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Village Agroforestry Systems and Tree-Use Practices: A Case Study in Sri Lanka

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This report synthesizes and builds on previous case studies conducted by the author in Sri Lanka under two regional studies initiated in 1989 by the Multipurpose Tree Species Research Network. The regional farm and village forestry study was an important first step in the systematic, comparative analysis needed to help predict possible patterns of tree and forest-use practices in areas of South and Southeast Asia under similar social and economic conditions. The preliminary analysis was conducted by scientists in 26 villages of Bangladesh, Indonesia, Nepal, Philippines, Sri Lanka, and Thailand. An interdisciplinary study on farmers' tree-breeding objectives interviewed farmers in 28 villages of Bangladesh, India, Indonesia, Nepal, Philippines, Sri Lanka, and Thailand to identify their preferences for tree characteristics. These characteristics, in turn, could form the basis for genetically improving trees to meet farmers' perceived needs.

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Summary

Village agroforestry systems in Sri Lanka are associated with age-old tree-use practices that have evolved through farmers' experience to meet survival needs. This paper presents a combined analysis of two related studies on farm- and village-forestry use practices and farmers' tree-breeding objectives in two villages in central Sri Lanka. These villages, Bambarabedda and Madugalla, comprised part of two regional studies in South and Southeast Asia. Household surveys combined with group interviews to develop a comprehensive view of farmers' land-use systems and their perceptions of the role of trees in those systems.

Tree products of food, fuelwood, fodder, timber, and mulch contribute directly to household survival. Benefits of village agroforestry systems are diverse, but food products are of outstanding importance among them. The ability of *Artocarpus heterophyllus* and *Cocos nucifera* to ensure food security during the dry season and to provide familiar, traditionally used food products throughout the year are reasons why these species are found widely in the study villages. Another important factor is their ability to adapt to a limited space in the face of limited land and still yield food products.

Also observed was the differential importance of state forest, homegarden, and farm cropland as sources of tree products. These differences relate to availability as well as household parameters.

Participatory sketching of tree ideotypes helped in understanding farmers' tree-breeding objectives, and how these objectives differed depending on a tree's ecological niche and the agroforestry production system. Again, more efficient space allocation was identified by farmers as a focus for tree improvement, along with improved quality and quantity of products.

These findings need to be further studied before intervention strategies are formulated. Efforts to promote agroforestry systems among small-scale farmers through introduction of improved varieties must recognize farmers' practices and expressed needs regarding tree products and characteristics. On this basis, priority species meriting improvement efforts in the study area are *Artocarpus heterophyllus*, *Tamarindus indica*, *Psidium guajava*, and *Madhuca longifolia*.

1. Introduction

1.1. Farm and Village Forests

Farm and village forests have been maintained as part of rural survival systems for generations, with their composition and structure often determined by the farmers. The composition of village forests, used as a common and free source, is often determined by natural conditions. The culture of tree-use practices depends not only on the type of products obtained, but also on socio-economic conditions, needs, desires, traditional technologies, as well as knowledge and experience of the users. Household food and energy requirements are well-recognized priorities. The priority assigned to the productive function of trees sometimes leads scientists to overlook their conservation and protective functions. The value of providing shade and coolness, for example, is often acknowledged only after the detrimental effects of clearing trees are realized.

In Sri Lanka, trees have been cleared from farmland to accommodate newly promoted agricultural monocrops and harvested for construction timber and other products to lessen financial hardship. Depletion of trees from farmlands and other supply sources has increased pressure on village forests. The result has been rapid fragmentation of village forests located on common lands and reserve areas. Attempts by the village forest users to enrich and restore the composition have been mostly negligible. This is largely because the people who plant trees do not have harvesting rights.

Before improving these circumstances, we must explore how traditional village communities meet their needs and examine how tree-use practices differ among communities and households. Broadly, users' perspectives vary not only with regard to tree products, but also with regard to species characteristics. In maintaining and growing trees within a limited land area, a farm family's decisions are influenced by a number of key issues related to their needs and experience. Thus, tree-use practices vary across regions, agro-ecological zones, and households.

Bearing this potential for diversity in mind, research was conducted in two villages to explore the farm and village tree-use practices. By identifying priority species, their uses, preferred characteristics, and locations for tree species, this study aimed to highlight aspects for incorporation into intervention programs. This research, which gives priority to farmers' expressed needs and views, can facilitate formulating a farmer-oriented approach to promoting tree species.

1.2. Agroforestry Systems

Agroforestry, in the broadest sense, encompasses a wide range of production systems, from forest to crop monocultures. In terms of composition, structure, management practices, and production functions, well-marked variations exist among these systems. Within the current context, it is a sustainable land-management system that increases total production,

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combines agricultural crops, tree crops, forest plants and/or animals simultaneously or sequentially and applies management practices compatible with the cultural patterns of the local population (Bene, Bealle, and Cote 1977). As land-use systems, agroforestry systems are distinguished by their diversity in composition and structure and the multiplicity of their output.

The manner in which farmers grow and maintain trees and perennial shrubs in a single production system with other components, such as agricultural crops and animals, is often determined by a number of external governance and intra-household characteristics. Changes in the overall economy and agriculture have overriding effects on farmers' agroforestry decisions. Household decisions on species selection also vary.

Many innovative technologies relating to agroforestry, from species selection to utilization, have evolved through experimentation. Traditional agroforestry systems, on the other hand, based largely on indigenous knowledge and species, are part of the cultural patterns of the community. The gap between these indigenous systems and modern innovations is wide, despite attempts to replicate traditional systems with external support. Integration of indigenous knowledge and experience in promoting agroforestry remains a prerequisite to ensure social acceptability and sustainability. Understanding local tree-use practices, then, is necessary for formulating adoptable agroforestry systems.

1.3. The National Situation

With the expansion of agriculture and settlements in Sri Lanka, a substantial area of forest land has been destroyed (from 46% in 1956 to 26% in 1982). The unrecognized transition associated with the decrease in numbers of trees on farmland is more widespread than these figures suggest. On an average, 40 to 70% of the trees on farmlands alone have been depleted since 1956 (Wickramasinghe 1990a). The direct implication on the environment is advancing desertification and deterioration of land resources. Its consequences for rural survival are the collapse of subsistence living, reduced household food security, and increased scarcity of tree-borne products.

Under these circumstances, it is important to see how people meet their needs with the limited resources available to them. Nearly 26% of the land cultivated is devoted to traditionally maintained homegardens. These are meant to provide owners with food, fuel, timber, and fodder while sustaining a livable environment.

Competition among tree users for common sources of tree products is heavy in areas where sources of supply are poor or inadequate. Dependence on tree products for food and fruit is heavy among the poor, who are unable to generate an adequate off-farm income to support a family or produce other commodities to meet the family's food needs. Apart from these factors, the culture of tree-use practices and local food habits have important effects on farmers' species decisions.

2. General Characteristics of the Study Areas

2.1. Location and Agro-ecological Setting

The villages selected for this study, Bambarabedda and Madugalla, are located in Sri Lanka's central highlands. The morphological diversity of this area has led to spatial differences in the distribution of population, agricultural land-use, and tree species. Villages are characterized by steeply sloping terrain of mountains and ridges and deeply incised valleys. The effect of this natural diversity on rural living is significant. To a great extent, the selected communities represent a number of features of highland villages. Settlements are confined to the foot of slopes where water is available and soil conditions are favorable for cultivation. Village expansion is restricted to tea lands established during the colonial administration of the nineteenth century. This has caused them to depend heavily on resources available within their village boundaries. However, with increasing population and scarcity of croplands, the expansion of village settlements into the steeply sloping terrain has occurred rapidly, particularly during the last three to four decades.

Both Bambarabedda and Madugalla are located within the Assistant Government Agent (AGA) Division of Udadumbara in Kandy District (Figures 1a and 1b). Both communities are remote, located within the catchment of Ma Oya, a tributary of the Mahaweli River. About 61 to 80% of Bambarabedda is mountainous; about 10 to 20% consists of rolling plains located along the river basins. In Madugalla, mountainous terrain is limited to 41-60%, a substantial proportion of which is on lower foot slopes and river terraces.

The differences between the agro-climatic conditions of these two villages are negligible. The average monthly temperature varies between 24° and 27° C. The lowest monthly temperatures are in January and February, the highest in April and May. The difference between monthly maximum and minimum temperatures is greatest in February when the maximum is 31° C and the minimum is 17° C. This marked difference is often a limiting factor in crop establishment.

These seasonal differences in the temperature, combined with the pattern of rainfall distribution, characterize the overall climate (Figure 2). The greatest rainfall is between October and February, when the northeast monsoon occurs. The next rainy season, which is less reliable, is called the southwest monsoon. It occurs between March and May. The area experiences two dry spells between these two rainy seasons, which are the slack seasons for agriculture.

Agro-ecologically, the area is located in the Intermediate Zone of the country (Figure 1a). Climatic conditions associated with this zone determine the cropping pattern and agricultural activities. For example, "Maha," the most prominent and reliable crop, is cultivated during the prominent rainy season between October and February, which is the peak season for agriculture. "Yala," a second crop, is grown after the shorter rainy season between March and May, the slack season for agriculture. Unlike Maha, Yala is unreliable.

