Chapter 6

Factors determining homegardens woody diversity: a case study in Thai Yuan homegardens

6.1 Introduction

Traditional homestead farming systems, known as ‘homegardens’, are multi-strata agroforestry systems that include small-scale fruit-, crop- and animal production in close proximity to the homesteads. Homegardens are found in many countries, especially in the tropics and subtropics (Kumar and Nair 2004). They are important in the daily lives of their owners because they provide households’ needs in both rural and urban areas (Kortright and Wakefield 2011). Plants grown, intentionally or unintentionally, in homegardens are important for household subsistence and economy. Caloric and nutritional supplies are obvious and significant benefits of homegardens (Balooni et al. 2014; Huai et al. 2011; Mendez et al. 2001; Perrault and Coomes 2008; Vlkova et al. 2010). Homegarden owners obtain a number of nourishing and convenient products from their homegardens (Kortright and Wakefield 2011). Surplus products from homegardens are sold at local markets and are important sources of supplementary cash income for many households (Akrofi et al. 2008; Arifin et al. 2012; Bassullu and Tolunay 2010; Bussmann et al. 2008; Huai et al. 2011; Mendez et al. 2001; Trinh et al. 2003; Yang et al. 2014). The orientation towards either food security or cash income generation depends on the family who owns the homegarden (Trinh et al. 2003). Many native or endangered species can be found in homegardens (Akinnifesi et al. 2010; Albuquerque et al. 2005; Milow et al. 2013) and they are niches for domesticating semi-wild species (Akinnifesi et al. 2010). Homegardens are also important places for experimentation with new cultivation techniques and new plant species (Akinnifesi et al. 2010; Kumar and Nair 2004) and households derive health benefits from plants with medicinal properties cultivated in homegardens (Balooni et al. 2014). Edible plants grown in homegardens provide food security not only for individuals and families but

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also for communities by benefiting community members to easier access a safe, nutritious, and cultural diets (Kortright and Wakefield 2011). Plants in homegardens contribute to carbon sequestration and mitigate effects of climate change (Balooni et al. 2014).

Most studies of homegardens refer to rural or deep rural homegardens. But homegardens are actually quite common in urban settings as well. Urban homegardens are important green spaces for urban residences and also enhance the communities' esthetic value (Balooni et al. 2014). So in urban areas, homegardens improve the community's micro-climate. Cultural identity and urban biodiversity are also conserved and presented in homegardens (Taylor and Lovell 2014). Urbanization is a strong and omnipresent process, especially in subtropical and tropical countries. This process comes with many changes to homegardens, such as reduced number and usages of plants in most categories but an increase of ornamental species (Hodel and Gessler. 1999; Poot-Pool et al. 2015; Quiroz et al. 2001; Trinh et al. 2003). So, although urbanization may not affect agrobiodiversity in homegardens, the components are differentiated (Poot-Pool et al. 2015). The inflation of the World's human population and infrastructure development lead to reduction of homegardens' size, and their shape may be restrained to a block and strip pattern (Arifin et al. 1998). The structure of many urban homegardens is also affected by socio-economic aspects such as commercialization which often causes an increase in the number of cash-generating species at the cost of species used for subsistence (Abdoellah et al. 2002; Vlkova et al. 2010).

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Functions of homegardens are related to their diversity of plants (Fernandes and Nair 1986; Kumar and Nair 2004; Peyre et al. 2006), which in turn is affected by many factors. Normally, plants in homegardens are tended and cultivated by their owners; so, owners' preferences are the main factor determining which species are found in the homegarden (Bardhan et al. 2012; Gajaseni and Gajaseni 1999; Srithi et al. 2012). Ecological factors are also important in determining which plants are found in homegardens. For example, homegardens at higher elevation usually possess lower diversity than those located at lower elevation (Hodel and Gessler 1999; Karyono 1990; Kehlenbeck 2007; Tesfaye 2005), although the opposite occur in arid regions (Norfolk et al. 2013). Homegardens' characteristics, such as size (Abdoellah et al. 2002; Hodel and Gessler. 1999; Kehlenbeck 2007; Quiroz et al. 2001) and age (Coomes and Ban 2004; Quiroz et al. 2001) also affect diversity, species richness, and abundance of plants grown in them. Intensive crop production for generating cash causes lower diversity and simplification in many homegardens (Nair 2006; Peyre et al. 2006; Wiersum 2006). Through the process of modernization, homegardens may lose their tree/shrub diversity, crop genetic variety, and the increase of external output (Peyre et al. 2006).

