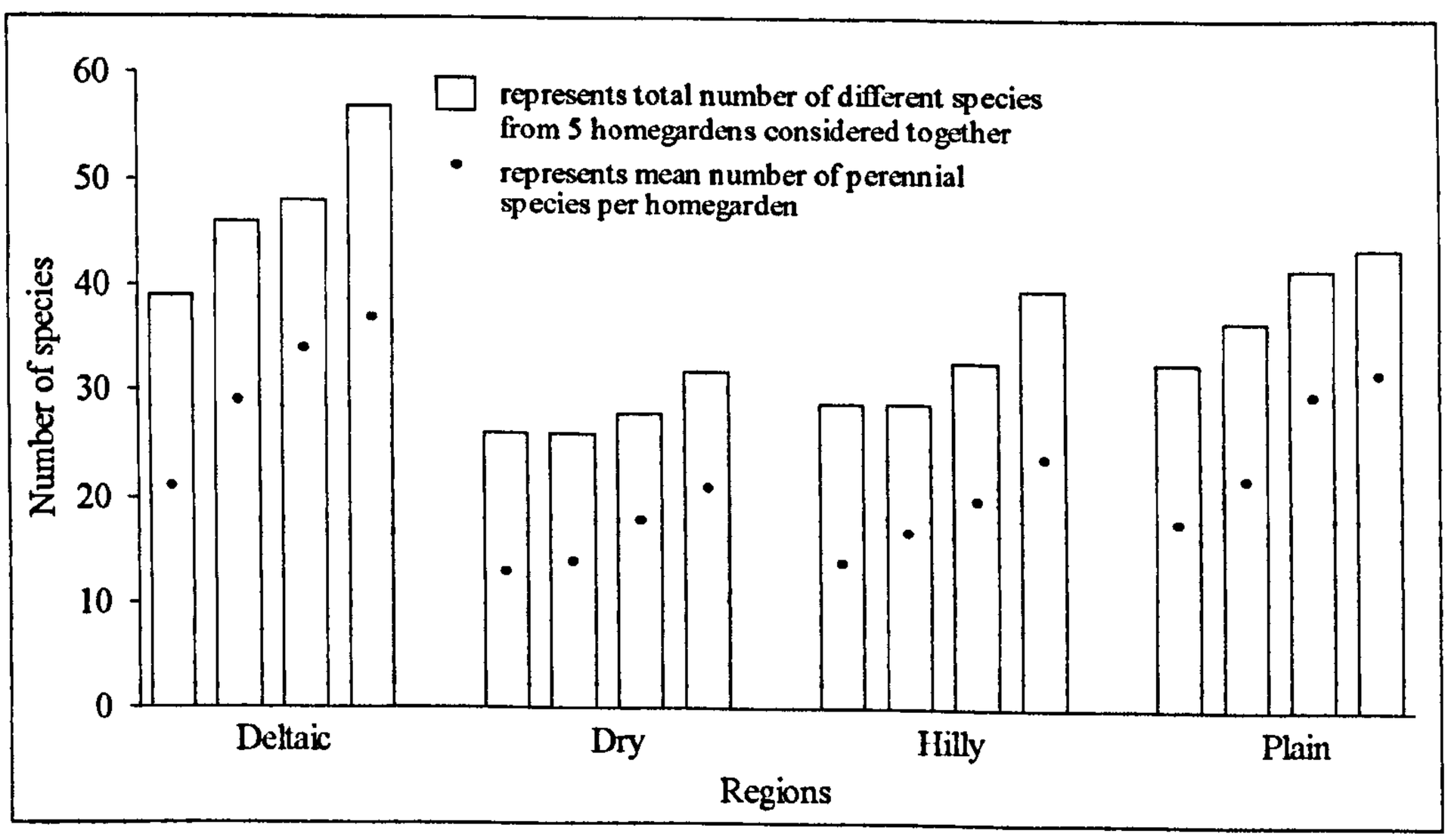
Fig. 4.6: DECORANA ordination of sixty homegardens of the wetter zones of Bangladesh: Deltaic (+ = marginal and small homegardens, x = medium and large homegardens); Hilly (∗ = marginal and small homegardens, ∗ = medium and large homegardens); and Plain (0 = marginal and small homegardens, θ = medium and large homegardens)



4.2.2 Species richness

A total of ninety two perennial species were recorded from the set of 80 homegardens surveyed. The complete floristic list is given in the Appendix 4. Marked variation in species richness was found in the homegardens of different regions (Fig. 4.7). The highest numbers of species were recorded in the homegardens of the Deltaic (67) and Plain (56) regions. Corresponding totals were 54 for the Hilly region and 46 for the Dry region respectively.

Fig. 4.7: Number of perennial species recorded in traditional homegardens by region and farm category



The ANOVA of the 80-homegarden set showed a significant interaction of region with homegarden size influencing species richness (Table 4.3). The influence of region and homegarden size were therefore considered further in separate ANOVAs (Table 4.4). Within regions there were significant differences in species richness associated with farm size. Within each homegarden size category there were significant differences among regions.

Table 4.3: Results of ANOVA test for the differences in number of species in different regions and farm categories

Sources of variation	df	SS	MS	F	P
Region (R)	3	2355.30	785.10	108.29	***
Farm (F)	3	1622.90	540.97	74.62	***
(R X F)	9	187.60	20.84	2.88	**
Error	64	464.00	7.25		
Total	79	4629.80			

***, ($p<0.001$); **, ($p<0.01$)

Table 4.4 (a): ANOVA testing significance of number of perennial species in homegardens of different regions, by homegarden size category

(i) Marginal

Sources of variation	df	SS	MS	F	P
Region	3	188.6	62.9	5.83	**
Error	16	172.4	10.8		
Total	19	361.0			

(ii) Small

Sources of variation	df	SS	MS	F	P
Region	3	606.0	202.0	32.06	***
Error	16	100.8	6.3		
Total	19	706.8			

(iii) Medium

Sources of variation	df	SS	MS	F	P
Region	3	938.55	312.85	49.86	***
Error	16	100.4	6.28		
Total	19	1038.95			

(iv) Large

Sources of variation	df	SS	MS	F	P
Region	3	809.8	268.93	47.78	***
Error	16	90.4	5.65		
Total	19	900.2			

Table 4.4 (b): ANOVA testing significance of number of perennial species in homegardens of different size, by region

(i) Deltaic

Sources of variation	df	SS	MS	F	P
Region	3	750.2	250.1	21.42	***
Error	16	186.8	11.7		
Total	19	937.0			

(ii) Dry

Sources of variation	df	SS	MS	F	P
Region	3	192.8	64.27	10.94	***
Error	16	94.0	5.87		
Total	19	286.8			

(iii) Hilly

Sources of variation	df	SS	MS	F	P
Region	3	241.0	80.33	16.91	***
Error	16	76.0	4.75		
Total	19	317.0			

(iv) Plain

Sources of variation	df	SS	MS	F	P
Region	3	626.55	208.85	31.17	***
Error	16	107.2	6.7		
Total	19	733.75			

***, ($p<0.001$); **, ($p<0.01$)

4.2.3 Species dominance and diversity

Species dominance

When all the 80 homegardens surveyed in the four regions were considered individually, *Musa* and *Mangifera indica* were present in every homegarden in every region. Another 23 species were present in at least one homegarden in each region. The relative importance values of the 25 common species given in Table 4.5 were used to rank the species in different regions as shown in Table 4.6.

Table 4.5: Relative Importance Values of the common species by region in traditional homegardens in Bangladesh

Scientific name	Common name	Regions			
		Deltaic	Dry	Hilly	Plain
Aegle marmelos	Woodapple	1.40	2.54	1.05	2.66
Albizia spp.	Koroi	3.31	1.55	3.42	15.69
Ananus sativus	Pineapple	2.91	4.36	11.62	8.53
Areca catechu	Betel nut	28.43	3.09	68.41	20.36
Artocarpus heterophyllus	Jack fruit	7.63	16.39	17.94	16.15
Averrhoa carambola	Star fruit	2.25	1.92	2.86	3.30
Bombax ceiba	Silk cotton	3.17	2.33	4.06	4.83
Carica papaya	Papaya	4.98	9.64	7.36	3.41
Citrus acida	Jambura	3.91	2.54	2.32	3.22
Cocos nucifera	Coconut	12.06	14.84	23.77	26.74
Colocacia indica	Aroid	3.26	2.20	3.55	4.39
Curcuma longa	Turmeric	5.62	12.05	3.08	6.20
Erythrina variegata	Madar	12.52	1.09	6.31	6.15
Grewia microcos	Asar	1.06	0.68	0.79	0.25
Lannea coromandelica	Badhi	7.88	4.26	3.48	8.48
Litchi chinensis	Litchi	2.02	4.26	2.71	0.55
Mangifera indica	Mango	24.21	20.75	23.00	24.38
Musa spp.	Banana	30.85	59.01	27.58	28.54
Psidium guajava	Guava	3.48	6.16	11.72	7.43
Punica granatum	Pomegranate	1.50	0.38	2.67	4.99
Samanea saman	Rain tree	29.48	5.36	10.33	6.53
Spondias pinnata	Hog-plum	6.02	0.70	2.23	0.23
Swietenia macrophylla	Mahagony	11.42	3.59	1.60	5.24
Syzygium spp.	Jam	4.61	3.51	6.71	4.81
Ziziphus jujuba	Jujube	2.37	2.32	4.45	4.25

Table - 4.6: Dominance rank of species by region, in Bangladesh homegardens

Scientific name	Regions				Mean dominance rank
	Deltaic	Dry	Hilly	Plain	
Musa spp.	1	1	2	1	1
Mangifera indica	4	2	4	3	2
Cocos nucifera	6	4	3	2	3
Areca catechu	3	13	1	4	4
Artocarpus heterophyllus	9	3	5	5	5
Samanea saman	2	8	8	10	6
Psidium guajava	15	7	6	9	7
Lannea coromandelica	8	10	15	8	8
Ananus sativus	19	9	7	7	9
Curcuma longa	11	5	17	11	10
Carica papaya	12	6	9	19	11
Erythrina variegata	5	20	11	12	12
Syzygium spp.	13	12	10	16	13
Swietenia macrophylla	7	11	23	13	14
Albizia spp.	16	19	16	6	15
Bombax ceiba	18	15	13	15	16
Colocacia indica	17	17	14	17	17
Ziziphus jujuba	20	16	12	18	18
Citrus acida	14	14	21	21	19
Litchi chinensis	22	10	19	23	20
Averrhoa carambola	21	18	18	20	21
Spondias pinnata	10	21	22	25	22
Punica granatum	23	23	20	14	22
Aegle marmelos	24	14	24	22	23
Grewia microcos	25	22	25	24	25

The mean dominance rank was determined by pooling the entire set of data for the 80 homegardens. From the table it is evident that the first species with the highest important value indices are food and fruit producing species and *Musa* spp. is the dominant species in the three regions except the hilly region. In the hilly region the most dominant species is *Areca catechu*. *Albizia* spp. is the dominant timber species in the plain region while it is *Samanea saman* in other regions.

Vertical dominance of species

The three dominant species in each stratum are shown in Table 4.7. The species are ranked in descending order according of relative importance values. A common pattern of vertical distribution of dominant species was observed

although the ranks varied amongst the farm categories within each region as well as amongst the regions.

Among the herbaceous species, *Curcuma longa* and *Anamus sativus* were dominant in the S_0 stratum of most of the homegardens. *Anamus sativus* was the common dominant species in the Plain region and *Curcuma longa* was the common dominant species in the Dry region.

The dominant species of S_1 stratum were *Musa* spp. and *Areca catechu* in most of the homegardens. *Areca catechu* was the common dominant species of the Deltaic region and *Musa* spp. was the common dominant species of the Dry, Hilly and the Plain regions, respectively.

In the S_2 stratum, *Musa* spp. was the only common dominant species of all the homegardens irrespective of farm categories and regions. *Areca catechu* and *Artocarpus heterophyllus* were also the common dominant species of this stratum in the Hilly region.

Areca catechu, Mangifera indica, Cocos nucifera and *Samanea saman* were some of the dominant species of S_3 stratum recorded from many homegardens. *Areca catechu* was the common dominant species of this stratum in the Hilly region.

The S_4 stratum of most of the homegardens was dominated by different *Bambusa* spp. and *Bambusa longispiculata* was the common dominant species in the Dry region.

The S_5 stratum was also dominated by different *Bambusa spp.* in many homegardens. The common dominant species of this stratum were *Mangifera*

indica in the Deltaic, *Bambusa balcooa* in the Dry and *Areca catechu* in the Hilly regions.

Table 4.7: The three species with highest importance value indices, by vertical stratum, in Bangladesh homegardens

Region	Farm category	Vertical strata					
		S_0	S_1	S_2	S_3	S_4	S_5
Deltaic	Marginal	*Areca catechu* *Mangifera indica* *P. sylvestris*	*Areca catechu* *Mangifera indica* *P. sylvestris*	*Areca catechu* *Musa* spp. *Mangifera indica*	*Areca catechu* *Samanea saman* *Mangifera indica*	*Samanea saman* *Cocos nucifera* *Mangifera indica*	*Samanea saman* *Areca catechu* *Mangifera indica*
	Small	*Areca catechu* *Mangifera indica* *Curcuma longa*	*Musa* spp. *Areca catechu* *Mangifera indica*	*Musa* spp. *Samanea saman* *E. variegata*	*Samanea saman* *B. longispiculata* *L. coromandelica*	*Samanea saman* *Albizia falcataria* *Mangifera indica*	*B. burmamca* *Albizia* spp. *Mangifera indica*
	Medium	*Areca catechu* *Mangifera indica* *Ananus sativus*	*Musa* spp. *Areca catechu* *Sesbania sesban*	*Musa* spp. *Areca catechu* *Swietema spp.*	*M. baccifera* *Samanea saman* *E. variegata*	*B. longispiculata* *Samanea saman* *Areca catechu*	*Mangifera indica* *Samanea saman* *Spondias pinnata*
	Large	*Curcuma longa* *D. embryopteris* *Ananus sativus*	*Musa* spp. *Mangifera indica* *Areca catechu*	*Areca catechu* *Musa* spp. *Mangifera indica*	*Areca catechu* *Mangifera indica* *Swietenia* spp.	*B. longispiculata* *Mangifera indica* *Areca catechu*	*B. burmanica* *Samanea saman* *Mangifera indica*
Dry	Marginal	*Curcuma longa* *Musa* spp. *Mangifera indica*	*Musa* spp. *Carica papaya* *Mangifera indica*	*Musa* spp. *Mangifera indica* *Melia azedarach*	*Mangifera indica* *Areca catechu* *A. heterophyllus*	*B. longispiculata* *Melia azedarach* *Azadirachta indica*	*B. balcooa* *Mangifera indica* *Melia azedarach*
	Small	*Curcuma longa* *Musa* spp. *Carica papaya*	*Musa* spp. *A. heterophyllus* *Ricinus communis*	*A. heterophyllus* *Musa* spp. *Mangifera indica*	*B. longispiculata* *A. heterophyllus* *Azadirachta indica*	*B. balcooa* *B. longispiculata* *Azadirachta indica*	*B. balcooa*
	Medium	*Mangifera indica* *Curcuma longa* *Ananus sativus*	*Musa* spp. *G. herbaceum* *Moringa oleifera*	*Musa* spp. *Mangifera indica* *Moringa oleifera*	*B. longispiculata* *Mangifera indica* *Melia azedarach*	*B. balcooa* *B. longispiculata* *Cocos nucifera*	*B. balcooa* *Dalbergia sissoo*
	Large	*Musa* spp. *Curcuma longa* *Cocos nucifera*	*Musa* spp. *A. heterophyllus* *Dalbergia sissoo*	*Musa* spp. *Cocos nucifera* *A. heterophyllus*	*B. longispiculata* *Dalbergia sissoo* *Cocos nucifera*	*B. longispiculata* *Mangifera indica* *A. heterophyllus*	*B. balcooa* *Cocos nucifera* *Dalbergia sissoo*
Hilly	Marginal	*Ananus sativus* *Areca catechu* *Citrus lemon*	*Areca catechu* *Mangifera indica* *Musa* spp.	*Areca catechu* *A. heterophyllus* *Musa* spp.	*Areca catechu* *Litchi chinensis* *Cocos nucifera*	*Areca catechu* *B. vulgaris* *Mangifera indica*	*Syzygium* spp. *Mangifera indica* *Areca catechu*
	Small	*Cocos nucifera* *Ananus sativus* *Areca catechu*	*Musa* spp. *Areca catechu* *Mangifera indica*	*Musa* spp. *A. heterophyllus* *Areca catechu*	*Areca catechu* *Samanea saman* *Mangifera indica*	*Areca catechu* *Samanea saman* *Mangifera indica*	*B. balcooa* *Areca catechu* *Cocos nucifera*
	Medium	*Musa* spp. *Cocos nucifera* *S. dichotoma*	*Areca catechu* *Musa* spp. *S. dichotoma*	*Musa* spp. *Areca catechu* *A. heterophyllus*	*Areca catechu* *Cocos nucifera* *A. heterophyllus*	*B. burmamca* *Cocos nucifera* *Mangifera indica*	*B. balcooa* *Areca catechu* *Cocos nucifera*
	Large	*Areca catechu* *Ananus sativus* *Cocos nucifera*	*Areca catechu* *Musa* spp. *Citrus lemon*	*Musa* spp. *Areca catechu* *A. heterophyllus*	*Areca catechu* *Cocos nucifera* *A. heterophyllus*	*Areca catechu* *B. burmanica* *Cocos nucifera*	*B. balcooa* *Areca catechu* *Cocos nucifera*
Plain	Marginal	*Ananus sativus* *Mangifera indica* *Curcuma longa*	*Areca catechu* *Mangifera indica* *Musa* spp.	*Musa* spp. *A. heterophyllus* *Mangifera indica*	*Cocos nucifera* *L. coromandelica* *Mangifera indica*	*B. burmamca* *A. heterophyllus* *Mangifera indica*	*Cocos nucifera* *Albizia spp.* *A. heterophyllus*
	Small	*Curcuma longa* *Areca catechu* *Ananus sativus*	*Musa* spp. *S. dichotoma* *Areca catechu*	*Musa* spp. *Albizia spp.* *Mangifera indica*	*Mangifera indica* *Areca catechu* *Samanea saman*	*B. burmanica* *Cocos nucifera* *Albizia spp.*	*B. balcooa* *Mangifera indica* *B. burmanica*
	Medium	*Citrus limon* *Ananus sativus* *Curcuma longa*	*Areca catechu* *Mangifera indica* *Musa* spp.	*Musa* spp. *Mangifera indica* *Areca catechu*	*Cocos nucifera* *Mangifera indica* *E. variegata*	*B. balcooa* *Cocos nucifera* *Albizia spp.*	*B. balcooa* *Albizia spp.* *B. burmanica*
	Large	*Areca catechu* *Ananus sativus* *Cocos nucifera*	*Musa* spp. *Areca catechu* *Cocos nucifera*	*Musa* spp. *Cocos nucifera* *Areca catechu*	*Cocos nucifera* *M. baccifera* *Areca catechu*	*B. balcooa* *Cocos nucifera* *Albizia spp.*	*B. vulgaris* *Samanea saman* *Terminalia arjuna*

Where : *A = Artocarpus, B = Bambusa, D = Diospyros, E = Erythrina, G = Gossypium, L = Lannea, M = Melocanna, P = Phoenix, S = Schumannianthus.*

Similarity of species

The Sϕrenson's similarity index of species expressed as percentage showed highest similarity between Plain and the Deltaic region followed by the Plain and the Hilly, Plain and the Dry, Hilly and the Deltaic, Dry and the Deltaic and Hilly and the Dry regions, respectively (Table 4.8). Thus contiguous regions have showed a higher magnitude of similarities.

Table 4.8: Sϕrenson's index of similarity (expressed as percentages) in perennial species composition for homegardens in different regions of Bangladesh

Regions	Regions		
	Deltaic	Dry	Hilly
Dry	60.18		
Hilly	64.46	60.00	
Plain	76.42	66.67	69.09

Diversity of species

Species diversity varies with region (Fig. 4.8). Except for the large homegardens, the highest species diversity was recorded from the Plain region followed by the Deltaic region. In the large homegarden category, those of the Deltaic region are more diverse than those of the Plain region.

Species in the homegardens of Plain region was more evenly distributed followed by the Deltaic region (Fig. 4.9). The homegardens of Dry and the Hilly regions showed a similar pattern of diversity distribution for the distribution of species evenness .

The ANOVA of the 80-homegarden set showed a significant interaction of region with homegarden size influencing species diversity and evenness (Table 4.9 & Table 4.10). The influence of homegarden size were therefore considered further in separate ANOVAs (Table 4.11 & Table 4.12). Within each homegarden size category there were significant differences among regions in both cases.

Table 4.9: Results of ANOVA test for the differences in diversity of species in different regions and farm categories

Sources of variation	df	SS	MS	F	P
Region (R)	3	9.3	3.11	105.38	***
Farm (F)	3	1.0	0.32	10.94	***
(R X F)	9	1.6	0.17	5.87	***
Error	64	1.9	0.01		
Total	79	13.8			

***, ($p<0.001$); **, ($p<0.01$)

Table 4.10: Results of ANOVA test for the differences in evenness of species in different regions and farm categories

Sources of variation	df	SS	MS	F	P
Region (R)	3	0.247	0.082	51.20	***
Farm (F)	3	0.047	0.016	9.72	***
(R X F)	9	0.143	0.016	9.88	***
Error	64	0.103	0.001		
Total	79	0.540			

***, ($p<0.001$); **, ($p<0.01$)

Table 4.11: ANOVA testing significance of species diversity in homegardens of different regions, by homegarden size category

(i) Marginal

Sources of variation	df	SS	MS	F	P
Region	3	1.35	0.45	9.03	***
Error	16	0.80	0.05		
Total	19	2.15			

(ii) Small

Sources of variation	df	SS	MS	F	P
Region	3	2.02	0.68	45.51	***
Error	16	0.24	0.02		
Total	19	2.26			

(iii) Medium

Sources of variation	df	SS	MS	F	P
Region	3	5.02	1.67	71.42	***
Error	16	0.37	0.02		
Total	19	5.39			

(iv) Large

Sources of variation	df	SS	MS	F	P
Region	3	2.46	0.82	25.3	***
Error	16	0.52	0.03		
Total	19	2.98			

***, ($p<0.001$)

Table 4.12: ANOVA testing significance of species evenness in homegardens of different regions, by homegarden size category

(i) Marginal

Sources of variation	df	SS	MS	F	P
Region	3	0.039	0.013	8.79	***
Error	16	0.024	0.001		
Total	19	0.063			

(ii) Small

Sources of variation	df	SS	MS	F	P
Region	3	0.064	0.0216	47.40	***
Error	16	0.007	0.0004		
Total	19	0.071			

(iii) Medium

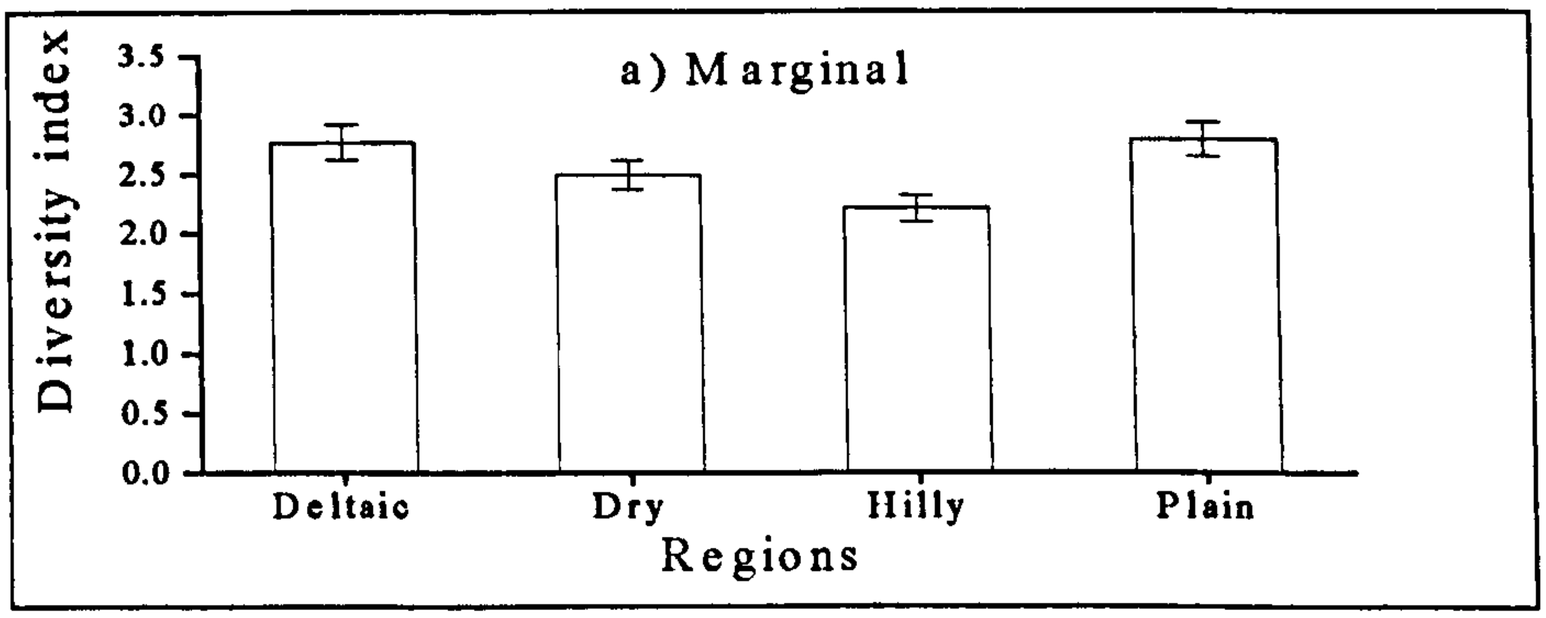
Sources of variation	df	SS	MS	F	P
Region	3	0.265	0.0886	111.06	***
Error	16	0.013	0.0007		
Total	19	0.278			