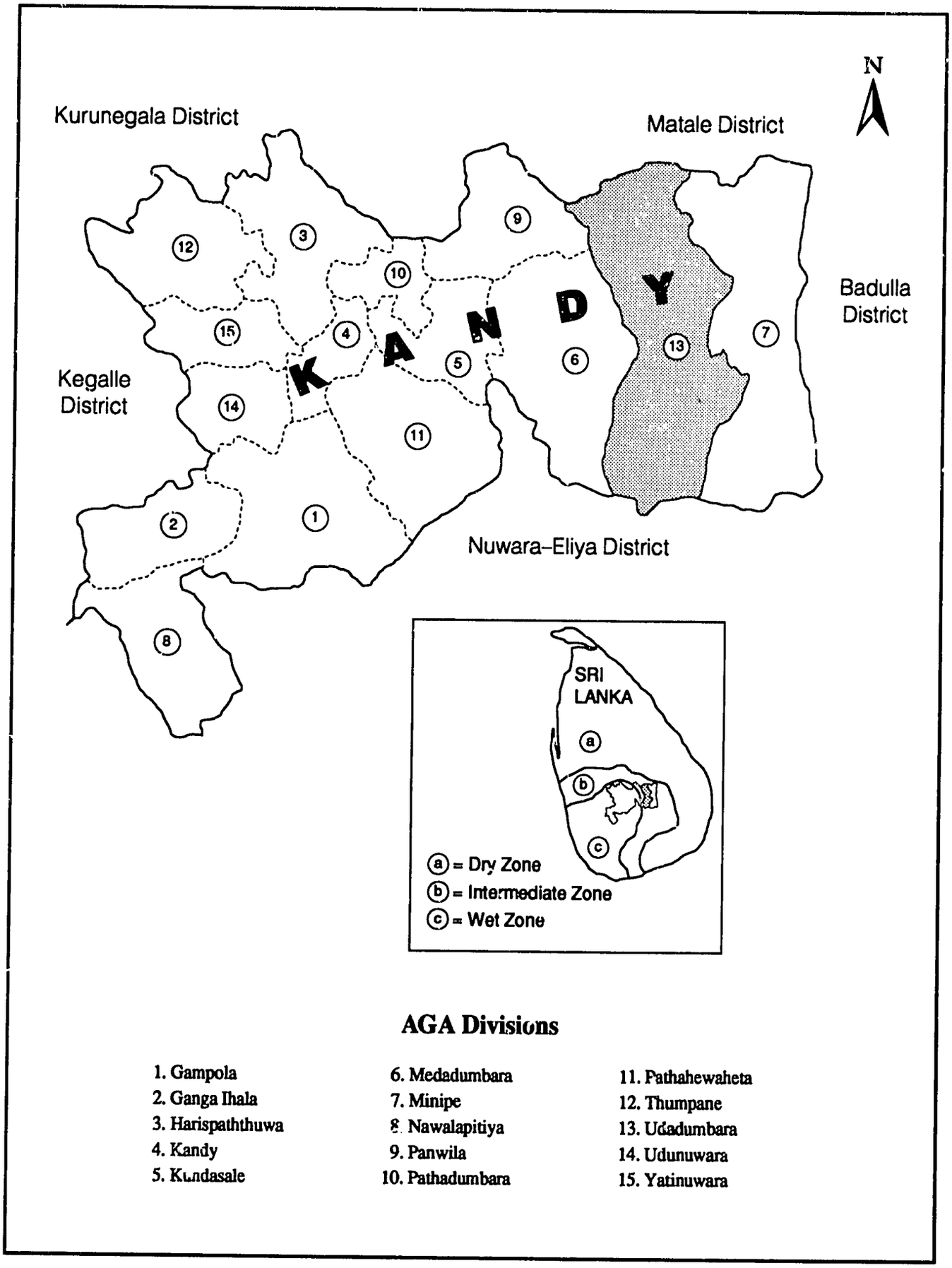

Figure 1a. Map showing AGA Divisions of the Kandy District of Sri Lanka

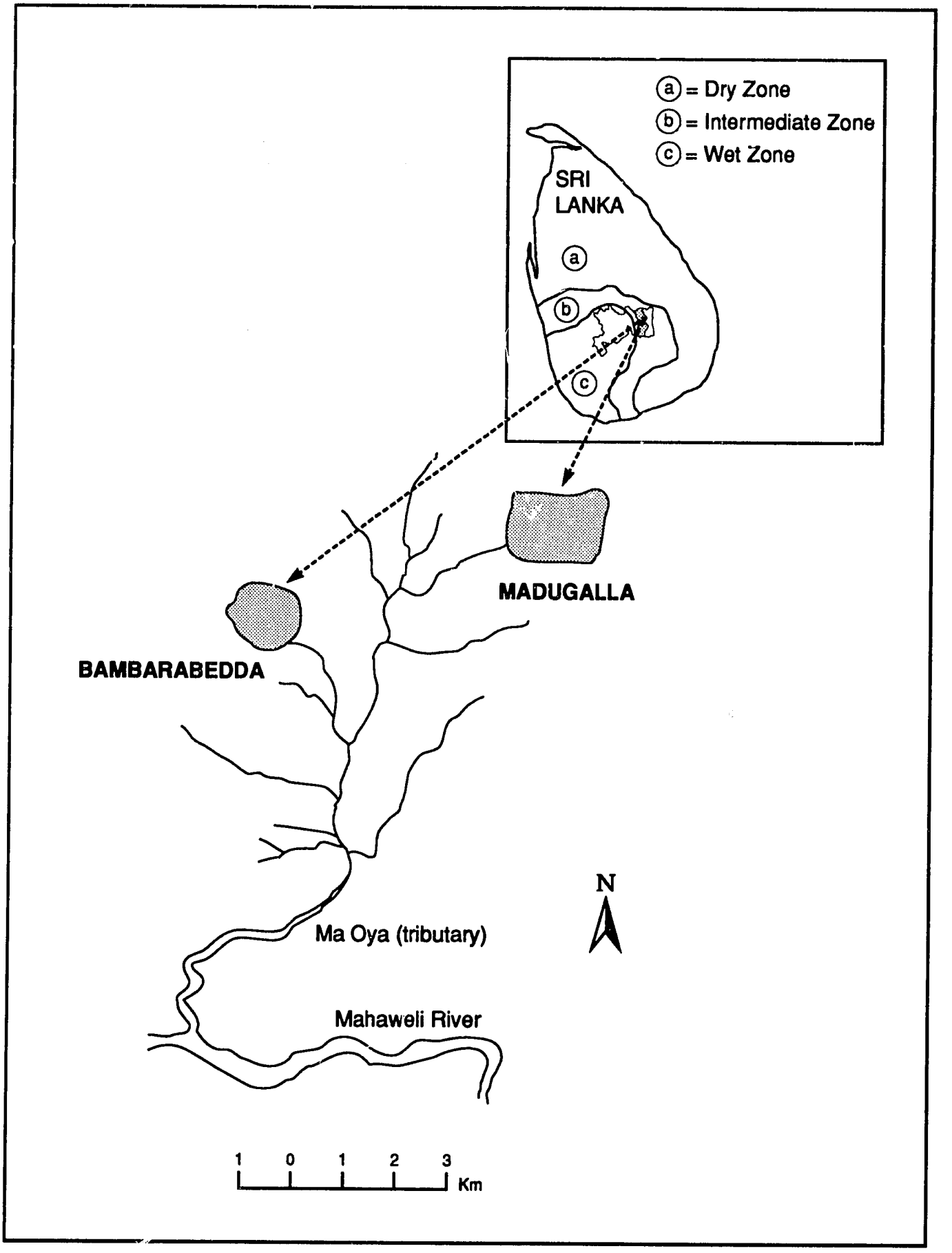

Figure 1b. Locations of Bambarabedda and Madugalla within the AGA Division of Udadumbara

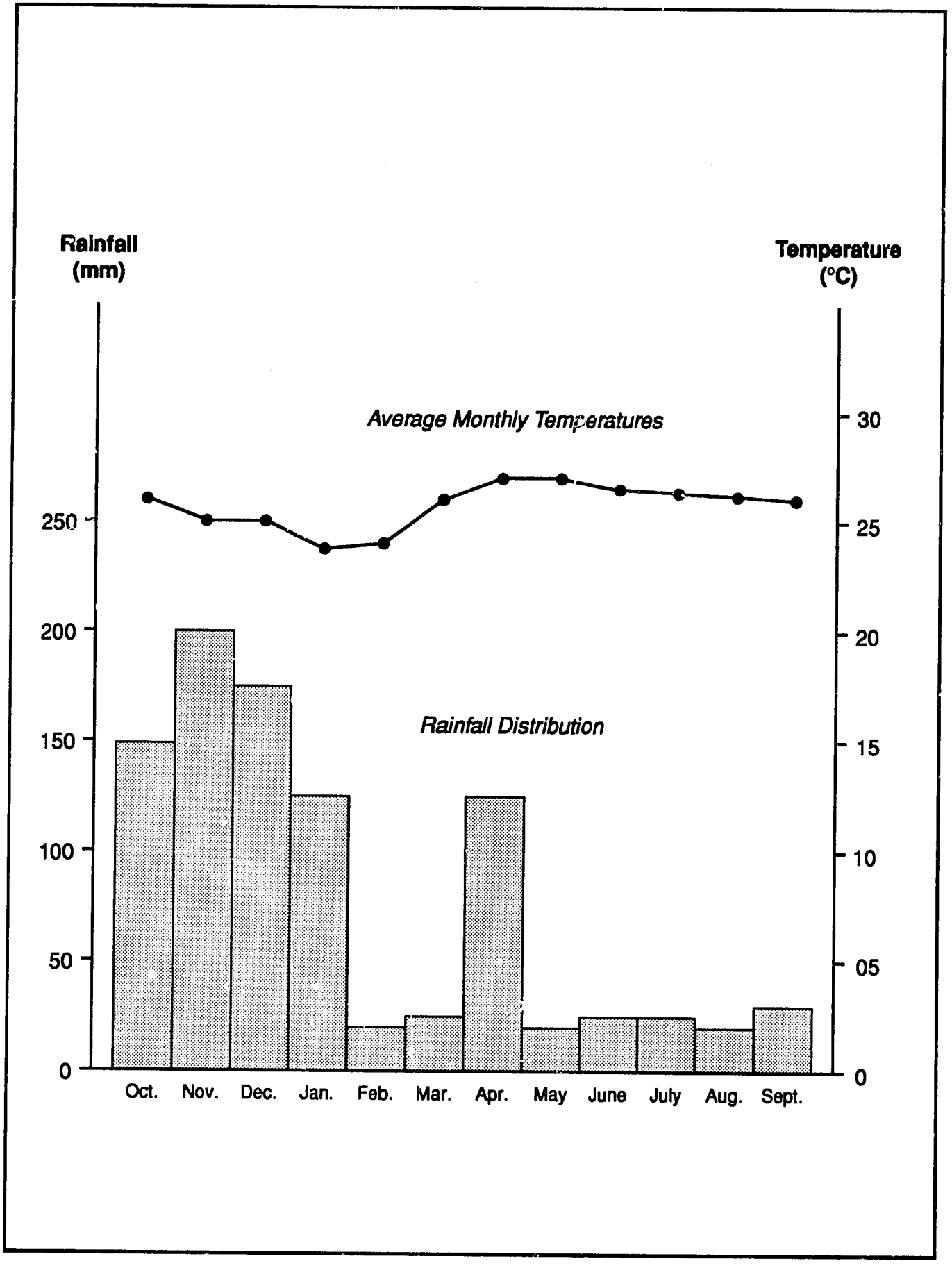

Figure 2. Average Monthly Temperatures and Rainfall Distribution in the Study Areas

The adverse effects of extreme seasonality on agriculture was crucial in both communities. For most inhabitants, agriculture remains the sole source of food, income, and employment. Under such circumstances, it is important to see how agricultural land use is designed to overcome the adverse effect of rainfall seasonality and fluctuations in crop production to eliminate the possible hardship during intermediate dry spells.

2.2. Land-Use Patterns

The extent of land available for the two communities varies considerably. The total land area in Madugalla is about 1,466 ha; in Bambarabedda it is only 349 ha. The predominant land-use systems are paddy rice, homegardens, and highland farming. The disparity in the distribution of land area between these villages becomes clear when non-agricultural areas are excluded. About 28% of the land in Bambarabedda is under forest and remains state property (Table 1). In Madugalla, the forested area is 33%. According to state legislation, dwellers have no legal access to forest resources. The direct implication is that dwellers must rely on their own resources to meet their needs.

Table 1. Land use in the study villages

	Bambarabedda		Madugalla	
Land use type	No. of ha	% of total land	No. of ha	% of total land
Forest (natural and plantation)				
Government	99	(28)	490	(33)
Private	0	(0)	0	(0)
Common	0	(0)	0	(0)
Agriculture				
Annual crops				
Rice	33	(9)	497	(34)
Other annuals	37	(11)	160	(11)
Perennial crops	6	(2)	0	(0)
Agroforestry	67	(19)	65	(4)
Fallow	34	(10)	73	(5)
Permanent Pasture	10	(3)	15	(1)
Homegardens	63	(18)	166	(11)
Unspecified				(1)
Total	349	(100)	1,466	(100)

Source: Wickramasinghe 1990b

The total land area under agricultural crop production is 177 ha in Bambarabedda and 795 ha in Madugalla. About 34% of the land in Madugalla is devoted to paddy, the staple diet; paddy is limited to 9% in Bambarabedda. Land devoted to perennial and agroforestry systems is 21% in Bambarabedda and only 4% in Madugalla. Land devoted to homegardens, the age-old indigenous agroforestry system in the country, is about 18% in Bambarabedda and 11% in Madugalla. The wide gap in land distribution between two villages becomes less significant in terms of actual area (Table 1). The percentage distribution of land among categories reveals priorities among the different alternatives. In Bambarabedda, the farmers' priority is on tree-based systems in areas where the potential for growing paddy is restricted by environmental limitations. In Madugalla, farmers grow tobacco in areas not used for paddy.

2.3. Land Tenure and Property Issues

Land tenure and property issues vary with differences in property ownership. Commonly, trees are owned by the person who owns the land. For trees on reserved land, which stretches along the hedges to the paddy tracts and river banks, tenurial rights were traditionally given to owners of adjoining lands or the paddy tracts. Acceptance of such traditional tenurial systems allows farmers use of resources without disputes.

This is not the same as state or common property. Strictly speaking, people have no access to state land (in this case, state forests). Use of state land either for cultivation or extracting wood, timber, and fuelwood are strictly prohibited. Still, collection from the state property continues. In addition, the seasonally fallowed croplands and degraded tea lands are commonly used for grazing animals. Although tenurial and property rights are not formally recognized, people tend to use the open state property freely. For private land, both tenurial and property rights are tightly bound up with land ownership. However, where private lands are neglected, resource-poor farmers tend to graze their animals and harvest tree products without obligation.