In homegardens, both herbaceous and woody species are presented. However, woody plants are the main component of most homegardens because they provide sustainable products and ecosystem services (Kindt et al. 2004). Most revenues from homegardens are generated by woody plant products (Kehlenbeck 2007). Moreover woody species are rarely affected by seasonal variation (Kabir and Webb 2008). Woody species always present in homegardens all year round while some herb species may disappeared during dry season (Cruz-Garcia and Struik 2015). However, there is only limited knowledge of how many species are grown in homegardens, and of the factors that control their diversity.

In this study, we selected homegardens in a semi-urban community to investigate their woody plant characteristics and the factors that determine the diversity of their woody plant component. Specifically we attempted to answer: 1) How many species of woody plants were there in the homegardens and what did their owners obtain from them? 2) Were there any economically important species and which were they? 3) Which factors, such as homegarden age and size, and family size, influenced the homegardens' diversity and richness?

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6.2 Methods

6.2.1 Study Area

Our research was conducted in the Takrai village of Mae Rim District, Chiang Mai Province, Thailand (18^{o}54.13'N, 98^{o}56.57'E; Fig. 1). Here the elevation is from 320–330 m.a.s.l, mean annual precipitation is 1144 mm and mean annual temperature is 27^{o}C. The village was officially established about 70 years ago and it has a long tradition of homegardening. The population was 1,536 with 955 males and 581 females in 2014. Agricultural areas around the village, owned by a few farmers, are cultivated with glutinous rice (*Oryza sativa* L. var. *glutinosa* (Lour.) Körn) and other herbaceous crops such as lettuce (*Lactuca sativa* L.) and Chinese mustard (*Brassica chinensis* L. var. *parachinensis* (L.H. Bailey) Sinskaya). Although woody species are rare in the arable land, they are still plentiful in most homegardens. So in this village, as in other villages in Thailand, homegardens are important places for conserving woody plants. Agriculture once was the main occupation for most villagers, but due to economic expansion and urbanization most farmers have now sold their rice field to become employees but they still maintain gardening and agricultural skills. The majority of Takrai's homegardens are at least 50 years old because most villagers have lived in the village through generations since the establishment of the village.

