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Article *in* Agroforestry Systems · February 2006

DOI: 10.1007/s10457-005-2919-x

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Agroforestry Systems (2006) 66:101–115
DOI 10.1007/s10457-005-2919-x

Dynamics of homegarden structure and function in Kerala, India

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Received 26 June 2004; accepted in revised form 24 February 2005

Key words: Biodiversity, Functional differentiation, Multispecies systems, Social adaptability, Socio-economic change

Abstract

Homegardens in Kerala have long been important multi-purpose agroforestry systems that combine ecological and socioeconomical sustainability. However, traditional homegardens are subject to different conversion processes linked to socioeconomic changes. These dynamics were studied in a survey of 30 homegardens. On the basis of a cluster analysis of tree/shrub species density and subsequent further grouping using homegarden size as additional characteristic, six homegarden types were differentiated. These were assessed regarding structural, functional, management and dynamics characteristics. Four development stages of homegardens were found along a gradient from traditional to modern homegardens. Fifty percent of the homegardens still displayed traditional features, whereas 33% incorporated modern practices. The process of modernisation includes a decrease of the tree/shrub diversity, a gradual concentration on a limited number of cash-crop species, an increase of ornamental plants, a gradual homogenization of homegarden structure and an increased use of external inputs. One homegarden was characterised as an adapted traditional homegarden combining multispecies composition and intensive management practices using internal inputs with commercial production. In comparison to modern homegardens, this homegarden type offers an example of an alternative development path in adapting homegardens to changing socioeconomic conditions. The study of structural and functional dynamics of homegardens offers the opportunity to understand the trends in socio-economic sustainability and how these relate to ecological sustainability.

Introduction

Homegardens are worldwide recognised as sustainable agroforestry systems. They can be characterised as a land-use system located close to the house where woody and non-woody species are intimately arranged in several overlapping canopy layers, sometimes in association with domestic animals. The basic objectives for maintaining this agroforestry system is to ensure availability of multiple products such as food, fuel, vegetables, fruits, fodder, medicines besides generating income and employment (Soemarwoto 1987; Hoogerbrugge and Fresco 1993; Kumar and Nair 2004). By combining tree growing and horticultural cultivation, farmers have developed an integrated agricultural and tree production system which makes an optimal use of the soil production

capacity, ensures multiple uses of natural resources, and provides multiple and sustained yields of different types of crops for subsistence and additional commercial use. They are therefore often considered as epitome of sustainability (Torquebiau 1992; Kumar and Nair 2004).

From a system-dynamics point-of-view, the concept of sustainability includes two main dimensions, i.e. ecological sustainability in the sense of keeping within ecological stability domains and social sustainability in the sense of adjusting to social dynamics (Wiersum 1995). Most studies on sustainability of homegardens have been focused on ecological sustainability, while social sustainability has been given much less systematic attention (Torquebiau 1992; Kumar and Nair 2004). Social sustainability may relate to either the social acceptability of homegardens within the livelihood systems of rural producers or to the ability of homegardens to adjust to socioeconomic change (Kumar and Nair 2004; Wiersum 2004). The structure and composition of homegardens can well be adjusted to various livelihood conditions such as size of landholdings, role of homegardens within the overall farming-system and degree of commercialisation (Wiersum 1982; Christanty et al. 1986; Soemarwoto 1987). Homegardens are not static, but have evolved over centuries thanks to adaptive abilities of farmers in responding to changing rural and livelihood conditions (Michon and Mary 1994; Kumar and Nair 2004). Traditionally, the homegardens mainly served to produce vegetables, fruits and other crops which supplemented the staple food crops produced on open croplands (Soemarwoto 1987; Kumar and Nair 2004). With the advent of commercialisation often an increase in selected cash crops such as coconut or rubber has been observed. The shift from subsistence-oriented agriculture to market economy often implies drastic structural and functional modifications, including a homogenisation of the homegardens structure and use of external inputs (Soemarwoto 1987; Kumar and Nair 2004).

Several authors have voiced concern that these developments result in the loss of some of the homegardens relevance and threaten their future development. Recently the question was even raised whether the homegardens are becoming dissolute or even extinct (Kumar and Nair 2004). The expressed fears that the traditional, diverse and ecologically sustainable homegardens will gradually dissolve into monospecific agricultural systems with uncertain sustainability are in stark contrast to the earlier ideas on homegardens as having a promising future (Soemarwoto 1987). The maintenance of multispecies and multistrata agroforests are deemed worthwhile because of the growing interest in developing multifunctional land-use systems which contribute not only to production objectives, but also to the objectives of biodiversity and environmental conservation (Wiersum 2004). In order to maintain the positive characteristics of the traditional homegardens it is therefore necessary to develop improved homegardens that counterbalance the ongoing homogenisation trend (Kumar and Nair 2004).

In order to better understand whether there is scope for such an alternative development path and whether it is possible to adapt homegarden systems to the changing rural conditions while still maintaining the positive features of the traditional homegardens, it is necessary to study the trends in homegarden dynamics in detail. Up till the present most homegarden studies have focused mainly on species inventories or system description (Nair 2001) and still little attention has been given to their structural and functional evolution. In the past, differences between homegardens were mostly described on the basis of characteristics such as size, structure (vertical stratification, diversity indices) or socioeconomic factors (level of inputs, subsistence/commercial production). Only recently studies have been undertaken to systematically classify the structure of homegardens using analytical methods such as cluster analysis common to vegetation science (Mendez et al. 2001; Leiva et al. 2002; Quiroz et al. 2002; Abebe 2005). These methods offer good opportunities for obtaining a systematic insight into different types of homegardens. The further evaluation of these different types in respect to socioeconomic conditions under which they evolved, can provide useful insights into the development trends of homegardens.

Homegardens have traditionally been managed and adopted by farmers rather than through agroforestry research (Nair 2001). Consequently, an interesting question is whether all farmers are following similar homegarden development trends, or whether farmers are following different pathways in maintaining their homegardens. The

recent advances in using statistical methods for classification of homegarden systems provides a good basis for assessing whether there exist differences in homegarden types and evaluating whether different types follow different development trends.