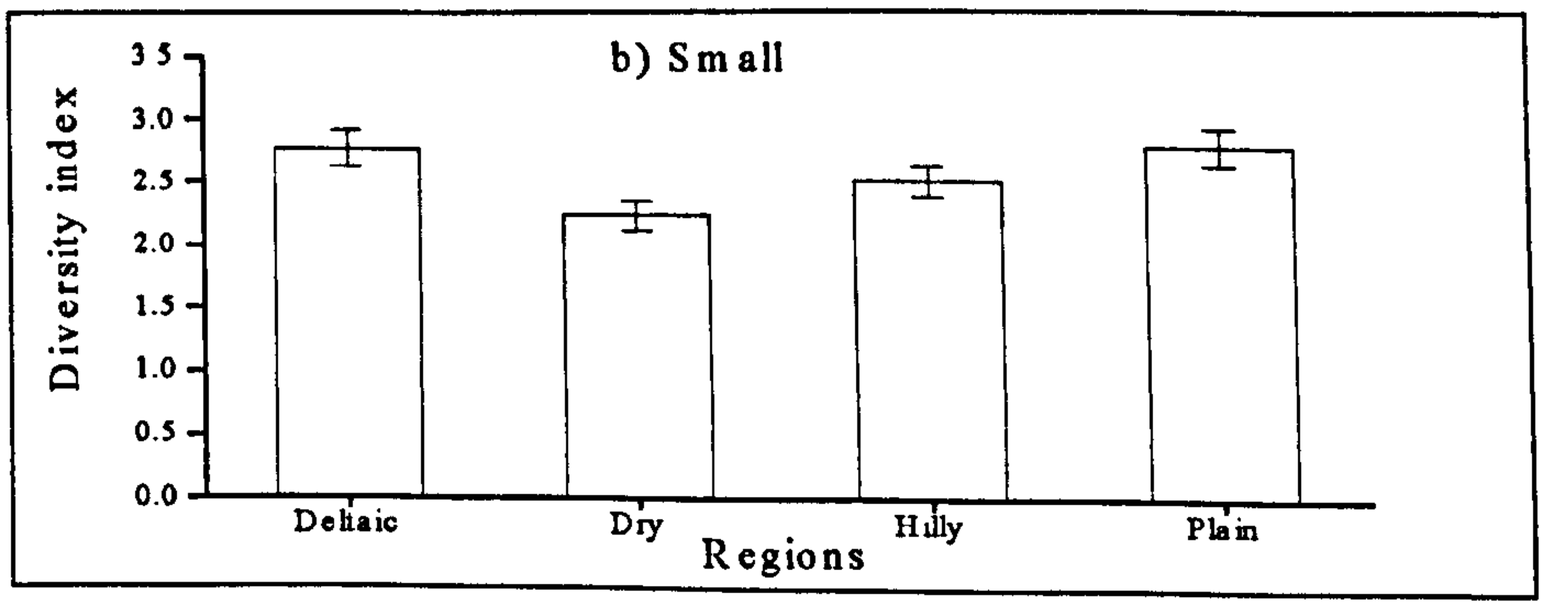
(iv) Large

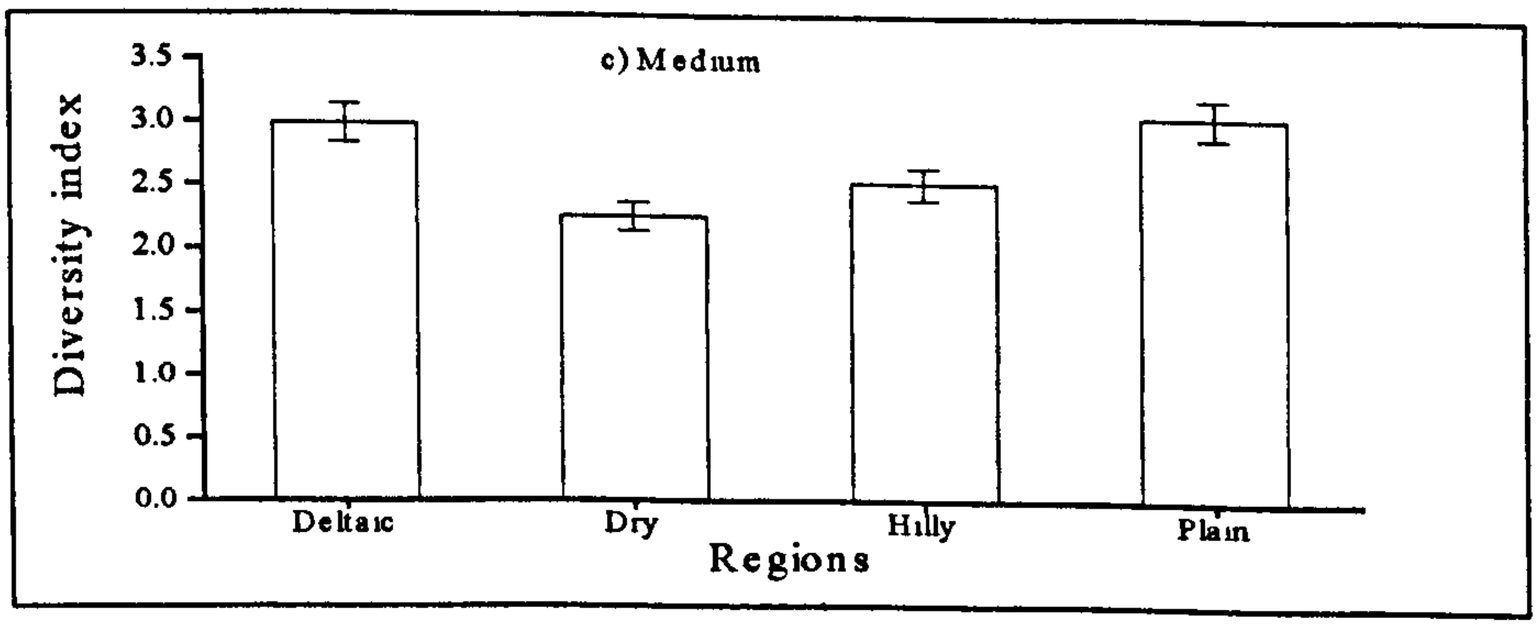
Sources of variation	df	SS	MS	F	P
Region	3	0.071	0.023	7.24	**
Error	16	0.052	0.003		
Total	19	0.124			

***, ($p<0.001$); **, ($p<0.01$)

Fig. 4.8: Species diversity of traditional homegardens in Bangladesh







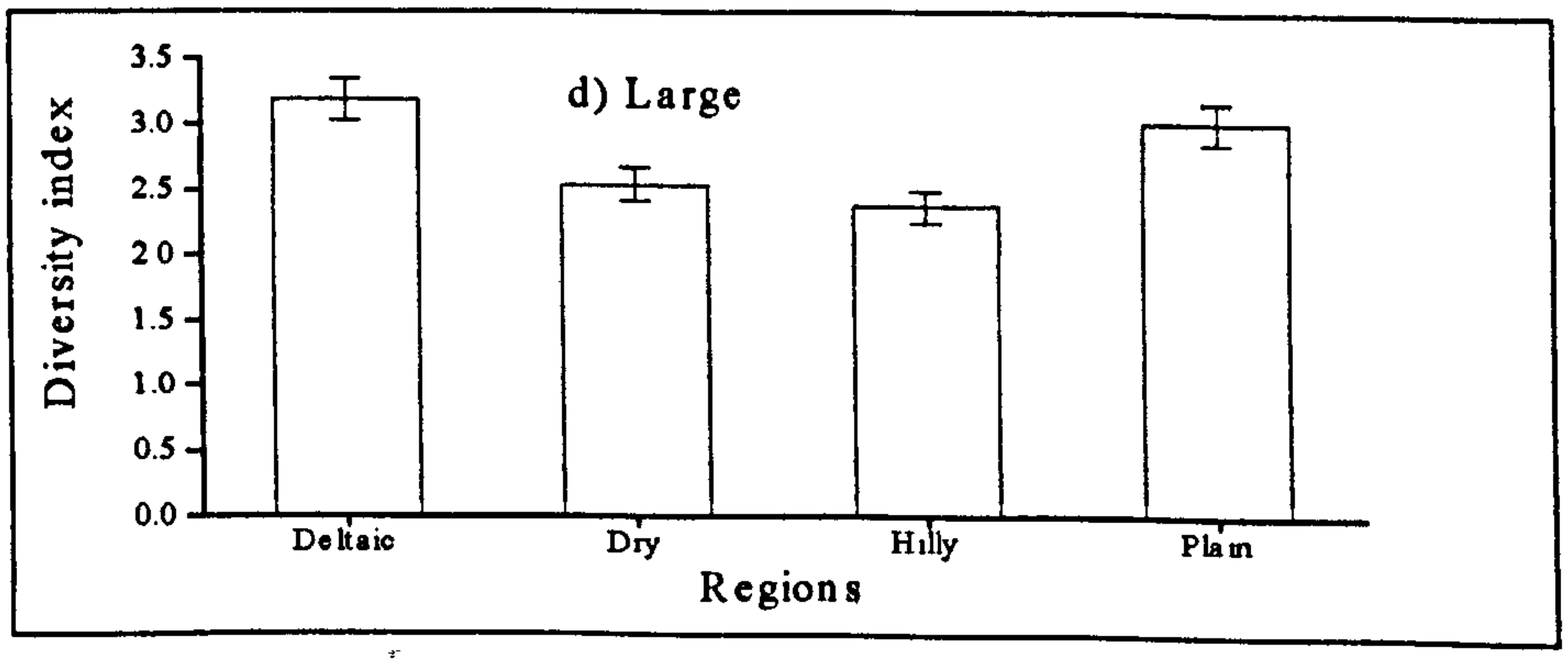
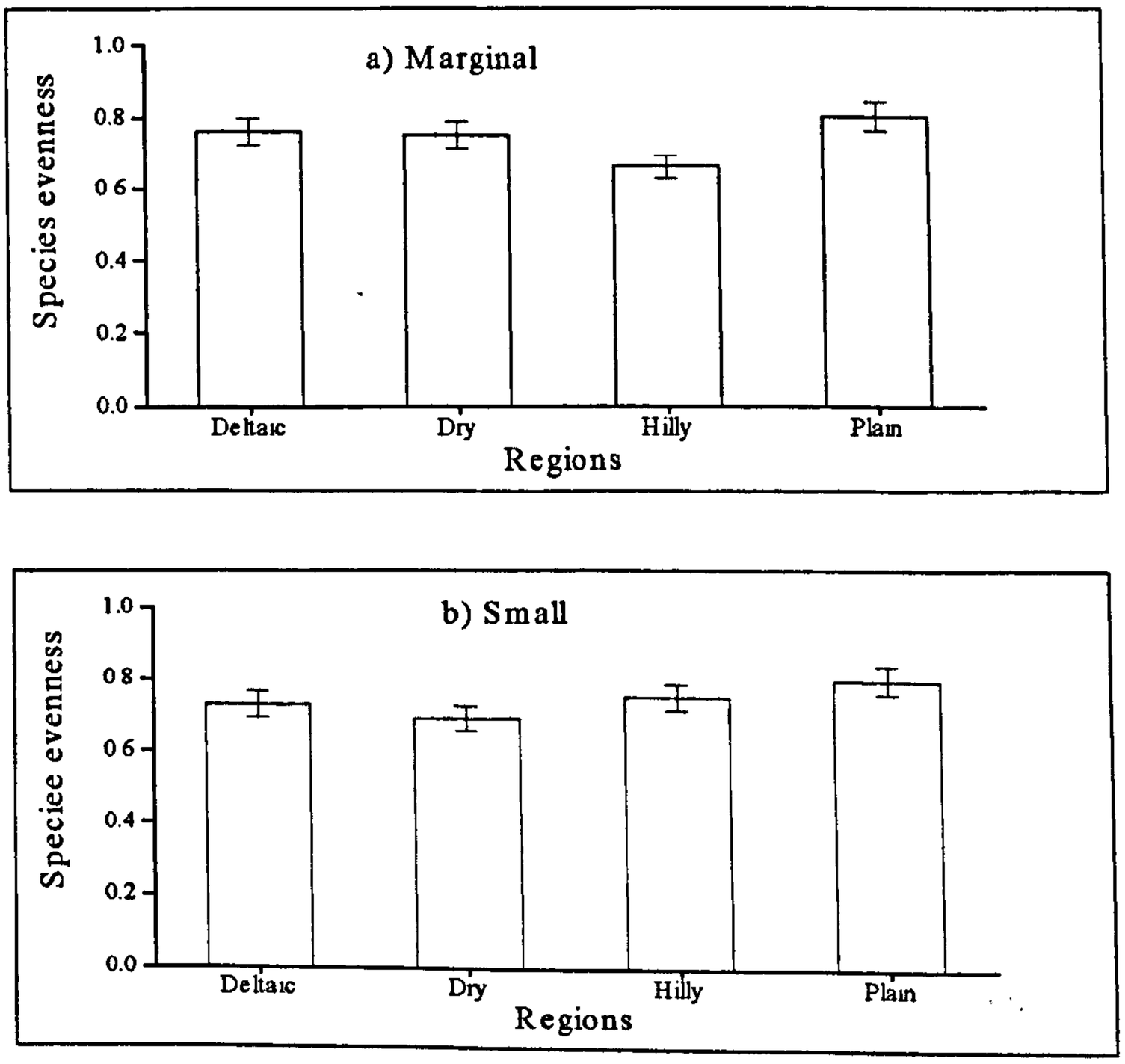


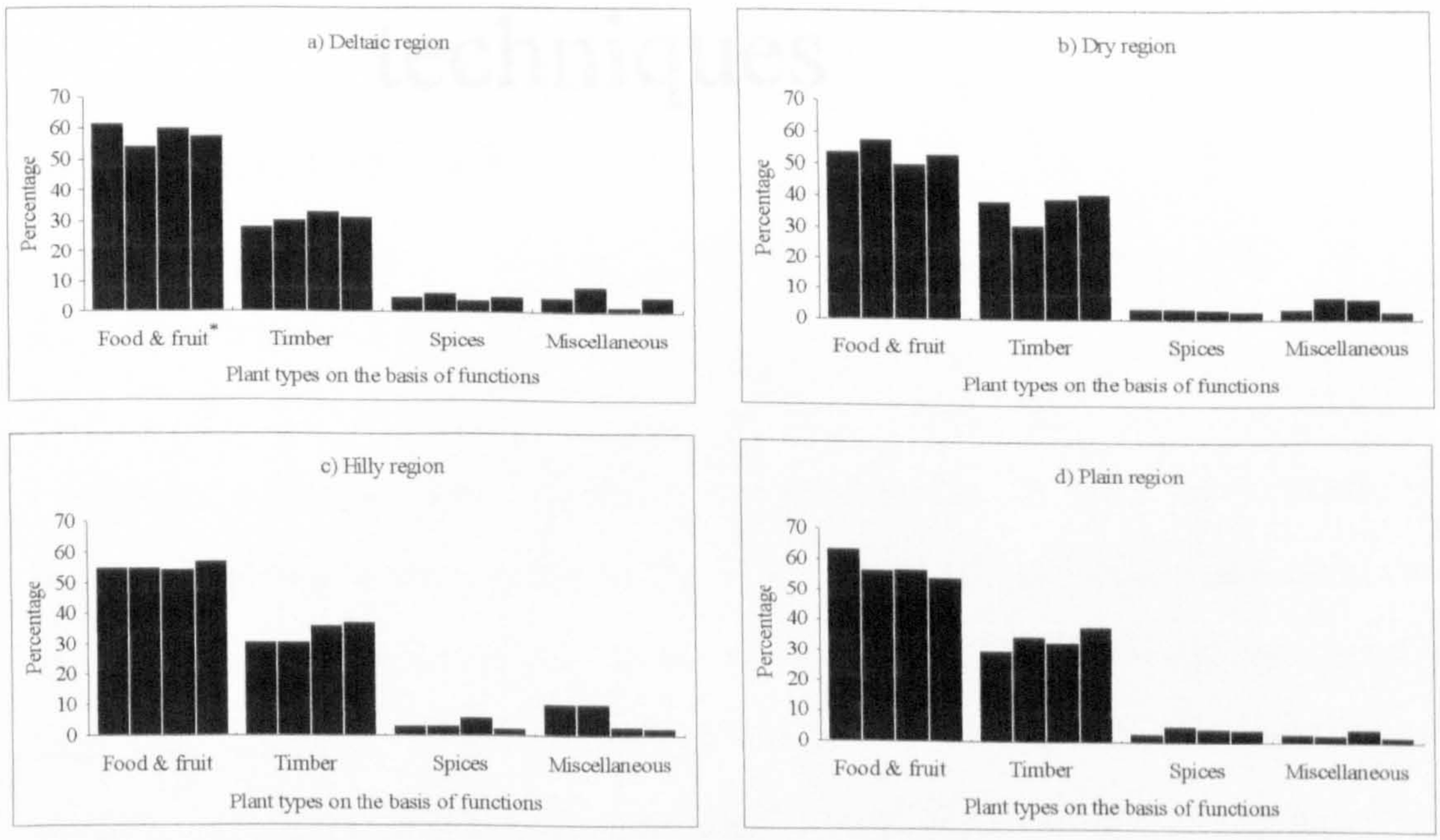
Fig. 4.9: Species evenness of traditional homegardens in Bangladesh



4.2.4 Functional species groups

Listing species by functions indicated that the proportion of food and fruit producing species accounted for more of the species present than any other functional group, followed by the timber species, the miscellaneous group and the spices, respectively (Fig. 4.10). Within each region, the number of perennial species present was significantly positively correlated ($p<0.01$) with homegarden size: Deltaic, $r = 0.86$; Dry, $r = 0.77$; Hilly $= 0.85$; Plain, $r = 0.77$.

Fig. 4.10: Functional species groups of traditional homegardens in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

Chapter 5
Results - Indigenous management techniques

Chapter 5

RESULTS - INDIGENOUS MANAGEMENT TECHNIQUES

Section One (5.1) of this chapter deals with indigenous application of silvicultural techniques in the homegardens. Section Two (5.2) describes farmers' knowledge on plant interactions in the homegardens. Gender roles in homegarden management are described in section Three (5.3). Section Four (5.4) deals with uses of the species. Farmers' awareness of different functional aspects of the homegardens are presented in Section Five (5.5) and Section Six (5.6) describes management problems of the homegardens.

5.1 Silviculture in the homegardens

5.1.1 Planting materials

Seeds, seedlings and vegetative propagules are all used by farmers to regenerate plants in homegardens (Fig. 5.1). Plants of seed origin include those raised on-farm from seed (i.e. those grown from direct-sowing) and arising naturally (wildings). Plants of seedling origin used include those purchased or given by others. Most of the food and fruit producing species are propagated from seeds and/or seedlings. *Ananus sativus*, *Citrus limon*, *Musa* spp. and *Punica granatum* are exceptions, being propagated vegetatively from root suckers or branch cuttings. Most timber species are propagated from seedlings but species easy to grow from seed (*Albizia* spp., *Samanea saman*, *Dalbergia sissoo*, *Melia azedarach* and *Azadirachta indica*) are also propagated from these if they are available in quantity. Some other timber species (*Bambusa* spp., *Lannea coromandelica*, *Erythrina variegata* and *Lawsonia inermis*) are propagated

vegetatively from root suckers or branch cuttings. All spices are propagated vegetatively.

Between farm categories within each region, Chi-Squared tests did not show any significant differences in the frequency of responses of using each planting materials, but in all the regions, a common trend of using greater proportions of seedlings and less of seeds as planting materials by the larger farmers were observed (Fig. 5.1). Between regions, Analysis of Variance showed significant differences in the percentage responses of farmers (transformed by Arc Sine) for using seedlings and both seeds and seedlings as planting materials (Table 5.1).

Table 5.1: ANOVA testing significance of using different planting materials by farmers of different regions

a) seedlings

Sources of variation	df	SS	MS	F	P
Region	3	217.45	72.48	17.48	***
Error	12	49.78	4.15		
Total	15	267.23			

b) Both seeds and seedlings

Sources of variation	df	SS	MS	F	P
Region	3	43.66	14.55	6.54	**
Error	12	26.70	2.22		
Total	15	70.36			

***, p<0.001; **, p<0.01

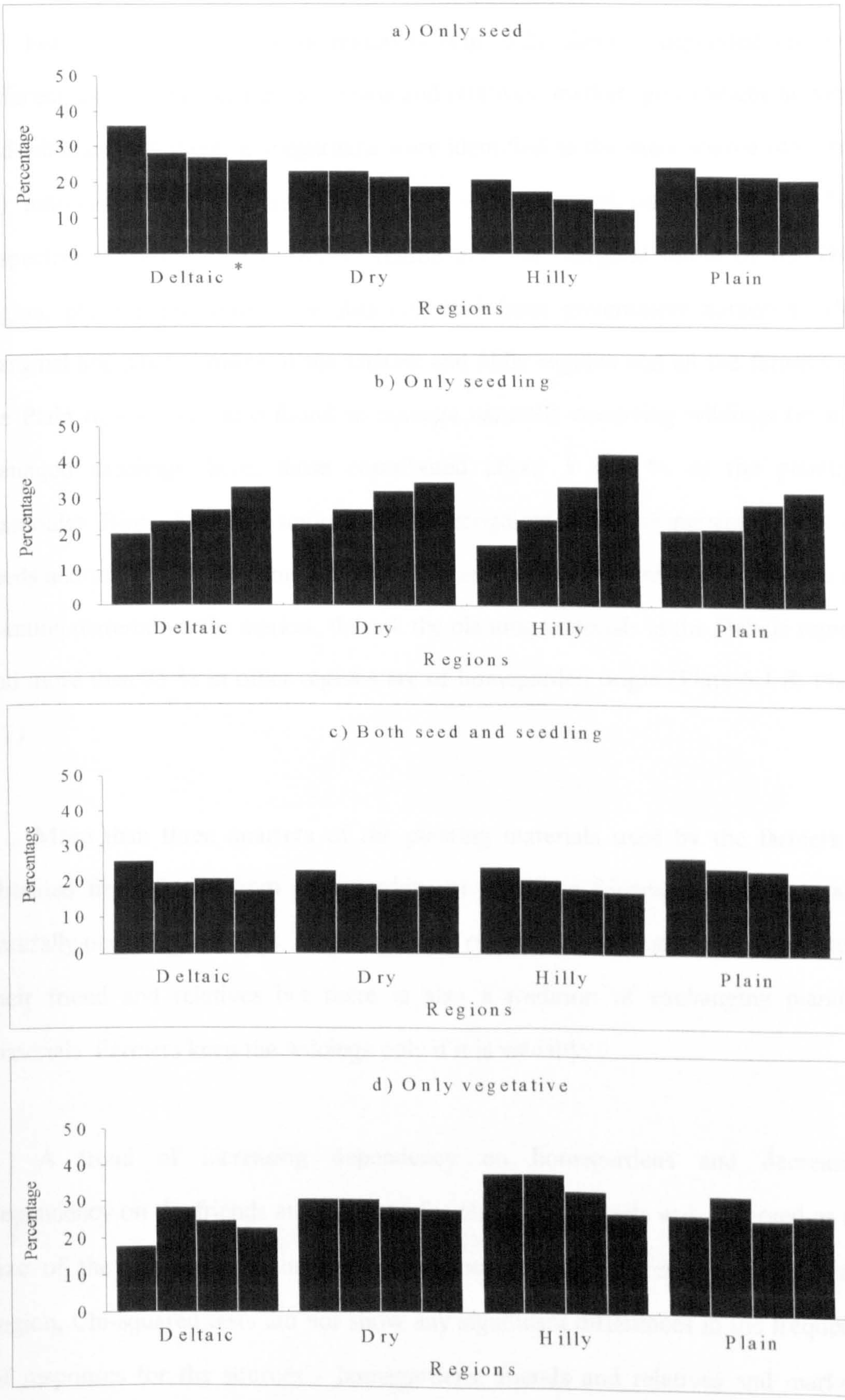
Advantages and disadvantages of different planting materials

Ease of growing and availability were the two advantages attributed by all the farmers to seed as a planting material (Table 5.2). Reduced survival and more susceptibility to damage from grazing animals were mentioned as disadvantages. Better survival and control of species identity were advantages recognised by farmers for using seedlings as planting material. Less susceptibility to damage from livestock as an advantage of seedlings was noted by the farmers of the Deltaic, Dry and the Plain regions. Lower availability of supply was the disadvantage mentioned by all farmers and marginal and small farmers (in all regions) also mentioned seedling cost as an additional disadvantage. Ease of availability, selection of varieties of proven quality of food and fruit producing species (principally *Mangifera indica* in the Dry region and *Ziziphus jujuba*, *Citrus limon* and *Musa* spp. in every region) were given as advantages of using vegetative propagules as planting materials. In the cases of *Ananus sativus*, *Citrus limon*, *Musa* spp., *Punica granatum*, *Bambusa* spp., *Lannea coromandelica*, *Erythrina variegata*, *Lawsonia inermis* and all spices no other mean of propagation is available. Good survival and fast subsequent growth were additional advantages reported by farmers in the Deltaic region and most (60 %) large farmers in the Plain region. Farmers in the Dry region mentioned early fruiting (in case of *Mangifera indica*) behaviour as an added advantage of vegetative propagation. The only disadvantage mentioned (by marginal and small farmers of the Dry region) was higher cost of vegetative propagules of *Mangifera indica*.

Table 5.2: Advantages and disadvantages of using different planting materials

Planting materials	Advantages	Disadvantages
Seed	• Easy to grow, • Easily available	• Less survival rate, • More damage by livestock
Seedling	• Better survival rate • Less damage by livestock • Desired species can be introduced	• Costly • Not readily available
Vegetative propagules	• Easily available • Better survival rate • Subsequent growth fast • Improved varieties can be introduced (in case of food and fruit producing species) • Only way to propagate • Early fruiting (in case of *Mangifera indica*)	• Costly

Fig. 5.1: Planting materials used to regenerate the species by regions in traditional homegardens in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

5.1.2 Sources of planting materials

For the supply of planting materials (Fig. 5.2), farmers depended on five different sources (homegardens, friends and relatives, market, government nursery and wildings). Of these, homegardens were identified as the main source (46 - 67 %) followed by friends and relatives (11 - 41 %) and market (4 - 21 %) respectively. Except in the Deltaic region and the marginal farms of the Dry region, planting materials were also collected from government nurseries. The marginal and small farmers of the Deltaic and Hilly regions and all the farmers of the Plain region were also found to manage naturally occurring wildings (in-situ managed seedlings: here, these contributed about 3 - 8 % of the planting materials). Birds, bats and squirrels were recognised as the dispersing agents of seeds and/or fruits for wildings. Small homegarden nurseries are the only source of planting materials in the market, thus all the planting materials in the Deltaic region and more than 85 % in other regions are of homegarden origin (Plate 5.1 & Plate 5.2).

More than three quarters of the planting materials used by the farmers is obtained free of cost from homegardens or from the friends and relatives and naturally occurring wildings. Farmers mostly obtain planting materials as gifts from their friend and relatives but there is also a tradition of exchanging planting materials. Farmers keep the wildings only if it is valuable.

A trend of increasing dependency on homegardens and decreasing dependency on the friends and relatives for planting materials was observed as the size of the homegardens increased. Between the farm categories within each region, Chi-squared tests did not show any significant differences in the frequency of responses for the sources - homegardens, friends and relatives and market . Between regions, Analysis of Variance showed significant differences (Table 5.3)

in the percentage responses of farmers (transformed by Arc Sine) for the sources - friends and relatives ($p<0.001$) and market ($p<0.01$) respectively. For the source market, the farmers of the Deltaic region depended more than other regions. The farmers of the Dry region depended on friends and relatives more than other regions.