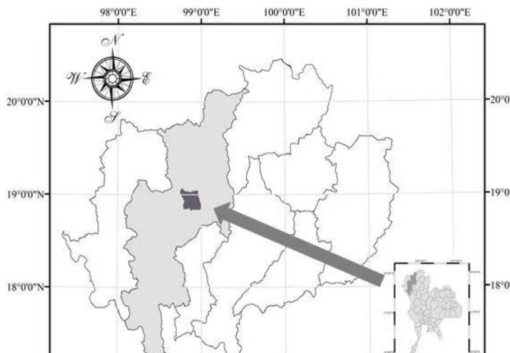

Figure 6.1. Location of the Mae Rim district, Chiang Mai Province

6.2.2 Inventories and Questionnaires

Woody plants inventories were done between July 2013 and June 2014 in 50 homegardens and covered 20% of the total of 249 households in the village. The inventories were initiated at a local guide's home and then continued northward along the village road. Every third homegarden was investigated. If the household head or his wife were not available at the visiting time the next house was selected instead. This method was repeated each day but in different directions. Every woody species in the homegarden was registered and its abundance was noted. For bamboos, a clump was counted as one individual. Lianas and species used only to fence the homegardens were excluded. Information about the use of each species was solicited from all family members who were available at the home at the visiting time. Only the main use of each species was recorded because that was assumed to be the main factor that influenced the owners' decision to cultivate the plant in their homegarden (Milow et al. 2013). The current market value and harvesting time of each cultivated woody species were recorded. In each homegarden, the household head and his wife were interviewed using a questionnaire (Table 1). The area of each homegarden was informed by the owners and confirmed with the title deed whenever possible. When such information was not available, the size was measured with measuring tape. The age of each homegarden was recorded using an ordinal scale: 1 for new-comer (<10 years), 2 for recent inhabitant (10–50 years), and 3 for those who lived more than one generation (>50 years). This ordinal scale suited the fact that most inhabitants could not remember the exact years they lived.

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Table 6.1 Variables collected from 50 randomly selected households in *Takrai* community. The unit described as used for NLPCA analysis.

Variable	Unit	Average			Range
		Mean	Mode	Median	
Adults in household	Number	2.69	3	3	1–6
Adult males	Number	1.44	2	1.5	0–3
Age of homegarden	“1”≤10 years, “2”=10–50 years, “3”>50 years	“1” = 5, “2” = 16, and “3” = 29			
Age of household head	Years	60.14	47	60.5	31–83
Age of oldest household member	Year	68.12	76	67	47–90
Earning household	Number	2.25	2	2	0–5
Education of household head	0= none, 1=primary school, 2=secondary school, 4 = Bachelor degree or higher, and 3 for between 2 and 4	–	1	1	0–6

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Table 6.1 (continued)

Variable	Unit	Average			Range
		Mean	Mode	Median	
Family size	Number	3.14	3	3	1-6
Gender of household head	1 = female, 2 = male	10 females, and 40 males			
Gender of oldest member	1 = female, 2 = male	16 females, and 34males			
Homestead size	m2	389.32	–	–	53–2,000
Literate household member	Number	2.92	3	3	0–5
Occupation of house hold head	0 = none, 1 = agriculture, 2 = other	"0" = 9, "1" = 25, "3" = 16			

6.2.3 Analyses

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Our variables included both numerical and non-numerical (nominal and ordinal scale) information in many dimensions. We used nonlinear principal component analysis (NLPCA) to reduce the dimension of the data. The goal of NLPCA is like that of standard principal components analysis (PCA), to reduce the complexity of the data sets. However, NLPCA can be used for analyzing variables with different measurement levels including nominal, ordinal, or numeric (Linting and Kooij, 2012). The program CATPCA (SPSS statistics ver. 17) was used to compute the NLPCA. Two outliers were excluded from this analysis so there are 48 households included in this computation. The Passive Treatment was used for missing data. Scree plots were also conducted to select a number of components and after iterant computations, we selected three components for this analysis. The NLPCA scores were used for computing the correlation with diversity indices. Correlations were calculated between diversity indices (Shannon index (H) and Gini-Simpson index (1-D)), evenness (E), species richness (S), and species abundance (N). Both species richness and abundance were log transformed. Spearman's rank correlation coefficient was chosen because diversity and evenness index were ordinal scales.

PLANT IDENTIFICATION AND CATEGORIZATION

Most plant species were identified in the field. For those that could not be identified in the field, voucher specimens were collected and identified in Ethnobotany and Northern Thai Flora Laboratory, Chiang Mai University. Plant specimens were deposited at the Herbarium of Department Biology, Chiang Mai University (CMUB). Each species was assigned to a use category following the Economic Botany Data Collection Standard (Cook 1995). Plants were noted as native if they originated in Thailand but exotic if they did not. The origin of the species followed the Tem Smitinand's Thai Plant Names (Pooma and Suddee 2014).