2.4. Socio-Demographic Features

Both communities in this study are located close to the Ma Oya River (Figure 1b). These are traditionally old villages, homogeneous in ethnic and religious composition. The average family size in Madugalla is 1.6 greater than that of Bambarabedda (Table 2). Although the number of households is nearly the same for both villages, the larger family size in Madugalla results in a population 274 greater than Bambarabedda. These demographic characteristics, combined with the land area data, result in the two distinct person-land ratios in Table 2. The extremely low person/land ratio in Bambarabedda means an increasing pressure on agricultural land. Moreover, the implication of this on the agriculture-dependent community is prevalent unemployment and underemployment, poor living conditions, and inadequate food supply and production. The disparity between villages

Table 2. General demographic and land distribution characteristics of the communities

Aspect	Bambarabedda	Madugalla
Total area (ha)	349	1,466
Number of households	398	334
Land per family (ha)	0.88	4.4
Land per family, excluding forests (ha)	0.62	2.8
Total population	1,600	1,874
Land per person (ha)	0.2	0.78
Land per person, excluding forests (ha)	0.16	0.5
Average family size	4.0	5.6
Number of children (6-11 years of age)	282	296

Source: Field information

is further widened by unequal land distribution in both communities. Poor-quality land and the seasonality of rainfall tend toward low output from the land available for crop production. This situation leads directly to over-exploitation of state properties in the villages and surrounding areas. Any development intervention should therefore address the problems in a community-oriented manner. In this context, a diagnostic approach to land and tree use practices is fundamental to planning socially acceptable land use and land management.

2.5. The Agroforestry Systems

The agroforestry designs prevalent in these villages have emerged without external inputs or advanced technologies. Many of the land-use systems are agro-silvicultural, although structure and composition vary among systems. With the agrarian changes of the last four decades, the tree component of the traditional farmlands has declined. If all the land-use systems that can be categorized as agroforestry systems are placed on a gradient, then a shift can be seen from homegarden to farmland. This means that indigenous species located on farmlands are disappearing to make way for promoting new crops.

The distribution of trees and tree-based systems can be prioritized as follows: 1) homegardens, 2) reserved areas, 3) hedges and hedgerows, 4) fences, 5) common land, and 6) highland farms. (This order was derived from farmers' statements in group meetings and is associated with density of tree species and diversity of species composition and utilization.)

The prominent place for trees in these villages is homegardens. Unlike the other systems, the homegarden has its own identity due to the dense composition, multistory structure, multiple composition, and existence of tended species. Trees along fences, hedges,

and hedgerows are maintained and protected as permanent features that indicate boundaries of land ownership. Thus, these species must be able to remain in a row without covering much of the land. The difference between fences and hedges is that hedges are not as linear as fences. They tend to be at least 1-2 m wide and consist of trees and bushes, rather than a single-stemmed species. Trees predominate in reserved areas and common land, varying in terms of physical form and management practices. In such areas, self-germinated species are widespread. The converse is true of homegardens. Farmers' ability to use the reserved and common land as common and free sources of supply is the main factor inhibiting tending trees in such areas. Although villagers collect a range of outputs from such areas, less effort is taken to enrich the area or protect against over-exploitation. The importance of tenurial rights and private ownership becomes apparent in promoting community agroforestry.

The model of tree distribution shown in Figure 3 enables us to explore the variations in farmers' preferences. If homegardens in this area are viewed as indigenous agroforestry systems, then the following facts, stressed in group discussions, can be emphasized:

- Farmers' experience with the compatibility between and complementary benefits of trees permit them to grow a variety of trees and crops in homegardens;

- Multiple outputs, which can be placed on a gradient prioritized according to use, is important in making decisions about trees;

- Farmers' interest in tending trees in close proximity to their dwellings needed mostly for household survival is an important issue. According to farmers' own descriptions, a homegarden means not only a piece of land adjoining their dwellings. It is a piece of land that provides them a range of products throughout the year for the survival of their family. It is maintained by minimum inputs, using labor and time of the family. In addition, the livable environment created by the family is an indicator of better family sustenance;

- Desire of growing trees that provide multiple products, especially food/fruit within close access to the kitchen has other implications. To women, the homegarden is a kitchen garden. Excess products obtained from such kitchen gardens enable them to get cash. By growing food- and fruit-producing species in close proximity to homes, they can protect the harvest and maintain and tend the trees with little effort.

In this context, decisions about the composition of village agroforestry systems created with indigenous knowledge and experience can be well-described. Differences in the composition and structure of the village agroforestry system and farmers' desires and attitudes about these differences are due to some underlying reasons. Sole ownership of the land and related tenurial rights make them grow the most productive species. At the same time, villagers tend to collect from state lands whatever products they can.

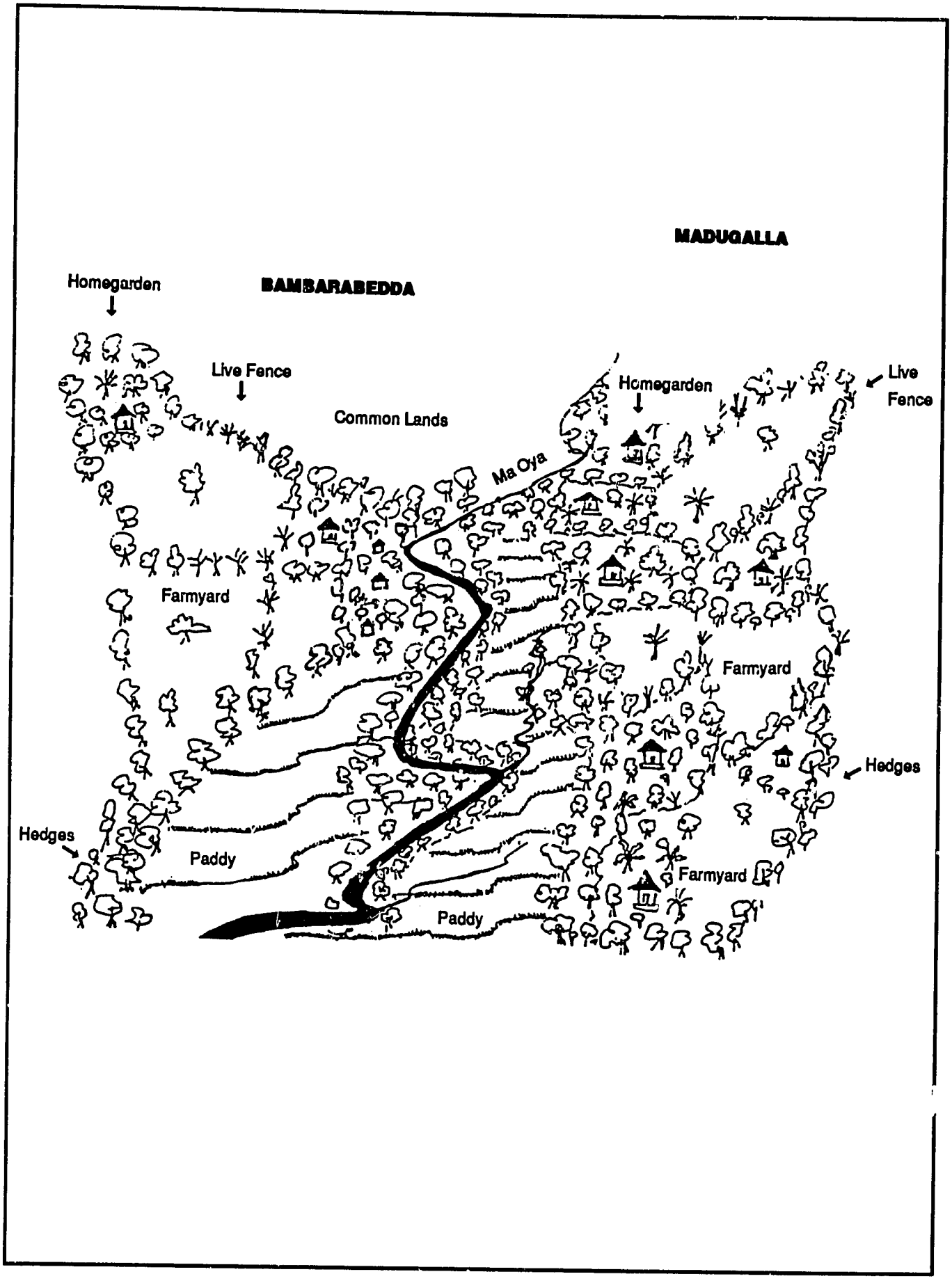

Figure 3. Common Models of Tree Distribution in the Study Villages

The type and number of species grown and maintained by farmers vary according to the composition and uses of a total land area. Often, if the condition of land is suitable and the extent adequate, a family's land is composed of three units: homegarden, paddy plot, and highland plot. To a great extent, this can be seen as a traditional way of allocating a family property. The main intention behind this type of division is to ensure self-sufficiency in family food production. The homegarden is the area from which most of the tree-borne food and fruits are obtained for the family pot. In addition, a variety of tubers, pods, pulses and green leaves are produced in small quantities and fuelwood used for a family consumption. In these areas, paddy is grown in monoculture. Yet, demarcation of paddy boundaries with a hedgerow on either side of a tract classifies it as a form of village agroforestry system. However, as it is meant to produce the family's staple diet, which is rice, interest in growing trees along the hedges is extremely low. The species grown along the hedgerows, fences, and reserve areas therefore differ from those in homegardens. To examine the situation more closely, a field investigation by household was carried out.

3. Methods

Fifty households were selected randomly from each of the two villages. For the inventory of tree-use practices, this sample was reduced to 25 households from each village. The regional network study employed the methods of sample selection and household survey described by Mehl (1990). In addition to the pre-formulated questionnaires, group discussions were held to identify farmers' tree-breeding objectives. Although the method used to obtain this information generally followed the methods described in the report of the regional tree-breeding objectives study by Chuntanaparb and Ranganathan (1990), many modifications were made.

Among the more noteworthy modifications were those related to participatory mapping. A visual image of village layout, shown in a mosaic of aerial photographs, helped locate specific visual features and identify village land-use patterns. This permitted the groups to analyze land-use practices and discuss specific issues related to tree management. For example, this tool enabled participants, both literate and illiterate, to discuss disliked characteristics of certain species that they managed.

After introducing line drawing examples of stem form and canopy shape, participants were invited to sketch drawings representing their own ideas about desirable characteristics. Ideotypes emerged through iterative changes based on participants' comments.

Then followed group discussion of undesirable tree characteristics. Finally, tree-breeding ideotypes were developed by refining the participants' sketches. The line drawings developed through this process helped show not only the ideotypes, but also the management practices that would be applied to species selected for different agroforestry systems.

4. Forest and Tree-Use Practices of the Villages

4.1. Features of the Study Sample

In the study area, law denies access to state forests and common property on reserve areas. The data gathered by the household survey shows a marked difference between these two villages. To simplify the wide range of differences that exist among households and between the two villages, all the households were categorized into three groups based on household income, housing condition, and land property. Table 3 shows that almost 86% of the sample households in Bambarabedda have incomes of less than US$ 40 per month, poor housing, and a total land area of less than 3 ha. This segment is comparatively lower in Madugalla, only 54% of the total sample. This difference between the two villages leads us to ask whether poor communities use forests and trees differently than do comparatively better-off communities.

In both villages, the primary source of income and employment is agriculture. Their sources of food include field crops, animal products, and tree products. Although households in this sample obtain an income by selling tree products, more than 80% require tree products to meet the daily needs of their families.