Plate 5.1: A homegarden nursery in the Deltaic region

Plate 5.2: A homegarden nursery in the Plain region

Table 5.3: ANOVA testing significance of using different planting materials sources by the farmers of different regions

a) Friends and relatives

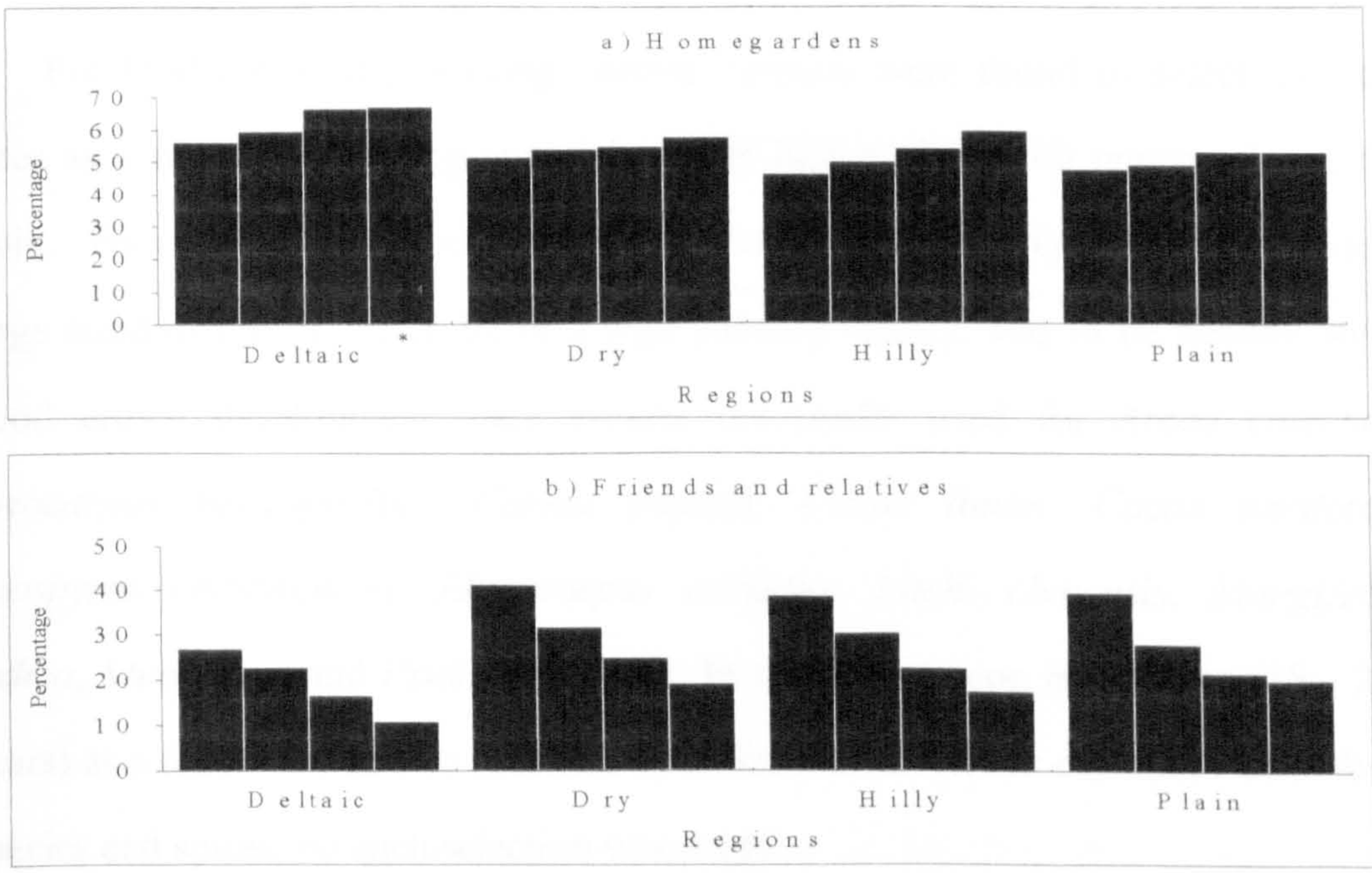
Sources of variation	df	SS	MS	F	P
Region	3	380.15	126.72	12.85	***
Error	12	118.29	9.86		
Total	15	498.44			

b) Market

Sources of variation	df	SS	MS	F	P
Region	3	218.16	72.72	9.27	**
Error	12	94.18	7.85		
Total	15	312.34			

*, $p<0.05$; **, $p<0.01$

Fig. 5.2: Sources of planting materials in traditional homegardens in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

5.1.3 Mother tree selection

For food and fruit producing species, farmers were found to select mother trees as a source of planting materials to get higher yield with improved quality fruits. Four criteria were considered by the farmers (Table 5.4): ability to produce large sized quality fruits, to be of a high yielding variety, and to be healthy with good crown development were criteria universally used for *Areca catechu*, *Artocarpus heterophyllus*, *Carica papaya*, *Citrus limon*, *Cocos nucifera*, *Diospyros embryopteris*, *Elaeocarpus robustus*, *Litchi chinensis*, *Mangifera indica*, *Musa* spp., and *Psidium guajava*. In the Hilly region middle age (15 - 20 years) as a criterion was also specified by all farmers for *Areca catechu*. For timber species and spices, no such selection was made.

Mother trees are selected from the existing trees of the homegardens. When the farmers exchange planting materials, they give high priority to the planting material from good mother trees.

Table 5.4: Criteria of mother trees as reported by the farmers for food and fruit producing species in homegardens in Bangladesh

Criteria of mother trees	Reported by and from
• Ability to produce big sized quality fruits	All farmers from all the regions
• High yielding variety	All farmers from all the regions
• Healthy with good crown development	All farmers from all the regions
• Middle age	All farmers from the Hilly region

5.1.4 Size of seedlings

Three sizes of seedlings were recognised by the farmers (Table 5.5). Medium sized seedlings were regarded as the best planting size for seedlings by all farmers. Farmers expressed the size in the traditional measuring unit ***Hatt*** (ca 45 cm). The perceived advantages and disadvantages of using different sizes of seedling are summarised in Table 5.5.

The advantages of small sized seedlings were recognised by all farmers but there were regional differences in perceived major advantages and disadvantages. Damage by livestock was not identified as a disadvantage in the Hilly region. Similarly, suppression by weeds was not mentioned as a disadvantage of small sized seedling by the farmers of the Dry region. All the first four advantages of medium sized seedlings were recognised by farmers in every region. More resistance to drought was recognised as an advantage only in the Dry region but tolerance of inundation was recognised by all farmers in the Deltaic and the Plain regions. The cost of medium sized seedlings was reported as a disadvantage by all farmers of the Dry region and 60 % of the marginal farmers of the Plain region. The uncertainty of availability medium-sized seedlings was a disadvantage recognised by all farmers. Use of large sized seedlings was restricted to the Dry region and these only for *Mangifera indica* (Plate 5.3). The associated advantages and disadvantages were recognised by all the farmers of this region.

5.1.5 Spacing followed at the time of planting in homegardens

No farmer reported maintaining any set spacing at the time of planting but in the first few years of homegarden establishment, attempts are made to maintain wide gaps between the plants. However, to meet the needs arising in the course of time, farmers introduced plants into gaps between existing plants and spacing became closer and more irregular.

Plate 5.3: Newly planted large sized seedlings of *Mangifera indica* in the Dry region

Table 5.5: Advantages and disadvantages of different sized seedlings

Seedling Size	Advantages	Disadvantages
Small (<45 cm)	• Easily available • Cheap	• Higher mortality rate • More susceptible to damage by livestock • Growth slow • More damage during transplant • Suppressed by weeds
Medium (68 - 90 cm)	• Mortality rate low • Less susceptible to damage by livestock • Fast subsequent growth • Easy to handle • More hardy to drought or flood water logging • Less chances to supress by weeds	• Costly • Not readily available
Large (> 90 cm)	• Protection cost minimal • Early fruiting	• Higher mortality rate • More susceptible to be wind thrown • Less resistant to drought condition

5.1.6 Cultural operations practised in the homegardens

Weeding, lopping, pruning, thinning and pollarding were cultural operations practised by farmers from all regions. Weeding was done at two scales. Minor weeding operations include removal at any time of weeds noticed on and around the access road was usually performed by the farmers themselves. The major weeding operation includes weeding of a part or all the homegardens and was performed on regular or irregular basis either by the farmers themselves or with the help of hired labour. In the Deltaic, Hilly and the Plain regions, all farmers practised a major weeding operation once or twice a year (Fig. 5.3). Increasing intensity of weeding was noted with increasing homegarden size in these regions. The farmers of the Dry region practise both regular and irregular weedings. There was also a common pattern of irregular weeding practised by marginal and small farmers in this region. Farmers who practise weeding twice a year perform the operation before and after the monsoon season. Farmers who practise the operation once a year usually do it during or after the monsoon period.

Farmers of the Dry region lop the leaves of *Artocarpus heterophyllus* for fodder during the dry season. Farmers from all the regions reported to perform pruning operation both regularly and irregularly either by themselves or with the help of hired labours (Fig. 5.4). Regular pruning was once a year, irregular pruning was every two to three years when homegardens were thought to have become untidy as a result of overgrowth. Normally both juvenile and old branches of food and fruit producing species are pruned after fruit production. In the case of timber species, the lower branches are always pruned during the dry season. In the Deltaic region, it was observed that the larger farmers practised more regular pruning while the reverse was the case for irregular pruning. Most (80%) farmers in the Dry region and all farmers in the Hilly region practised irregular pruning. In the Plain region all the farmers practised regular pruning.

No regular thinning schedule was practised by farmers. Instead farmers reported irregular thinning, performed once every five to ten years either by themselves or with the help of hired labour. In every region, pollarding was restricted to *Ziziphus jujuba*.

Reasons given by the farmers for practising different cultural operations

The only reason reported for practising weeding was removal of unwanted seedlings to reduce competition for nutrients. The weeds removed are used as mulch, soil cover or cattle feed and are sometimes allowed to rot in the homegarden or are used to make farmyard manure.

The only reason identified for lopping was collection of fodder. Five reasons were given by farmers for practising pruning operation and four were found common to all regions (Fig. 5.5). Most fruit producing trees were pruned to increase fruit production. Farmers pruned timber species to enhance stem quality and to increase volume production. Pruning of over storey species was to reduce shade on desired plants in lower strata. These three reasons were reported by the farmers of all the regions. In the Deltaic, Dry and the Plain regions, farmers also pruned to meet demand for fuelwood. The uses of pruned materials, in all regions, were as fuelwood, as fodder, supports for climbing vegetables and as building materials.

Thinning was done for three reasons, two common to every region (Fig. 5.6). Farmers of the Deltaic, Dry and Plain regions thinned their homegarden plants to meet demand for fuelwood and building materials. Farmers in the Hilly region removed diseased or unwanted plants through thinning to provide more room to the valuable species. Pollarding was to increase diseased free fruit production and to meet fuelwood demand.

Fig. 5.3: Weeding intensity practised by the farmers in the homegardens of Bangladesh by farm category

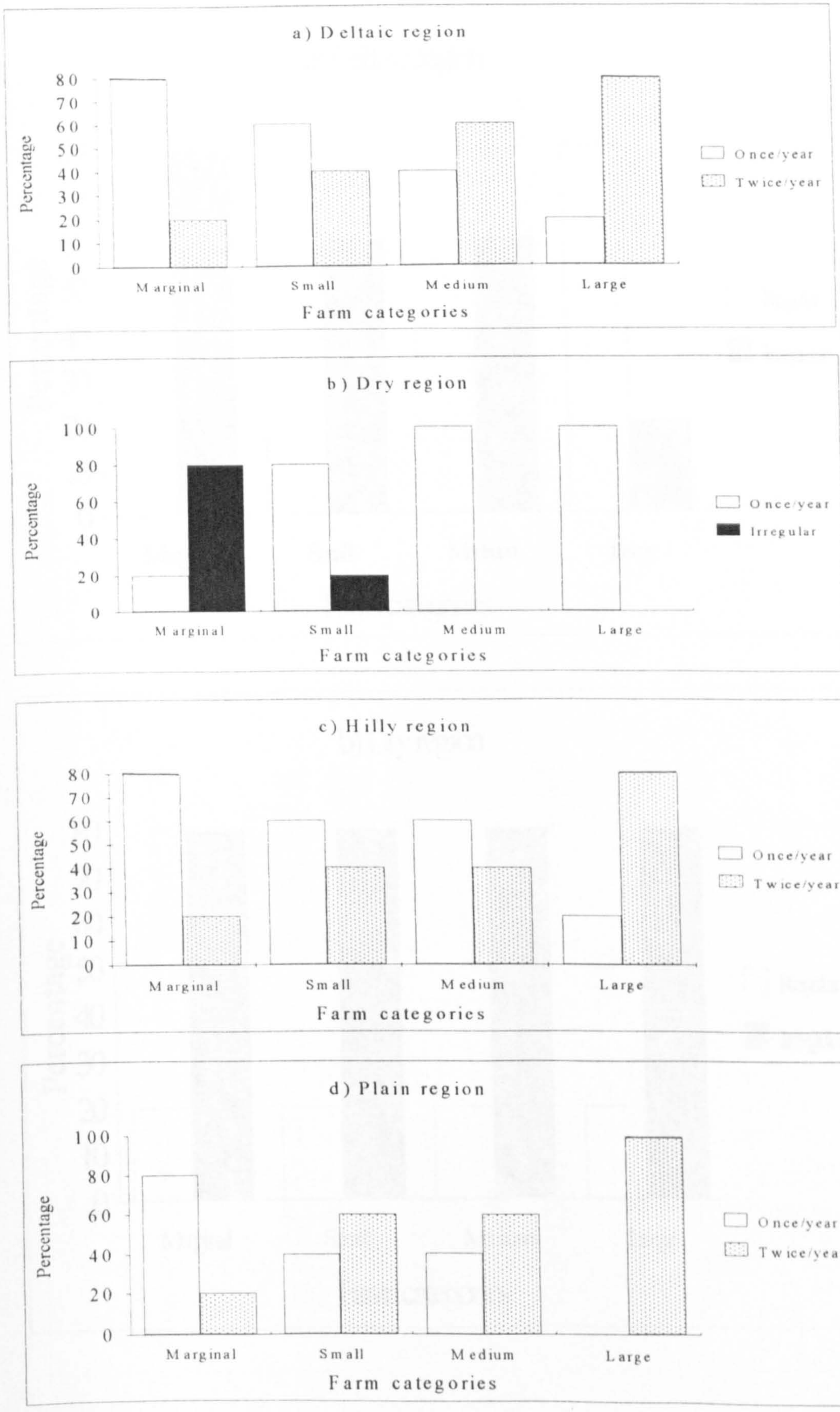
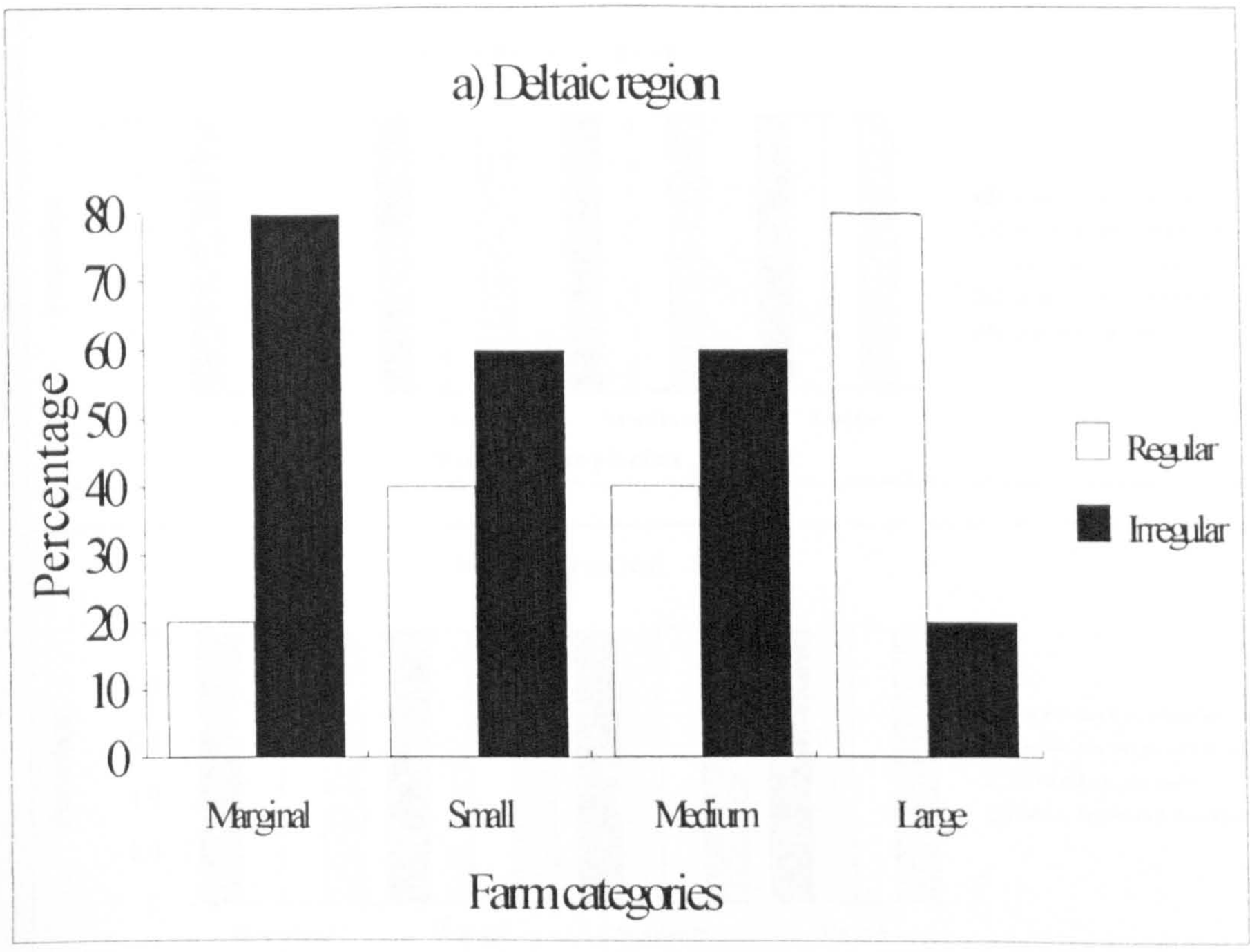


Fig. 5.4: Pruning operations practised by the farmers in the homegardens of Bangladesh by farm category



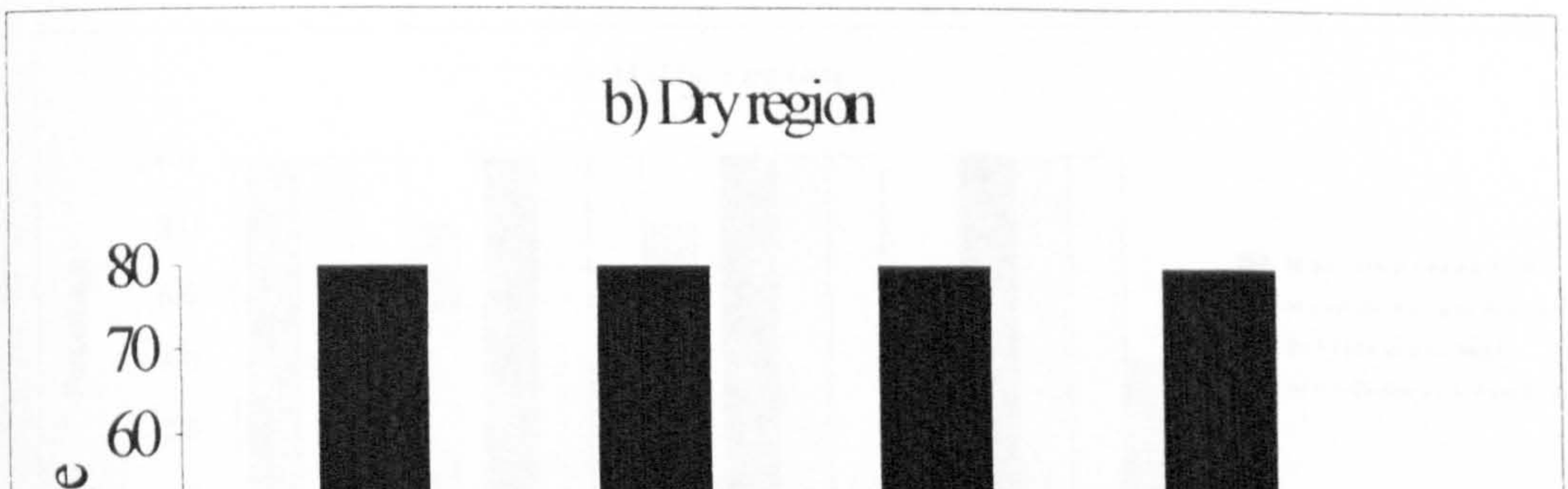


Fig. 5.5: Reasons attributed by the farmers for pruning in homegardens

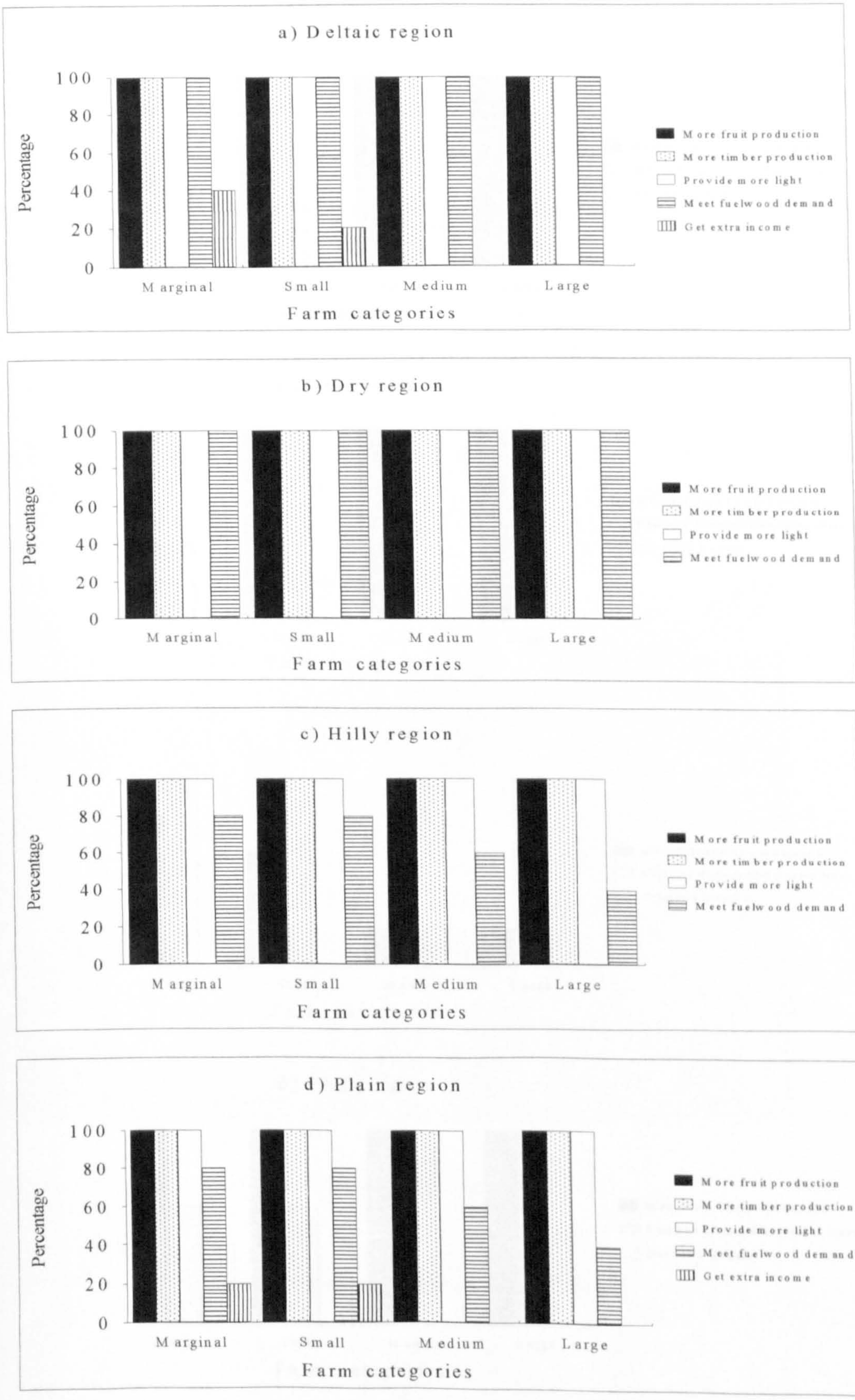
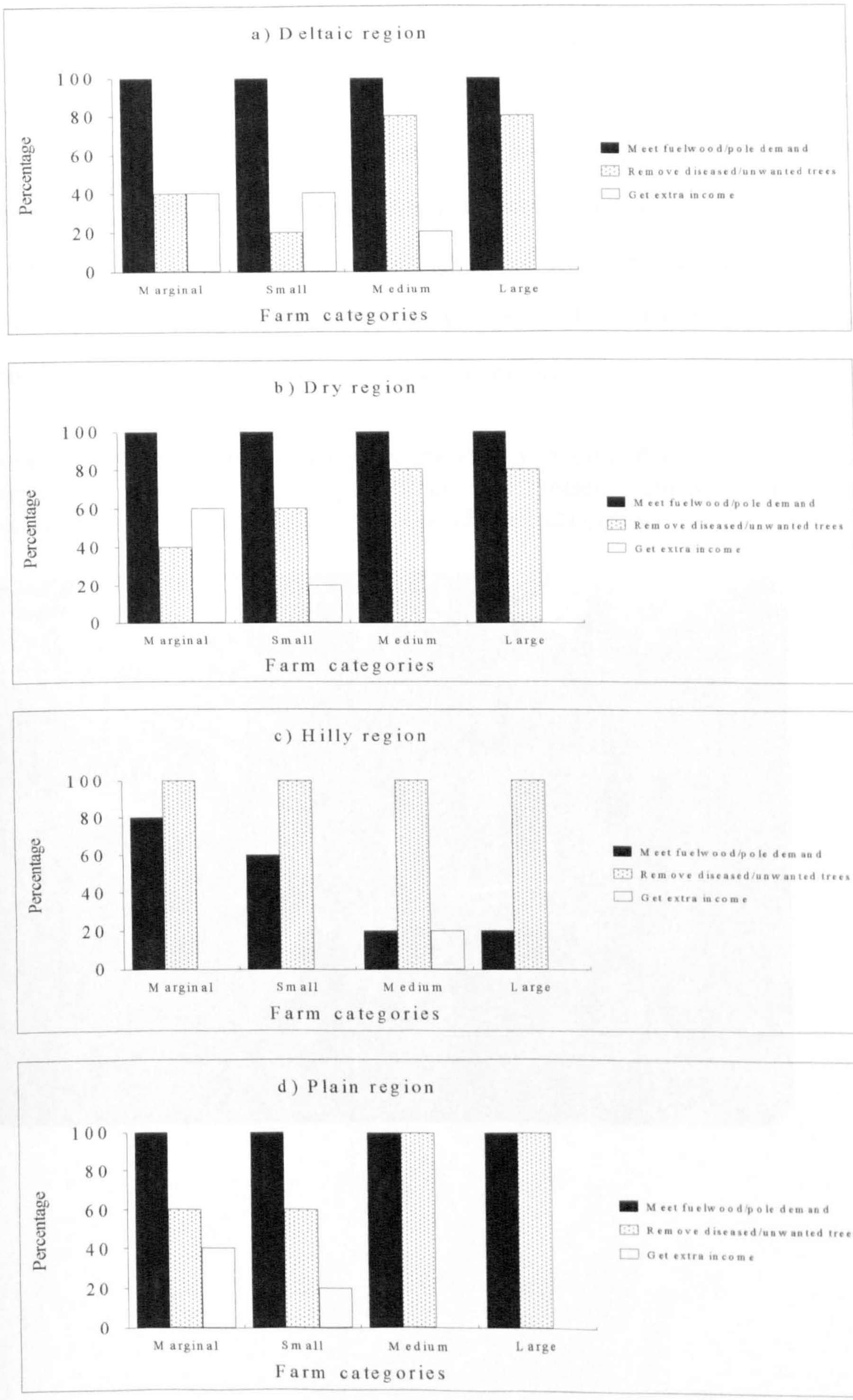


Fig. 5.6: Reasons attributed by the farmers for thinning in homegardens



5.1.7 Watering and Fertilising in homegardens

Any new plantings in the homegardens is during the monsoon, under rainfed conditions. Farmers maintain irregular watering schedules and in all regions watering is done only during the dry season. In the Dry region, marginal and small farmers irrigate the whole homegarden once while medium and large farmers irrigate twice or more depending on availability of irrigation water (Plate 5.4). In other regions watering was restricted to fruit trees and undertaken at a frequency (once in a week-month) depending on the time available.