The aim of this paper is to assess the nature of dynamics of homegarden characteristics. Based on a field study in Palghat district, Kerala, India it focuses on the following questions:

1. What different types of homegarden are present in the study area and what are their characteristics?
2. What changes in homegarden structural, functional and management characteristics took place during the last decade?
3. What conclusion can be drawn regarding the position of the different homegarden types on an evolutionary axis?

Material and methods

Study site

One of the tropical regions where concerns about the future of homegardens have been raised is the Indian state of Kerala. In this region the values of homegardens as multi-purpose production systems combining ecological and socioeconomical sustainability are well recognized (Nair and Sreedharan 1986; Jose and Shanmugaratnam 1993; Kumar et al. 1994). Various scientists have voiced concern that socioeconomic changes and related adoption of modernised managerial systems cause a negative conversion process of homegardens in this region (Jose and Shanmugaratnam 1993; John and Nair 1999; Santhakumar 2002). Several government development programs want to assist the farmers to raise their cash incomes and therefore promote the conversions of homegardens towards cash-cropping systems by providing loans and subsidies for rubber (*Hevea brasiliensis*) or other cash-crop cultivation. Moreover, government controls on timber production discourage the growing of timber in homegardens (Ouseph 2002).

In view of these developments, Kerala offers a good opportunity to study the development trends in agroforestry systems. For this purpose, a case-study was carried out in two *panchayats* (Mundur and Puduparyaram) of Palghat district in the central part of Kerala. The region is characterised by a tropical humid climate with a monsoon pattern of rainfall. The topography is rolling to hilly and main soil types are dystric nitosols (FAO 1977).

Data collection

Within the two study *panchayats* a stratified sample of 30 farm households was selected. The sample was stratified according to total landholding size, i.e. small (<1 ha, $n = 10$), medium (1 to 2 ha, $n = 10$) and large (>2 ha, $n = 10$). The households were selected on the basis of information from a local rural development organisation (Integrated Rural Technology Center, Palghat district) and from referrals from initial respondents.

In the homegardens of each household a detailed survey of the composition and management practices was made. The survey consisted of an inventory of trees and shrubs species and a count of all individuals per species. Only presence was recorded for herbs and (bi)-annuals. The species were classified according to their use into the categories fruits and nuts, staple food, beverage and stimulant, spices, timber and firewood, medicinal products, religious plants, ornamentals, multipurpose species with more than four uses, and other, see Annex 1. Rubber was the only species used exclusively as a cash crop and classified as such. During the survey oral information was also collected on the management practices for individual species based on the approach developed by Wiersum and Slingerland (1996). In this approach five main practices are distinguished: controlled utilisation, protection and maintenance, stimulation of desired products, regeneration and interface management. The first four categories represent an increasing input of human energy per unit of land (Wiersum 1997). Additional information concerning the homegarden size, the overall strategy in homegardens orientation (subsistence or commercial orientation) and management inputs were collected using structured interviews. In these interviews additionally information was collected on changes in homegarden structure and management during the last ten years. This concerned both changes in homegarden composition and spatial arrange-

ments (including homegarden size) as well as in management practices (changes in vegetation structure, production characteristics, and chemical input use).

Data processing and analysis

For classification of the 30 homegardens a hierarchical cluster analysis was applied using tree/shrub species density (number of individuals per species per unit area) as main variable. In the cluster analysis, chi-square as distance or similarity measure and between group average linkage method were used. Nine clusters were distinguished of which five consisted of only one homegarden. Those five 'single' clusters were reclassified based on homegarden size into two new types. A group of four small homegardens and a 'group' of one big homegarden resulted.

The resulting 6 homegarden types were assessed with respect to their structural and functional characteristics. The following parameters were used:

Structural characterisation of homegardens: homegarden size (including the house), total density of trees per homegarden, species richness and evenness (except for species that could not be counted). The richness and evenness of species were computed using Shannon's and Simpson's diversity indices (following Huston 1994). As only three of the six types had a sufficient number of homegardens, statistical analysis were only applied to differences among these homegarden types. Differences were tested using ANOVA for all the parameters except for number of species and tree density as populations were not normally distributed even after transformation. In this case a non-parametric Kruskall and Wallis test was applied.

Functional characteristics: proportions of mean number of trees per use category and the differentiation in home or cash orientation in production were used. Relative contribution of each use group was calculated and compared within each homegarden type. Annual staple food crops and 'other' crops were not included in this analysis; coconut and rubber were treated as separate categories in view of their high value according to both farmers' opinion and actual presence.

For each homegarden type also the management characteristics and dynamics were assessed. The management was characterized in respect to management intensity, spatial arrangement and use of management inputs. The assessment of the management intensity was based on a detailed assessment of the management practices for the seven most common and preferred species (rubber, coconut, arecanut, mango, jackfruit, teak and neem); the management intensity was characterised comparatively according to the technique of Wiersum and Slingerland (1996). The characterisation of management inputs was based on an assessment of the internal and external inputs applied in cultivating the seven tree species. The dynamics of each homegarden type was qualitatively assessed according to the changes in homegarden size, vegetation structure (introduction of new species, changes in respect to ornamental and medicinal plants, and changes in spatial arrangements) and production characteristics (change of homegarden orientation and evolution of chemical input use).

The data on homegarden composition were analysed using the statistical package SPSS 10.0 (SPSS Inc.). On the basis of their structural, functional, management and dynamics characteristics, the different homegarden types were ordered along a gradient from traditional to modern homegardens.

Results

Differentiation of homegarden type

Distinction in homegarden types

On the basis of a cluster analysis using a dissimilarity index of 12.2 as a cut-off point, the 30 selected homegardens were categorized into nine clusters with a different pattern in tree/shrub species density (Figure 1). As five clusters consisted of one homegarden only, a further qualitative assessment was made to further delineate different homegarden types. Four clusters (clusters 4, 5, 6 and 7) which were similar in respect of their very small size (0.12–0.2 ha) were combined. Cluster 8 was maintained as a specific type due to its bigger size (0.81 ha) and specific structure. Consequently, the nine clusters were regrouped in six homegarden types for further analysis (Figure 1).