Field crop products are meant for subsistence and cash, depending on the nature of the crop and quantities produced. Madugalla, the better-off community, has a specific identity in terms of producing cash crops. About 68% sell either a portion of the products or the whole harvest. Whole harvest of tobacco, widely cultivated in Madugalla, is grown for sale. Tobacco is less prominent among farmers in Bambarabedda, mainly due to their lack of land

Table 3. Number of households in each community, by level of wealth

	Bambarabedda		Madugalla	
Wealth category*	No. of households	% of total households	No. of households	% of total households
Low	43	(86)	27	(54)
Medium	6	(12)	17	(34)
High	1	(2)	6	(12)
Total	50	(100)	50	(100)

* Low = monthly income < US$40, dwelling with floor area < 50 m², and family landholding < 3ha
Medium = monthly income US$41-80, dwelling with floor area 51-100 m², and family landholding 3.1-10 ha
High = monthly income > US$80, dwelling with floor area > 100 m², and family landholding > 10 ha
Source: Wickramasinghe 1990b

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on which to grow such cash crops. The other category of crops, grown partly for the market, is vegetables. Various vegetables are popular among small-scale producers in Bambarabedda, but they are produced seasonally and in small quantities. The direct implication for Bambarabedda is greater dependency on various types of income-generating activities, such as livestock rearing.

Four reported types of livestock are kept in these villages: cattle, water buffalo, goats, and chickens. Rearing animals is more common in Bambarabedda than in Madugalla. Nearly 68% of the households in Bambarabedda and 36% in Madugalla are engaged in keeping small livestock. Cattle reared in these two villages are used in caravans to carry crop products to transport roads and markets. (This is the primary mode of transport in Bambarabedda.) Water buffalo are reared for agricultural work. Agro-silvopastoral systems are popular among dwellers in Bambarabedda, where market-oriented, agricultural crop monocultures like tobacco are not widespread.

Extent of farmland varies considerably among households. On the average, a family in Madugalla owned nearly 3 ha of land compared to 1 ha in Bambarabedda. However, in actual terms, the land owned by a small-farm family in these areas ranged between .2 and 1 ha, while a medium-sized farm ranged between 1 and 4 ha. Medium- and large-scale farmers are better-off in terms of income, food production, and employment. Less competition for land was observed among the larger farm categories.

The area of land cultivated by the sample households and the number of plots owned by them also varied. As shown in Table 4, the number of families having two or three plots is higher in Madugalla. Another feature seen here is the bigger farm plots and also homegardens. This means less dependence on external sources to fulfill household needs.

The villagers' access to common property (village forests, state forests, reserve lands, fallow, and hedgerows) has a number of practical implications. The information gathered regarding their perceptions on this matter reflects the nature of their links with such properties (Table 5). No access to village forests was reported by 82% of the families in Bambarabedda, while unrestricted use of village forests was reported by 70% in Madugalla. (The reason farmers in Madugalla have unrestricted use of village forests is that small forest patches are found scattered along the banks of the Ma Oya tributary, which flows through the village, as well as on the margins of paddy tracts. In Bambarabedda, on the other hand, the Ma Oya does not flow through the village; thus, the forest is not located in scattered patches but is clearly separated from the settlement area and continues into protected forested areas.)

4.2. Forest-Use Practices

Aspects considered regarding forest use practices are limited to a wide range of common forest uses. The levels at which farmers depend on various sources to obtain products vary by availability and access, in addition to needs and traditional practices. Villagers most

Table 4. Farm plots per household and their primary uses

	Bambarabedda	Madugalla
Total area cultivated (ha)	61.55	149.3
Total number of farm plots	113	126
Number of households with one plot	50	50
size range (ha)	0.05-1.2	0.02-2.0
primary use	homegarden	homegarden
Number of households with two plots	23	43
size range (ha)	0.05-2.0	0.2-3.2
primary use	annual crops	annual crops
Number of households with three plots	17	21
size range (ha)	0.4-2.0	0.8-4.8
primary use	annual crops	annual crops
Number of households with four plots	2	0
size range (ha)	0.4-2.0	-
primary use	agroforestry	-

Source: Wickramasinghe 1990b

Table 5. Household views regarding access to common property[a,1,2]

Common property type	No access		Unrestricted use		Controlled use		Seasonal use		Common property not used	
	BB	MD	BB	MD	BB	MD	BB	MD	BB	MD
Commons	1	42	25	5	24	2	-	-	-	1
Fallow	5	11	38	39	7	-	-	-	-	-
Barren land	5	3	31	42	12	4	1	1	-	-
Village forest	41	9	1	38	6	3	2	-	-	-
State forest	43	43	1	4	6	3	-	-	-	-

[a]Numbers indicate number of households
[1]BB = Bambarabedda
[2]MD = Madugalla
Source: Wickramasinghe 1990b

commonly reported that forests are traditionally used to obtain (in order of priority): 1) food and fruit, 2) fuelwood, 3) fodder for animals, 4) timber, 5) medicinal stuffs, 6) agricultural poles and fencing materials, and 7) industrial raw materials.

With the depletion of forests and trees from freely-used common areas, villagers depend more on other sources. Tables 6 and 7 reveal that many households presently obtain fuelwood and construction materials from state forests, while their main source of food is their own homestead and farmland. Timber use is almost insignificant because timber is not needed continuously. Fodder use is also less significant because stall-feeding animals with tree fodder is little practiced.

This data reveals the difference in species distribution by their sources. Many species in large state forests are used to meet community needs, whereas a lesser number are reported from the homegardens. Diversity in species composition is greater where land area on each source of supply is bigger. This is particularly so with regard to the better-off of Madugalla where the land area on each source of supply is comparatively bigger.

Priority placed on the sources of supply in terms of priority products varies. Comparison of Tables 8 and 9 indicates the importance of government forest in providing fuelwood, construction timber, fruit/food, and fodder. This is because, in the absence of reserved areas and village forests within closer access, and the limited extent of farmland, paddy tracts, and homegardens, villagers depend largely on state forests. This is particularly true in Bambarabedda. Conversely, if the sources of supply are large, pressure on a single source is less, as in the case of Madugalla. In such areas, the distance travelled to collect products is also less. Many households in Bambarabedda travel more than 3 km per trip to collect tree products. This is so among 18 households in getting fuelwood, 6 in getting fodder, 10 in getting fruit and food, and 13 in getting construction materials. Excluding fodder, none of the other purposes requires daily trips; it was difficult to determine an average weekly distance travelled due to extra-household variations.

However, households of the whole sample in both communities (almost 15 in Bambarabedda and 8 in Madugalla) used state forest to get construction materials during the period 1950-1970. After 1970, this number decreased to 6 in Bambarabedda and 2 in Madugalla. This is due to the rapid depletion of timber species and mature trees. As a consequence, purchases of construction materials have increased substantially.

Dependency of these villages on forest for tree fodder is extremely low. The types of animal feed and method of feeding tend to vary seasonally. Although stall feeding is not widely practiced, feeding methods vary according to the rhythm in cultivation (Table 10). During cultivation, farmers keep animals in stalls and feed them on fodder and grass, depending on their availability.

Table 6. Uses of forest and tree species in Bambarabedda*

	Government Forest					Homestead					Farmland					Purchased				
	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C
Acacia caesia	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Adutilon asiaticum	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Alstonia macrophylla	-	3	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Areca catechu	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artocarpus heterophyllus	5	1	4	-	-	-	11	10	-	10	2	-	2	-	-	-	-	-	-	1
A. incisus	-	-	1	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Canarium zeylanicum	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Careya arborea	-	7	3	-	5	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cocos nucifera	-	-	-	-	2	-	-	18	-	2	-	11	8	-	-	-	-	-	-	5
Croton laccifer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dichrotachys cinerea	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus camaldulensis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Eugenia faranica	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E. malaccensis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Exacum trinerva	10	6	-	-	-	1	-	-	-	-	2	1	-	-	-	1	-	-	-	-
Grewia tilifolia	-	4	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macia caesia	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Madhuca longifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Mangifera indica	-	2	3	-	2	-	6	3	-	-	-	1	2	-	-	-	4	-	-	-
Melia azedarach	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Michelia champaca	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Musa acuminata	-	11	2	-	4	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
M. sapientum	-	1	-	-	-	-	-	3	-	-	6	-	2	-	-	-	3	-	-	1
Neolitsea cassia	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Persea gratissima	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	3	-	-	-
Phyllanthus emblica	-	-	6	-	-	-	-	-	-	1	-	-	1	-	-	-	3	-	-	-
Pongamia pinnata	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Psidium guajava	-	-	10	-	-	-	5	1	-	-	-	-	4	-	-	-	1	-	-	-
Pterocarpus marsupium	-	2	-	-	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3
Sesbania bispinosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Tamarindus indica	-	4	-	-	2	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
Terminalia belerica	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thespesia populnea	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Numbers indicate number of households using the product from that source.

Fo = Fodder, Fw = Fuelwood, F = Fruit and Food, T = Timber, C = Construction

Source: Field information

Table 7. Uses of forest and tree species in Madugalla*

	Government Forest					Homestead					Farmland					Purchased				
	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C
Acacia caesia	-	-	-	-	-	-	2	1	-	-	-	1	-	-	-	-	-	-	-	-
Adina cordifolia	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Aegle marmelos	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Albizia odoratissima	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alstonia macrophylla	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Areca catechu	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Artocarpus heterophyllus	2	2	1	-	-	4	2	5	-	4	3	-	-	-	1	-	-	-	-	2
A. incisus	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-
Azadirachta indica	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Careya arborea	-	3	-	-	-	-	2	-	-	1	-	1	-	-	1	-	-	-	-	-
Carissa spinaram	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Clerodendrum serratum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cocos nucifera	-	1	-	2	-	-	6	6	-	6	-	-	-	1	2	-	-	-	1	12
Croton aromaticus	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Elaeocarpus serratus	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eugenia malaccensis	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Exacum trinerva	5	5	-	-	-	1	5	-	-	-	3	3	1	-	2	-	-	-	-	-
Grewia tilifolia	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Litsea glutinosa	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-
Macaranga petata	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Madhuca longifolia	-	7	-	-	5	-	2	-	1	-	-	-	-	1	-	-	1	-	1	-
Mangifera indica	-	-	6	-	2	-	4	9	-	-	-	-	3	-	-	-	-	-	-	-
Michelia champaca	-	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2
Musa acuminata	-	1	3	-	1	2	1	10	-	-	1	-	5	-	-	-	-	-	-	-
Paspalum scrobiculatum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Persea gratissima	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piper nigrum	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Phyllanthus emblica	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pongamia pinnata	-	3	-	-	-	-	1	-	-	-	-	1	-	-	1	-	1	-	-	-
Psidium guajava	-	1	6	-	-	-	-	3	-	-	-	-	1	-	-	-	-	-	-	-
Pterocarpus marsupium	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
Salacia reticulata	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Sesbania bispinosa	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. grandiflora	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tamarindus indica	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thespesia populnea	-	1	-	-	3	-	1	-	-	1	-	-	-	-	-	-	-	-	-	1
Vitex altissima	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V. pinnata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Zizyphus napeoa	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* Numbers indicate number of households using the products from that source.
Fo = Fodder, Fw = Fuelwood, F = Fruit and Food, T = Timber, C = Construction
Source: Field information

Table 8. Ranking of sources to meet community needs for products, collectors, and availability in Bambarabedda*

	Government Forest					Homestead					Farmland					Purchased					Purchased Non-Tree Product				
	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C
Importance of source																									
Primary	12	24	14	-	18	2	-	5	-	-	2	-	4	-	1	1	1	3	1	4	-	-	-	-	1
Secondary	3	-	1	-	3	1	1	2	-	1	11	13	9	1	5	-	-	4	-	5	-	-	-	-	9
Minor	-	-	-	-	-	-	2	-	-	1	-	1	-	-	-	7	-	3	-	1	4	-	3	-	8
Consumption pattern																									
Household use	15	22	14	-	-	3	3	7	-	-	13	4	13	1	-	8	1	10	-	-	4	-	3	-	1
Household use and sale	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Sale and trade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seasonality																									
Year-round	2	10	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seasonal	13	14	11	-	-	2	3	11	-	-	14	14	9	1	-	8	1	10	1	-	4	-	3	-	-
Collector																									
Male adult	1	6	1	-	-	1	-	1	-	-	2	4	2	-	-	1	-	1	-	-	-	-	-	-	-
Female adult	4	2	3	-	4	1	1	2	-	-	5	2	4	-	2	1	1	-	-	-	-	-	-	-	4
Male child	14	18	12	-	19	1	1	5	-	2	11	9	6	1	5	6	1	7	1	11	2	-	2	-	13
Female child	4	19	12	-	7	-	-	8	-	2	7	13	8	-	2	-	-	6	-	5	2	-	1	-	1
Distance travelled																									
< 1 km	2	-	-	-	1	1	-	7	-	3	1	2	1	1	-	-	-	-	-	1	-	-	-	-	-
1-2 km	4	5	4	-	4	2	3	1	-	-	5	7	2	-	2	-	-	-	-	2	-	-	-	-	2
2-3 km	3	3	-	-	1	-	-	-	-	-	4	2	2	-	-	-	-	-	-	-	-	-	-	-	-
> 3 km	6	18	10	-	13	-	-	-	-	1	4	4	4	-	3	8	2	8	1	9	4	-	3	-	16

* Numbers indicate number of households.