Plate 5.4: Irrigation in the homegardens in Dry region. Branches of *Moringa oleifera* are seen on the left upper corner - the species is always planted in the corner of the homegarden due to its allelopathic effects (see section 5.2.3)

No chemical fertiliser was reported to be used by the farmers but organic fertiliser and salt was used by all farmers for *Cocos nucifera* - although only at the time of planting. Farmers reported that soil fertility in homegardens was maintained naturally with faeces of livestock that graze freely there (Plate 5.5), with kitchen waste, with leaf litter and with the mud of fish ponds.

Plate 5.5: Livestock - a natural source of manure in homegardens

5.2 Plant interactions

Interviews were conducted about five species most attractive to farmers (Table 5.6) in each region with the aim of gathering indigenous knowledge about pair wise negative and positive interactions between species. Species preference varied with region and with farm category within region. Interactions involving shade, water and nutrients, pests and diseases and soil were mentioned. In interview, farmers also mentioned species which were not preferred..

5.2.1 Sunlight/shade

Farmers identified desirable combinations of species on the basis of shade interactions and these were expressed in terms of relative heights, crown dimensions and light requirements.

Plant height categories

Farmers grouped their homegarden plants into four height categories (Table 5.7). Some of the species were restricted to only one of the four regions as indicated in the table. In categorising plants into different height classes, heights of the mature plants were considered. Farmers described strata in the traditional terms:

khub choto gasch (ground vegetation), not exceeding more than 2 ***hatts*** (ca 90 cm),

choto gasch (lower storey species) not exceeding more than 10 ***hatts*** (ca 4.5 m),

moiddham gasch (medium storey species) not exceeding more than 20 ***hatts*** (ca 9 m), and

boro gasch (upper storey species) exceeding more than 20 ***hatts*** (ca >9 m).

Every farmer was assigned at least two of the species tabulated to every stratum recognised.

Table 5.6: Percentage of positive responses given, by farm category and region in Bangladesh

Regions	Preferred species	Farm category			
		Marginal	Small	Medium	Large
Deltaic	*Areca catechu*	80	60	100	100
	Artocarpus heterophyllus	60	60	100	100
	Cocos nucifera	100	100	100	100
	Mangifera indica	60	80		
	Samanea saman	100	100	100	100
	Spondias pinnata	20			
	Swietenia macrophylla	80	100	100	100
Dry	*Artocarpus heterophyllus*	60	100	60	40
	Azadirachta indica	100	100	100	100
	Cocos nucifera	40	20	100	60
	Dalbergia sissoo	100	40	40	100
	Mangifera indica	100	100	100	100
	Melia azedarach	100	100	60	60
	Swietenia macrophylla		40	40	40
Hilly	*Areca catechu*	100	100	100	100
	Artocarpus heterophyllus	40	100	100	100
	Carica papaya	60	40	100	100
	Cocos nucifera	100	100	100	100
	Mangifera indica	100	100	100	100
	Psidium guajava	100	60		
Plain	*Albizia* spp.	100	100	100	100
	Areca catechu		40	100	100
	Artocarpus heterophyllus	100	100	40	100
	Cocos nucifera	100	60	60	
	Mangifera indica	100	100	60	60
	Samanea saman			40	100
	Swietenia macrophylla	100	100	100	40

Table 5.7: Plant height categories perceived by farmers for traditional homegardens in Bangladesh

Storey occupied	Plant species
Ground	*Ananus sativus* *Curcuma longa* *Glycine max* (Deltaic region) *Zingiber officinale* (Deltaic region)
Lower	*Carica papaya* *Citrus limon* (Deltaic, Hilly & Plain regions) *Erythrina variegata* *Moringa oleifera* (Dry region) *Musa* spp. *Psidium guajava*
Medium	*Areca catechu* *Artocarpus heterophyllus* *Azadirachta indica* (Dry region) *Dalbergia sissoo* (Dry region) *Mangifera indica* *Melia azedarach* (Dry region) *Spondias pinnata* *Swietenia macrophylla* *Ziziphus jujuba*
Upper	*Albizia* spp. *Bambusa* spp. *Borassus flabellifer* (Deltaic, Dry & Plain regions) *Cocos nucifera* *Samanea saman*

Plant crown dimensions and foliage categories

Farmers recognised four crown size categories: large, medium, small and very small (Table 5.8). The species within the medium crown size category were further grouped according to foliage density (thick, moderate or thin) depending on regions. Traditional terms used by farmers to recognise crown dimensions were:

boro chura (large crown) measuring > 20 ***hatts*** (ca >9 m),

moiddham chura (medium crown) measuring about >10 - 20 ***hatts*** (ca >4.5 - 9 m),

choto chura (small crown) measuring about 5-10 ***hatts*** (ca 2.25 m - 4.5 m),

khub choto chura (very small crown) measuring about 1-2 ***hatts*** (ca 45 cm - 90 cm) from one end to the other end,

The traditional terms and farmers' definition used to categorise plants on the basis of foliage characteristics were:

patla pata (thin foliage) through which sunlight can easily pass to the under storey,

kom ghono pata (moderate foliage) through which sunlight can pass to the under storey but at least half of it is trapped in the upper storey,

beshi ghono pata (thick foliage) through which sunlight does not pass to the under storey.

Farmers in the Deltaic, Hilly and Plain regions divided medium crowned trees into foliage categories of thick and moderate. The category of thin foliage was an additional division made only by the farmers in the Dry region. Every farmer assigned at least one of the species tabulated to every category recognised.

Plant categories on the basis of sunlight requirements

On the basis of sunlight requirement, farmers recognised four classes: strong light demander, medium light demander, moderate light demander and shade lover (Table 5.9). Traditional terms used by farmers to recognise plants of different light intensity requirements were:

sayar gasch (shade loving plants, which grow well in shade),

motamote alor gasch (moderate light demanding plants, which grow well under the partial shade of plants with moderate foliage),

moiddham alor gasch (medium light demanding plants, which grow well under the partial shade of plants with thin foliage), and

beshi alor gasch (strong light demanding plants, which require complete sunlight).

Every farmer assigned at least one of the species tabulated to every category recognised.

Table 5.8: Plant crown categories perceived by farmers for traditional homegardens in Bangladesh

Crown dimension	Plant species
Large crown with thick foliage	*Samanea saman* *Albizia* spp.
Medium crown with thick foliage	*Artocarpus heterophyllus* *Mangifera indica* *Spondias pinnata* *Swietenia macrophylla*
Medium crown with moderate foliage	*Azadirachta indica* (Dry region) *Borassus flabellifer* (Deltaic, Dry & Plain regions) *Cocos nucifera* *Dalbergia sissoo* (Dry region) *Erythrina variegata* *Melia azedarach* (Dry region) *Psidium guajava* *Ziziphus jujuba*
Medium crown with thin foliage	*Moringa oleifera* (Dry region)
Small crown	*Areca catechu* *Bambusa* spp. *Carica papaya* *Citrus limon* (Deltaic, Hilly & Plain regions) *Musa* spp.
Very small crown	*Ananus sativus* *Curcuma longa* *Glycine max* (Deltaic region) *Zingiber officinale* (Deltaic region)

Table 5.9: Plant categories on the basis of sunlight requirements as perceived by farmers for traditional homegardens in Bangladesh

Light intensity required	Plant species
Strong light demander	*Albizia* spp. *Artocarpus heterophyllus* *Bambusa* spp. *Borassus flabellifer* (Deltaic, Dry & Plain regions) *Cocos nucifera* *Mangifera indica* *Samanea saman*
Medium light demander	*Areca catechu* *Azadirachta indica* (Dry region) *Dalbergia sissoo* (Dry region) *Melia azedarach* (Dry region) *Spondias pinnata* *Swietenia macrophylla* *Ziziphus jujuba*
Moderate light demander	*Carica papaya* *Erythrina variegata* *Musa* spp. *Moringa oleifera* (Dry region) *Psidium guajava*
Shade lover	*Ananus sativus* *Citrus limon* (Deltaic, Hilly & Plain regions) *Curcuma longa* *Glycine max* (Deltaic region) *Zingiber officinale* (Deltaic region)

All the upper storey species are strong light demanders, medium storey species are mostly medium light demanders, lower storey species are mostly moderate light demanders and species in the ground vegetation shade lovers (Table 5.10). Farmers have considerable knowledge about sunlight requirements of each important species in the homegardens and they manage the vertical structure by keeping these requirements in mind.

Table 5.10: Summary table indicating storey occupied, crown dimensions and light requirements of species as perceived by farmers from traditional homegardens in Bangladesh

Storey occupied	Crown dimension and foliage characteristics	Light requirements	Species
Upper	Large & thick	Strong	*Albizia spp.* *Samanea saman*
	Medium & moderate	Strong	*Cocos nucifera* *Borassus flabellifer*
	Small	Strong	*Bambusa spp.*
Medium	Medium & thick	Strong	*Artocarpus heterophyllus* *Mangifera indica*
		Medium	*Spondias pinnata* *Swietenia macrophylla*
	Medium & moderate	Medium	*Azadirachta indica* *Dalbergia sissoo* *Melia azedarach* *Ziziphus jujuba*
	Small	Medium	*Areca catechu*
Lower	Medium & moderate	Moderate	*Erythrina variegata*
			Psidium guajava
	Medium & thin		*Moringa oleifera*
	Small		*Carica papaya* *Musa spp.*
		Shade	*Citrus limon*
Ground	Very small crown	Shade	*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*

Optimum species combinations

Optimum species combinations are those where under storey species receive adequate sunlight transmitted through the canopy of the over storey species. Optimum species combinations (Table 5.11) are thus likely to be affected by the foliage characteristics of the species.

Table 5.11: Optimum combinations of species

Upper storey	Medium storey	Lower storey	Ground storey
Albizia spp. *Samanea saman*			*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*
Cocos nucifera *Borassus flabellifer*		*Carica papaya* *Erythrina variegata* *Musa* spp. *Moringa oleifera* *Psidium guajava*	*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*
Bambusa spp.	*Areca catechu* *Azadirachta indica* *Dalbergia sissoo* *Melia azedarach* *Ziziphus jujuba*	*Carica papaya* *Erythrina variegata* *Musa* spp. *Moringa oleifera* *Psidium guajava*	*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*
Upper storey species very sparsely distributed	*Artocarpus heterophyllus* *Mangifera indica*		*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*
	Spondias pinnata *Swietenia macrophylla*		*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*
	Areca catechu *Azadirachta indica* *Dalbergia sissoo* *Melia azedarach* *Ziziphus jujuba*	*Carica papaya* *Erythrina variegata* *Musa* spp. *Moringa oleifera* *Psidium guajava*	*Ananus sativus* *Curcuma longa* *Glycine max* *Zingiber officinale*

Of these possible combinations, farmers mentioned only a few which have positive interactions regarding shade. *Erythrina variegata* is used in the Deltaic region as a shade tree. Farmers plant seeds and seedlings of *Areca catechu* under its shade. During the first five years after planting, branches of *Erythrina* are moderately pruned to provide moderate to medium sunlight to *Areca catechu* and the trees are finally removed after six to eight years when *Areca catechu* starts fruiting. . Branches of *Erythrina* are used as live fence and fuelwood. Leaves are used as fodder.

In the Dry region, *Curcuma longa* is planted under the shade of *Musa* spp. Shade cast by the broad leaves of *Musa* spp. protects *Curcuma longa* from intense heat during summer.

In the Hilly region, two to four vegetative propagules of *Anamus sativus* are planted around a seedling of *Areca catechu* at the time of planting mainly for protection (Plate 5.6). Farmers reported that only *Anamus sativus* grew well under the partial or complete shade of *Areca catechu*. These two species are commercially the most important in the homegardens of this region.

Plate 5.6: *Anamus sativus* under the shade of *Areca catechu* - a common combination in the homegardens of Hilly region

In the Plain region, *Anamus sativus* are planted under the shade of *Artocarpus heterophyllus* (Plate 5.7), the main commercial fruit and timber species of this region. Besides providing fruits, *Anamus sativus* acts as a live fence, keeping away goats that would damage the *Artocarpus* bark by peeling, and sometimes also damage the fruits. The thorny leaves of *Anamus sativus* also act as a barrier against the theft of fruits of *Artocarpus heterophyllus*.

Plate 5.7: *Anamus sativus* under the shade of *Artocarpus heterophyllus* - a common combination in the homegardens of Plain region

All farmers recognise that trees with medium to large laterally spreading crowns and thick foliage are more detrimental to the growth of the under storey species than trees with moderate crowns with moderately thick foliage. Shade reduces fruit production and, in case of timber species, volume production. Tree species specially mentioned in this connection include *Albizia* spp., *Mangifera indica*, *Samanea saman*, *Spondias pinnata* and *Swietenia macrophylla*.

5.2.2 Water and nutrients

Farmers reported that perceived optimum combinations of plants with respect to interactions affecting water and nutrient requirements often were based on the root penetration of the species. Two categories of root penetration were recognised by them:

ogovir shikor (shallow rooted) that penetrate up to depths as greater as three ***Hatts*** (ca 1.35 m) under ground, and

govir shikor (deep rooted) that penetrate deeper.

Shallow rooted species mentioned were *Ananus sativus, Carica papaya, Citrus limon, Curcuma longa, Glycine max, Moringa oliefera, Musa* spp. and *Zingiber officinale*. All other species listed in the table were regarded as deep rooted plants. *Albizia* spp., *Bambusa* spp., *Borassus flabellifer*, *Cocos nucifera* and *Samanea saman* are the species of high water and nutrient requirements mentioned by the farmers. Though all farmers are aware that shallow-rooted species combine well with deep-rooted species, in practice most deep-rooted species were found to grow with other deep-rooted species. Shortage of land was the explanation offered by them. However, on the basis of water and nutrient requirements, farmers were found to grow some of the important species in particular locations of the homegarden. For example, *Borassus flabellifer* is grown in pond banks (mostly banks on the south side of the pond) is a common practice in the Deltaic region for two reasons. *Borassus flabellifer* requires more water than other species - here it can take up sufficient water from the pond. The second reason is that fishes rest in the middle of the pond at mid day - and only the shade of *Borassus flabellifer*'s crown is cast over this part of the pond. Moreover, the sound of the wind in the crown of this species causes fish in the pond to run, which accelerates their growth. Similarly *Bambusa* spp. were grown almost exclusively at the western side of homegardens in every region, due to their high water

requirement. There is less incidence of sunlight and hence less evapo-transpiration at the west side of the homegarden. *Bambusa* spp. at the west side also protect the living quarters against tornadoes which mostly approach from this side.

5.2.3 Soil

Farmers base some combinations of plants on soil interactions - soil improvement properties (positive) and allelopathic effects (negative). Only a few species, all legumes (*Erythrina variegata, Albizia* spp., *Glycine max, Dalbergia sissoo*), were reported to increase soil fertility. *Albizia* spp. excepted, these legumes could be a good combination with any other species with medium crown and moderate foliage. Farmers in the Dry region attributed to *Moringa oleifera* excretion of toxic substances to the soil, making it unsuitable for the growth of associated species. This was why marginal and small farmers did not grow this species in their homegardens. Medium and large farmers of the Dry region plant this species only at the corners. They do this to protect the garden and living quarters from snakes. They believe that the roots of *Moringa* are so poisonous that snakes will not enter homegardens where it is planted.

5.2.4 Pests and diseases

Farmers in the Dry region mentioned incidence of insect attack in the fruits of *Musa* spp., *Carica papaya, Mangifera indica* and *Litchi chinensis*, all species commercially very important in this region. Farmers plant *Azadirachta indica* among these species to protect their fruits from insect attack and believe that leaves of the species are poisonous to insects.

5.3 Gender roles

Divisions of labour for household activities and labour requirements in homegarden management were assessed and related to gender roles through participatory calendars. Gender participation in decision making and access to resources was also assessed.

5.3.1 Division of labour

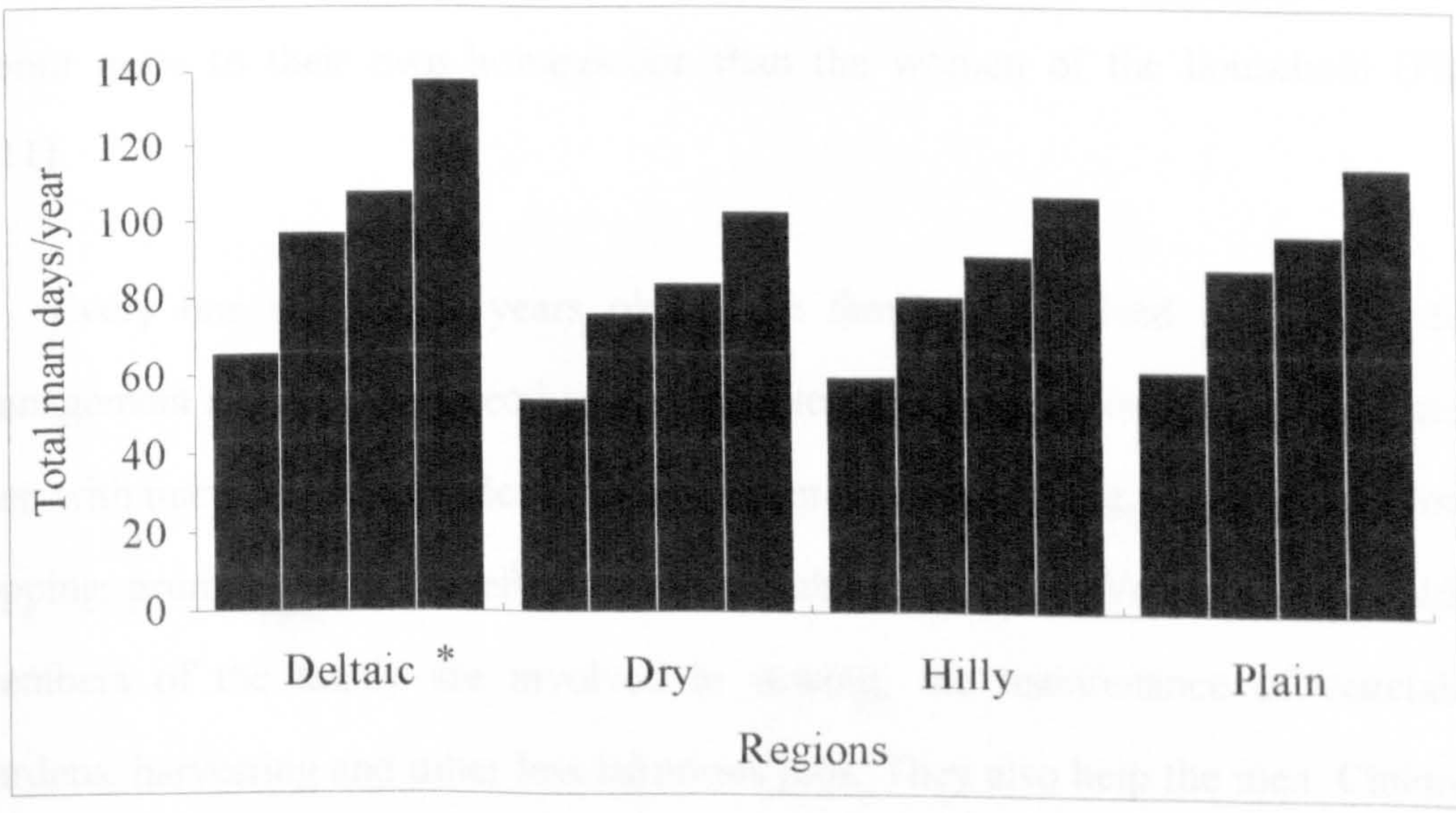
Traditionally there is a clear sharing of tasks among family members. Men are responsible for farm work and with a few exceptions they also manage the household budget. The responsibility of the women in the small, medium and large farm categories in all regions includes looking after the houses and children, tending poultry and cattle and maintaining homegardens. Women and children in the marginal farm category are also involved in collecting fuelwood and cowdung and working as labour in the homegardens of other farm categories. In the Dry region women of the marginal farm category also supply daily labour in the crop fields (Plate 5.8).

Plate 5.8: Women working in the crop field in Dry region

5.3.2 Labour requirements and gender concern in homegarden management

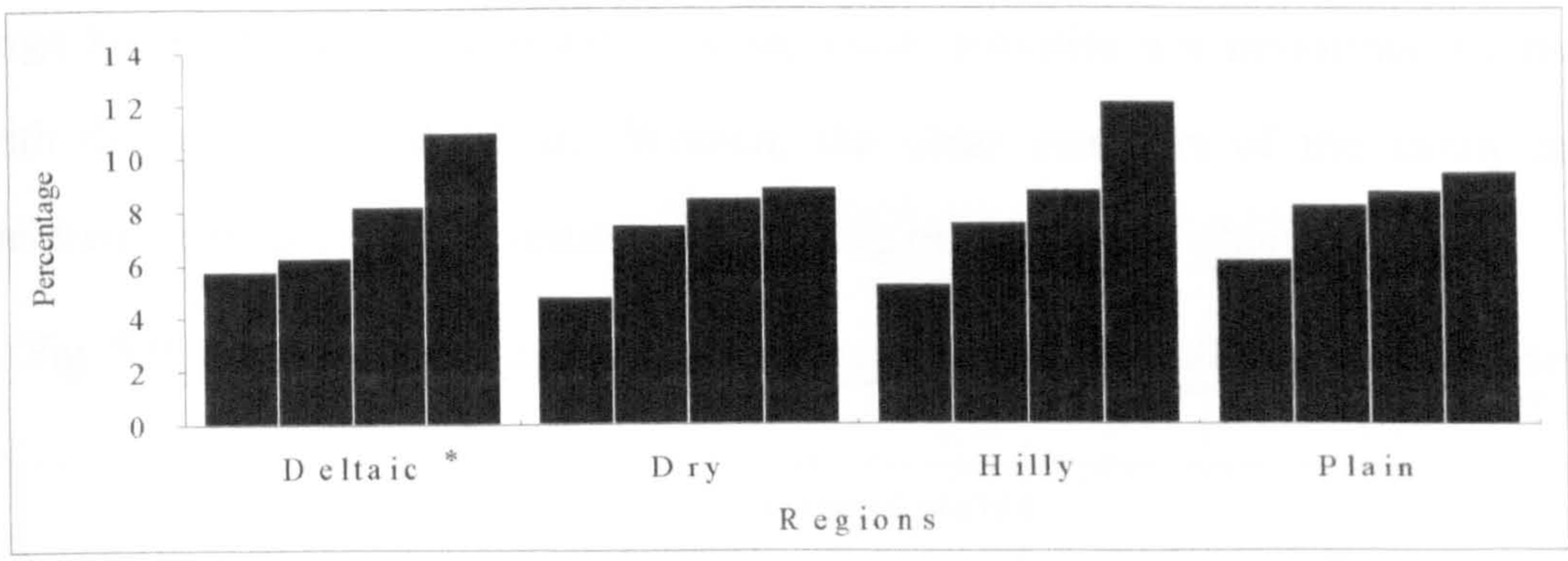
The management of traditional homegardens in the study areas in Bangladesh require less (only 30 - 40 %) labour input than agricultural production system. Various homegarden management activities are distributed equally throughout the year and labour requirements are also more or less equally distributed. The work force typically consists of men, women and children of different ages and they devote their labour on full and part time basis to various homegarden operations. For the purposes of comparison, the total labour force is expressed as total man days/year (one man day = 8 hours of work by an adult man/woman or 2.5 children below 15 years of age). In all regions, a common trend of utilising more labour is observed in the larger homegardens (Fig. 5.7). Farmers, however, spend only 4.8 - 12.2 % of their total labour in homegarden management (Fig. 5.8).

Fig. 5.7: Total labour required for the management of traditional homegardens in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

Fig. 5.8: Percentage of total labour devoted to homegarden management in Bangladesh



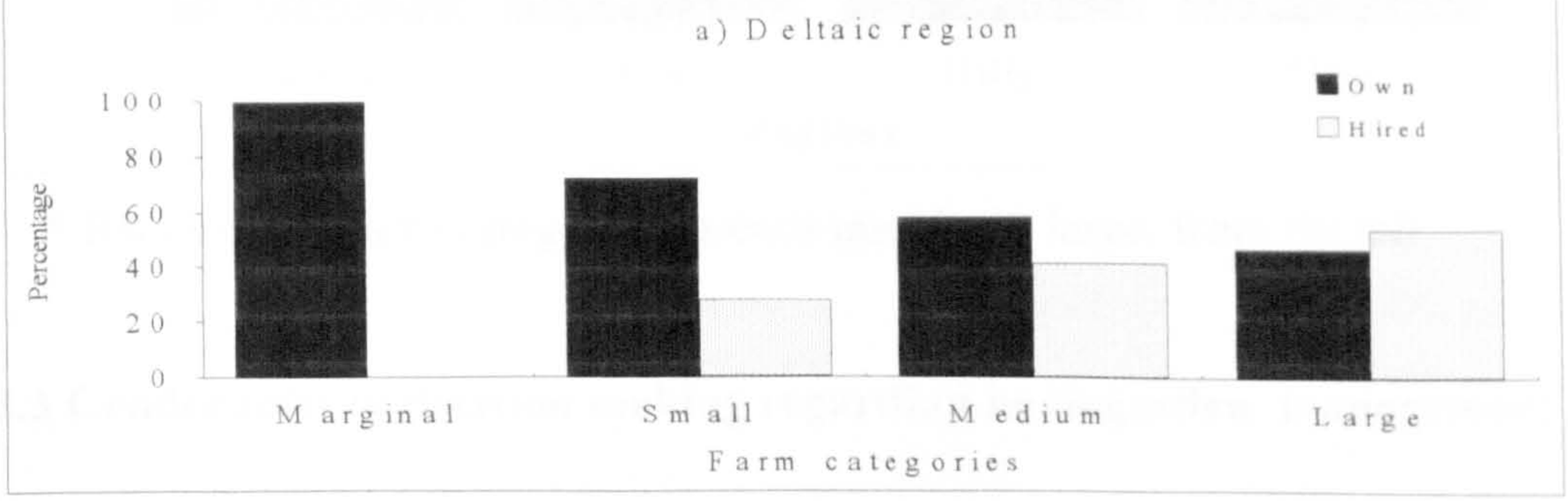
* Bars indicate farm category sequence marginal - large, from the left

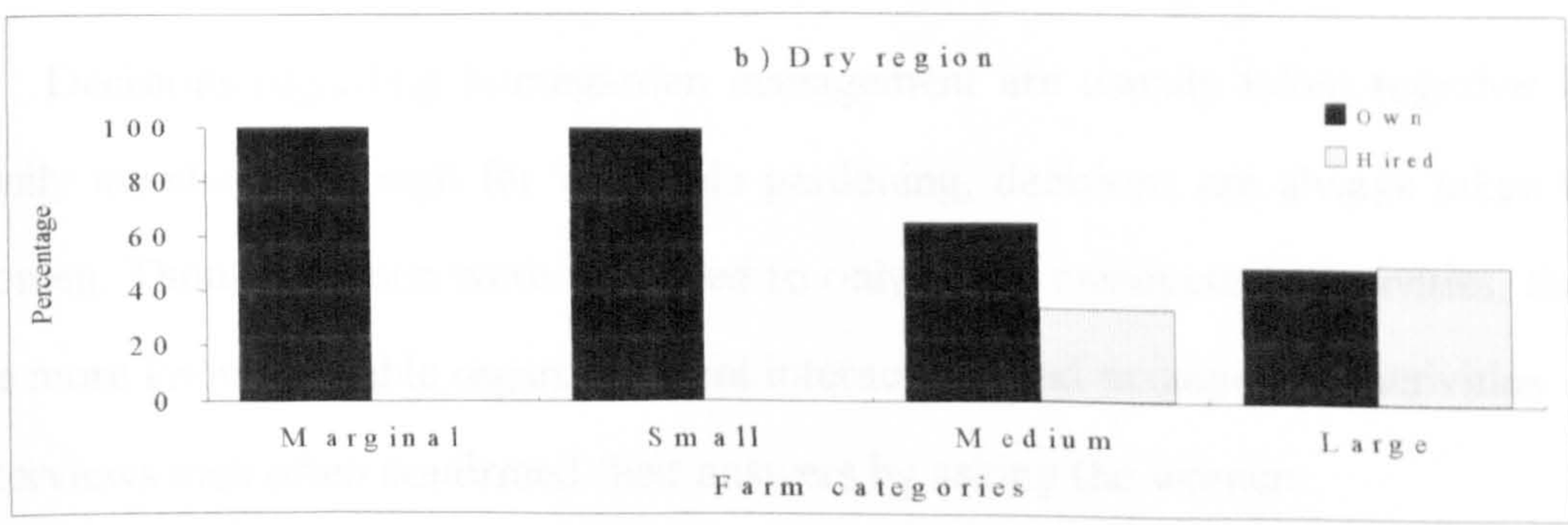
The marginal farm category of all regions and the small farm category of the Dry region are completely dependent on their own labour to manage their homegardens (Fig. 5.9). The remaining farm categories of all regions also depend on hired labour (up to as much as 57 % of the labour need) to manage their homegardens. In all regions a trend of increasing dependency on hired labour is observed in the larger farm categories. Farmers devote only 4 - 7.5 % of their active time to homegarden management (Fig. 5.10). Nevertheless, men contribute labour more to their own homegarden than the women of the household (Fig. 5.11).