6.3 Results

6.3.1 Woody Species found in Homegardens and their Functions

There were 92 woody species in the 50 investigated homegardens. Both the median of individuals and number of woody species found were eight (Table 2). Most woody species and individuals (49% and 71% respectively) were edible. Among these edible species, woody fruit plants were the largest group. There were 26 (56%) edible fruit producing species out of the 47 species that produced edible parts. Surplus from household consumption was, in general, shared between neighbors and kin. These fruit trees not only provided edible part they also provided shade for their owners and shade loving species in lower strata of the homegardens.

There were 48 native species and 44 exotic species (52% and 48%, respectively). The difference between these numbers was insignificant (χ^2, $p = 0.677$).

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Mango tree was the most common species, found in 64% of the studied homegardens. However, the most abundant species was the white fig (*Ficus virens* L.). This species produced edible young leaves favored by local people.

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Table 6.2 The number of plant species and individuals found in 50 urban homegardens in northern Thailand.

	Homegarden data		Tree species data		Species found						Individual found					
	Tree sp. found in HG	No. of trees in HG	No. of ind.	No. of HG found	EnU	F	FA	Ma	Me	SU	EnU	F	FA	Ma	Me	SU
Max.	34	79	47	22	12	16	6	2	1	1	27	45	56	8	1	1
Min.	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Med.	8	8	3	2	1	5.5	1	0	0	0	1	7	2	0	0	0

Abbreviations: EnU = environmental uses; F = foods; FA = food additives; HG = homegarden; Ind. = individual; Ma = materials; Me = medicines; SU = social uses

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6.3.2 Factors Correlated with Homegardens' Diversity

The Spearman's rank correlation test between the diversity indices showed significant correlations between abundance and all diversity indices, except with the evenness (Table 3). This means that homegardens with more woody plant individuals tended to have more species and higher diversity than homegardens with lower overall abundance. Although positive correlations appear between diversity indices (H, 1-D, and Ln(S)) and abundance (Ln(N)), evenness (E) seemed to be correlated with the abundance in different ways. Evenness is negatively correlated with tree abundance. Homegarden with low overall abundance of woody plants would be more similar in a number of individuals (abundances) of the species (higher evenness) whereas homegardens with high overall abundance would have less similar abundances of species (lower evenness). Moreover, there was no significant correlations between evenness and neither diversity nor species richness.

A summary of the 13 variables is shown in Table 1. The results of NLPCA test are summarized in Table 4. The results of correlation test between NLPCA and diversity indices showed that the scores were low and just the 3rd dimension was significantly and negatively correlated to the two diversity (H and 1-D) indices and species richness (Table 5). The 3rd dimension had two positive eigenvalues (household head occupation and education) and one negative value (age of household). This contradiction suggests that new-comers or recent inhabitants had higher education and did not prefer an agricultural career. The negative correlation between this dimension and diversity indices suggests that older homegardens owned by farmer who had lower education level tended to have higher plant diversity, and vice versa.

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The other dimensions were not correlated with woody species diversity, but the relation of variables in each dimension describe the overall image of household characteristics in this village. The first dimension was related to family size, which included number of adults; family members; number of literate members; number of income earning family members, gender of household's head and oldest family member. Most family members in each household were adult and a larger family tended to have more adults. In other words each family tended to have only one or two children. Most families had only three members in a household (Table 1): two parents and a child. This is a basic characteristic of families in urban areas. More adults in a family, commonly, meant that there were more members who could generate income, and more members with higher education. Household's head corresponded to a member, who makes most decision within the household, and mostly they were the oldest male member or the second oldest if the oldest was too old. Moreover, female-headed families appeared only when the husband had died or, in rare cases, they were divorced. So these families tended to have less family member than families headed by a man.