Fo = Fodder, Fw = Fuelwood, F = Fruit and Food, T = Timber, C = Construction

Source: Field information

Table 9. Ranking of sources to meet community needs for products, collectors, and availability in Madugalla*

	Government Forest					Homestead					Farmland					Purchased					Purchased Non-Tree Product				
	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C	Fo	Fw	F	T	C
Importance of source																									
Primary	2	7	6	1	8	6	8	9	-	3	4	2	4	-	3	-	1	6	-	9	1	-	-	-	-
Secondary	4	6	3	-	1	2	9	8	2	6	4	4	6	-	5	-	-	4	-	5	2	-	-	-	1
Minor	-	-	3	-	1	-	1	1	-	-	-	2	2	-	-	-	-	5	1	2	3	-	6	-	8
Consumption pattern																									
Household use	6	13	12	-	-	8	18	18	-	-	8	8	12	-	-	-	1	15	-	-	6	-	6	-	-
Household use and sale	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Sale and trade	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Seasonality																									
Year-round	1	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Seasonal	6	15	12	1	-	8	16	19	1	-	8	12	9	-	-	-	-	13	1	-	6	-	6	-	-
Collector																									
Male adult	6	12	8	1	10	3	5	8	1	12	1	4	7	-	5	-	1	8	1	16	1	-	7	-	8
Female adult	1	16	4	1	5	5	16	14	1	1	1	7	7	-	2	-	-	10	1	3	3	-	4	-	-
Male child	2	-	5	-	-	3	1	4	-	2	3	4	-	-	1	-	-	3	-	4	2	-	3	-	-
Female child	-	5	4	-	-	1	3	6	-	-	1	4	-	-	-	-	-	2	-	1	-	-	-	-	-
Distance travelled																									
< 1 km	3	6	2	-	3	8	19	8	-	13	6	8	7	-	4	-	-	-	-	1	-	-	-	-	-
1-2 km	3	11	7	1	3	-	2	-	1	-	2	-	-	-	-	-	-	-	1	1	-	-	-	-	-
2-3 km	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-
> 3 km	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	10	-	1	4	-	6	-	9

* Numbers indicate number of households.

Fo = Fodder, Fw = Fuelwood, F = Fruit and Food, T = Timber, C = Construction

Source: Field information

Table 10. Livestock farming in the study villages

	Cattle	Water buffalo	Goats	Chickens
Bambarabedda				
Number of households	15	8	2	5
Stock	40	27	6	40
Type of feed				
Leaves, flowers, and other tree products	14	8	2	-
Grass and other range products	14	8	2	2
Crop and grain residues	-	-	-	4
Purchased feed	-	-	-	4
Feeding method				
Stall feeding/cut and carry from own source	-	1	-	-
Stall feeding/cut and carry from other source	-	1	-	-
Tethered	14	7	2	5
Roam untethered	17	7	2	4
Madugalla				
Number of households	8	-	2	4
Stock	34	-	14	23
Type of feed				
Leaves, flowers, and other tree products	7	-	2	-
Grass and other range products	7	-	2	-
Crop and grain residues	-	-	-	4
Purchased feed	-	-	-	1
Feeding method				
Stall feeding/cut and carry from own source	3	-	1	-
Stall feeding/cut and carry from other source	3	-	1	-
Tethered	4	-	2	3
Roam untethered	4	-	-	4

Source: Wickramasinghe 1990b

Among forest products, fuelwood is the most extensively used. In the two communities studied here, fuelwood is the main source of energy used in domestic cooking. It is also the source of energy used in tobacco curing. The tobacco industry is the largest consumer of fuelwood, which results in an increasing scarcity of fuelwood, particularly the better wood for domestic consumption. The pattern of supply, demand, and utilization varies among households and environmental and socio-economic conditions are affected by a number of interrelated factors.

The amount of fuelwood used in domestic cooking varies remarkably. This is not due to family size alone, but also to the amount of time it takes for the wood to burn, number of pots prepared, and meals cooked per day. The average amount of fuelwood consumed by a family in cooking was extremely high in Madugalla. (The amount varies between 15 and 20 kg per day.) This is mainly because meals are cooked in large quantities for farm workers during the agriculture seasons. If the food prepared is only for the family, this amount is reduced to about 11 kg per day. Consumption of fuelwood by the poor, who do not eat three cooked meals per day, varies between 8 and 10 kg in the Bambarabedda sample. Therefore, wood demand is not only site-specific but also varies among households.

The primary sources of fuelwood supply also varies between the communities and among households. In Bambarabedda, where the person/land ratio is extremely low and reserved land is scarce, the main source of supply is state forest. In addition to the state forests, own sources of wood supply from homegardens, hedges, and fences become important in Madugalla (Tables 11 and 12). Comparison of data on species distribution explains why fuelwood comes from a range of species in their own sources in Madugalla (Table 13). There, species diversity is available in their hedgerows to the paddy tracts and homegardens. In Bambarabedda, where species variation and sources of supply are low, villagers tend to depend on external sources of supply. However, group discussions revealed that the pressure on state property and reservations is increasing due to greater demand for domestic consumption. This is also attributed to the competition between domestic consumers and industry for fuelwood.

Due to expanded tobacco cultivation in the area, exploitation of forest sources for fuelwood for curing tobacco had increased tremendously. At present, thousands of cubic meters of forest wood are being transported from the dry zone and are piled up at regional fuelwood depots for future consumption. With the depletion of forests, all the wood energy consumed for tobacco curing is purchased. Between 1980 and 1990, the price of a cubic meter of wood more than doubled. According to the data gathered, about 3,600-4,000 kg of wood is needed to cure 1,000 kg of tobacco, costing Rs. 3,700-4,000 (about US$93-100).

As better-quality wood is needed in tobacco curing, competition between households and tobacco barn owners is not great. Yet, what had happened in the past was a tremendous reduction in the availability of dead wood, branch wood, and wood sticks often collected for domestic consumption. The harvesting of mature trees and bushes for tobacco curing has

Table 11. Priority ranking of the species in the two villages

Species	Bambarabedda		Madugalla	
	No.of Hh Growing	Rank	No.of Hh Growing	Rank
Artocarpus heterophyllus	24	1	11	1
Cocos nucifera	19	2	8	3
Mangifera indica	4	4	4	6
Artocarpus altilis	3	5	-	-
Gliricidia sepium	6	3	6	4
Coffea arabica	3	5	-	-
Psidium guajava	1	6	-	-
Tamarindus indica	1	6	-	-
Madhuca longifolia	-	-	9	2
Persea gratissima	-	-	2	7
Acacia caesia	-	-	1	8
Croton laccifer	-	-	1	8
Pongamia pinnata	-	-	4	6
Musa acuminate colla	-	-	2	7
Eugenia faranica	-	-	2	7
Careya arborea	-	-	1	8

Hh = Households
Source: Wickramasinghe 1991b

reduced the tree density and the species composition, which has led to exploitation of even poor-quality wood and bushes for fuelwood, contrary to state laws meant to protect forest resources.

4.3. Species Grown

The number of species found among the sample households is 8 in Bambarabedda and 12 in Madugalla. As shown in Table 13 and Figure 4, the farmers' preference for *Artocarpus heterophyllus, Cocos nucifera*, *Mangifera indica*, and *Madhuca longifolia* indicates their priority uses expected through tending trees. Moreover, Table 13 shows how the uses of each of the three top priority species are concentrated heavily on their food-producing ability. In Bambarabedda, the farmers' criteria for selecting the first two priority species are related to food/fruit production. This is so for 96% of the households studied. The two species considered important here are *Artocarpus heterophyllus*, which ranked first priority among 56%, and *Cocos nucifera*, which is ranked highest by 44%. The farmers' second priority is again clustered around food-producing species and concentrated heavily on *Artocarpus heterophyllus* and *Cocos nucifera*. Great diversity is found below the levels of first and second priority, at which point species like *Mangifera indica*, *Coffea arabica*, *Artocarpus*

Table 12. Tree species grown by farmers and their ranking by household*

	Bambarabedda					Madugalla				
	Priority					Priority				
Species	1	2	3	4	Total occurrence	1	2	3	4	Total occurrence
A. heterophyllus	14 (56)	10 (40)			24	5 (26)	6 (24)			11
Cocos nucifera	11 (44)	8 (32)			19	7 (28)	1 (4)			8
Mangifera indica		3 (12)	1 (4)		4	3 (12)		1 (4)		4
Gliricidia sepium		2 (8)	4 (16)		6	1 (4)	2 (8)	3 (12)		6
Coffea arabica		1 (4)	1 (4)	1 (4)	3					0
Artocarpus altilis		1 (4)	2 (8)		3					0
Psidium guajava			1 (4)		1	1 (4)	4 (16)			5
Tamarindus indica				1 (4)	1					0
Madhuca longifolia					0	5 (20)	3 (12)	1 (4)		9
Persea gratissima					0	2 (8)				2
Acacia caesia					0	1 (4)				1
Croton laccifer					0				1 (4)	1
Pongamia pinnata					0		3 (12)	1 (4)		4
Musa acuminate colla					0		1 (4)	1 (4)		2
Eugenia faranica					0		1 (4)	1 (4)		2
Careya arborea					0		1 (4)			1
Not reported			16 (64)	23 (92)			3 (12)	17 (68)	24 (96)	

*Figures in parentheses are percentages represented by the adjacent number of households.
Source: Wickramasinghe 1991b

Table 13. Primary uses and availability of priority species in the study villages[a,b,c]

Bambarabedda

Species	Household Number																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Artocarpus heterophyllus	*2f	*1f	*1f	*1f		*1f	*1f	*1f	*1f	*1f	*1f	*1f	*2f	*2f	*2f	*1f	*2f	*1f	*1f	*1f	*2f	*2f	*2f	*1f	*2f
Cocos nucifera	*1f		*2f		*1f	*2nf	*2f			*2f	*2f	*2f	*1f	*1f	*1f	*2f	*1f		*2f	*1f	*1f	*1f	*2f		*1f
Mangifera indica	*3f			*2f														*2f						*2f	
Coffea arabica						*	*3f	*2f																	
Tamarindus indica						3f	*																		
Gliricidia sepium		*2nf	*3nf		*2f					3nf						*3nf		*3nf							
Psidium guajava				*3f																					
Artocarpus altilis							*		*2f								*3f								