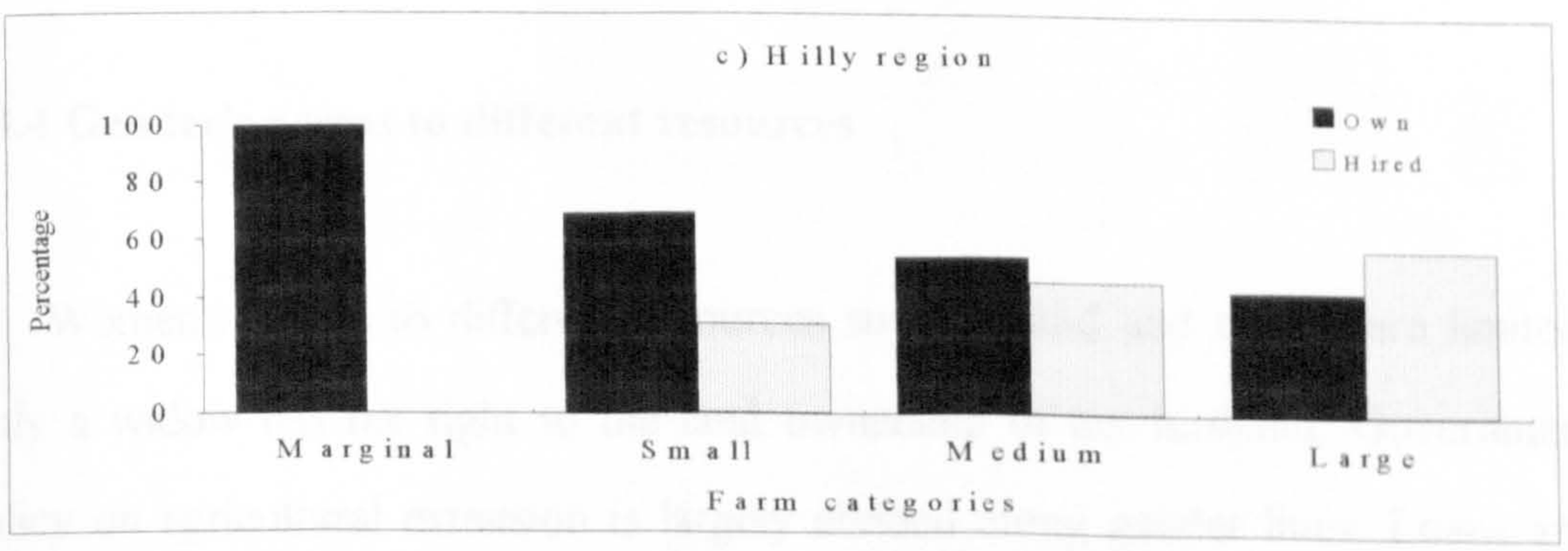
Every one over eight years old in the family is involved in homegarden management activities irrespective of farm categories and regions. In every region men with marginal homegarden are involved in clearing, hoeing, planting, weeding, lopping, pruning, thinning, selling and other laborious work. Women and the older members of the family are involved in sowing, the maintenance of vegetable gardens, harvesting and other less laborious jobs. They also help the men. Children are involved in watering and help other members of the family as required. In the small homegardens of every region most management is done by men; farmers in the Deltaic, Hilly and Plain regions also hire labour occasionally to help them. Women, the older members of the family and children are involved in sowing,

maintenance of vegetable gardens and harvesting of products. In the medium and large homegardens of all regions, management activities are performed by men with the help of hired labour. Women, the older members of the family and children are involved in harvesting and planting of ornamental plants.

Fig. 5.9: Sources of labour (%) for the management of traditional homegardens in Bangladesh







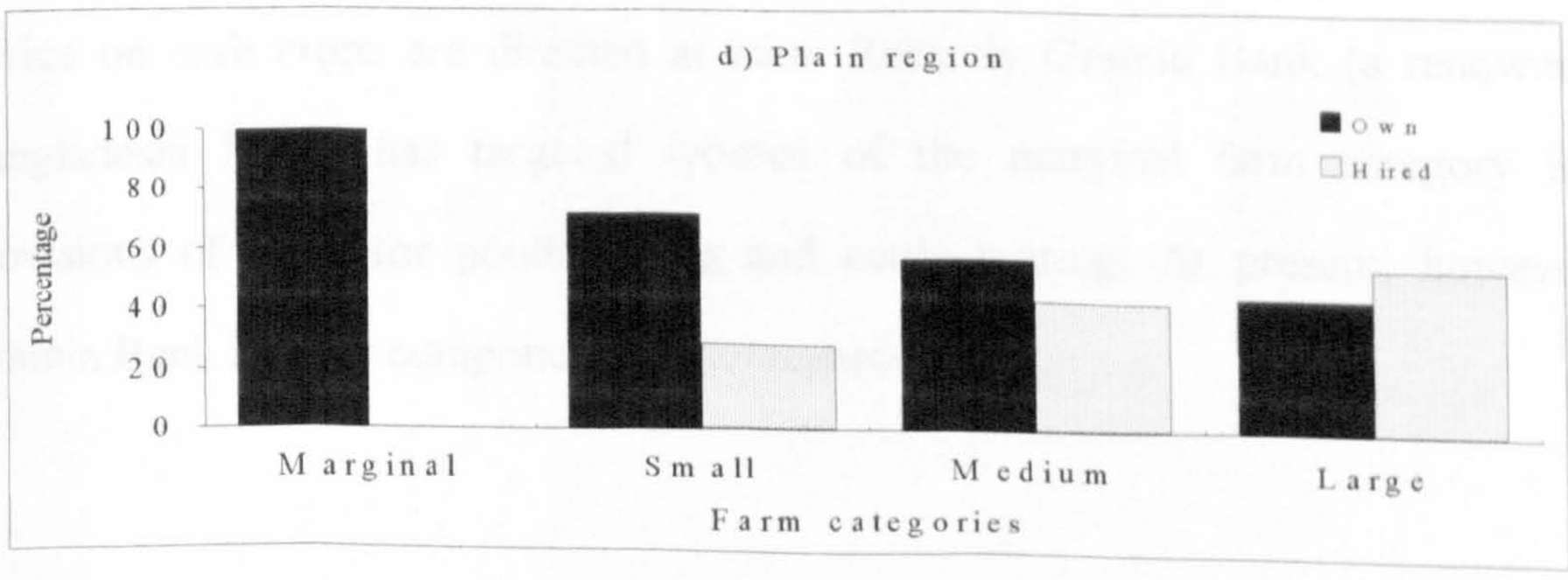
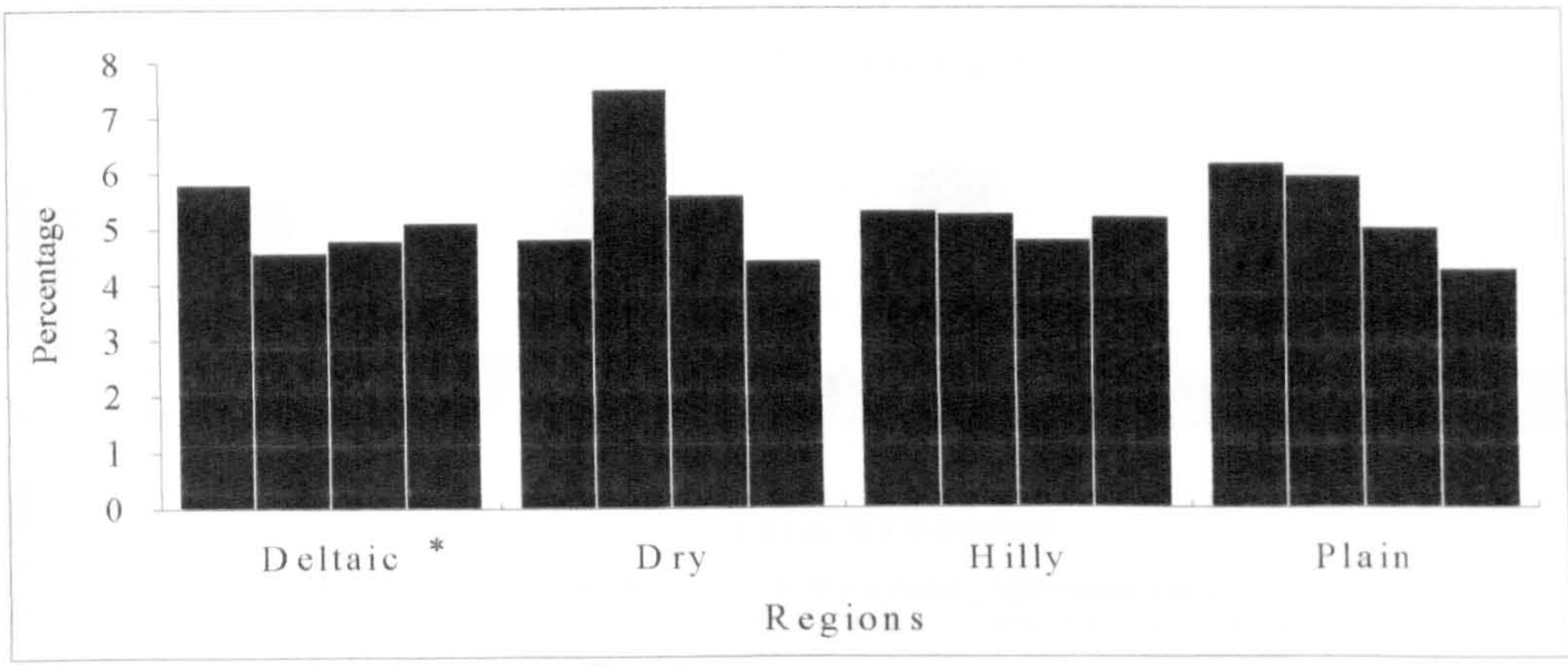


Fig. 5.10: Percentage of farmers' active time devoted to homegarden management in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

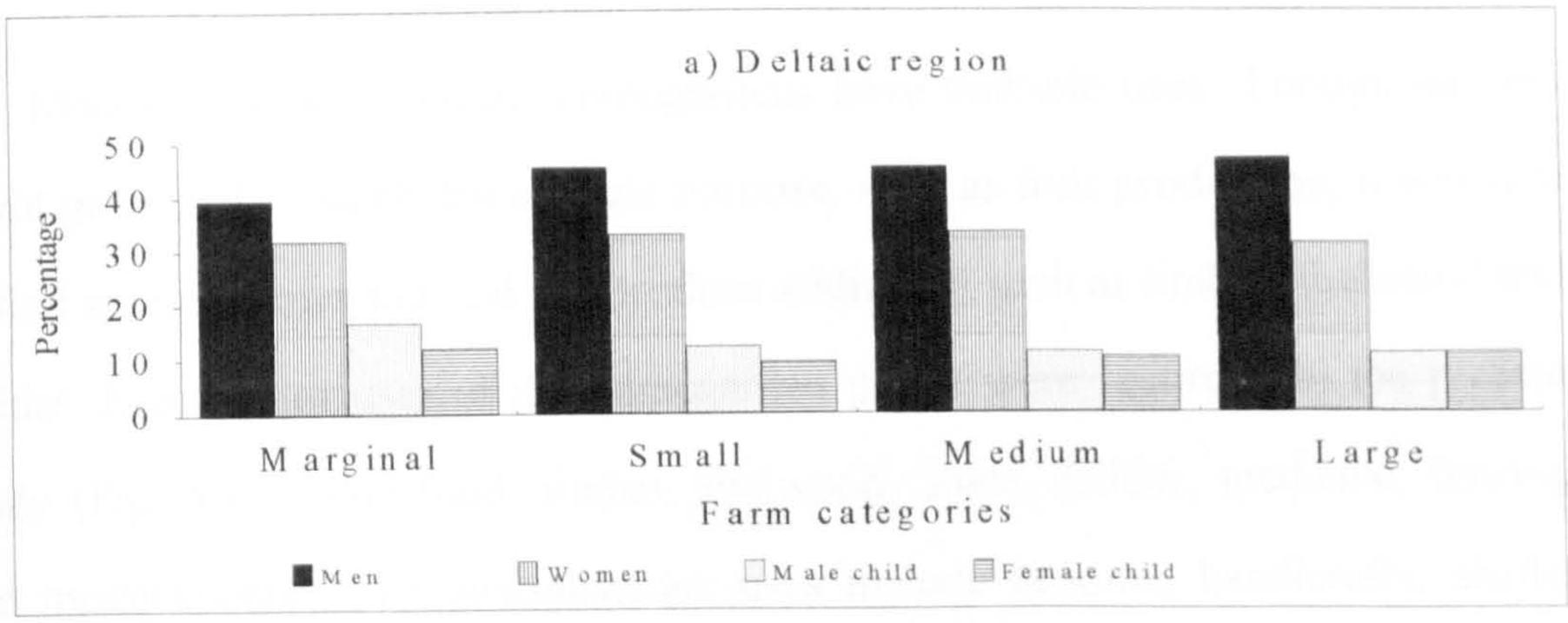
5.3.3 Gender roles in decision making regarding homegarden management

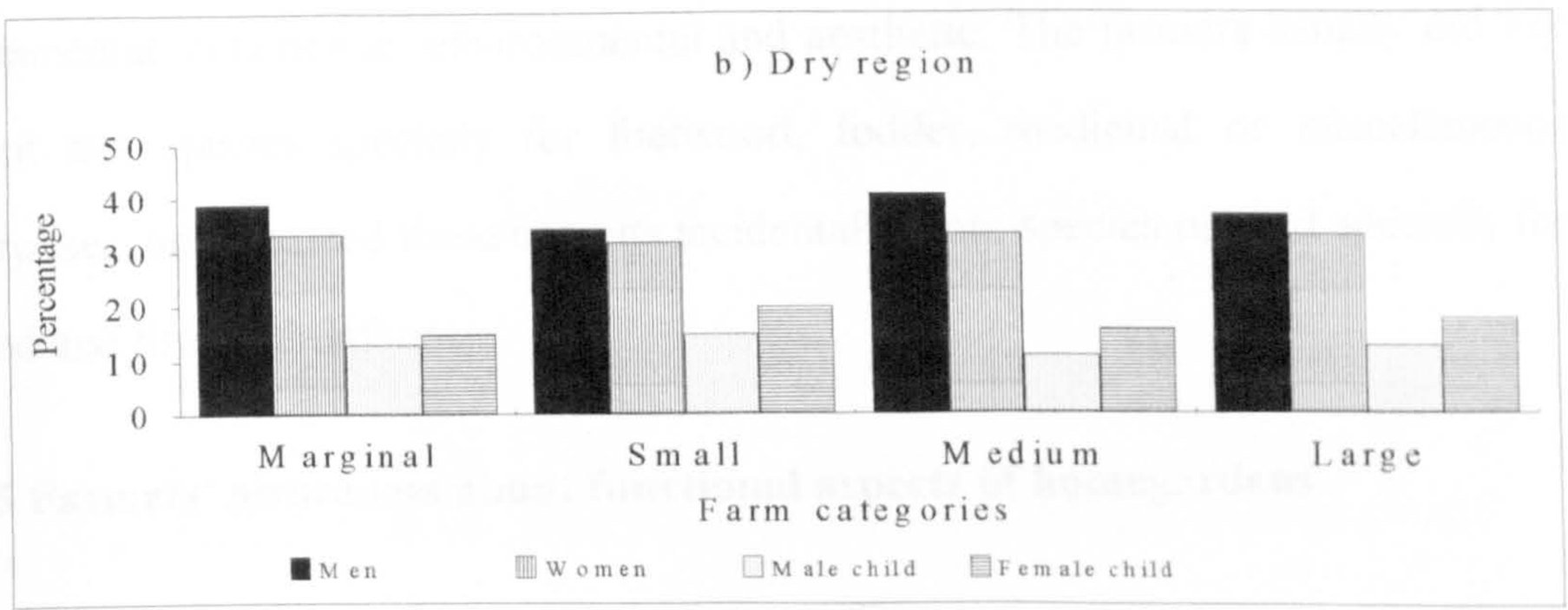
Decisions regarding homegarden management are usually taken together by family members although for vegetable gardening, decisions are always taken by women. Though women were restricted to only a few management activities, they are more knowledgeable regarding plant interactions and management activities. In interviews men often confirmed their answers by asking the women.

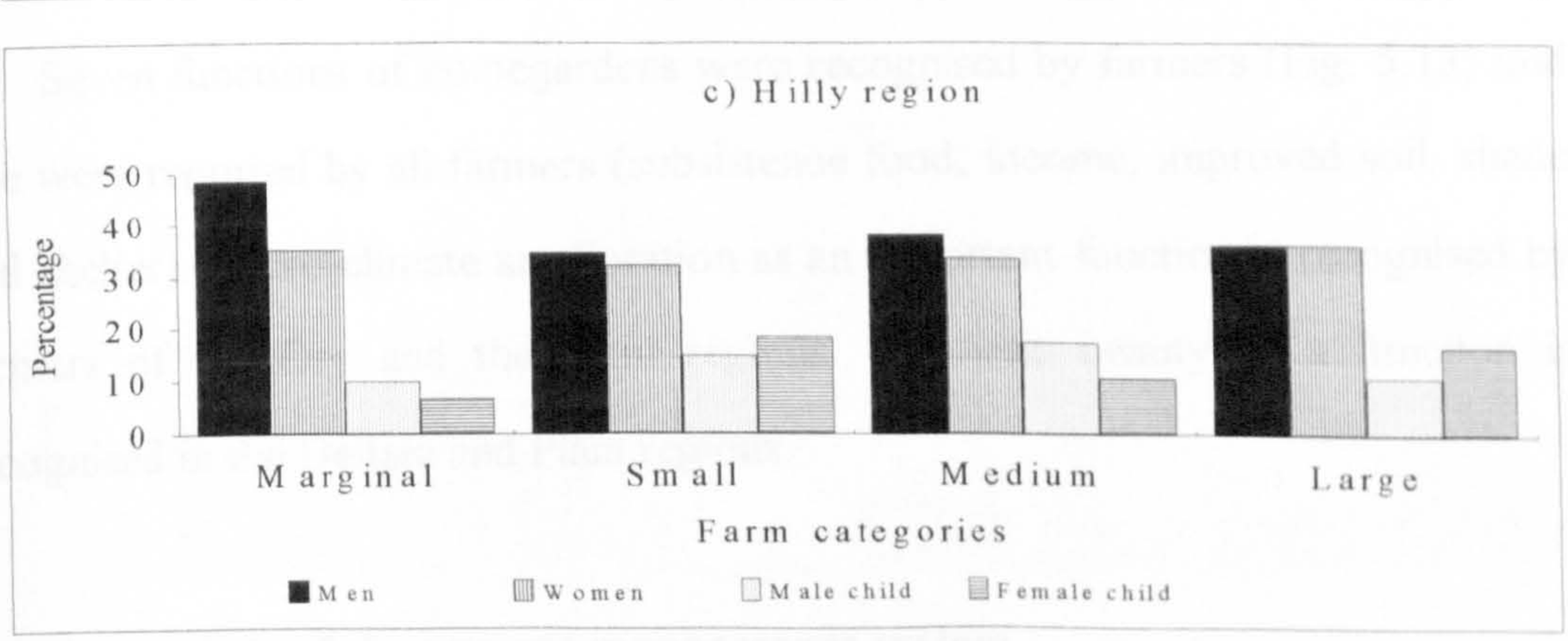
5.3.4 Gender's access to different resources

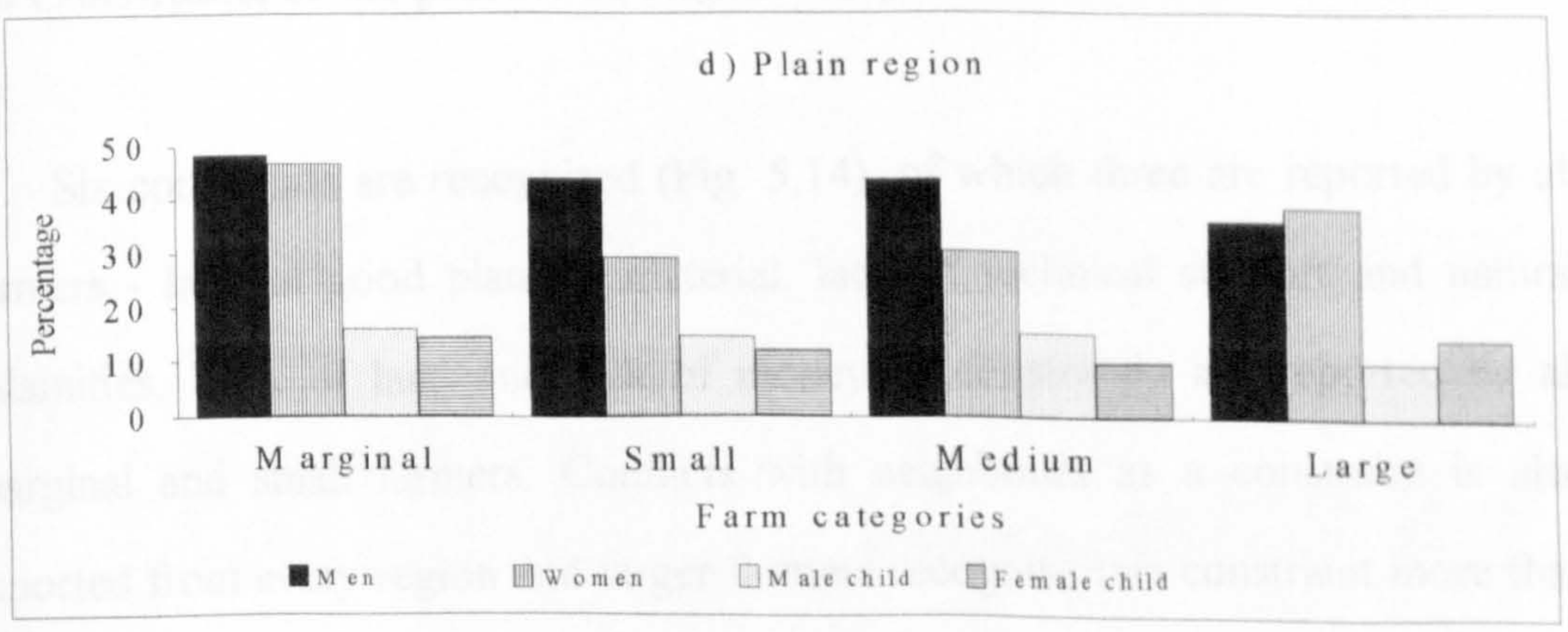
Women's access to different resources such as land and capital are limited. Only a widow has the right to the land ownership of her husband. Government policy on agricultural extension is largely divided along gender lines. Loans and advice on cash crops are directed at men. Recently Gramin Bank (a renowned Bangladeshi NGO) has targeted women of the marginal farm category for provisions of loans for poultry birds and cattle rearing. At present, however, Gramin Bank ignores components of homegardens.

Fig. 5.11: Percentage contribution of household labour, by gender to homegarden management in Bangladesh









5.4 Uses of the species

Most of plants grown in homegardens have multiple uses. Though farmers might grow a plant solely for a single purpose, such as fruit production, it was rare to find species grown that did not produce additional such as timber, fuelwood and fodder. Eight major uses of the homegarden plants were recorded in the present study (Fig. 5.12): fruit/food, timber, fuelwood, spice, fodder, medicine, fencing and miscellaneous. The miscellaneous uses include brooms, handicrafts, shade, ornamental, ceremonial, environmental and aesthetic. The farmers usually did not plant any species specially for fuelwood, fodder, medicinal or miscellaneous purposes, but obtained these benefits incidentally from species planted specially for food and fruit and timber.