Table 6.3 Correlation between diversity indices (Spearman's rank)

	H	1-D	Ln(S)	Ln(N)	E
H	1	.983	.986	.932	.098
1-D	**	1	.956	.893	.018
Ln(S)	**	**	1	.961	-.209
Ln(N)	**	**	.956	1	-.376
E	ns	ns	ns	*	1

*$P < 0.05$, **$P < 0.001$; ns, not significant

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Table 6.4 Results of a non-linear principal component analysis on 13 variables collected from 50 urban homegardens in *Takrai* village in northern Thailand

Variable	Dimension		
	1	2	3
Adult males in household	0.402	**0.723**	0.251
Age of oldest member	0.085	**0.975**	0.093
Gender of household head	**0.768**	**0.209**	0.471
Adult in household	**0.921**	0.262	0.247
Gender of oldest member	**0.575**	-0.290	-0.322
Occupation of household head	-0.171	-0.398	**0.722**
Family size	**0.925**	0.125	0.331
Education of household head	-0.547	-0.069	**0.639**
Age of homegarden	-0.313	0.362	**-0.474**
Literate household member	**0.880**	0.129	0.315
Homestead size	-0.167	**0.437**	-0.278
Age of household head	-0.709	**0.766**	0.032
Earning household member	**0.765**	0.140	-0.092

Bold values indicate those factor scores that dominate the dimension

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Table 6.5 Correlation between diversity indices and NLPCA (Spearman's rank)

Dimension	Diversity indices				
	H	1-D	Ln(S)	Ln(N)	E
D_1	-0.155	-0.168	-0.132	-0.173	-0.070
D_2	-0.042	-0.054	-0.033	-0.032	-0.151
D_3	**-0.363**	**-0.369***	**-0.362**	-0.327	-0.018

*$P < 0.05$

As described above, most of family heads were oldest male so the positive relation between age of household head and age of oldest member in 2nd dimension was predictable. Male head family also indicated more adult males in family than female head family. Family with older family head seemed to possess larger homestead size.

6.4 Discussion

6.4.1 Woody Species' Richness and Functions in Homegarden

The studied urban homegardens were important places for keeping plants used in daily life, especially for daily consumption. So edible species were one of the most important components in these homegardens. For this reason, many researchers across the world have reported on the abundance of food plants in homegardens (e.g. Abebe et al. 2006; Gajaseni and Gajaseni 1999; Wezel and Ohl 2006). In other words, the main function of homegardens was food production (Abebe et al. 2006; Gajaseni and Gajaseni 1999; Wezel and Ohl 2006). So giving more attention to homegarden development could improve the food security of households in the future (Kebebew et al. 2011). Moreover, it should be noted here that products were sustainably generated from these woody plant species (Kehlenbeck et al. 2007; Kindt et al. 2004). Sharing surplus fruits between kin and neighbors were common and important. This indicated

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that homegardens were also important food sources for the community which helps to promote community food security (Kortright and Wakefield 2011).

Out of 92 woody species, 48% were exotic. The presence of exotic plants appeared to be a common feature of urban homegardens (Hodel and Gessler 1999; Poot-Pool et al. 2015). The commonness of native plant species in all household underlined the significance of homegardens for the conservation (Akinnifesi et al. 2010; Albuquerque et al. 2005; Das and Das 2015). However, continued urbanization would weaken this role of homegardens and this role may become obsolete if they were not promoted nor sponsored by any organizations in the future.

The most common woody species was the mango tree. This species was presented in 32 of the 50 studied homegardens. The mango tree is very easy to cultivate (Alam 2012) and it is found in many homegardens throughout the tropics (e.g. Abebe et al. 2010; Alam 2012; Kabir and Webb 2008; Vlkova et al. 2010; Wezel and Ohl 2006), so the commonness of this species was not surprising. Moreover, mango is one of the most important economic fruits in Thailand and found across the country. Mango fruits were eaten fresh as a snack or cooked as spicy salad while ripe fruits are eaten as dessert fruit. Young mango leaves were also cooked as sour salad. In this study we focused only at species level not variety level, but our observations showed that there were many varieties of mango trees. Different varieties had different fruit taste; color; and size, tree size, and taste of young leaves and were used for different purposes. So, homegardens were very important place for *in situ* conservation of genetic diversity of this economic plant. A study of Shan (an ethnic group in Thailand and Mynmar) homegardens in northern Thailand also found that mango tree was the most common species (Panyadee et al. 2012).