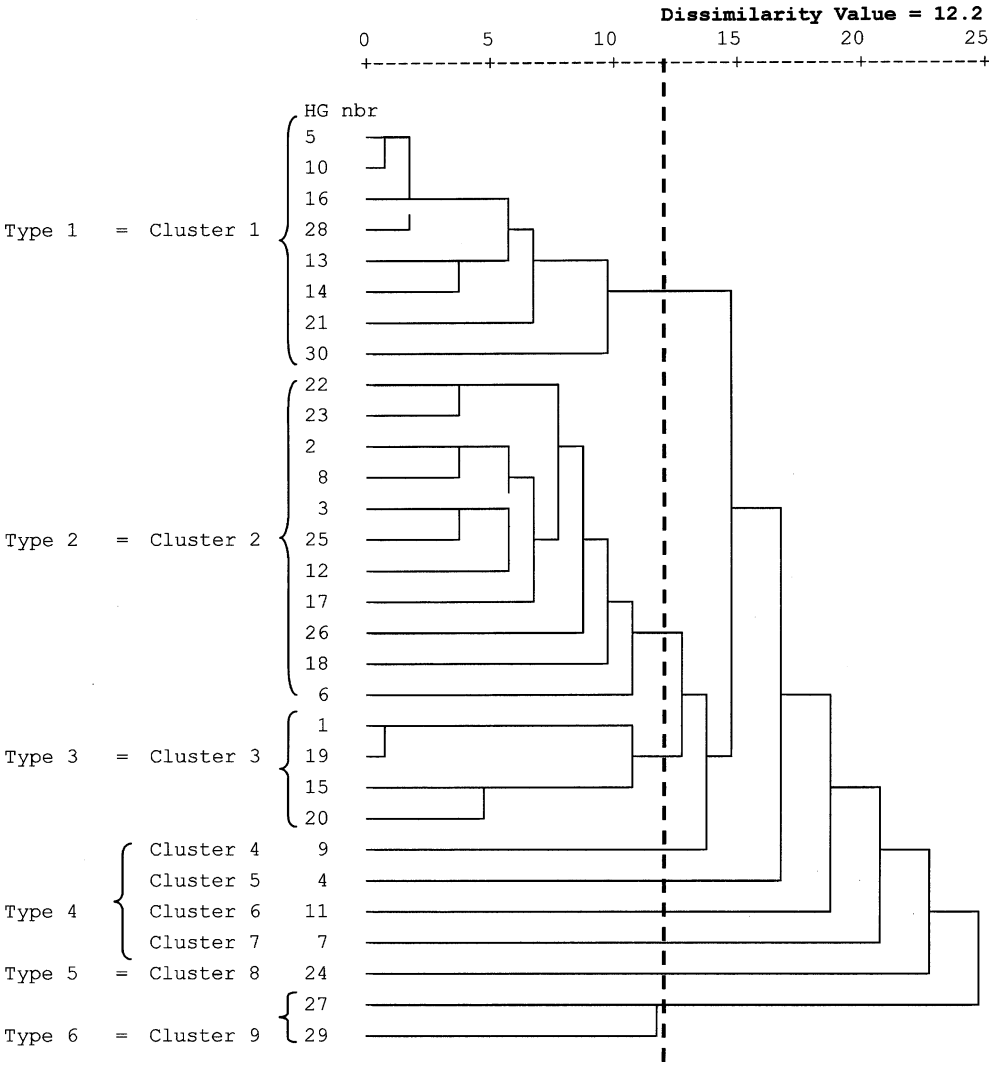

Figure 1. Hierarchical classification of 30 homegardens, Kerala, India.

Structural characteristics

The different homegarden types showed important variations in all their structural characteristics except for the number of species (Table 1). Although the average number of species in the various homegarden types ranges from 17 to 51, in types 1, 2, 4 and 6 the average number of species per homegarden are relatively similar. Types 2, 3 and 4 are small homegardens, whereas types 5, 6 and 1 are much larger. Types 1, 2 and 3 have a much lower tree density than types 4, 5 and 6. Types 1, 3 and 6 have lower species diversities (higher Simpson and lower Shannon indices) compared to types 2, 4 and 5. Finally, types 1 and 6 have lower evenness values than the other garden types. This indicates that in these homegarden types production is oriented toward fewer species compared to types 2, 4 and 5.

Further statistical tests were applied on types 1, 2 and 3 (Table 1). Type 1 is significantly bigger in size than types 2 and 3. The three types are significantly different in respect to their number of species, but have similar tree/shrub densities per homegarden. Concerning the diversity indices, type 1 is statistically less diverse and has a lower evenness compared to type 2. Type 3 is intermediate.

In general, there is a tendency that with an increase in size of homegardens, from type 4 (very small) to types 2 and 3 (small) to type 1 (medium)

Table 1. The structural characteristics of six homegarden types, Kerala, India.

	Homegarden types						Tests		
	1 (n = 8)	2 (n = 11)	3 (n = 4)	4 (n = 4)	5 (n = 1)	6 (n = 2)	Type	$*F/\chi^2$	p
Homegarden size (ha)	0.72[a] (0.117)	0.40[b] (0.076)	0.24[b] (0.057)	0.14 (0.020)	0.81 (na)	1.01 (0.200)	A	4.04	0.034
Number of species	27.1 (3.47)	28.7 (1.33)	17.7 (3.09)	27.5 (3.77)	51.0 (na)	24.0 (3.00)	KW	6.14	0.046
Density (ind/ha)	555.5[a] (57.99)	449.0[a] (54.89)	621.3[a] (128.94)	1105.8 (137.68)	1671.6 (na)	1387.9 (46.62)	KW	2.74	0.254
Simpson's index	0.35[a] (0.077)	0.08[b] (0.007)	0.20[ab] (0.028)	0.09 (0.015)	0.09 (na)	0.51 (0.068)	A	9.33	0.001
Shannon's index	0.79[a] (0.108)	1.24[b] (0.020)	0.89[a] (0.092)	1.21 (0.076)	1.32 (na)	0.50 (0.087)	A	13.18	0.001
Evenness	0.56[a] (0.060)	0.86[b] (0.013)	0.72[b] (0.052)	0.84 (0.018)	0.77 (na)	0.36 (0.049)	A	16.65	0.001

Values in parentheses represent the standard error (na – not applicable).
Values with different letters among homegardens are significantly different.
Tests: A – ANOVA; KW – Kruskall Wallis.
*F value for ANOVA, χ^2 values for Kruskall and Wallis tests.

and type 6 (very big), there is an increase in the Simpson's diversity index, a decrease in the Shannon's diversity, and a decrease in the evenness index. Only homegarden type 5 does not fit in this tendency; this big homegarden has a low Simpson's diversity index, a high Shannon's diversity index and a high evenness index.