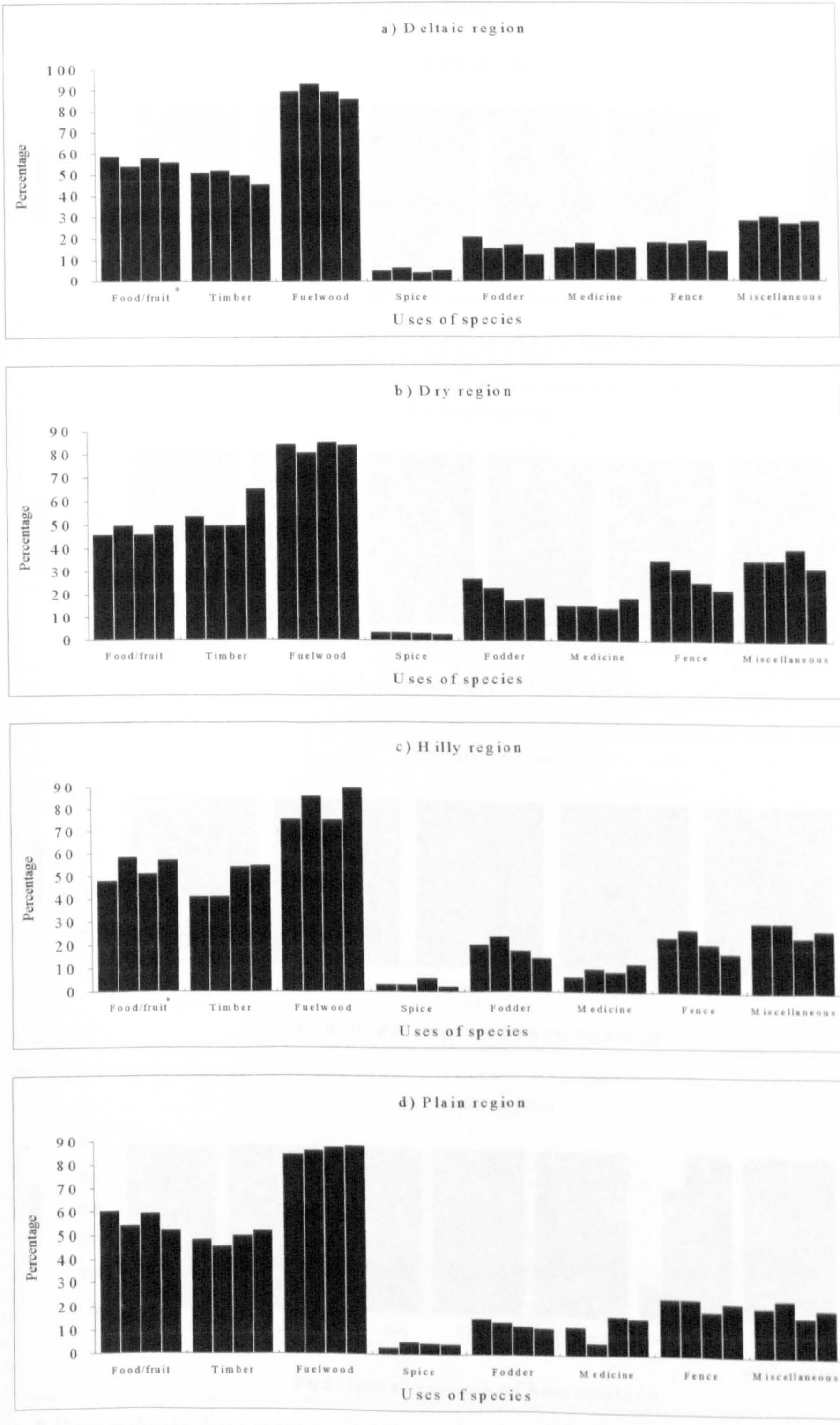
5.5 Farmers' awareness about functional aspects of homegardens

Seven functions of homegardens were recognised by farmers (Fig. 5.13) and five were reported by all farmers (subsistence food, income, improved soil, shade and shelter). Micro-climate amelioration as an important function is recognised by farmers of the Dry and the Plain regions. Aesthetic beauty as a function is recognised in the Deltaic and Plain regions.

5.6 Constraints of the present management system

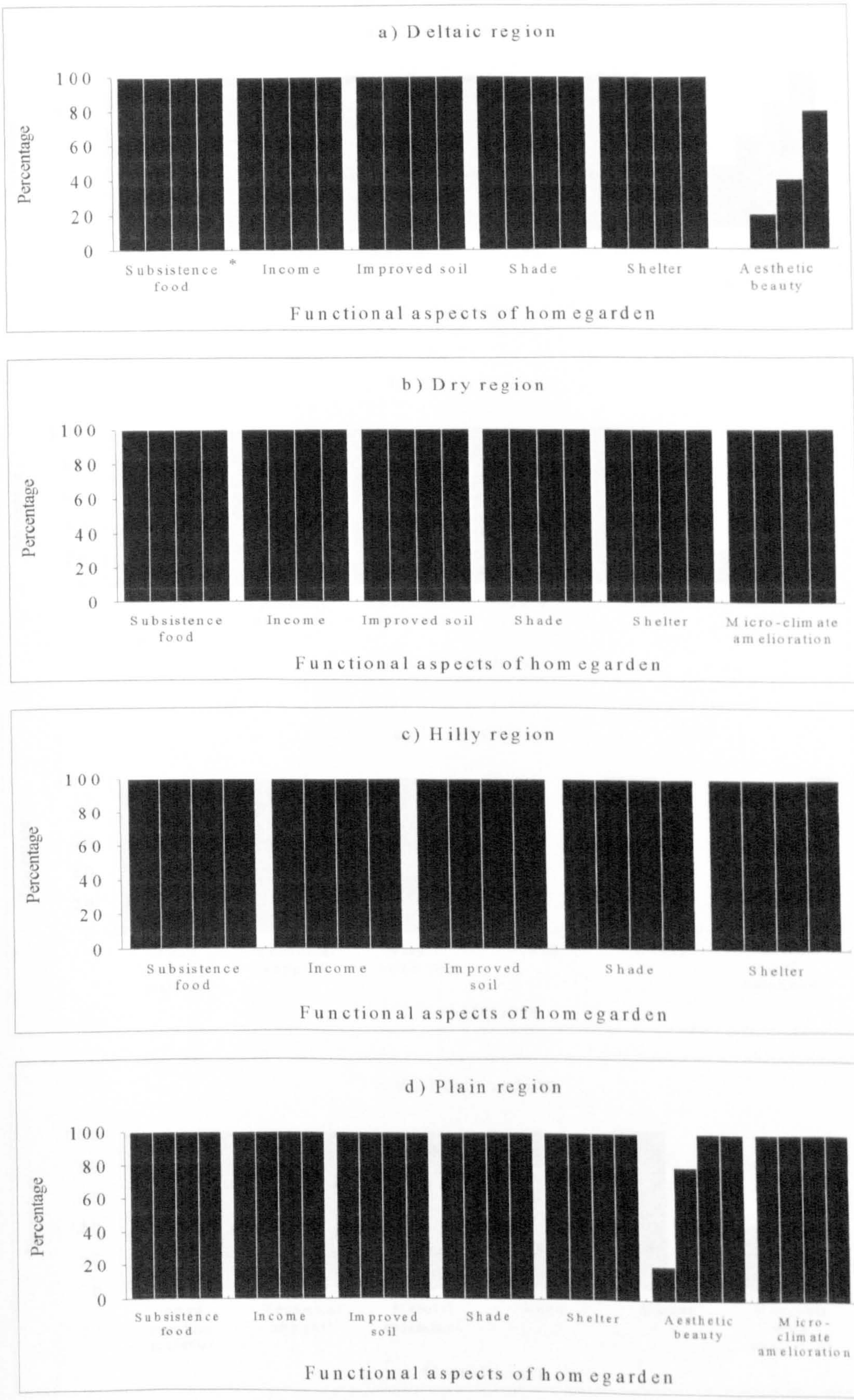
Six constraints are recognised (Fig. 5.14), of which three are reported by all farmers - lack of good planting material, lack of technical support and natural calamities. Lack of land and lack of money as constraints are reported by all marginal and small farmers. Conflicts with neighbours as a constraint is also reported from every region and larger farmers recognise this constraint more than the smaller one.

Fig. 5.12: Uses of species by region in traditional homegardens in Bangladesh



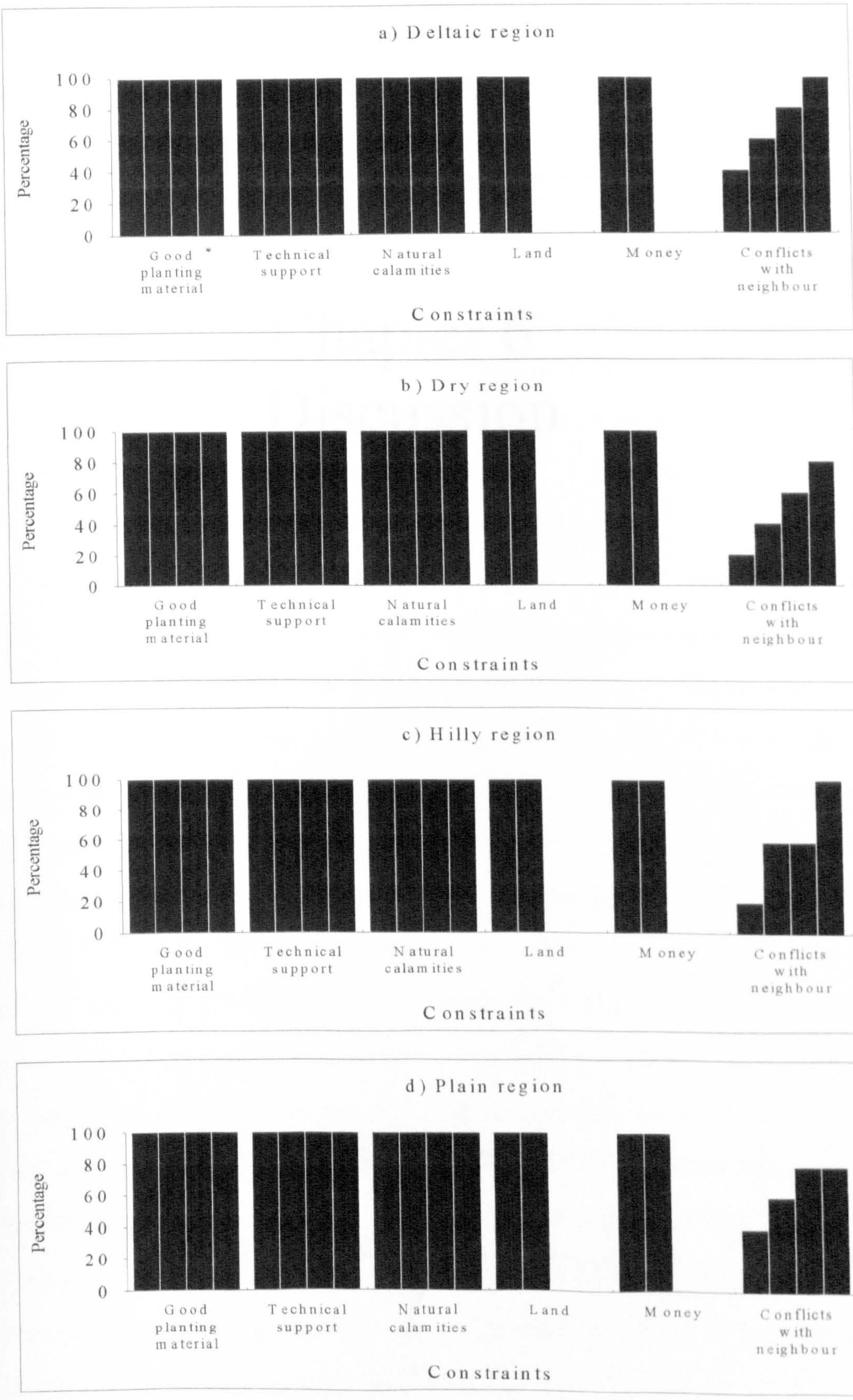
* Bars indicate farm category sequence marginal - large, from the left

Fig. 5.13: Responses of farmers on different functional aspects of homegardens in Bangladesh, express as percentage of farmers in each category that stated the function was important



* Bars indicate farm category sequence marginal - large, from the left

Fig. 5.14: Percentage of responses on constraints of the present homegarden management systems in Bangladesh



* Bars indicate farm category sequence marginal - large, from the left

Chapter 6
Discussion

Chapter 6

DISCUSSION

Homegardens in Bangladesh are an age-old form of agroforestry which meets the basic needs of farmers and is, at the same time, an important source of income. Systematic research on homegardens remains in its infancy in Bangladesh. The present study has involved assessing the structure, species composition and diversity and documenting indigenous management in traditional homegardens, providing a basis for addressing developmental and research issues concerned with increasing and sustaining homegarden production.

Despite regional differences in species composition there is much consistency in homegarden structure throughout Bangladesh. Farmers consciously enact spatial arrangement patterns for species: mostly planting in mixture at the border ensuring multiple utility of the homegarden edges. This intimacy of mixing of species presumably reduces the spread of pests or diseases through the system in a part of the garden allocated to species not needing management attention on a daily basis. Kumar *et al.* (1994) observed a similar situation in Kerala homegardens, India. The plants of the homegarden edge serve the multipurpose needs of the farmers not only by providing products but by also acting as a live fence and as boundary demarcation. The central area (mostly a part of quadrants 2 and 3) of the homegardens accommodates yards, cattle and poultry sheds, ponds and the vegetable gardens and other small, pure stands of annual crops which require regular tending. Food and fruit producing species dominate the part of the homegarden near the living quarters. Here fruits are safest from theft. Wickramasinghe (1992) observed a similar distribution pattern of food and fruit producing species in the homegardens of Sri Lanka.

To avoid damage to the living quarters during pruning and final felling, the farmers prefer remote parts of their homegardens for growing large species for timber. Similar observations have been made by Christanty *et al.* (1986) in west Javanese homegardens and by Sommers (1978) in Philippine homegardens.

The multilayered canopy configuration of the homegardens with less plant density and species richness in the upper two strata (>7 m height) generates gradients of light intensity and quality through the lower strata. In these strata, different species flourish where the light regime suits them better than their associates. Soemarwoto (1987) observed a similar situation in Javanese homegardens. Higher plant density and species richness in strata up to 7 m in height simplifies the harvesting of products by women and the children: many products are taken off the plants at heights <2 m.

The consistency in homegarden structure is due to generally limited climatic variation - the whole country is subject to humid Köppen climates, although different subdivisions apply in the different regions:

Deltaic: Aw (Tropical humid savanna, winter dry season)

Dry: Caw (Mediteranean subtropical humid, winter dry season)

Hilly: Am (Tropical monsoon rain forest)

Plain: Am (Tropical monsoon rain forest)

Also, the local populations have been faced with a need to be self supporting and have therefore adopted a system of land use which ensures that household needs in terms of food and fruit, vegetables, timber, fuelwood, spice, medicinal, fodder, raw materials for handicrafts can all be met throughout the year from the homegardens and staple foods (rice, wheat and cereals) can be met from small fields of agricultural crops.

In addition, there are cultural similarities which are common throughout Bangladesh which are reflected in some homegarden features (e.g. fish in the homegardens).

The numbers of perennial species recorded from the homegardens of each region (26 - 57) are high but consistent with those reported for earlier inventories (20 - 52) carried out by the Bangladesh Agricultural Research Institute at different farming systems research sites (Abedin and Quddus, 1990). Higher numbers of species were recorded from the Deltaic region (67 species altogether reported in 20 homegardens surveyed) where the agricultural land remains under water most of the year. Here, farmers have developed a homestead based subsistence system where they raise nurseries of valuable species. The geographic isolation of this region is a likely cause for people to grow such a diversity of plant species because of the need to be self sufficient with locally available resources. At the other extreme, in the Dry region, adverse environmental conditions (such as low rainfall, intense heat and low soil fertility) restrict the variety of species that are rewarding to grow. The Dry region is, as a result, the poorest in terms of species richness (46 species altogether reported in 20 homegardens surveyed). Contiguous regions have high species similarity (as high as 76% between Deltaic and Plain region). Kumar *et al.* (1994) also observed similar situation in Kerala homegardens, India.

The differences in species composition thus arise from the environmental contrasts between regions, not withstanding the generally humid climate. Important soil and climatic differences between regions which are involved are indicated in Table 6.1.

Table 6.1: Soil and climatic differences in different regions in Bangladesh

Regions	Typical soil	Typical climatic seasonality	Typical temperature ranges
Deltaic	Silty loam & clay	• Annual precipitation: 2037 mm, • Maximum precipitation: June (436 mm), • Dry season: November to March (10 - 42 mm)	18.8 to 28.9°C
Dry	Silty loam to silty clay loam	• Annual precipitation: 1695 mm, • Maximum precipitation: July (405 mm), • Dry season: November to April (0 - 54 mm)	17.8 to 29.2°C
Hilly	Clay loamy & sand	• Annual precipitation: 4037 mm, • Maximum precipitation: July (1166 mm), • Dry season: December to March (7 - 19 mm)	20.3 to 28.2°C
Plain	Clayey to clay loam & sandy loam	• Annual precipitation: 2295 mm, • Maximum precipitation: July (496 mm), • Dry season: November to March (5 - 48 mm)	19 to 28.9°C

Despite variation in species composition between regions, a basic set of species was always common to all regions. For example *Musa* spp. and *Mangifera indica* were recorded from all 80 homegardens surveyed. Early fruiting behaviour, a function as famine food during food shortages, ease of growing and managing, availability of vegetative propagules, multiple uses and high income from sales of fruits have made *Musa* spp. one of the most common components in the homegardens of Bangladesh. Similarly, *Mangifera indica* is regarded as a multipurpose tree species by farmers, and its wood can burn green which is seen as an especially valuable characteristic.

Not all key resource species in the homegardens have ecological amplitudes to tolerate the national range of environmental variation and still be productive. Specific roles are therefore played by different species in different regions (Table 6.2).

Table 6.2: Localized roles of species* in different regions in Bangladesh

Roles	Regions			
	Deltaic	Dry	Hilly	Plain
Vegetables	*Dillenia indica*	*Moringa oleifera*	*Citrus grandis*	*Dillenia indica*
Fruits	*Annona squamosa* *Tamarindus indica*	**No use of**: *Citrus limon,* *Diospyros embryopteris*	*Elaeocarpus robustus* **No use of**: *Borassus flabellifer,* *Eugenia javanica,* *Phoenix sylvestris*	*Tamarindus indica* *Elaeocarpus robustus*
Spices	*Cinnamomum zeylanicum,* *Zingiber officinale*	**No use of**: *Cinnamomum tamala*		
Timber	*Cassia fistula,* *Lagerstroemia speciosa,*	*Azadirachta indica,* *Dalbergia sissoo,* *Melia azedarach,* *Odina wodier,* *Toona ciliata,* **No use of**: *Tectona grandis,* *Terminalia catappa*	*Cassia fistula,* *Dipterocarpus turbinatus,* *Gmelina arborea,* *Michelia champaca,* **No use of**: *Anthocephalus chinensis*	*Terminalia arjuna,* *Lagerstroemia speciosa,* *Toona ciliata,*

* Species entered are those typical of only one or two of the four regions, or ("No use of") are absent or rarely present in one region but commonly present in the remaining three.

No fruit species is specially characteristic of Dry region and only those fruit species having wide range of adaptability are present in this region. *Citrus limon* is a common cash crop in other regions and grows well every where, but it is very scarce and in high demand in this region. High yielding variety of this species could be introduced to increase cash income from the homegardens. Growing of more spices in homegardens is a social culture in the Deltaic region. Thus two species of spices unique to the region have contributed to the highest species richness in the country. There are also distinctive sets of timber species in the Dry and the Hilly regions. Except *Cassia fistula*, other species exclusive to the Hilly region are important timber species in the hill forests. Seedlings of these species are available in the local forest nurseries. Traditionally farmers know the uses of these species better than any other species. In the Dry region furniture made of *Azadirachta indica* and *Melia azedarach* are high in demand due to their higher durability. It is a social tradition in this region of giving furniture (as dowry) of these species to the bridegroom. *Dalbergia sissoo* is a drought tolerant species and have introduced in the early sixties in this region when aridification was first detected. *Odina wodier* is regarded as a poor man's timber tree in this region.

The growing of food plants in the homegarden is primarily with home consumption in mind. Thus food and fruit producing species predominate. Although no quantitative figure is available for species composition patterns in homegardens across the world, the studies of Michon *et al.* (1983) in Java; Sommers (1978) in Philippines; McConnell and Dharmapala (1973) in Sri Lanka; Boonkird *et al.* (1984) in Thailand and Khaleque (1987) in Bangladesh acknowledge the predominance of fruit and food producing species in Asian homegardens.

Multiple uses and commercial values determine species dominance in the homegardens. With few exceptions species dominance varies with regions. As a

cash earner *Musa* spp. is dominant in the Deltaic, Dry and Plain regions. *Mangifera indica* is an important cash crop in the Dry region. Due to their higher quality there, mangoes from the Dry region are in high demand throughout the country. The commercial value of mango thus makes it the second most important homegarden species in this region in financial terms. Similarly *Areca* nut produced in the Hilly region is high in demand through out the country due to its more tranquillising property. Farmers maintain this species in the homegardens as a commercial crop and it is dominant in this region. *Samanea saman* is maintained as an insurance crop in homegardens in the Deltaic region to meet unforeseen expenses such as a marriage ceremony, building of new houses and buying of draught animals. A 12-15 years old tree can be sold up to Tk. 15000.00 (US$ 375.00).

High species diversity of fruit species in the homegardens can act as an *in situ* germ plasm conservation site specially for fruit trees. By identifying fruit plants in the homegardens with special characteristics and undergoing more intensive genetic and other scientific research to ensure genetic potentiality will help to establish *in situ* gene bank. The productivity of already existing poor quality and poorly yielding fruit trees could also be increased by special horticultural technologies (tree renovation).

Propagation techniques used by farmers for different species indicate their intimate knowledge about species regeneration. For the species which could be grown using more than one techniques, compromises are always made on availability and cost of the planting materials.

The variety of sources from which farmers reported obtaining planting materials indicate the potentiality of homegardens (more than three quarters are of homegarden origin) in the study areas. The study of Leuchner and Khaleque

(1987) in different agro-ecological zones of Bangladesh also supports the finding. Planting materials are often regarded as a traditional gift item and this has become a cultural characteristics all over the country. It ensures farmers' active involvement in tree planting activities in the study areas.

Farmers have sound understanding about mother tree selection for fruit trees. The criteria considered by farmers to select mother trees indicate that they try to maintain genetic potentiality of their homegardens from the best available sources to get better quality fruits with maximum yield.

Though no set spacing between plant is maintained at any level of homegarden establishment, farmers try to minimise competition between plants in the homegardens and increase the yield of fruit and timber by practising different cultural operations (weeding and pruning). Similar observations have been made by Alam *et al.* (1990).

Management operates at an effective but simple level, constrained by the lack of opportunities/resources to make it more sophisticated. This has the advantage of predictability and much easier transference of skills between generations. The resilience and robustness of the homegarden resources has made it possible to secure adequate yields with minimal attention, so cultural operations are simple and rarely intensive. Species needing constant careful attention have been eliminated over time leaving those better adapted. This is a matter of relevance when proposals to introduce new germplasm are considered - the new species/varieties should be equally adapted to the level of management traditionally operating.

The cost of homegarden management are low. The main cost is in the collection of planting materials (which is, in fact, less than a quarter of the total

requirements) and hiring labour to help in different management activities (as much as 57% of the total labour requirements). No chemical fertiliser is used at any level. Farmers are confident that the soil fertility of the homegardens need not to be maintained as it is naturally maintained by leaf litter, faeces of livestock that graze freely there, kitchen waste and the mud of fish ponds. Similar observations were made by Dadhwall *et al.* (1989) and Nair and Sreedharan (1986) in Kerala homegardens, India; and by Hossain *et al.* (1988) and Alam *et al.* (1990) also for Bangladesh. Farmers in the Dry region reduce pest and disease attack to fruits by silvicultural techniques (planting neem) instead of using pesticides which is expensive and hazardous to human and animal health. Homegardens provide one of the highest returns on investment of any production options for most families.

Farmers have more knowledge about above-ground interactions than below-ground interactions. This is probably simple because above-ground interactions are more readily observed. Farmers' knowledge of above ground interactions are based largely on an understanding of the relative effect of shade caused by different species which according to them are often influenced by relative height, crown dimension and sunlight requirements of different species. A basic conceptual understanding of the interactive process is consistently held by the farmers. However, detailed knowledge about species-specific tree attributes varied amongst farmers - and farmers only categorise tree species which they have cultivated in their homegardens and of which they have direct management knowledge. This indicates that farmers' knowledge is largely practical in nature. Southern (1994) also made similar observation in Kandy homegardens, Sri Lanka. Farmers knowledge of below-ground interactions is confined to on understanding of the attributes of plant root systems - principally the penetration of roots and their variability between species. However, farmers applied their knowledge of plant interactions only in a few cases (e.g. optimum combination based on positive interactions of shade) and for the negative interactions of shade, no optimum

combination was maintained. This may be attributed to the fact that farmers have wide-ranging domestic needs but limited land resources on which to thrive for both food and cash crops.

Farmers are also aware of species that can improve or reduce soil fertility. They always try to confine plants with allelopathic effects and high water and nutrient requirements in particular locations within their homegardens so that they do not harm other species. Thus farmers do not restrict the plants grown to those which will increase soil fertility or at least would have no allelopathic effects to associate plants.

There is a clear sharing of tasks between women and men for the management of homegardens. Women and children contribute a significant proportion of household labour for homegarden management though their roles and involvement vary with farm categories and regions. Similar observations are made by Hossain *et al.* (1988) in Bangladesh. Women are more knowledgeable than men in many aspects of homegarden management, but their role is not recognised by the family and the society and access to various resources are limited. Similar comments have also been made by Ahmed (1993). It is impossible to develop the homegardens without taking help from women. Giving due respect to their indigenous knowledge and to encourage them in more homegarden production activities, present government policy should be changed and low interest credit facilities should be provided to them so that besides managing homegardens, they can invest in more income generating activities related to homegardens (such as lac culture, sericulture and apiculture). Village women's association should be formed to provide them with training and extension supports and to familiarise them with innovative technologies so that they can improve the productivity of the homegardens. NGOs, such as Gramin Bank, could play an important role by extending the scope of their rural development activities to include homegardens.

The contribution of children in homegarden management can not be ignored. To encourage their more participation in tree planting activities, school nursery could play an important role. The children will be able to learn more about nursery raising and plantation techniques of important species by active participation in school nurseries.

Farmers obtain a variety of products from the homegardens. Although more than three quarters of the species in the study areas provide fuelwood, yet there is an acute shortage of fuelwood for domestic cooking. Consequently, the people are burning agricultural residues and animal dung which are traditional sources of farm manure. One third of the animal dung which would otherwise be used to help maintain soil fertility and productivity is now burned as fuel (Islam, 1994). Burning residues and dung affects the sustainability of agricultural production. Crop yields are declining although farmers apply recommended fertilisers (BARC, 1994). This has been attributed to declining soil organic matter and nutrient content due to the continuous removal of residues. Kabaara (1964) reports that cowdung is balanced with respect to nitrogen and phosphorus, thus producing better growth effects in crop fields. Livestock, an important component of farming systems and used for draught power and milk, also face an acute shortage of fodder (Torquebiau, 1991). This situation could be overcome by introducing multipurpose tree species in the homegardens (e.g. *Acacia auriculiformis*, *Leucaena leucocephala*, *Albizia chinensis*). These species will provide fuelwood, fodder, timber and green manure on the homegardens thus reducing pressure on existing cowdung and crop residues which could be used in crop fields to increase productivity.

It is noteworthy that the level of awareness about the functional aspects of homegardens among farmers is high in every region. The large scale similarities in responses to subsistence food, income, improved soil, shade and shelter indicate the significance of homegardens in the country. However, farmers do not fully

utilise their awareness and knowledge due to the lack of quality planting materials, funds and extension support. Similar observations were made by Hossain *et al.* (1988), Alam *et al.* (1990)and Miah *et al.* (1990). in different agro-ecological zones in Bangladesh. Though the government has taken initiatives to distribute seedlings among farmers at a subsidised rate through "Thana Banayan Prokolpo", that project has failed fully to achieve its objectives as the services have not yet reached all categories of farmers. Moreover, no need assessment exercise is conducted before raising seedlings for distribution. As a result farmers are not always interested to collect seedlings from the project nursery where they are available. Thus government and different non-government organisations should play a definite role by making all categories of farmers accessible to the high quality inputs (e.g. quality planting materials of desired species) and technologies of production and maintenance of the species. Low interest credit facilities should be provided to the smaller farmers as they lack cash which they can use for procurements of high yielding planting materials of desired species.