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6.4.2 Economic Species in Homegardens

Woody trees in homegardens can generate sustainable income. This is another important role of the studied homegardens beside food production. Among nine economic species found in this study, the most important one was the white fig (*Ficus virens* L.). White fig is one of the most popular seasonal vegetables in northern Thailand. It is a deciduous species that can produce young leaves two times a year between February–March. The young leaves are cooked as sour curry or spicy salad. In term of income generation, the amounts of cash income from a tree seemed to be small (about 80 US$ per year) but there is no expense involved in generating this income. Like most trees in homegardens, this species needs neither special attention nor supplies like water or fertilizers. For a family with an elderly head, income from this tree was very important because one tree provided money equal to 1/3 of the annual elderly care allowances.

6.4.3 Factors Determining Homegardens' Diversity

Homegardens with higher numbers of plant individuals seemed to have more species richness and diversity. A positive effect of woody plant abundance on species richness and diversity was also found in farms in western Kenya (Kindt et al. 2004). Normally, sites with high tree abundance tend to be dominated by a few species with economic importance (Kindt et al. 2004). This correlation, however, had low R^2 value which means low predictive power; homegardens with higher woody species abundance do not absolutely need to have lower evenness than homegardens with lower woody species abundance.

The significant correlation between homegardens' diversity and 3rd dimension of NLPCA suggested that only household head occupation, education, and age of household drove the homegardens' diversity. Age of the homegarden is another important factor determining homegarden features (Coomes and Ban 2004; Quiroz et al. 2001). Older homegardens always had higher diversity and species richness because of accumulation over time (Blanckaert et al. 2004; Tesfaye 2005). Moreover, older homegardens may have better conditions for growing more species (Bannister and Nair 2003; Kindt et al. 2004). Higher educated household heads were always expected to have a non-agricultural career which leads to less experience and skill for cultivating plants (Salam et al. 2000). Therefore, their homegardens occasionally had fewer plant species and lower diversity. The trend and policy of governance in increasing the time of education would gradually decrease plant diversity in homegardens. So it should be an important issue that there should be any attempt to increase and promote diversity in homegardens.

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Generally, larger homegardens seem to possess more woody plant individuals and diversity because woody plants need space for growing (Abdoellah et al. 2002; Hodel and Gessler. 1999; Kehlenbeck 2007; Quiroz et al. 2001). The insignificant correlation between size and woody plant abundance or diversity found in this study could possibly be caused by vegetable cultivation. Although homegardens with bigger size possess more space for woody cultivation, cultivating vegetables generates more income than woody species. For this reason, some owners of large homegarden decided to cut down some woody plants to make the place for more profit generating vegetables such as lettuce (*L. sativa* L.) and Chinese mustard (*B. chinensis* L. var. *parachinensis* (L.H. Bailey) Sinskaya). But other owners liked to have their homegardens full of shading trees. As mentioned by many reports, the emergence of commercial crops caused the loss of plant diversity in homegardens (Abdoellah et al. 2002; Vlkova et al. 2010). Moreover, this fact shows another important factor determining homegardens' diversity and composition which is the owners' personal decisions as noted by many reports (Bardhan et al. 2012; Gajaseni and Gajaseni 1999; Srithi et al. 2012).

6.5 Conclusions

There are 92 woody species (48 native and 44 exotic species) reported here from urban homegardens in northern Thailand. Most of them are edible species. The most common species was the mango tree while the most abundant species was the white fig (*Ficus virens* L.). Both of them are economically important species.

Woody species in homegardens were important sources of constant supplementary income, especially from white fig trees which was the most important economic tree species in this community. Conserving this species could secure constant income and food from year to year and generation to generation

Many factors contributed to the urban homegardens' diversity: household head's occupation; education; and age of household, are statically correlated with homegardens' woody plant diversity. We did not find that the homegarden size determined their species richness and diversity even if that relationship has been reported from many other parts of the world.

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