Functional characterisation

The various homegarden types differ in functional characteristics (Figure 2). A range from five to nine use categories was present in the homegarden types. Fruits and nuts, spices, timber and coconut, are present in all homegarden types. In two types only one use group consists of more than 50% of all trees: rubber in type 1 and beverage in type 6. The relatively less important use categories are the ones of religious, medicinal and multipurpose trees.

The different types of homegardens can be ordered along a gradient from predominately monoproduction to intensive multiple cropping: type 1 is predominantly focused on rubber production, type 3 and 4 are characterized by a mixture of fruit trees and coconuts, type 6 by a mixture of fruit trees and beverage crops with some additional spices and timber trees, type 2 by a mixture of coconut, fruit trees and timber trees, and type 5 by an intensive mixture of timber trees, spices, fruit trees and beverage crops. These

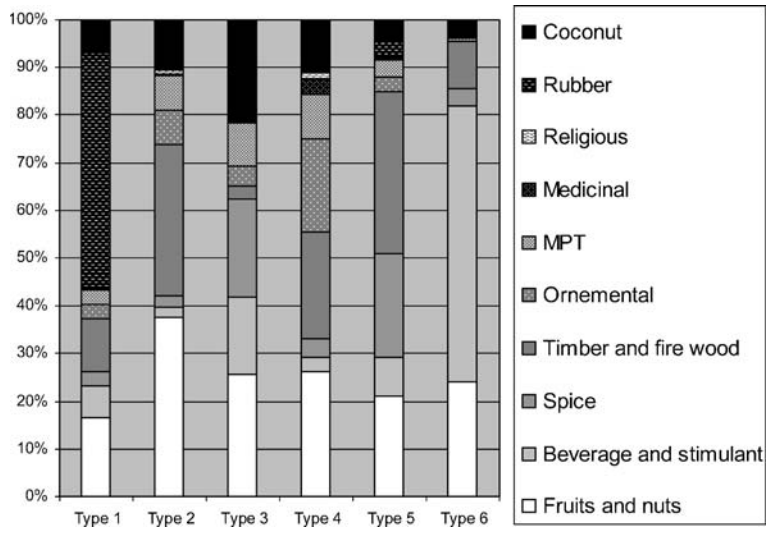

Figure 2. Functional characteristics of six different homegarden types, Kerala, India (% of number of individuals in each functional use group).

Table 2. Management practices of seven common species in different homegarden types.

				HG types					
				1	2	3	4	5	6
RUBBER			presence	8/8	0/11	0/4	0/4	1/1	0/2
	Management		latex tapping	8	-	-	-	1	-
			weeding	6	-	-	-	1	-
			removing competition	4	-	-	-	0	-
			sanitary pruning	0	-	-	-	1	-
			cut low branches	0	-	-	-	1	-
			spatial arrangement	2	-	-	-	2	-
	Inputs	Int	organic fertilisation	8	-	-	-	1	-
		Ext	bought seedlings	7	-	-	-	1	-
			chemicals	8	-	-	-	0	-
COCONUT			presence	8/8	11/11	4/4	4/4	1/1	2/2
	Management		nut harvesting	8	11	4	4	1	2
			weeding	8	6	3	0	1	2
			watering	0	4	2	2	0	2
			ringing	8	9	4	0	0	2
			sanitary pruning	0	0	0	0	1	0
			removing competition	4	6	2	0	0	0
			leaf harvesting	0	5	2	0	0	2
			canopy prunings	0	0	0	0	1	0
			spatial arrangement	2	2	2	2	2	2
	Inputs	Int	organic fertilisation	7	10	4	3	1	2
			mulching	8	10	4	3	0	1
			seeding	0	0	0	0	0	2
			nursery	0	0	2	0	0	1
		Ext	bought seedlings	5	7	2	4	1	0
			chemicals	5	0	2	0	1	0
ARECANUT			presence	3/8	1/11	4/4	0/4	0/1	2/2
	Management		nut harvesting	3	1	4	-	-	2
			weeding	3	1	0	-	-	2
			watering	2	0	0	-	-	2
			ringing	3	1	2	-	-	1
			sanitary pruning	0	0	0	-	-	1
			removing competition	0	0	0	-	-	1
			spatial arrangement	2	2	1/2	-	-	1/2
	Inputs	Int	organic fertilisation	3	1	3	-	-	2
			mulching	2	0	2	-	-	0
			seeding	2	0	0	-	-	1
			nursery	0	0	1	-	-	1
		Ext	bought seedlings	0	1	0	-	-	1
			chemicals	2	0	0	-	-	0
MANGO			presence	7/8	11/11	4/4	4/4	1/1	2/2
	Management		fruit harvesting	7	11	4	4	1	2
			sanitary pruning	2	5	2	0	1	1
			rejuvenation pruning	0	0	0	0	1	0
			canopy pruning	0	0	0	0	1	0
			lopping	2	2	2	0	1	0
			weeding	0	0	0	0	1	0
			cutting low branches	0	0	0	0	1	0
			spatial arrangement	4	4	4	4	4	4
	Inputs	Int	organic fertilisation	0	0	0	0	1	0
			seeding	3	3	0	0	0	0
			nursery	0	3	3	0	1	0
			protecting natural regeneration	0	0	0	2	0	1
			plant cuttings	0	0	0	0	0	1
		Ext	bought seedlings	3	5	0	3	0	0
			chemicals	0	3	0	0	0	0