Extension services must be strengthened in the study areas to provide technological supports to the farmers. In fact due to the lack of any institutional base, agroforestry extension support in the study areas is very poor. Government has the infrastructure in its institutional network and personnel, but the infrastructure has not yet been used to elevate homegardens to their proper place of importance. Since agroforestry encompasses a number of components, so it needs an integrated research approach to develop. No research institute has an agroforestry division in Bangladesh. Currently agricultural institutes concentrate on food and fruit production while forestry institutes on timber quality of timber trees. Bangladesh Agricultural Research Council (BARC) is co-ordinating agroforestry activities through the formation of a National Agroforestry Working Group (NAWG) which includes members from research, development, extension and educational institutes of agriculture and forestry including a few non-

government organisations. But these activities are still limited to exchanges of views and no linked research has been possible for want of a sound agroforestry policy. An integrated approach through institutional development is therefore, urgently needed to improve the productivity and ensure the sustainability of the system. A sound agroforestry policy should be developed by the government with provision for all possible helps to encourage agroforestry activities in the country. .

There is an additional factor which would aid the homegarden development: political commitment. The politicians need to realise the importance of homegardens. Particularly it is the duty of the extension agents and organisations engaged in agroforestry research not only to laise with farmers but equally to convince the politicians of the importance of homegardens in our daily life, for it is the extension service which is best placed to do so.

Chapter 7
Conclusions and recommendations

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The present study indicates that there is a regional pattern to homegarden character in Bangladesh. Through the present study it is possible to identify features basic to Bangladesh homegardens generally and features with particular regional significance. These are indicated in the first six conclusions. Conclusions 7 - 13 refer to management practices while conclusions 14 - 19 are in relation to farmers' indigenous knowledge.

1. Throughout Bangladesh a wider range of plants are grown at the homegarden edge.

2. Food and fruit producing species dominate the part of the homegardens near the living quarters.

3. Remote parts of homegardens are preferred for timber trees.

4. Plant density and species richness are lower among plants reaching heights which exceed >7 m.

5. Environmental factors reduce diversity significantly in the Dry region but in the Deltaic region combine with socio-economic adaptation to needs to cope with periods of isolation by flood water, resulting in a relatively high species richness.

6. Food-and-fruit producing species predominate in the homegardens. Despite regional variations in species composition, *Musa* spp. and *Mangifera indica* are recorded from all 80 homegardens surveyed.

7. All sorts of planting materials (seeds, seedlings and vegetative propagules) have been used by farmers to regenerate homegarden plants.

8. More than three quarters of the planting materials are of homegarden origin.

9. Farmers prefer medium sized seedlings for planting due to the advantages associated with management and costs.

10. Farmers traditionally select mother trees for fruit producing species in the homegardens.

11. Cultural operations are simple and rarely intensive and usually practised to minimise competition between plants and increase yield of fruits and timber. Weeding and pruning are cultural operations commonly practised in homegardens.

12. An irregular watering schedule is maintained for homegarden plants and the application is restricted to the dry season only.

13. Fertility of the homegardens are maintained naturally from leaf litter, faeces of animals, kitchen waste and the mud of fish ponds.

14. There is a clear sharing of tasks between men and women for homegarden management. Farmers spend only 5 - 12 % of their labour and 4 - 7.5 % of their active time in homegarden management.

15. The criteria considered by farmers to select a mother tree indicate their sound understanding about genetic potentiality of the mother trees.

16. In the Dry region farmers practice silvicultural method to protect fruits in the homegardens from insects and pests.

17. Farmers have more knowledge about above-ground interactions than below-ground interactions. Farmers apply their knowledge of plant interactions but only in certain (and few) cases (e.g. optimum combination based on positive interactions for shade).

18. Farmers try to confine plants having allelopathic effect and water and nutrient requirements in particular locations within homegardens so that they do not harm other species.

19. Women are more knowledgeable than men in many aspect of homegarden management, but their access to various resources is limited.

7.2 Recommendations

To increase homegarden productivity and sustainability, following recommendations are made:

7.2.1 Management recommendations

1. The results of the present study reveal that farmers have considerable knowledge about different aspects of homegarden management including genetic potentiality of fruit trees, plant interactions and allelopathic effects of homegarden plants. It is therefore recommended that scientists made more effort to elicit farmers' indigenous knowledge and practices in order to increase the understanding of the functions of homegardens. Since indigenous knowledge are always complimentary to scientific knowledge, thus by combining indigenous knowledge and ecological wisdom of the villagers with scientific knowledge higher productivity of homegardens may be achieved without causing any environmental degradation.

2. More income generating activities should be created from homegarden sources including sericulture and lac culture as there is great demand for silk and lac in the country and homegardens have a great potentiality in promoting such practices. Mulberry (*Morus alba*) is a very hardy and versatile tree and grows well under a wide range of agro-climate and soil conditions. It could be introduced in the homegardens for sericulture. *Ziziphus jujuba* is a multipurpose fruit tree commonly found in all regions. It's number could be increased in the homegardens for lac culture.

7.2.2 Research recommendations

1. A detailed study to investigate nutrient recycling in homegardens is recommended. This will ensure to find if scope exists to increase homegardens productivity by adding more compost and organic manure.

2. Though the species combinations reported to have positive interactions in terms of shade are available in all regions, but their application are restricted to one particular region. So recommendations are made to study the extrapolability of all combinations of species presently practised in different regions to every region.

3. Though farmers are knowledgeable about the interactions of plants in the homegardens, but no quantitative data is available in this field. So a detailed study of the plant interactions is recommended.

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Appendices

APPENDICES

Appendix 3.1: General background information of the study areas

Parameters		Regions				Sources
		Deltaic	Dry	Hilly	Plain	
Study areas	Village	Ruiya	Vobanipur	Jilonza	Perul	
	District	Barisal	Dinajpur	Cox's Bazar	Comilla	
Location	Latitude	22.42° N	25.39° N	21.27° N	23.28° N	BBS (1994)
	Longitude	90.23° E	88.40° E	91.59° E	91.11° E	
Number of households in the study villages	Landless	56	73	47	46	Field survey (1992 - 93)
	Marginal	51	39	44	52	
	Small	48	37	42	37	
	Medium	30	23	27	31	
	Large	18	11	22	23	
Government Forests in the sample districts	Total area (ha)	0	10105	117774	1696	Forestry Master Plan (1992)
	% of total land of the district	0	2.94	47.26	0.55	
Home garden area of the sample districts	Total area (ha)	11761	15668	11579	16615	BBS (1994)
	% of total land of the district	4.21	4.56	4.65	5.39	

Appendix 3.2: Questionnaire of the Preliminary Socio-economic survey

Date			

Region	District
Village	
1. Name of the House Head	Sex: M / F

2. Household Size

Sex	0-5	5-15	15-30	30-60	> 60	Total	Grand Total
Male							
Female							

3. Educational Status of the House Head	No Formal Education
	Primary (Up to year 5)
	Junior (Up to year 8)
	Secondary (Up to year 10)
	Higher Secondary (Up to year 12)
	Graduation

4. Total Operational Land Holdings (decimal)

Homegarden	
Agricultural lands	
Others	

5. Total annual Income (in ' 000' Tk)

Sources	Total Income	Grand Total
Primary		
Secondary		

6. Total Livestock Resources

Cattle	Goat	Poultry Bird

Appendix 3.3: Socio-economic conditions of respondents in the study areas

a) Distribution of mean household size (persons per household) by farm category

Farm category	Regions			
	Deltaic	Dry	Hilly	Plain
Marginal (n=5*)	5.4 (0.89)	5 (0.71)	5.6 (1.52)	6.6 (0.89)
Small (n=5*)	5.6 (1.14)	5.2 (0.84)	5.6 (1.14)	6.6 (1.14)
Medium (n=5*)	5.6 (0.55)	5.2 (0.84)	5.6 (0.55)	6.4 (1.14)
Large (n=5*)	5.8 (0.83)	5.4 (0.89)	6.0 (0.71)	5.8 (1.30)
All (n=20*)	5.6 (0.83)	5.3 (0.73)	5.7 (0.98)	6.35 (1.09)

* indicates number of households sampled in each farm category

Figures in parenthesis indicate standard deviation

b) Mean operational land holdings by farm category and region

Farm category	Homegarden (ha)				Agricultural land (ha)			
	Deltaic	Dry	Hilly	Plain	Deltaic	Dry	Hilly	Plain
Marginal n=5*	0.05 (0.01)	0.05 (0.02)	0.05 (0.01)	0.04 (0.01)	0.09 (0.1)	0.27 (0.3)	0.26 (0.2)	0.18 (0.1)
Small n=5*	0.10 (0.01)	0.12 (0.01)	0.10 (0.01)	0.11 (0.02)	0.36 (0.2)	0.56 (0.1)	0.51 (0.3)	0.37 (0.2)
Medium n=5*	0.17 (0.01)	0.17 (0.02)	0.18 (0.02)	0.17 (0.01)	0.73 (0.5)	1.00 (0.4)	0.89 (0.6)	0.74 (0.4)
Large n=5*	0.23 (0.01)	0.24 (0.02)	0.24 (0.02)	0.29 (0.01)	0.82 (0.3)	1.64 (0.7)	1.16 (0.4)	1.11 (0.3)
All n=20*	0.14 (0.01)	0.15 (0.01)	0.15 (0.01)	0.15 (0.1)	0.50 (0.4)	0.87 (0.7)	0.71 (0.5)	0.60 (0.4)

* indicates number of households sampled in each farm category

Figures in parentheses indicate the standard deviation

c) Mean number of livestock resources owned by sample households in different regions

Types of livestock	Farm category n=5*	Regions			
		Deltaic	Dry	Hilly	Plain
Cow	Marginal	0.20 (0 - 1)	0.00	1.20 (1 - 2)	0.80 (0 - 2)
	Small	0.80 (0 - 2)	0.60 (0 - 2)	2.40 (1 - 4)	1.60 (1 - 2)
	Medium	1.00 (0 - 2)	1.20 (1 - 2)	3.60 (3 - 5)	2.40 (2 - 3)
	Large	2.60 (2 - 4)	2.00 (1 - 3)	6.40 (3 - 8)	2.60 (2 - 4)
Goat	Marginal	1.20 (1 - 2)	1.00 (1 - 1)	2.20 (1 - 3)	1.20 (1 - 2)
	Small	1.80 (1 - 2)	1.40 (1 - 2)	4.20 (3 - 5)	1.80 (1 - 4)
	Medium	2.00 (1 - 3)	2.00 (1 - 3)	4.60 (3 - 6)	2.80 (2 - 5)
	Large	3.20 (2 - 5)	3.20 (2 - 4)	8.00 (5 - 11)	3.80 (3 - 5)
Poultry	Marginal	3.40 (1 - 7)	2.20 (2 - 3)	1.80 (1 - 3)	2.80 (2 - 4)
	Small	11.00 (8 - 16)	4.00 (2 - 7)	3.00 (2 - 4)	6.00 (4 - 8)
	Medium	16.00 (10 - 22)	10.40 (7 - 14)	7.80 (6 - 11)	11.20 (8 - 14)
	Large	25.00 (18 - 34)	22.00 (18 - 26)	14.80 (11 - 18)	24.00 (20 - 28)

* indicates the number of households sampled in each farm category

Figures in parenthesis indicate the range

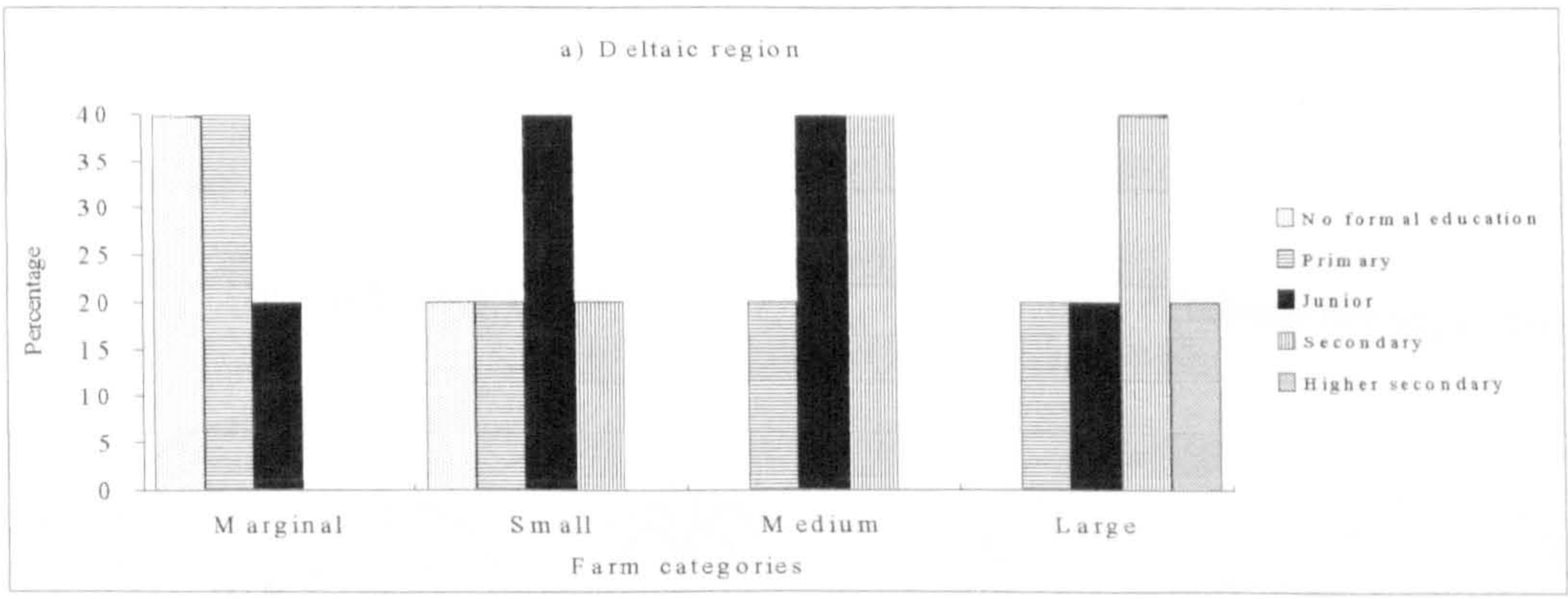
d) Mean annual income (in '000' Tk*) of the sample households by farm category and region

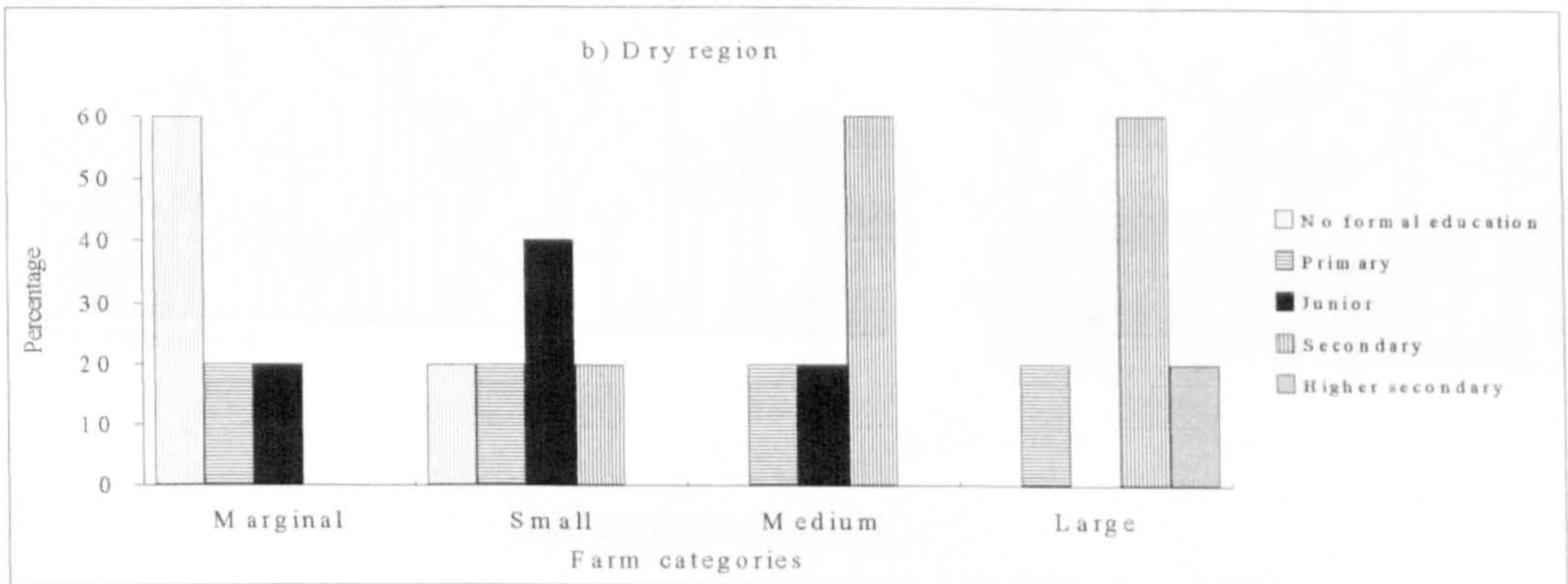
Farm category	Annual income	Regions			
		Deltaic	Dry	Hilly	Plain
Marginal n=5**	Mean	28.62	26.10	33.60	39.10
	Range	22.30 - 31.80	16.00 - 43.50	27.00 - 40.00	28.00 - 55.00
Small n=5**	Mean	39.80	34.94	42.80	52.00
	Range	36.00 - 50.00	23.00 - 40.00	21.00 - 80.00	41.00 - 62.00
Medium n=5**	Mean	52.60	47.40	60.40	63.90
	Range	39.00 - 74.00	35.00 - 66.00	47.00 - 80.00	45.00 - 81.50
Large n=5**	Mean	74.00	72.96	91.00	94.80
	Range	55.00 - 85.00	61.80 - 90.00	75.00 - 100.00	74.00 - 120.00

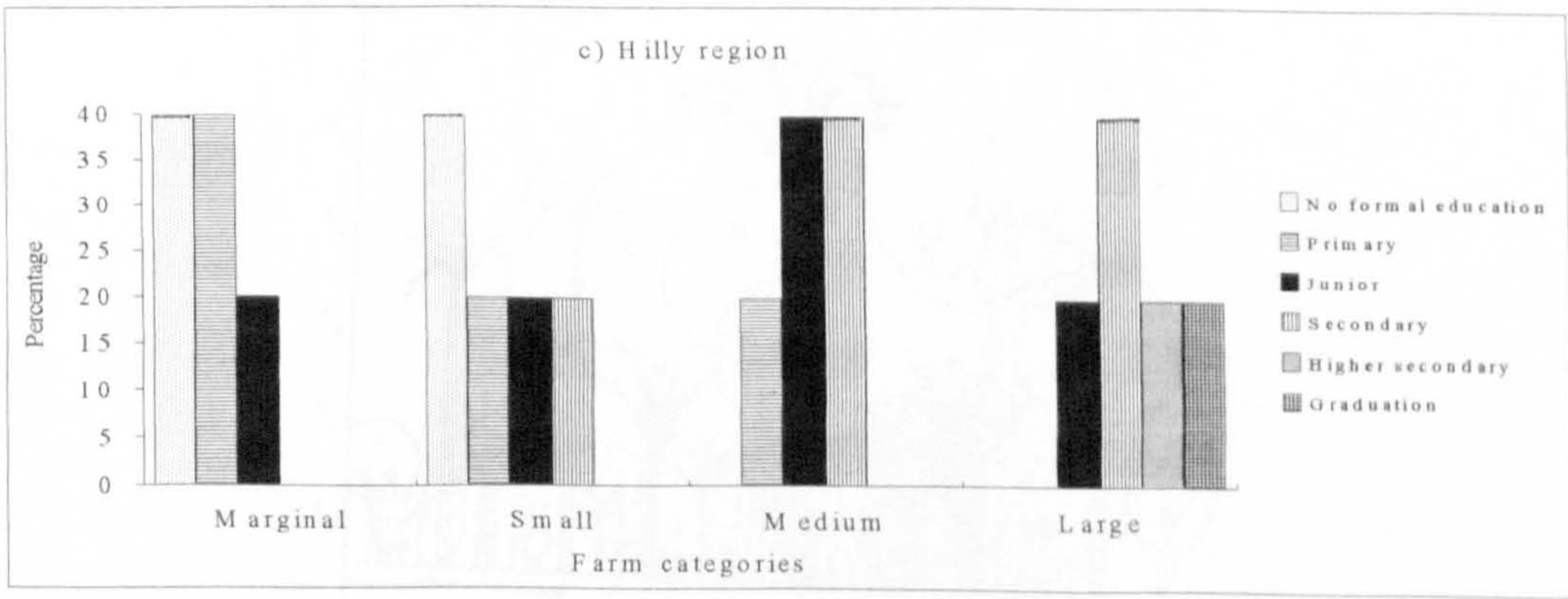
*Tk 40.00 = 1 US$

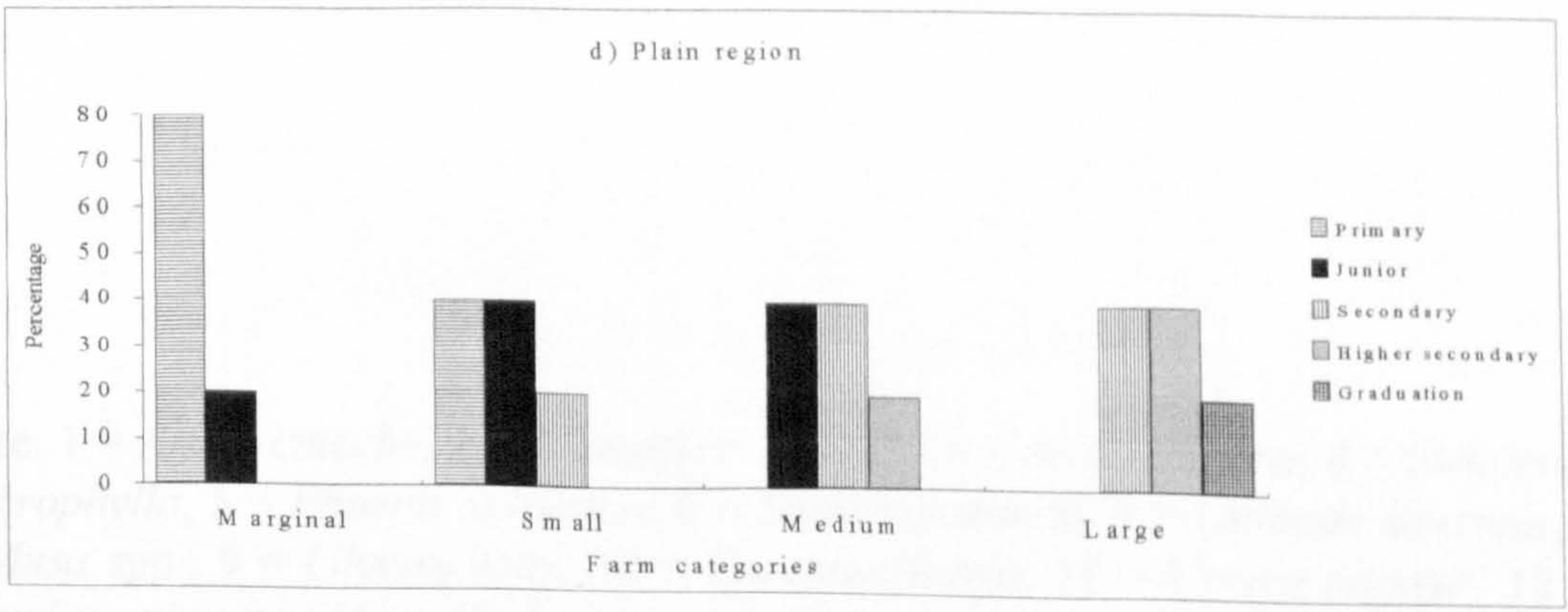
** indicates the number of households sampled in each farm category