Madugalla

Species	Household Number																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Artocarpus heterophyllus	*2f		*1f			*2f			*2f	*2f	*2f			*2f		*1f			*1f					*1f	*1f
Cocos nucifera	*1f				3f	*1f	*1f	*1f	*1f	*1f		*2f					*1f								
Mangifera indica					*1f							*1f	*3f					*1f							
Gliricidia sepium		*1nf						*2nf				*3nf	*2nf				*2nf			*3nf		*3nf			
Psidium guajava					*2f						*1f				*2f	*2f			*2f						
Persea gratissima				*1f									*1f												
Careya arborea							*2f													*2f					
Acacia caesia																						*1nf			
Madhuca longifolia														*1f	*1f			*2f	*3f	*1f	*1f		*1f	*2f	*2f
Musa acuminate colla														*3nf											
Pongamia pinnata																					*2nf	*2nf	*2nf		*3nf

[a] * = present in the household area

[b] 1 = first priority species, 2 = second priority species, 3 = third priority species

[c] f = primary use is food, nf = primary use is nonfood

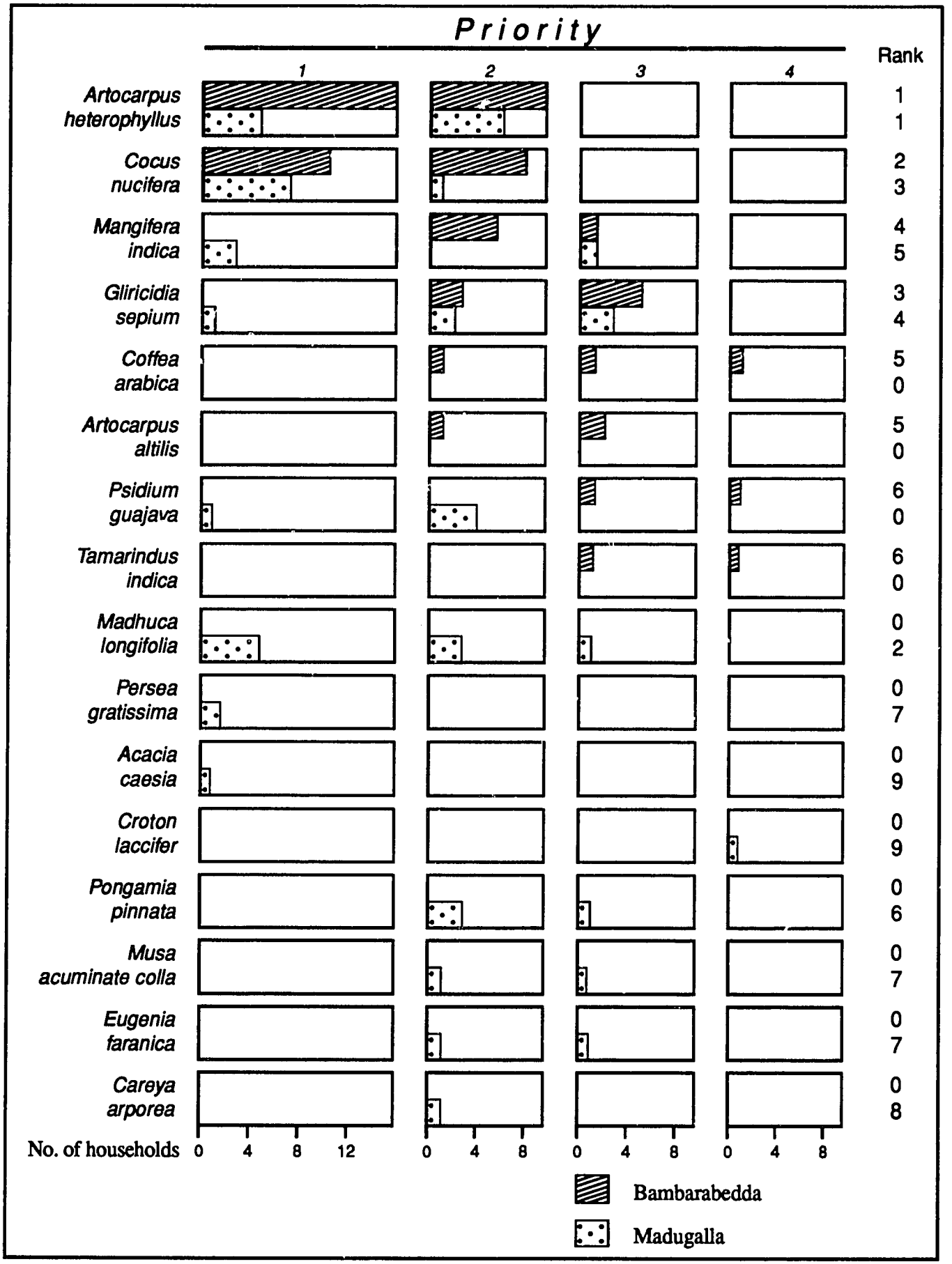

Figure 4. Tree Species Grown in the Two Villages by Number of Households

altilis, *Tamarindus indica*, and *Gliricidia sepium* are included. Except for *Gliricidia*, selection of these species shows a preference for food production either for household consumption or market. In homegardens, many of these are often grown in the same plot. Here the tradition of filling gaps in homegardens with transplanted seedlings of preferred species, along with naturally germinated individuals, should be stressed.

In Madugalla, the situation is more complex. Table 11 shows that species diversity is greater there. Sources of supply are also large. Of the two most popular species, *Cocos nucifera* is marginally preferred (28%) over *Artocarpus heterophyllus* (26%) in Madugalla. Two explanation can be given for this. First, *Cocos nucifera* is valued for its many uses in cooking. Secondly, jackfruit is used less frequently as a rice substitute; more than 75% of the families in Madugalla produce rice for family consumption. A marked feature of the households in Madugalla is the variability in their priority (Tables 12 and 13). This is due to some species being located in reserve lands and hedgerows, not predominantly homegardens.

4.4. Tree-Use Practices

Most trees grown, maintained, and protected by villagers are meant to provide multiple products. Under many circumstances, the popularity of species expresses the traditional tree-use practices and expected products or uses. Villagers priority for tree species is determined by their ability to produce the most essential products. These are food/fruits or nuts, fuelwood, timber, fencing materials, and agricultural poles, mulch and such products as medicinal stuff and roofing materials. Using tree products to provide domestic food and energy, materials for construction and fencing, and agricultural poles are traditional practices. All the species reported by households in Bambarabedda are food-producing species, except for *Gliricidia sepium*. All these priority species provide fuelwood (Table 14). Except for a few bushy and single-stemmed species like *G. sepium*, *Coffea arabica*, and *Psidium guajava*, all yield a final timber harvest. The exception of *Gliricidia* is due to its ability to provide the best fencing materials, support for pepper vines, and mulch.

Table 14. Primary uses of tree species by sample households in Bambarabedda*

Species	Food/Fruit	Poles/ Fuelwood	Timber	Fodder	Fencing	Mulch	Other (roofing) materials
Artocarpus heterophyllus	24 (96)	24 (96)	24 (96)	-	-	-	-
A. altilis	3 (12)	3 (12)	3 (12)	-	-	-	-
Cocos nucifera	19 (72)	19 (72)	19 (72)	-	-	-	19 (72)
Mangifera indica	4 (16)	4 (16)	4 (16)	-	-	-	-
Coffea arabica	3 (12)	3 (12)	-	-	-	-	-
Tamarindus indica	1 (4)	1 (4)	1 (4)	-	-	-	-
Gliricidia sepium	-	-	-	-	6 (24)	6 (24)	-
Psidium guajava	1 (4)	1 (4)	-	-	-	-	-

*Numbers in parentheses represent percentages.

An outstanding feature of tree uses noted in Bambarabedda is the farmers' preference for species that produce products needed by the household, among which food is foremost. The ability of *Artocarpus heterophyllus* to ensure food security during the dry season is the primary reason for its widespread use. *Cocos nucifera*'s popularity is similarly explained; although it is not the rice substitute that jackfruit is, coconut milk is used in many curries.

A similar situation is observed in Madugalla regarding the most popular species. In this village, the priority order of the species changes slightly due to the wider occurrence of *Madhuca longifolia*, which produces fruit, fuelwood, and a final harvest of timber. Species of secondary importance produce only a few products (Table 15). In Madugalla, farmers can obtain fuelwood from a range of species, more than observed in Bambarabedda due to the scattered occurrence of many self-germinated species in the reserve land and hedges.

Both villages evidence the importance of multiple products for farmers. Farmers' are particularly concerned about this aspect when their land and effort is given over to tending trees. If the trees are self-germinating and located on common property, the farmers' concern about multiple products is less apparent.

Among the most popular food/fruit producing species, *Artocarpus heterophyllus* and *Cocos nucifera* are the most promising, given farmers' preferences and the species' ability to produce most needed food stuffs continuously for household consumption. Although some

Table 15. Primary uses of tree species by sample households in Madugalla*

Species	Food/Fruit	Fuelwood	Poles/ Timber	Fodder	Fencing	Mulch	Other (roofing) materials
Artocarpus heterophyllus	11 (44)	11 (44)	11 (44)	-	-	-	11 (44)
Cocos nucifera	8 (32)	8 (32)	8 (32)	-	-	-	8 (32)
Mangifera indica	4 (16)	4 (16)	4 (16)	-	-	-	-
Croton laccifer	-	-	-	-	-	1 (4)	-
Gliricidia sepium	-	-	-	-	6 (24)	6 (24)	-
Psidium guajava	5 (25)	5 (25)	-	-	-	-	-
Persea gratissima	2 (8)	2 (8)	-	-	-	-	2 (8)
Careya arborea	2 (8)	2 (8)	-	-	-	-	-
Acacia caesia	-	1 (4)	-	-	-	-	-
Madhuca longifolia	9 (36)	9 (36)	9 (36)	-	-	-	9 (36)
Musa acuminate colla	-	2 (8)	2 (8)	-	-	-	-
Pongamia pinnata	-	4 (16)	4 (16)	-	-	-	4 (16)

*Numbers in parentheses represent percentages.

peak seasons for bearing fruit are evident, some forms of edible stuffs are available from these species throughout the year. This stands in marked contrast to the fruit-bearing pattern of species like *Mangifera indica*, *Tamarindus indica*, and *Madhuca longifolia*, which fruit during only one season.

Nearly 96% of the sample households in Bambarabedda and 44% in Madugalla grow *Artocarpus heterophyllus*. In both areas, jackfruit flakes are cooked and eaten, either as a substitute for rice or in curries. Immature fruits are prepared for vegetable dishes, chutney, and other ways by mixing the finely chopped pieces with coconut. Mature seeds are boiled and eaten or prepared in curries, and ripened fruits are often eaten as a desert. The thorny outer cover is also used as fodder. Traditional food-preserving technologies are used to keep the excess for off-seasons.

What is missing in these villages is a marketing infrastructure, which could help farmers earn cash from these products. Agroforestry is confined to meeting survival needs; household cash needs are met through other work. This results in the mobilization of male labor, which has a high degree of freedom, while agroforestry tasks are allocated to women, for whom domestic tasks are assigned priority.

The second priority species in the area is *Cocos nucifera*. Nearly 72% of households in Bambarabedda and 32% in Madugalla grow this as a priority species in their homegardens. Coconut milk is used in all curries; coconut is therefore extensively used in each meal. The other two priority species are *Mangifera indica* and *Madhuca longifolia*. *Mangifera indica* is mostly grown for fruit, while farmers maintain self-germinated *Madhuca longifolia* mostly for its kernels and timber. Kernels of *Madhuca longifolia* has been used traditionally to extract edible oil, which has been used as a medicine.

These facts highlight trees' biological ability to increase food security and farmers' recognizing this in their selection of priority trees. Food-producing trees thus engage the interest of resource-poor people, particularly where agroforestry is intended as a development strategy.

5. Farmers' Tree-Breeding Objectives

Although plant geneticists in Sri Lanka have adopted technologies for promoting short-duration, agricultural crops, efforts to improve tree species for farmers have been negligible. Agricultural innovations have concentrated heavily on developing high-yielding crop varieties. As a consequence, the role of trees in meeting subsistence needs and providing conservation and protective functions have been overlooked, as have traditional management practices and technologies. This has resulted in the disappearance of some species traditionally used and maintained by farmers. Over decades, the diversity of species composition of farmlands, particularly the tree composition, has decreased for lack of effort taken to promote these species through genetic improvement.