				HG types					
				1	2	3	4	5	6
JACKFRUIT			presence	8/8	10/11	4/4	3/4	1/1	2/2
	Management		fruit harvesting	8	10	4	3	1	2
			sanitary pruning	3	3	2	0	1	1
			rejuvenation pruning	0	0	0	0	1	0
			canopy pruning	0	0	0	0	1	0
			lopping	0	2	0	0	1	0
			weeding	0	0	0	0	1	0
			cutting low branches	0	2	0	0	1	0
			spatial arrangement	4	4	4	4	4	4
	Inputs	Int	organic fertilisation	0	0	0	0	1	0
			seeding	4	5	0	2	0	1
			nursery	0	0	0	0	1	0
			protecting natural reg.	2	0	2	0	0	1
		Ext	bought seedlings	0	0	0	0	0	0
			wildings	0	3	0	0	0	0
TEAK			presence	6/8	10/11	1/4	3/4	1/1	2/2
	Management		sanitary pruning	2	2	0	0	1	2
			rejuvenation pruning	0	0	0	0	1	0
			canopy pruning	0	0	0	0	1	0
			lopping	3	2	0	0	1	2
			weeding	0	2	0	0	1	1
			cutting low branches	0	0	0	0	1	1
			coppicing	0	0	0	0	1	1
			spatial arrangement	4	4	1	4	4	1/4
	Inputs	Int	organic fertilisation	0	2	0	0	1	0
			nursery	0	2	0	0	1	1
			protecting natural reg.	4	3	0	2	0	0
		Ext	bought seedlings	4	3	1	0	0	1
NEEM			presence	5/8	5/11	0/4	2/4	1/1	0/2
	Management		leaf harvesting	3	5	-	0	1	-
			sanitary pruning	0	2	-	0	1	-
			rejuvenation pruning	0	0	-	0	1	-
			lopping	0	0	-	0	1	-
			cutting low branches	0	0	-	0	1	-
			spatial arrangement	1	4	4	4	1/4	4
	Inputs	Int	organic fertilisation	0	0	-	0	1	-
			nursery	0	0	-	0	1	-
			protecting natural reg.	5	3	-	1	0	-
		Ext	bought seedlings	0	0	-	1	0	-

Presence: a/b a – number of homegardens with species; b – number of homegardens studied (-) tree is not present.
HG – Homegardens; Int – Internal; Ext – External.
Legends for spatial arrangements: 1 – borders; 2 – rows; 3 – strips; 4 – scattered.

characteristics are related to the differences in whether farmers are cash or home consumption oriented. Farmers managing type 1 and 6 are cash orientation as reflected by the dominance of rubber and beverage producing crops or stimulant producing trees respectively. In these gardens cash crops represent more than half of the total number of trees. Also the farmer managing homegarden 5 is cash-production oriented, but in this case there is no clear crop dominance. The managers of homegarden type 3 are focused on both cash production (coconuts) and subsistence production (fruits). The homegarden types 2 and 4 are both home consumption oriented. These homegardens are small in contrast to the cash-oriented types 5 and 6 which are larger in size. The garden type 1 with highest production specialization in rubber production is of medium size.

Management characteristics

Generally speaking most management practices concern the manipulation of the tree environment rather than the tree itself. Sanitary pruning, rejuvenation pruning, canopy pruning to increase light penetration and cutting low branches are seldom, whereas weeding, fertilization and crop spacing are more common (Table 2). In particular cash crops are subjected to a variety of management practices. The most intensively managed species are coconut (*Cocos nucifera*), rubber (*Hevea brasiliensis*) and arecanut (*Areca catechu*); their cultivation includes use of chemical fertilizers and insecticides, systematic weeding, organic fertilization and row arrangement of trees. They are also relatively often protected from competitors and are the only crops that receive watering. Fruit trees and neem (*Azadirachta indica*) receive less attention (selective weeding, some application of organic fertilisation). The valuable timber species teak (*Tectona grandis*) receives no particular attention to increase productivity.

The different homegarden types can be arranged along a gradient of management intensity. The small-sized types 4 and 2 are on one end of this gradient characterised by low to medium management with a concentration on internal inputs and with random arrangement of trees. On the other extreme of the gradient, the medium to big sized homegarden types 1, 5 and 6 are subject to a more intensive management with use of both internal and external inputs such as chemical fertilizers and insecticides and bought seedlings. In this case, row planting is dominant. The small-sized type 3 has intermediate characteristics, with only a medium intensity of management, but with a dominant spatial arrangement in row. In summary, the homegarden types with a small size tend to be managed with a lower intensity than big ones, but their production is more diverse. Type 5 has the distinctive feature of being a large garden with very intensive management but low use of external inputs; this homegarden is oriented at multiple-production.

Changes in homegarden during the last decade

During the last decade hardly any change in homegarden size took place. However, several changes in the structure and function occurred; these varied for the different homegarden types (Table 3). Spices (black pepper, *Piper nigrum*) and ornamental species are the only use categories that have been introduced in all homegarden types except in types 5 and 3 where they were already present. Ornamentals are usually cultivated around and in front of the house and along paths. Black pepper is usually associated with palm trees in order to benefit from their soil management and inputs. Some farmers reported difficulties to harvest the palm nuts without damaging the pepper vines. Also some other support trees such as *Erythrina* were introduced. In five out of the six homegarden types fruit trees have also been introduced. They are usually cultivated close to the house, except for big trees such as mango (*Mangifera indica*) or jackfruit (*Artocarpus heterophylla*) or when planted in a large scale. Another change regards medicinal plants. In the homegarden types 1, 5 and 6 many farmers have partially removed the medicinal species.

Few structural and functional changes have occurred in types 2 and 4, especially when compared to types 1 and 6. The large majority (93%) of the homegardens of types 2 and 4 are still subsistence oriented, just as they were 10 years ago. Crop introductions do not concentrate on any specific species or use and are of low intensity (less than 50 individuals per species). These homegardens have preserved the traditional features; they still have a multistoried

Table 3. Species introductions and changes in spatial arrangements in the period 1993–2003 in six homegarden types, Kerala, India.