e) Educational status of the sample house heads (%) by farm categories





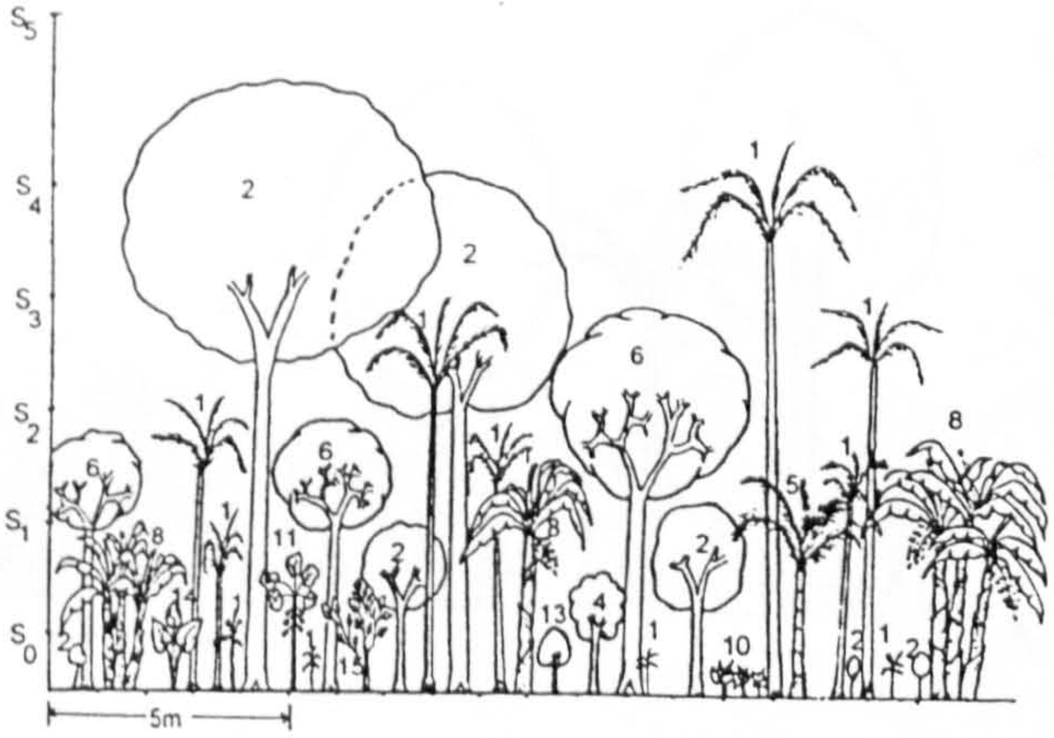




Appendix 4.1: Profile diagrams of the traditional homegardens in Bangladesh

Deltaic region

Small homegarden



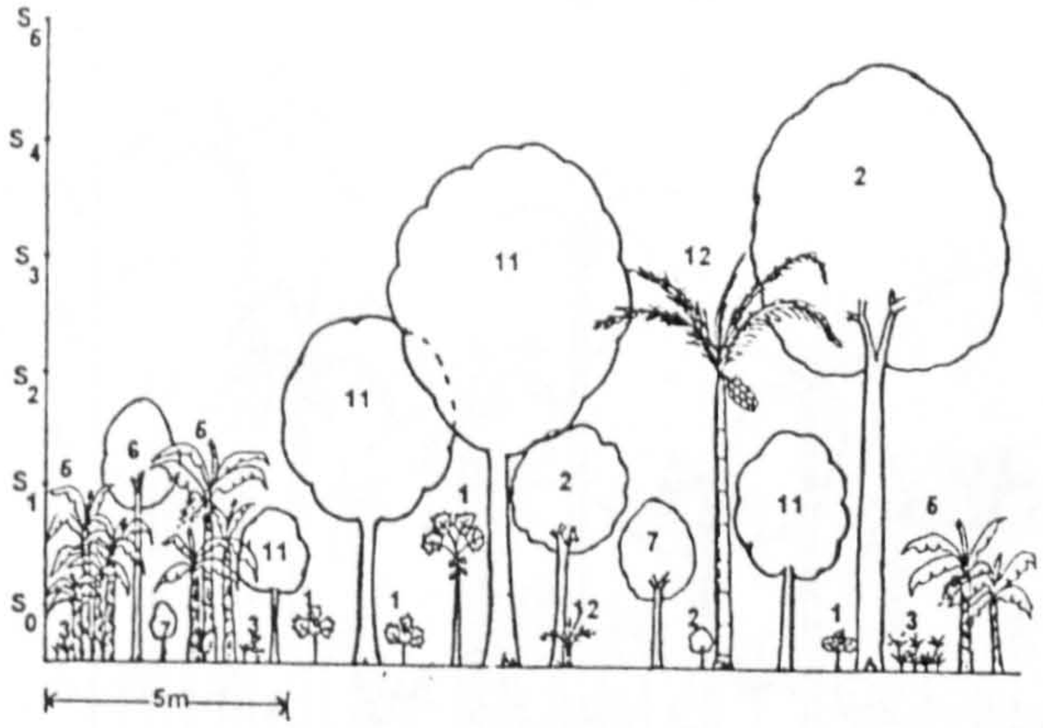
Medium homegarden

Large homegarden

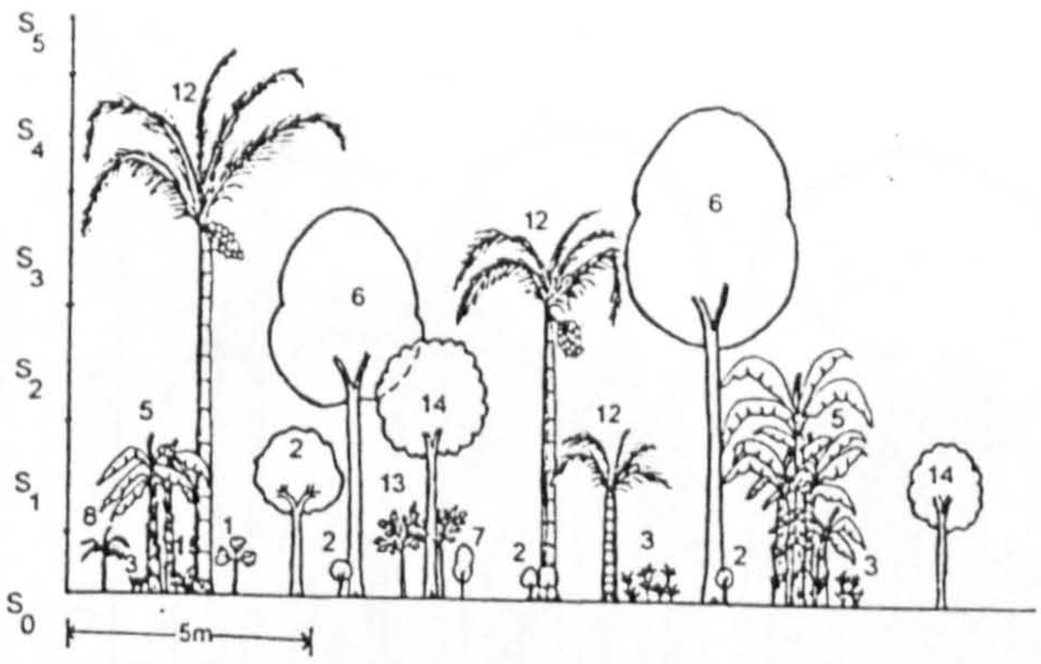
Note: 1 = *Areca catechu*, 2 = *Mangifera indica*, 3 = *Cocos nucifera*, 4 = *Swietenia macrophylla*, 5 = *Phoenix sylvestris*, 6 = *Samanea saman*, 7 = *Ocimum sanctum*, 8 = *Musa* spp., 9 = *Glycine max*, 10 = *Curcuma longa*, 11 = *Carica papaya*, 12 = *Spondias pinnata*, 13 = *Diospyros embryopteris*, 14 = *Colocacia indica*, 15 = *Citrus limon*, 16 = *Erythrina variegata*, 17 = *Anthocephallus chinensis*, 18 = *Ananus sativus*

Dry region

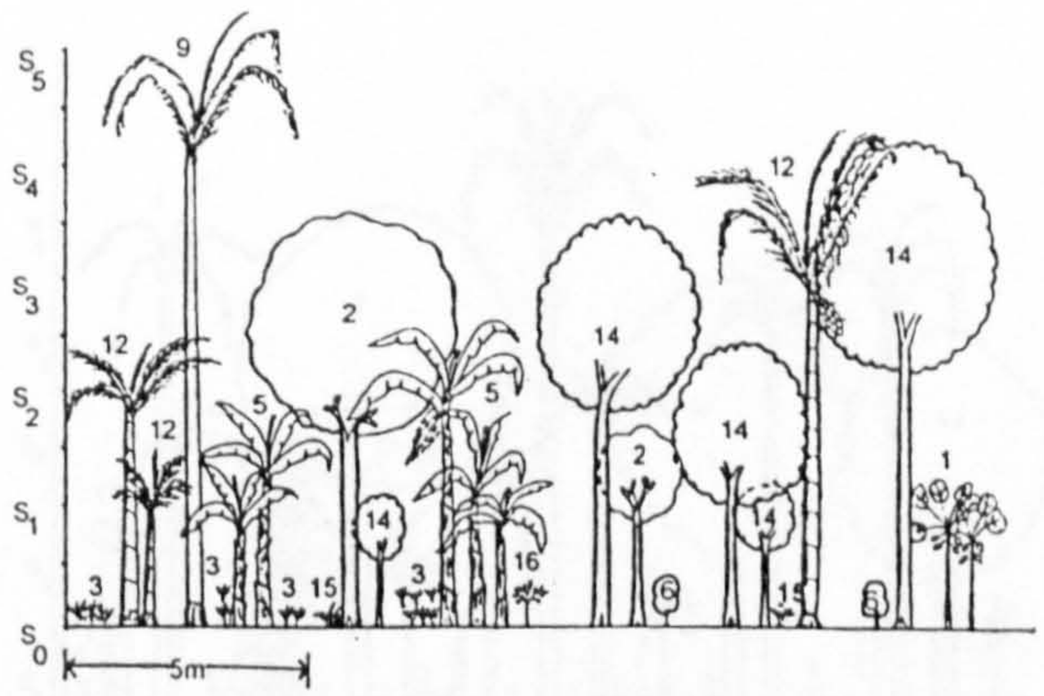
Small homegarden



Medium homegarden



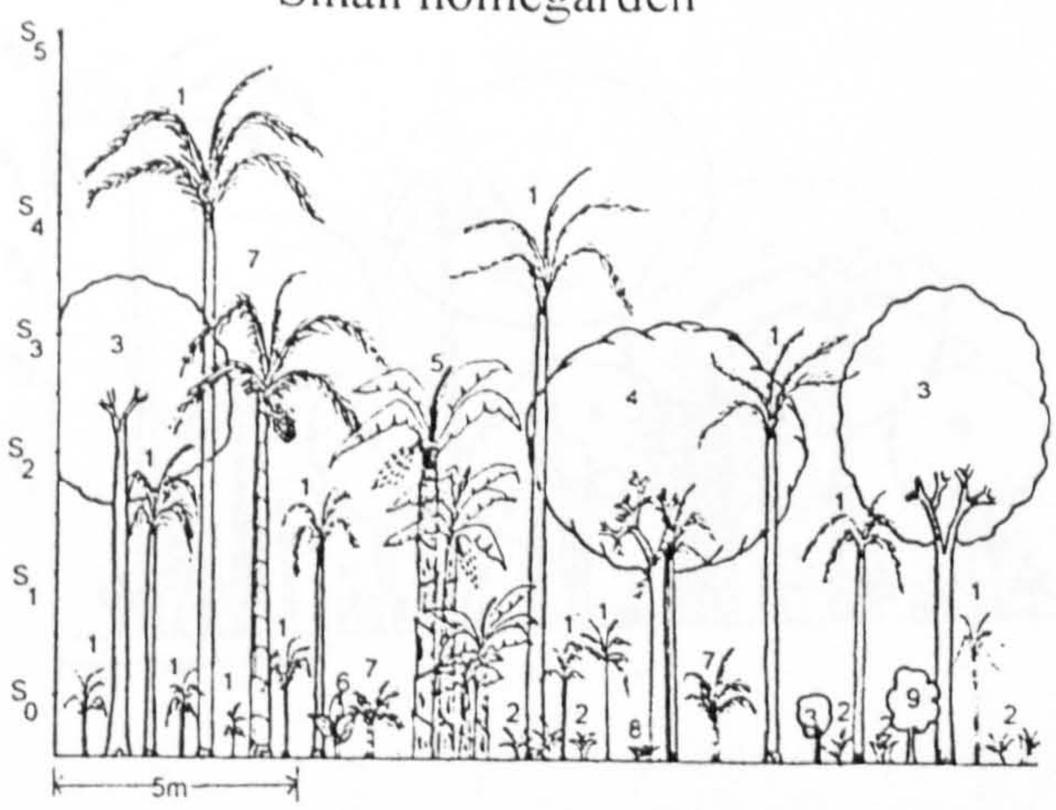
Large homegarden



Note: 1 = *Carica papaya*, 2 = *Mangifera indica*, 3 = *Curcuma longa*, 4 = *Cocolacia indica*, 5 = *Musa* spp., 6 = *Melia azedarach*, 7 = *Azadirachta indica*, 8 = *Phoenix sylvestris*, 9 = *Areca catechu*, 10 = *Bambusa* spp., 11 = *Artocarpus heterophyllus*, 12 = *Cocos nucifera*, 13 = *Gossypium herbaceum*, 14 = *Dalbergia sissoo*, 15 = *Ananus sativus*, 16 = *Ocimum sanctum*

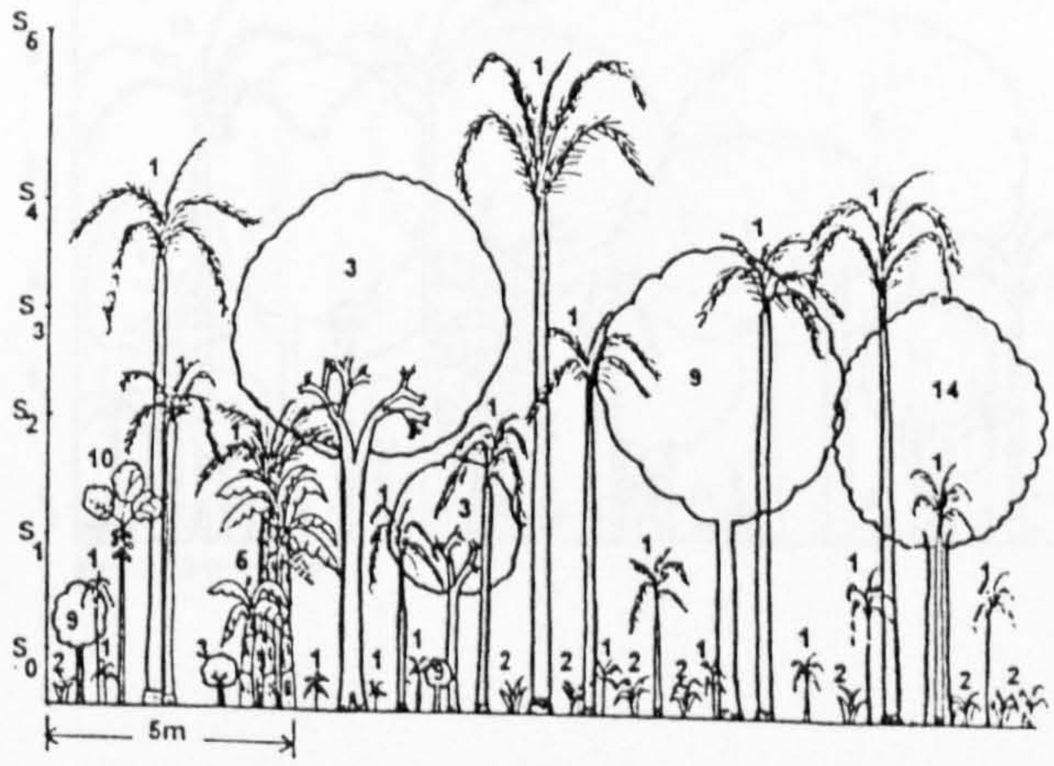
Hilly region

Small homegarden



Medium homegarden

Large homegarden

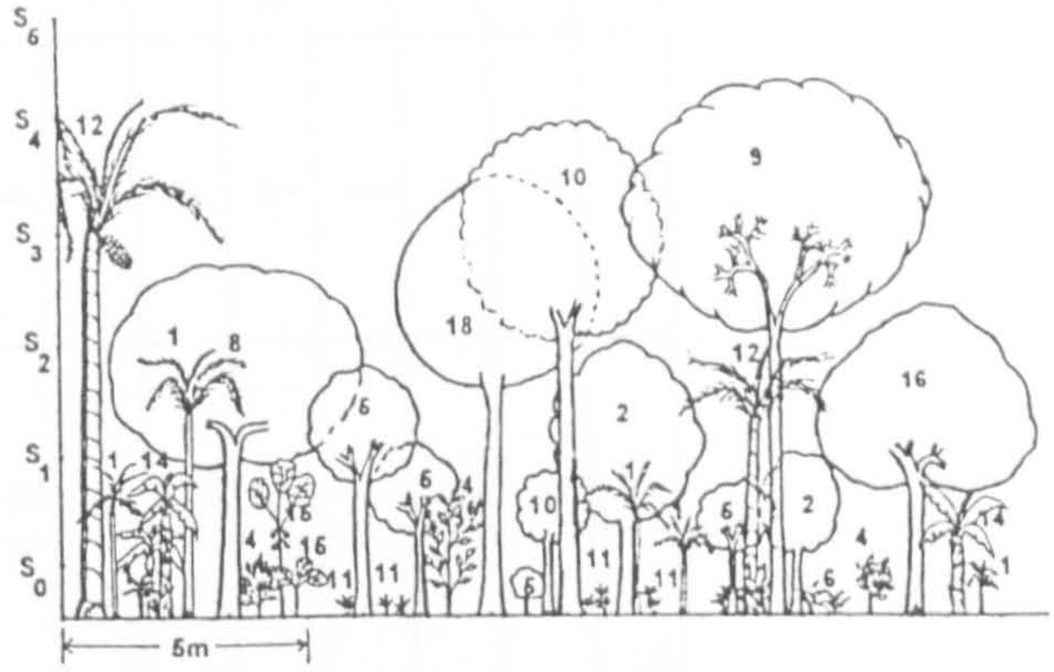


Note: 1 = *Areca catechu*, 2 = *Anamus sativus*, 3 = *Mangifera indica*, 4 = *Samanea saman*, 5 = *Musa* spp., 6 = *Colocacia indica*, 7 = *Cocos nucifera*, 8 = *Curcuma longa*, 9 = *Artocarpus heterophyllus*, 10 = *Carica papaya*, 11 = *Dipterocarpus turbinatus*, 12 = *Erythrina variegata*, 13 = *Citrus limon*, 14 = *Swietenia macrophylla*

Plain region

Small homegarden

Medium homegarden



Large homegarden

Note: 1 = *Areca catechu*, 2 = *Artocarpus heterophyllus*, 3 = *Colocacia indica*, 4 = *Citrus limon*, 5 = *Mangifera indica*, 6 = *Anamus sativus*, 8 = *Albizia* spp., 9 = *Samanea saman*, 10 = *Swietenia macrophylla*, 11 = *Curcuma longa*, 12 = *Cocos nucifera*, 13 = *Diospyros embryopteris*, 14 = *Musa* spp., 15 = *Carica papaya*, 16 = *Psidium guajava*, 17 = *Citrus grandis*, 18 = *Erythrina variegata*

Appendix 4.2: Plant species of the traditional homegardens in Bangladesh

No	Family	Scientific name	Common name	Plant form*	Function*	Reported from	Uses*
1	Amaranthaceae	*Achyranthes aspera* (Wall.) Hook	Apang	S	O	Deltaic	3,6
2	Anacardiaceae	*Odina wodier* Roxb.	Jiga	T	T	Dry	2,3
3	Anacardiaceae	*Lannea coromandelica* (Houtt.) Merr.	Badhi	T	T	All regions	2,3,5,7,8
4	Anacardiaceae	*Mangifera Indica* Linn.	Mango	T	F	All regions	1,2,3,5
5	Anacardiaceae	*Spondias Pinnata* (L.f.) Kurz	Hog-plum	T	F	All regions	1,2,3
6	Annonaceae	*Annona reticulata* Linn.	Custard apple	T	F	Deltaic, Hilly & Plain	1,3
7	Annonaceae	*Annona squamosa* Linn.	Sorifa	T	F	Deltaic	1,3
8	Annonaceae	*Polyalthia longifolia* (Sonnerat) Thwaite	Debdaru	T	T	Deltaic	2,3,8
9	Apocynaceae	*Alstonia scholaris* (Linn.) R. Br.	Chatim	T	T	Deltaic & Plain	2,3,8
10	Araceae	*Colocasia indica* (Lour.) Spach	Aroid	H	F	All regions	1
11	Bombacaceae	*Bombax ceiba* Linn.	Silk cotton	T	T	All regions	2,3,8
12	Bromeliaceae	*Ananas sativus* (Lindley) Schultes f.	Pine apple	H	F	All regions	1
13	Burseraceae	*Bursera serrata* Colebr.	Gutgutia	T	T	Deltaic & Plain	2,3
14	Caricaceae	*Carica papaya* Linn.	Papaya	T	F	All regions	1
15	Casuarinaceae	*Casuarina equisetifolia* Linn.	Yew tree	T	T	Hilly	2,3
16	Combretaceae	*Terminalia arjuna* W & A	Arjun	T	T	Plain	2,3,6
17	Combretaceae	*Terminalia catappa* Linn.	Kat badam	T	T	Deltaic, Hilly & Plain	2,3

18	Cucurbitaceae	*Coccinia cordifolia* Dc.	Kougola	T	F	Deltaic & Hilly	1,2,3
19	Dilleniaceae	*Dillenia indica* Linn.	Chalta	T	F	Deltaic & Plain	1,3
20	Dipterocarpaceae	*Dipterocarpus turbinatus* Gaertner f.	Gorjon	T	T	Hilly	2,3
21	Ebenaceae	*Diospyros embryopteris* Pers.	Gab	T	F	Deltaic, Hilly & Plain	1,2,3
22	Elaeocarpaceae	*Elaeocarpus robustus* Roxb.	Olive	T	F	Hilly & Plain	1,2,3
23	Euphorbiaceae	*Phyllanthus emblica* Linn.	Amoloki	T	F	Deltaic & Hilly	1,3,6
24	Euphorbiaceae	*Ricinus communis* Linn.	Verenda	S	O	Dry & Plain	6
25	Gramineae	*Bambusa balcooa* Roxb.	Barak bans	T	T	Dry, Hilly & Plain	2,3,5,7,8
26	Gramineae	*Bambusa burmanica* Gamble	Jai bans	T	T	Deltaic, Hilly & Plain	2,3,5,7,8
27	Gramineae	*Bambusa longispiculata* Gamble	Tolla bans	T	T	Deltaic & Dry	2,3,5,7,8
28	Gramineae	*Bambusa vulgaris* Schrad. ex Wends	Baijja bans	T	T	Hilly & Plain	2,3,5,7,8
29	Gramineae	*Melocanna bambusoides* Trin.	Muli bans	T	T	Deltaic & Plain	2,3,5,7,8
30	Gramineae	*Schumannianthus dichotoma* Gagnep.	Patipata	S	O	Hilly & Plain	8
31	Labiatae	*Ocimum sanctum* Linn.	Tulsi	S	O	Deltaic, Dry & Plain	6,8
32	Lauraceae	*Cinnamomum tamala* Fr. Nees	Bay leaf	T	S	Deltaic, Hilly & Plain	3,4
33	Lauraceae	*Cinnamomum zeylanicum* Blume	Cinnamon	T	S	Deltaic	3,4
34	Lecythidaceae	*Barringtonia acutangula* (Linn.) Gaertn.	Hijol	T	T	Deltaic & Hilly	2,3
35	Leguminosae	*Acacia auriculiformis* Cunn. ex Benth.	Acacia	T	T	Hilly & Plain	2,3
36	Leguminosae	*Albizia falcataria* (Linn.) Fosberg	Malocanna	T	T	Deltaic & Dry	2,3
37	Leguminosae	*Albizia procera* (Roxb.) Benth.	Koroi	T	T	All regions	2,3

38	Leguminosae	*Caesalpinia crista* Linn.	Koromcha	T	F	Deltaic	1,3
39	Leguminosae	*Cajanus cajan* Linn.	Pigeon pea	S	F	Deltaic, Dry & Hilly	1,3,5,7
40	Leguminosae	*Cassia fistula* Linn.	Sonalu	T	T	Deltaic & Hilly	2,3,8
41	Leguminosae	*Cassia siamea* Lamk.	Minjiri	T	T	Deltaic	2,3
42	Leguminosae	*Delonix regia* (Bojer ex Hook.) Rafin.	Krisnochura	T	T	Hilly	2,3,8
43	Leguminosae	*Erythrina variegata* Linn.	Madar	T	T	All regions	2,3,5,7,8
44	Leguminosae	*Glycine max* Linn.	Soyabean	H	F	Deltaic	1
45	Leguminosae	*Leucaena leucocephala* (Lamk) deWit.	Ipilipil	T	T	Dry	3,5
46	Leguminosae	*Pongamia glabra* Vent Jard.	Karung	S	O	Deltaic	6
47	Leguminosae	*Samanea saman* (Jacq.) Merr.	Rain tree	T	T	All regions	2,3
48	Leguminosae	*Sesbania sesban* (Cav.)	Doincha	T	T	Deltaic	3
49	Leguminosae	*Dalbergia sissoo* Roxb. ex DC.	Sissum	T	T	Dry	2,3
50	Leguminosae	*Tamarindus indica* Linn.	Tamarind	T	F	Deltaic & Plain	1,2,3
51	Lythraceae	*Lagerstroemia speciosa* (Linn.) Pers.	Jarul	T	T	Deltaic & Plain	2,3
52	Lythraceae	*Lawsonia inermis* Linn.	Mendi	T	O	Deltaic, Dry & Hilly	3,8
53	Magnoliaceae	*Michelia champaca* Linn.	Champa ful	T	T	Hilly	2,3,8
54	Malvaceae	*Gossypium herbaceum* Linn.	Cotton plant	S	O	Dry	3,8
55	Malvaceae	*Hibiscus rosa-sinensis* Linn.	China rose	S	O	Hilly	3,7,8
56	Meliaceae	*Aphanamixis polystachya* (Wall.) Parker	Roina	T	T	Deltaic & Plain	2,3

57	Meliaceae	*Azadirachta indica* A. Juss.	Neem	T	T	Dry	2,3,6
58	Meliaceae	*Melia azedarach* Linn.	Ghora Neem	T	T	Dry	2,3
59	Meliaceae	*Swietenia macrophylla* King.	Mahogony	T	T	All regions	2,3
60	Meliaceae	*Toona ciliata* M.J. Roemer	Poma	T	T	Dry & Plain	2,3
61	Moraceae	*Artocarpus lakoocha* Roxb.	Dewa	T	F	Deltaic, Hilly & Plain	1,3
62	Moraceae	*Artocarpus heterophyllus* Lamk.	Jack fruit	T	F	All regions	1,2,3,5
63	Moraceae	*Ficus racemosa* Linn.	Fig	T	T	Deltaic & Plain	3,5
64	Moraceae	*Morus alba* Linn.	Mulberry	T	O	Dry	3
65	Moringaceae	*Moringa oleifera* Lamk.	Sajna	T	F	Dry	1,3
66	Musaceae	*Musa* spp. Linn.	Banana	T	F	All regions	1,3,5,7
67	Myrtaceae	*Eucalyptus camaldulensis* Dehn.	Eulcalyptus	T	T	Dry & Hilly	2,3
68	Myrtaceae	*Eugenia javanica* Lamk.	Star apple	T	F	Deltaic, Dry & Plain	1,2,3
69	Myrtaceae	*Psidium guajava* Linn.	Guava	T	F	All regions	1,2,3
70	Myrtaceae	*Syzygium cumuni* (Linn.) Skeels	Jam	T	F	All regions	1,2,3
71	Oxalidaceae	*Averrhoa bilimbi* Linn.	Balemboo	T	F	Hilly	1,3
72	Oxalidaceae	*Averrhoa carambola* Linn.	Star fruit	T	F	All regions	1,3
73	Palmae	*Areca catechu* Linn.	Betel nut	T	F	All regions	1,2,3,7,8
74	Palmae	*Borassus flabellifer* Linn.	Palmyra Palm	T	F	Deltaic, Dry & Plain	1,2,3,7,8
75	Palmae	*Cocos nucifera* Linn.	Coconut	T	F	All regions	1,2,3,7,8

76	Palmae	*Phoenix sylvestris* (Linn.) Roxb.	Date palm	T	F	Deltaic, Dry & Plain	1,3,8
77	Piperaceae	*Piper longum* Linn.	Pipul	S	O	Deltaic	3,6
78	Punicaceae	*Punica granatum* Linn.	Pomegranate	T	F	All regions	1,3
79	Rhamnaceae	*Ziziphus jujuba* (Linn.) Gaertn.	Jujube	T	F	All regions	1,2,3,6
80	Rubiaceae	*Anthocephallus chinensis* (Lamk.) A. Rick ex Walp	Kadam	T	T	Deltaic, Dry & Plain	2,3,8
81	Rutaceae	*Aegle marmelos* (Linn.) Correa	Wood apple	T	F	All regions	1,2,3,6
82	Rutaceae	*Citrus acida* (Linn.)	Jambura	T	F	All regions	1,3
83	Rutaceae	*Citrus grandis* (Linn.) Osbeck	Pomelo	T	F	Hilly	1,3
84	Rutaceae	*Citrus limon* (Linn.) Burm. f.	Lemon	S	F	Deltaic, Hilly & Plain	1,6
85	Rutaceae	*Citrus reticulata* Blanco	Orange	T	F	Deltaic & Plain	1,3
86	Rutaceae	*Feronia limonia* (Linn.) Swingle	Kath bael	T	F	Deltaic	1,2,3
87	Sapindaceae	*Litchi chinensis* Sonn.	Litchi	T	F	All regions	1,2,3
88	Tiliaceae	*Grewia microcos* Linn.	Asar	T	T	All regions	2,3
89	Verbenaceae	*Gmelina arborea* Roxb.	Gamar	T	T	Hilly	2,3
90	Verbenaceae	*Tectona grandis* L.f.	Teak	T	T	Deltaic, Hilly & Plain	2,3
91	Zingiberaceae	*Curcuma longa* Linn.	Turmeric	H	S	All regions	4,6
92	Zingiberaceae	*Zingiber officinale* Roscoe	Ginger	H	S	Deltaic	4,6

Plant Form: T= Tree, S= Shrub, H= Herb
Function: F= Food/fruit producing species, T = Timber and fuelwood species, S = Spices and O = Other species.
Uses: 1 = Food/fruit, 2 = Timber, 3 = Fuelwood, 4 = Spice, 5 = Fodder, 6 = Medicine, 7 = Fence and 8 = Others.