While the indigenous agroforestry systems of Sri Lankan homegardens have been maintained by non-scientists, scientists can contribute in many ways to promote greater productivity, diversity, and enhanced returns to the family. Scientists can learn many lessons from farmers and, in turn, collaborate with them in developing techniques and new varieties that can be integrated into their farms. Plant breeding could help small-scale subsistence farmers improve both the trees' products and physiological arrangement in a limited area. Applied to well-known tree species like *Artocarpus heterophyllus*, *Tamarindus indica*, and *Madhuca longifolia*, technologies in genetic improvement could enhance economic returns.

This process should follow a procedure that gives priority to understanding farmers' needs and problems while accommodating their indigenous knowledge. The information from group discussions permits us to outline some relevant facts.

5.1. Ideotype Specification for Tree Improvement

There are underlying reasons why certain trees are found only at specific locations in villages. According to farmers' own perceptions, certain undesirable physiological features like canopy shape, stem form, foliage characteristics, and rooting habits--either singly or in combination--prevent wider propagation of trees. Farmers used a number of good examples to demonstrate why they do not grow species like *Artocarpus altilis*, *Tamarindus indica*, and *Madhuca longifolia* in their homegardens. Farmers are unable to get a good harvest if they narrow the canopy width to accommodate them in homegardens with others. The broader canopy and larger number of twigs are necessary for a better harvest. Farmers find it difficult to grow such species, particularly due to the scarcity of land. Farmers view *Artocarpus heterophyllus*' tolerance to pruning for fuel and fodder as advantages.

Ideotypes preferred by farmers are determined by various factors. As their priority is for multiple products, all the required characteristics cannot be combined to create an ideal tree. But best-suited species can be identified. As summarized in Table 16, the farmers' concern

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Table 16. Ideotype specifications for agroforestry

Products and services required	Food, erosion control, windbreak, fuelwood, timber, mulch, fodder
Selection criteria	Vigor, pest and disease resistance, easy propagation/germination
Ancillary information	Tolerates dry season, poor-fertility soils, and low soil moisture
Crown	Dense, narrow round, bole ratio = 15-20
Stem	Straight/multiple stems (varies according to conditions)
Roots	Geotropic angled
Response to management	Pollarding, branch pruning
Deciduousness	Continuous vegetal cover

Source: Field information

in integrating trees into their farms without reducing their multiple benefits is the challenge to be met. Some characteristics, like deciduousness and tolerance to dry seasons, indicate their desire for perennial vegetal cover, as well as production ability. The physiographic characteristics preferred by the farmers are meant to increase the variety of crops/trees grown on their land.

5.2. Planting Niches

The nature of the priority products that farmers could obtain from trees has been considered in determining the planting niches for trees. For example, the ideal place for food-producing trees is homegardens. Growing food-producing species near a house minimizes the theft of fruits and permits harvest of fruits at various stages of maturity as required to optimize the use of products. Farmers also consider fruit-bearing trees around a house as a blessing to the household. Lumber species found in homegardens are self-germinated. Often, these are characterized by a straight stem and narrow canopy. Species that produce lumber and firewood are also accommodated for long-term cash returns.

Based on the information gathered on farmers' perceptions, preferred locations and disliked characteristics of the trees were identified. Farmers select species for specific locations according to their experience in tending and maintaining trees; their choices for homegardens and other locations display clear differences (Tables 17 and 18).

Ideotypes identified by farmers for specific niches express their concern over space requirements. They are also influenced by environmental conditions and the farmers' knowledge of crop requirements. Farmers in group discussions stated they are unable to

Table 17. Tree products, planting niches, source of planting materials, and disliked characteristics in Bambarabedda by household*

	Products	Planting niches	Source of planting materials	Disliked characteristics
Artocarpus heterophyllus	1. Fruit 2. Branches 3. Timber 4. Leaves	1. Homegardens 2. Field margins 3. - 4. -	1. Naturally germinated 2. Neighbor 3. Purchased	1. Height 2. Widespread lateral roots
Cocus nucifera	1. Nut 2. Cadjan 3. Wood 4. -	1. Homegardens 2. Intercropped with annual crops 3. - 4. -	1. Purchased 2. Germinated 3. -	1. Lateral roots 2. -
Mangifera indica	1. Fruit 2. Branches 3. Timber 4. -	1. Homegardens 2. Field margins 3. Intercropped with annual crops 4. -	1. Purchased 2. Naturally germinated 3. -	1. Broad canopy 2. Lateral roots
Gliricidia sepium	1. Stem 2. Poles 3. Leaves 4. -	1. Intercopped with annual crops 2. Field margins 3. Homegardens 4. -	1. Propagated 2. Neighbor 3. -	1. - 2. -
Artocarpus atillis	1. Fruit 2. Branches 3. Timber 4. -	1. Homegardens 2. Field margins 3. - 4. -	1. Purchased 2. Neighbor 3. -	1. Broad canopy 2. Lateral roots
Tamarindus indica	1. Fruit 2. Branches 3. Timber 4. -	1. Homegardens 2. Field margins 3. - 4. -	1. Naturally germinated 2. Neighbor 3. -	1. Broad canopy 2. Lateral roots

*Numbers indicate priority level
Source: Field information

Table 18. Tree products, planting niches, source of planting materials, and disliked characteristics in Madugalla by household*

	Products	Planting niches	Source of planting materials	Disliked characteristics
Cocus nucifera	1. Nut 2. Cadjan 3. Bole	1. Homegardens 2. Intercropped with annual crops 3. -	1. Purchased 2. Germinated 3. -	1. Lateral roots 2. Height
Artocarpus heterophyllus	1. Fruit 2. Branches 3. Bole	1. Homegardens 2. Field margin 3. Intercropped with annual crops	1. Naturally germinated 2. Purchased 3. -	1. Widespread lateral roots 2. Broad canopy
Maducca longifolia	1. Fruit 2. Branches 3. Bole	1. Common land 2. Field margin 3. -	1. Naturally germinated 2. - 3. -	1. Broad canopy 2. -
Psidium guajawa	1. Fruit 2. Branches 3. -	1. Homegardens 2. Common land 3. Field margin	1. Naturally germinated 2. - 3. -	1. - 2. -
Pangamia pinnata	1. Bark 2. Branches 3. Bole	1. Common land 2. Field margin 3. -	1. Naturally germinated 2. - 3. -	1. Broad canopy 2. Lateral roots
Gliricidia sepium	1. Stem 2. Poles 3. Leaves	1. Field margin 2. Homegardens 3. Intercropped with annual crops	1. Propagated 2. Neighbor 3. -	1. - 2. -
Mangifera indica	1. Fruit 2. Branch 3. Bole	1. Homegardens 2. Common land 3. Field margin	1. Naturally germinated 2. Purchased 3. Neighbor	1. Broad canopy 2. Lateral roots

*Numbers indicate priority level
Source: Field information

grow straight- and long-stemmed species on sloping land with wide exposure. If they do, the stems grow crooked at about 2-3 m above the ground. This is one of the reasons for farmers not having single-stemmed species on their farmlands. The necessity for introducing species capable of withstanding wind for such areas was mentioned.

As pointed out by the farmers, the specific conditions under which trees are to be planted must be examined before promoting trees for these areas. Two important conditions are soil and moisture conditions. Particularly in the highlands, soil is shallow, heavily degraded, infertile, and water retention is low. Species for such terrains must tolerate such conditions. For this reason, use of the local gene pool for selecting germplasm is important for better survival.

5.3. Tree Ideotypes for Specific Locations

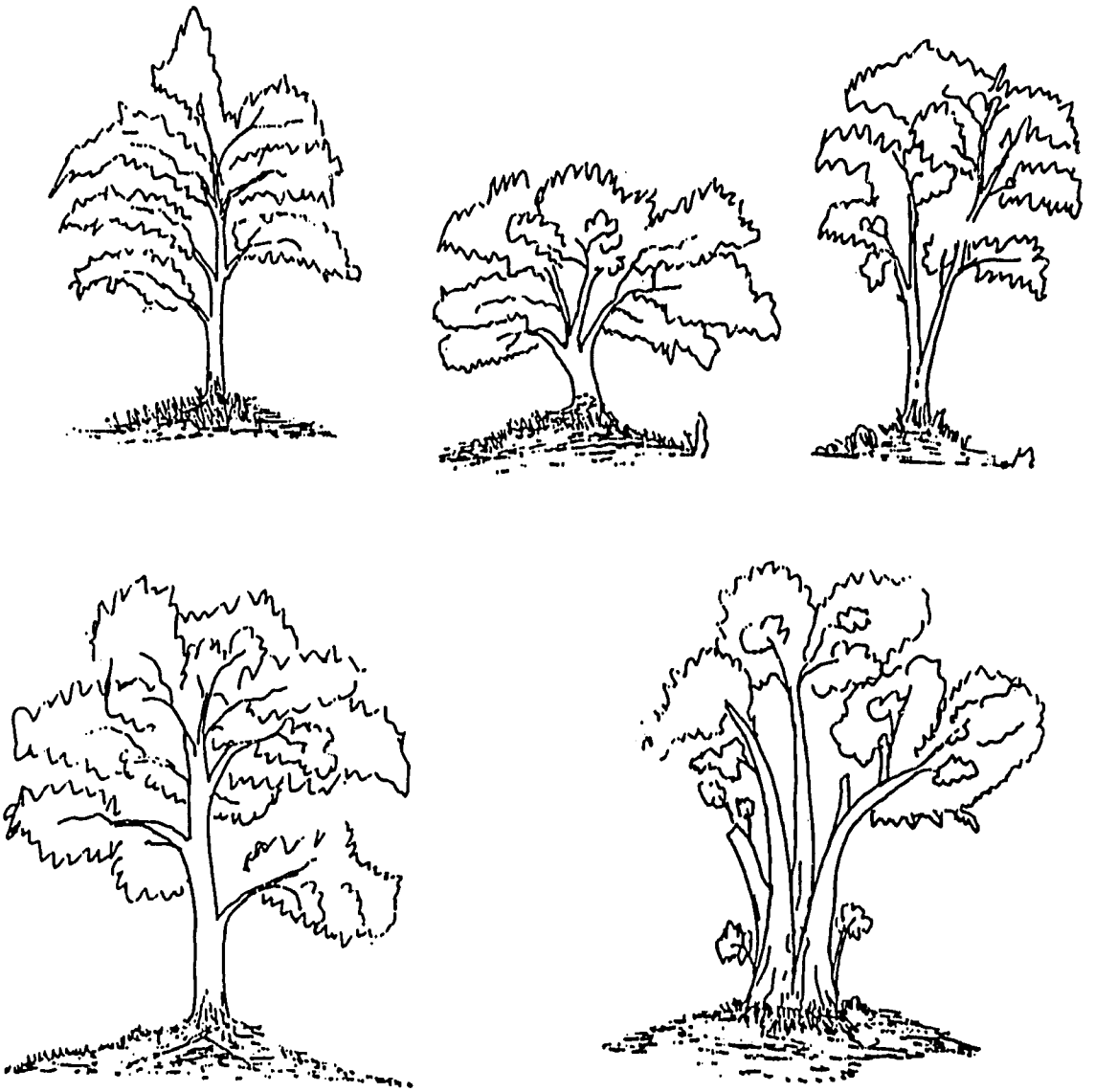
Farmers' tree improvement requirements differ, depending on the farm system and niche in which the trees are to be grown. For example, the preferred physiographic arrangement of *Artocarpus heterophyllus* varied according to whether the planting site was owned. For common land, farmers identified a wide-canopied tree, while for their own private land (hedge or homegarden) they preferred a narrower canopy.

Thus, the line drawings produced by the villagers through participatory mapping vary depending on whether the land is common land, farmland, or homegarden, regardless of species. Most striking is their ability to distinguish ideotypes by planting niches, offering several possible arrangements for each niche.