	Introduced uses/species	Rate of introduction	Spatial arrangements of trees	
			10 years ago	Nowadays
Type 4	Spices (pepper)	Low	Random	Random
	Fruits (*Citrus*, guava)	Low		
	Beverage (coffee)	Low		
	Ornamentals	Low		
Type 2	Spices (pepper)	Low	Random	Random
	Fruits (*Citrus*, Guava, *Anona*, papaya)	Low		
	Ornamentals	Low		
Type 3	Spices (pepper)	Low	Row	Row
	Fruits (guava, jack, cashewnut, papaya)	Low		
Type 5	Beverage (arecanut)	Low	Partly random, partly rows	Partly random, partly rows
	Cash (rubber)	Low		
	Ornamentals	Low		
Type 6	Timber (teak)	Low	Random	Row
	Ornamentals	Low		
	Beverage (arecanut, coffee)	High		
	Spices (pepper)	High		
	Fruits (banana)	High		
Type 1	Spices (pepper)	Low	Random	Row
	Fruits (guava, *Citrus*)	Low		
	Ornamentals	Low		
	Cash (rubber)	High		

Low – less than 50 individuals introduced in total.
High – more than 50 individuals introduced in total.

structure, high diversity and low dependency on external inputs. In contrast, 60% of farmers managing types 1 and 6 have shifted to a cash strategy with a modernized management oriented toward a few cash crops such as rubber, arecanut and coffee. The introduction of these commercial crops resulted in important structural and functional changes. The canopy became less stratisfied and species diversity was reduced, notably in respect to species producing fruit and nuts, timber and medicines. This caused a reduction in the multiple functions of homegardens. This change was most dominant in case of increased rubber cultivation, as this species is always grown as a monoculture. Coconut and arecanut are often still intercropped. Moreover, 70% of the farmers increased their use of chemical inputs.

No clear pattern could be deduced concerning the dynamics of the homegarden types 3 and 5. Although the production pattern of type 3 changed, its vegetation structure did not undergo any fundamental modification and the predominant spatial arrangement of trees remained in rows. The owner of type 5 follows a long-term cash strategy oriented toward timber production. The farmer has been able to follow the market demand by introducing more rubber and arecanut trees. However, these introductions did not affect structural characteristics and vegetation structure.

Table 4. Ordination of homegarden types along a gradient from traditional to modernised homegarden, Kerala, India.

	Type(s)	No. of HG	Size	Orientation	Nature of production	Tree/shrub diversity
Traditional	2, 4	15	(very) Small	Home	Multiple	High
Adapted traditional	6	1	Big	Cash	Multiple	High
Incipient modern	3	4	Small	Home and cash	Multiple	Medium
Modern	5, 1	10	Medium to very big	Cash	Mono	Low

Classification of homegarden types on an evolutionary axis

On the basis of their structural and functional characteristics and dynamics, the different homegarden types can be ordered along a gradient from traditional to modernised homegardens (Table 4). The homegarden types 2 and 4 are small in size and have a high diversity and a random arrangement of trees. Few changes occurred during the last decade and traditional features of homegardens have been preserved (high diversity, multistoried canopy and multi-production). These homegardens are oriented toward home-consumption and few products are sold. The management practices are predominantly based on internal inputs, although in type 2 some external inputs are also used. On the basis of these characteristics they can be characterised as traditional homegardens. These traditional homegardens can be contrasted with homegarden types 1 and 6, which can be characterised as being modern. In these modern homegarden types farmers have adopted a cash-orientation and have introduced several new management practices. In these relatively big homegardens the production became oriented at a few cash crops which are systematically arranged in rows. In the case of rubber, part of the homegarden is even transformed into single species plantation. Also, the use of external inputs (bought seedling, chemical fertilizers and insecticides) has increased.

Type 3 can be considered as incipient modern type as it shares both traditional and modern characteristics. This homegarden type consists of small homegardens with medium diversity, and involves a low management intensity that depends predominantly on external inputs. Although type 5 is characterised by its cash orientation including introduction of new cash crops such as rubber and systematic spacing of trees, it still maintains the multi-species composition of the traditional homegardens. The garden is very intensively managed, but mostly with internal inputs by using organic fertilisation and mulching for soil management and by regenerating trees by protecting natural regeneration, seeding, and using local plant material such as plant cuttings. Thus, although this homegarden was adapted to the modern cash economy, it maintained several of the characteristics of the traditional homegardens.

Discussion and conclusion

This study shows that homegardens should not be considered as being static. Rather their composition and management is gradually evolving in response to the socioeconomic dynamics. Only 50% of all respondents still followed traditional homegarden management practices, whereas 33% of all respondents have adopted modern practices by increasingly moving towards concentrated cash crop production and use of external inputs. Traditional homegardens were mostly of small size, while modern homegardens are much larger. This parameter should not be interpreted as the only, or main, feature influencing the development path of homegardens. Other factors, such as the role of the homegarden in the overall farming system and the degree to which a household has access to off-farm employment and income (Wiersum 2004) might be of more importance. Unfortunately, these factors could not be taken into account in the present study.

Our data reinforce the general fears regarding the loss of traditional characteristics of homegardens and their gradual demise into cash crop production systems (Kumar and Nair 2004). Because of the rise of market economy, agriculture in Palghat region is currently struggling to find new intensification strategies. Although traditional Kerala homegardens are reputed to be sustainable in both biophysical and socioeconomic terms, they do gradually change from a traditional type to a more modern one. This process of modernization often brings with it a decrease of the tree/shrub diversity, a gradual concentration on a limited number of cash-crop species, gradual homogenization of homegarden structure and increased use of external inputs.

Interestingly, however, one farmer in our sample had combined an increased orientation at cash crop production with the maintenance of a high species diversity and use of internal rather than external inputs. This example shows that there is not one uniform trend towards the modernisation of homegardens in Kerala, but that alternative pathways exist. Moreover, this example also shows that homegardens may be modernised, while still maintaining many of traditional ecological features ensuring ecological sustainability. On the basis of such examples new development policies

Annex 1. Tree species in homegardens, Kerala, India, arranged by functional use groups.

Use	Latin name	Family	English name	Malayalam name
Fruits and nuts				
	Passiflora edulis	Passifloraceae	Passion fruit	*Passion fruit*
	Anacardium occidentale	Anacardiaceae	Cashewnut	*Kasumavu*
	Ananas comosus	Bromeliaceae	Pineapple	*Kaithachakka*
	Mangifera indica	Anacardiaceae	Mango	*Mavu*
	Citrus sp.	Rutaceae	Lemon	*Narakam*
	Psidium guajava	Myrtaceae	Guava	*Pera*
	Aegle marmelos	Rutaceae	Bael	*Kuvalam*
	Tamarindus indica	Caesalpiniaceae	Tamarind	*Puli*
	Musa spp.*	Musaceae	Banana	*Banana*
	Alpinia glabra	Zingiberaceae	West indian shery	
	Carica papaya	Caricaceae	Papaya	*Papaya*
	Flacourtia indica	Flacourtiaceae	Governor's plum	*Chalir*
	Indigofera tinctoria	Fabaceae	Indian indigo	*Neelamari*
	Lawsonia inermis	Lythraceae	Hennea	*Mailanchi*
	Punica granatum	Punicaceae	Pomegranate	*Mathalam*
	Annona reticulata	Annonaceae	Custard apple	*Ramapazham*
	Annona indica	Annonaceae		*Atha*
	Annona squamosa	Annonaceae	Seed apple	*Sithaparam*
	Artocarpus heterophyllus	Moraceae	Jackfruit	*Plavu*
	Phyllanthus distichus	Euphorbiaceae		*Arineli*
	Emblica officinalis (syn. *Phyllanthus emblica*)	Euphorbiaceae	Gooseberry	*Nelli*
	Lana sp.	Komokiideae	Jamba	*Chamba*
	Manilkara achras (syn. *Achras sapota*)	Sapotaceae	Sapota	*Sapota*
	Spondias pinnata	Anacardiaceae	Wild mango	*Ambalam*
	Syzygium cuminii	Myrtaceae	Black plum	*Njaval*
	Syzygium jambos	Myrtaceae	Rose apple	*Champa*
Beverage and stimulant				
	Piper betle	Piperaceae	Betel leaf	*Betel leaf*
	Coffea arabica	Rubiaceae	Coffee	*Kapi*
	Areca catechu	Palmaceae	Arecanut	*Adeka*
Spices				
	Piper nigrum	Piperaceae	Black pepper	*Kurumulaku*
	Cinnamonum zeylanicum	Lauraceae	Cinnamon	*Karuvappatta*
	Cinnamonum verum	Lauraceae		
	*Zingiber officinale**	Zingiberaceae	Ginger	*Inchi*
	*Capsicum annuum**	Solanaceae	Green chili	*Cheni*
	Mentha arvensis	Lamiaceae	American wild mint	*Pudena*
	Pimenta officinalis	Myrthaceae	Allspice	*Sarvasugandhi*
	Murraya koenigii	Rutaceae	Curryleaf	*Kariveppu*
	*Curcuma longa**	Zingiberaceae	Turmeric	*Mannal*
	Myristica fragrans	Myristicaceae	Nutmeg	*Jati*
Timber and fire wood				
	Ailanthus triphysa	Simaroubaceae	White sirus	*Maty*
	Ceiba pentandra	Bombacaceae	White silk cotton	*Llavam*
	Pavetta indica	Rubiaceae	Yellow paveta	*Mania paveta*
	Terminalia arjuna	Combretaceae	Arjun	*Maruthu*
	Terminalia catappa	Combretaceae	Indian almond	*Badam*
	Terminalia paniculata	Combretaceae		*Maridu*
	Tectona grandis	Verbenaceae	Teak	*Tekku*
	Xylia xylocarpa	Leguminoseae	Iron wood	*Irul*
	Artocarpus hirsuta	Moraceae	Wild jack	*Anjli*
	Swietenia mahogany	Meliaceae	Mahogany	*Mahagany*
	Lablab purpureeus	Leguminoseae	Indian butter bean	*Aviram*
	Phyllanthus reticulatus	Euphorbiaceae		*Neelooram*
	Acacia mangium	Leguminoseae	Mangium	*Mangium*

Annex 1. Continued.

Use	Latin name	Family	English name	Malayalam name
	Albizia odoratissima	Fabaceae	Black siris	*Pulivaka*
	Bombax ceiba	Bombacaceae	Red cotton tree	*Elavu*
	Calophyllum elatum	Guttifereae		*Punna*
	Cleistanthus collinus	Euphorbiaceae		*Udugu*
	Santalum album	Santalaceae	Sandalwood	*Agil*
	Sapindus laurifolia	Sapindaceae	Soap nut tree	*Oorinjimaaram*
	Bridelia retusa	Euphorbiaceae		*Kayani*
	Ficus bengalensis	Moraceae	Banyan tree	*Banian*
	Ficus hispida	Moraceae		*Paragom*
	Grewia tilifolia	Tiliaceae	Unnam	*Chadachi*
	Macaranga indica	Euphorbiaceae		*Vatta*
	Madhuca longifolia	Sapotaceae	South indian mahoca	*Irrippa*
	Mallotus philippensis	Euphorbiaceae	Kamala	*Sinduramaram*
	Melia azedarach	Meliaceae	Persan lilac	
	Mimusops elengi	Sapotaceae	Bullet wood tree	*Erany*
	Polyalthia longifolia	Annonaceae	Mast tree	*Arana*
	Pongamia pinnata	Leguminoseae	Pongam oil tree	*Ungu*
	Pterocarpus marsupium	Fabaceae	Indian kino tree	*Venga*
	Schleichera oleosa	Sapindaceae	Ceylon oak	*Poovam*
	Streblus asper	Moraceae	Siamese rough bush	*Parakam*
	Strychnos nux-vomica	Strychnaceae	Strychnine	*Kanniram*
	Thespesia populnea	Malvaceae	Indian tulip tree	*Pumaram*
	Wrightia tinctoria	Apocynaceae	Indrajav	*Dandapala*
	Pandanus sp.	Pandanaceae	Screw pine	
	*Carthamus tinctorius**	Asteraceae	Saflower	*Chendurakam*
Ornamentals				
	Hibiscus rosa-sinensis	Malvaceae	Chinese hibiscus	*Chembaruthi*
	Hibiscus spp.	Malvaceae	Hibiscus	*Hibiscus*
	Rosa sinensis	Rosaceae	Rose	*Rosa*
	*Baliospermum montanum**	Zingiberaceae	Croton	*Nagadandi*
	Bougainvillea spectabilis	Nyctaginaceae	Bougainvillea	
	Jasmonum sp.	Oleaceae	Jasmine	*Mulla*
	Calendula officinalis	Asteraceae	Marigold	*Chendumali*
	Clerodendrum paniculatum	Verbenaceae	Krishnacrown	*Krishnakereedam*
	Codiaeum variegatum	Euphorbiaceae	Croton	
	Crossandra undulaefolia	Acanthaceae	Yellow crossandra	*Kanakamparam*
	Delonix regia	Leguminoseae	Gulmohar	*Gulmohar*
	Gardenia lucida	Rubiaceae	Brilliant gardenia	*Sugandaraj*
	Hygrophila auriculata	Acanthaceae	Long leaved barleria	*Chuli*
	Vitex negundo	Verbenaceae	Changing rose	*Karinochi*
	Caesalpinia pulcherrima	Fabaceae	Peacock flower	*rajumali*
	Mussaenda indica	Rubiaceae	Mussaenda	*Mussanda*
	Nyctanthes arbor-tristis	Oleaceae	Coral jasmin	*Pavizhamulla*
	Garcinia gummigutta	Guttifereae		*Kudampulli*
	Lagerstroemia lanceolata	Lythraceae	Benteak tree	*Ventekku*
	*Chromolaena odorata**	Asteraceae	Communist patcha	
	Tabernaemontana divaricata	Apocynaceae	Forbiden root	*Nandiavratam*
Multipurpose Trees				
	Azadirachta indica	Meliaceae	Neem	*Veppu*
	Cocos nucifera	Arecaceae	Coconut	*Tenjia*
	Borassus flabellifer	Arecaceae	Palmyra	*pana*
	Caryota urens	Arecaceae	Elephant tree	*Erampana*
	Adathoda sp.*	Acanthaceae	Malabar nut	*Adalodakom*
	*Manihot glaziovii**	Euphorbiaceae	Cera rubber	
	Bambusa spp.*	Poaceae	Bamboo	*Mula*
	*Gliricidia sepium**	Leguminoseae	Quick stick	*Sheemakkonna*