Figure 5 shows that trees for common land need to have either widespread branching or a broad canopy. This is because common lands are perceived as a public area and source of products. Common lands are unplanned, and trees grow there by natural regeneration. Villagers obtain products from them freely. One reason for preferring well-branched or broad-canopied trees is related to the desired products: fuelwood, small timber, and fodder. In fact, many unmanaged species possess broad canopies. These products are harvested in greater amounts from *Madhuca* [illegible] naturalized varieties of *Mangifera indica*, and *Tamarindus indica* found on com[illegible] Their broad canopies promote greater fruit production.

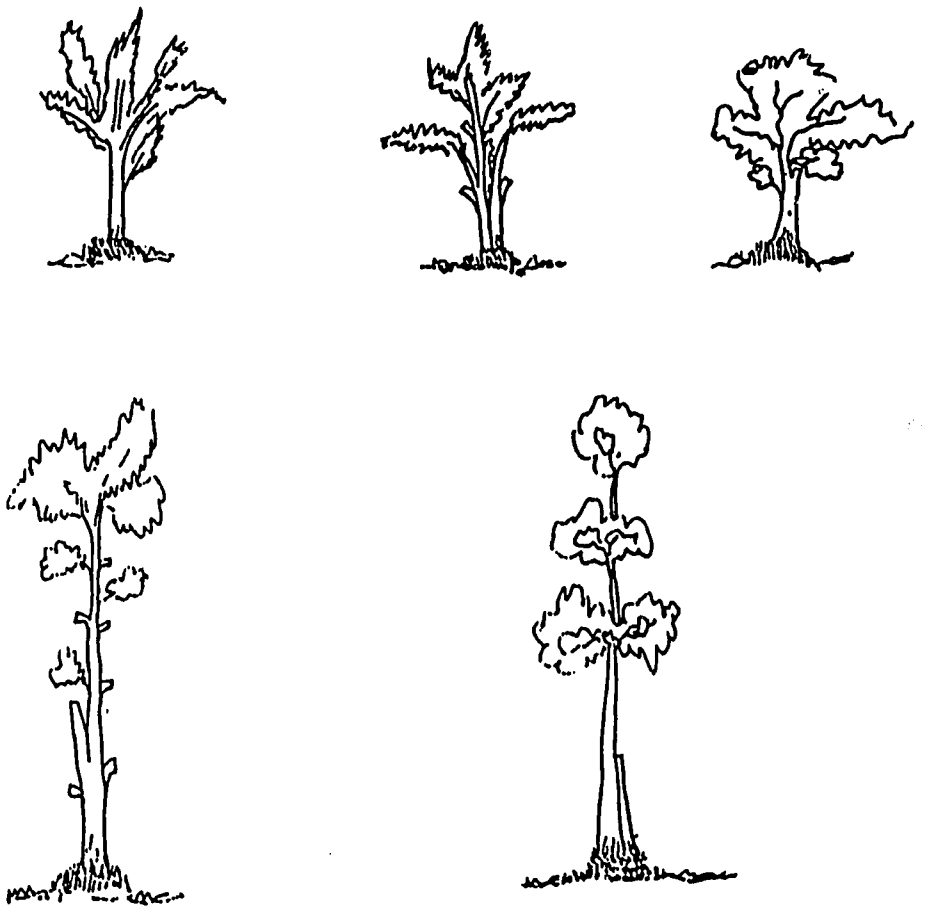
When these are compared wit[illegible] farmland, we can see a marked difference: the canopy is clearly narrowed and [illegible] 6). This is expected to occur by pruning branches. The narrowed crown is [illegible] luce the shading effect and competition with nearby crops.

Many ideotypes were identified for homegardens (Figure 7). To an extent, this indicates the need for homegardens to accommodate different species that can complement each other.



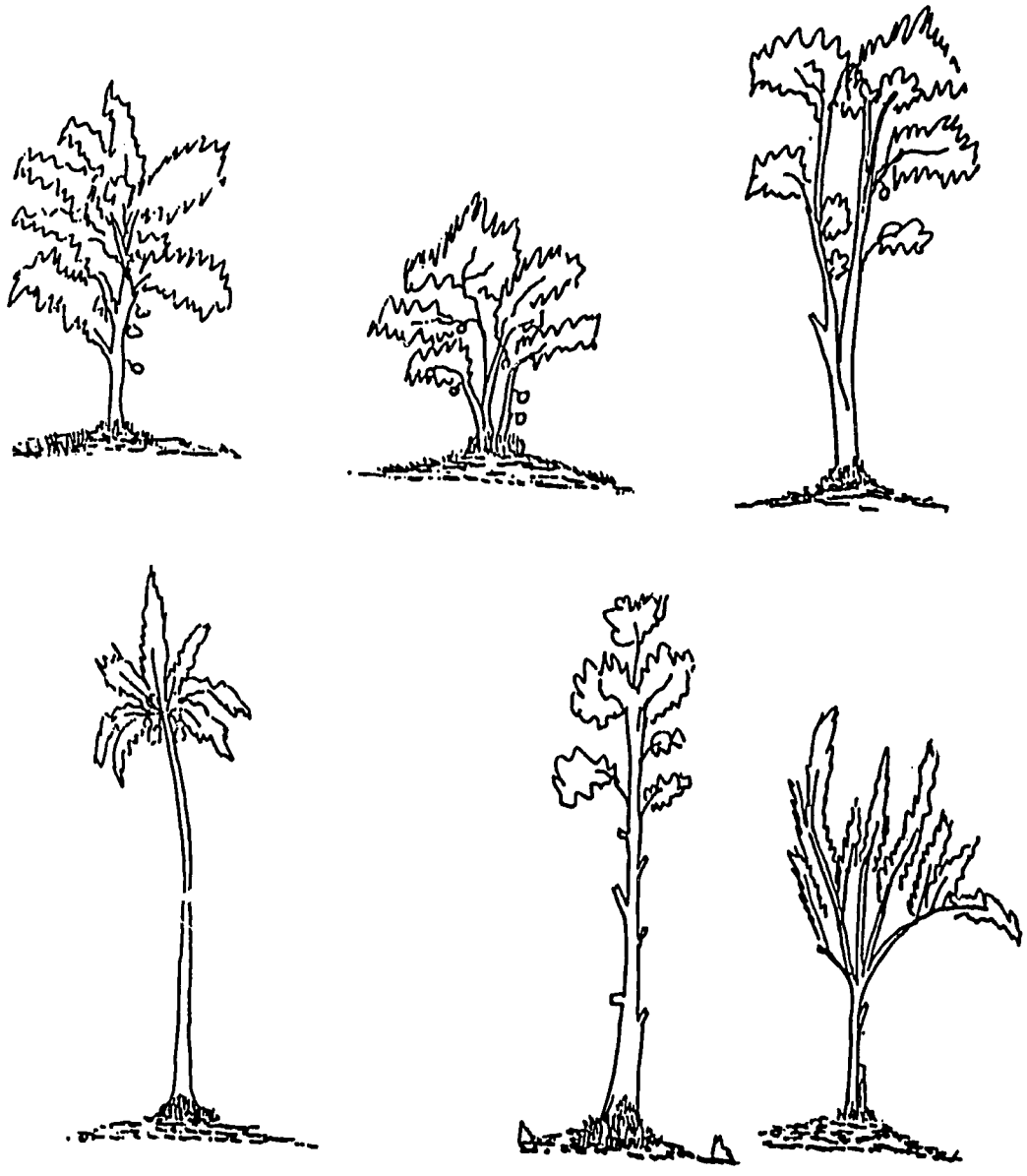
Canopy	Stem	Roots
Broad and dense (Diameter = 6–8 m)	Multiple, strong timber	Deep tap root with lateral roots

Figure 5. Farmers' Ideotypes for Trees on Common Land



Canopy	Stem	Roots
Narrow (Diameter = 1–2m)	Short/tall, easily pruned	Deep tap root

Figure 6. Farmers' Ideotypes for Trees on Farm Land



Canopy	Stem	Roots
Broad/narrow (Diameter = 2–6 m)	Multiple– or single–stemmed	Deep tap root

Figure 7. Farmers' Ideotypes for Trees in Homegardens

Pruning can help control potential competition. Differences among these ideotypes reflect the priority of stem form, branching habit, and adoptability of management for trees in homegardens. Fruit should be borne on the stems, leaving the possibility of harvesting branches for fuel. In this respect, *Artocarpus heterophyllus*, which produces fruits along the trunk, is preferred over *Artocarpus altilis*, which does not.

Farmers proposed several ideotype options for each planting niche. In fact, the farmers' objectives are not separated from the site at which the trees are to be grown and the need for diversifying biological and production systems. Their recognition of this and their concern for trying to incorporate species with a variety of characteristics should be considered when formulating adoptable designs. Another point to remember is that farmers' drawings are often limited by what they have seen locally.

5.4. Sources of Planting Materials

Most planting materials are obtained freely from neighbors. Maintenance of self-germinated individuals is also common, particularly from common areas, hedges, and homegardens (Tables 17 and 18). For better-quality stock, seedlings of *Cocos nucifera*, *Mangifera indica*, and *Artocarpus altilis* are purchased.

In selecting planting materials from the neighborhood, farmers are guided by their priority needs, tastes, and characteristics of the species they like. Their ability to share planting materials indicates the possibility for propagating trees species widely if products and characteristics are agreeable.

The flow of information from one family to another goes along with the habit of sharing tree products, as well as planting materials. Fruits of mango, tamarind, jackfruit, and guava are shared with neighbors and seeds of preferred varieties are planted by each household. Seeds germinated in garbage heaps are of the varieties consumed by the household.

Conclusions

Transforming these findings into operational intervention programs will be complex, but is necessary to promote adoptable tree-use practices. This information related to tree-use practices can be interpreted in various ways according to one's objectives, but the major points are as follows:

1. Farmers' priority for tree species varies according to the primary needs of the farmer family. In the study villages, food and fruits are the priority products cited by small-scale farmers.

2. Farmers' dependence on their own sources of supply is greater in communities where sources of supply are limited. Therefore, farmers' needs and choices should be considered when promoting trees.

3. Tree improvements needed by farmers vary according to the locations and characteristics of the ecological niches in which they can plant trees. For example, for *Mangifera indica*, *Tamarindus indica*, and *Madhuca longifolia*, which produce bunches of fruits/pods on twigs, farmers prefer a multiple branching habit. Yet in most cases such species will be better accommodated in locations where more space can be provided. For *Artocarpus heterophyllus*, on the other hand, it is important to produce more fruit in the lower portion of the stems, the goal being greater fruit quantity within easy reach.

4. The best suited tree characteristics cannot be determined by considering either the tree species or its products in isolation. Shade, cooiness, and a dense and narrow canopy, which are often preferred for the homegardens, will not be the characteristics preferred for farmland. On farmland, farmers like narrow-canopied, single-stemmed species that can grow along fences or in alleys. Similarly, the farmers' priority for species that produce mulch and control erosion differ.

5. Easy and regular harvest of branches must be possible where farmers depend on trees for fodder and fuelwood. In this respect, the total biomass production needs consideration.

6. An attempt must be made to obtain the best germplasm from the local gene pools for further improvement. This would enable geneticists to apply genetic improvement to promote important local species. This is also essential in gaining farmers' reliance over the materials promoted by the scientists.

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7. In deciding on genetically improved varieties it is important to assess site suitability. Here modeling of species growth/biomass production on environmental parameters, including crop-environment interactions, is appropriate. The interactive function of atmospheric energy and soil moisture are key environmental conditions determining potential growth performance (see Wickramasinghe 1988).

8. With limited area, there is a need to reduce trees' space requirements. Canopy width and rooting system are the two features that need to be controlled. Plant improvement effort must have, as a target, more produce from a small parcel of land. In this respect, it is also necessary to know the complementary benefits of species and their compatibility.

9. Defining farmers' tree-breeding objectives is not intended to identify an ideal tree or an ideal ideotype. It is to promote best-suited characteristics in order to both maximize outputs and to diversify a tree's products.

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