Annex 1. Continued.

Use	Latin name	Family	English name	Malayalam name
	Cassia fistula	Fabaceae	Indian laburnum	*Kanikkonna*
	Erythrina indica (syn. *Erythrina variegata)*	Fabaceae	Indian coral tree	*Murikku*
Medicinal				
	*Vetiveria zizanoides**	Gramineae	Vetiver	*Ramacham*
	Calycopteris floribunda	Commelinaceae		*Pullani*
	Ophiorrhiza mungos	Rubiaceae	Mongoose plant	*Avil pori*
	Rauwolfia serpentina	Apocynaceae	Serpentine root	*Sarppagandhi*
Other				
	Glycosmis pentaphylla	Rutaceae	Ash sheora	*Panal*
	Nerium oleander	Apocynaceae	Indian oleander	*Areli*
	*Euphorbia nerifolia**	Euphorbiaceae	Cactus	*Cactus*
	*Benincasa hispida**	Cucurbitaceae	Ash gourd	*Kumbalam*
	Amaranthus sp.	Amaranthaceae	Pigweed	*Cheera*
Religious				
	Ixora coccinea	Rubiaceae	Jungle flameisora	*Techi*
	Thevetia peruviana	Apocynaceae	Yellow oleander	*Kolambi*
	Aegle marmelos	Rutaceae	Bael tree	*Kuvalam*
	Bauhinia variegata	Fabaceae	Variegated bauhinia	*Mandaram*
	Plumeria rubra	Apocynaceae	Temple tree	*Ezhachempakam*
	*Ocimum gratissimum**	Lamiaceae	Basil	*Ramatulasi*
	*Ocimum sanctum**	Lamiaceae	Cherry tree	*Tulasi*
	Alstonia scholaris	Apocynaceae	Scholar tree	*Pala*
	Michelia champaca	Magnoliaceae	Yellow champaka	*Champakam*
Rubber				
	Hevea brasiliensis	Euphorbiaceae	Rubber	*Rubber*
Staple food				
	*Maranta arundinacea**	Marantaceae	Arrowroot	*Kuwa*
	Dioscorea sp.*	Dioscoreaceae	Yam	*Chena*
	*Colocasia esculenta**	Araceae	Taro	*Chempu*
	*Manihot utilissima**	Euphorbiaceae	Cassava	*Kappa*
	Moringa oleifera	Moringaceae	Drumstick	*Muringa*

*Only presence noted, number of individuals not counted.

might be identified which aim at optimal combination of ecological and productive features of the homegardens rather than optimizing cash crop production only.

Although the study was mainly focused on ascertaining trends in tree composition resulting from the process of commercialisation, also other trends influencing the composition of the homegarden vegetation were observed: i.e. an increase in the use of ornamental plants and an increase in staple food production. The trend in gradual replacement of functional plants to ornamentals has also been observed in cases where people became richer (Christanty et al. 1986). The gradual increase in staple food production was specifically found in cases where homegardens were the last remaining farming unit of poor households (Wiersum 1982). Unfortunately, little attention has been given towards systematically studying under which set of conditions these different trends in homegarden development occur, to what extent they are interrelated, how they are related towards changes in livelihood conditions, and what their impact is on biodiversity.

Our study further shows that it is incorrect to assume an unilinear homegarden development, rather different pathways in homegarden development may co-exist. At present rural areas are subject to many socioeconomic changes (Ashley and Maxwell 2001). The notion of homegardens being sustainable need therefore to be specified in respect to ecological and social sustainability respectively. Whereas the concept of ecological sustainability is time-independent, the concept of social sustainability includes the notion of agroforestry systems adjusting in a timely fashion to changing rural conditions. With respect to the potential of traditional agroforestry systems such

as homegardens, the focus in assessing social sustainability should not only be on the question of whether the system fits into the traditional farming and livelihood systems, but also on the question of whether these agroforestry systems can be adjusted to modern rural conditions while still maintaining their features of ecological sustainability. Our study shows that research based on detailed assessments of the actual dynamics in the features of traditional agroforestry systems is rewarding. Such studies may indicate that different developments trajectories are being followed. The understanding of these development pathways and the factors involved offers good scope for the identification of options for further modification of agroforestry systems with a proven history of being ecologically sustainable (Kumar and Nair 2004).

Acknowledgement

The fieldwork for this research was accomodated by the Integrated Rural Technology Center at Palakad, Kerala. Dr. Unnikrishnan provided valuable background information and important assistance to the organisation of the survey. Additional information on the status of homegardens was provided by Dr. Mohan Kumar and Dr. Sankar from the Kerala Forestry Research Institute and Mr. K.P. Ouseph and M. Shetty from the Kerala Forest Department.

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