Rural Homegardens in Central Sulawesi, Indonesia: An Example for a Sustainable Agro-Ecosystem?

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1 Introduction

1.1 Homegardens: Definition and functions

Homegardens are one of the most complex and diverse agro-ecosystems worldwide. Homegarden systems have existed for millennia (KUMAR & NAIR, 2004; SOEMARWOTO & CONWAY, 1992) in many tropical regions, where they played an important role towards the development of early agriculture and domestication of crops and fruit trees, a still ongoing process (KIMBER, 1978; MILLER & NAIR, 2006; NIÑEZ, 1987; SMITH, 1996). The high and maintained diversity of both cultivated and wild plant species makes homegardens suitable for *in situ* conservation of plant genetic resources (ALVAREZ-BUYLLA ROCHES et al., 1989; DAMANIA, 1996; MAXTED et al., 1997; WATSON & EYZAGUIRRE, 2002). Individual homegardens have been continuously cultivated for many decades and even centuries, for example, in Sri Lanka (HOCHEGGER, 1998). For this reason, homegardens are generally regarded as a sustainable agro-ecosystem (CHRISTANTY, 1990; KUMAR & NAIR, 2004; SOEMARWOTO & CONWAY, 1992; TORQUEBIAU, 1992). However, quantitative support for this statement is rare, as most of the published homegarden studies are rather descriptive. This might be due to the difficulty or even impossibility to measure sustainability *per se*, resulting in an indirect assessment by using more or less widely accepted sustainability indicators (HUXLEY, 1999; GLIESSMAN, 1990a; KUMAR & NAIR, 2004; PIEPHO, 1996; TORQUEBIAU, 1992), as presented in detail under 1.2.2.

As the appearance of homegardens is highly variable, there are several definitions of this system. Homegardens are commonly defined as:

> A piece of land with a definite boundary surrounding a homestead, being cultivated with a diverse mixture of perennial and annual plant species, arranged in a multi-layered vertical structure, often in combination with raising livestock, and managed mainly by household members for subsistence production (CHRISTANTY, 1990; FERNANDES & NAIR, 1986; HOOGERBRUGGE & FRESCO, 1993; KUMAR & NAIR, 2004; RUGALEMA et al., 1994; SOEMARWOTO, 1987).

NAIR & KUMAR (2006) emphasised that the multi-layered vegetation structure as well as the intimate combination of trees, shrubs, and annual crops are essential for the concept of homegardens, whereas physical proximity to the homestead is, in some situations, not crucial.

Besides definition, also classification of homegardens is difficult due to their variable appearance. They have been commonly classified on the basis of garden characteristics that are easy to investigate, such as age or succession stage (herbaceous, shrub, fruit tree, and timber tree stages), dominating species, structure (e.g. vertical stratification, integration of livestock), or socio-economics (e.g. level of inputs, budget/subsistence/commercial production, or level of urbanisation/ornamentalisation) (CHRISTANTY, 1990; DE CLERCK & NEGREROS-CASTILLO, 2000; DEL ANGEL-PÉREZ & MENDOZA B., 2004; MICHON & MARY, 1994; NIÑEZ, 1987). However, a classification based on certain socio-economic characteristics such as traditional versus modern gardens, as suggested by MICHON & MARY

(1994), could be biased by individual ways of assessing these criteria by the researcher. Multivariate analyses (e.g. cluster analysis) used for classification may avoid such bias and has recently been performed in some studies (e.g. BLANCKAERT et al., 2004; KEHLENBECK & MAASS, 2004; MÉNDEZ et al., 2001; PEYRE et al., 2006; TESFAYE ABEBE et al., 2006). Despite the number of classification schemes proposed for tropical homegardens, none has been universally accepted.

The multiple roles of tropical homegardens

The basic function of homegardens is subsistence production, particularly in rural areas (Figure 1.1) (KUMAR & NAIR, 2004; SOEMARWOTO & CONWAY, 1992). Because of the high plant species diversity existing in homegardens, a wide spectrum of multiple-use products can be generated with relatively low labour, cash, or other external inputs (CHRISTANTY, 1990; HOCHEGGER, 1998; SOEMARWOTO & CONWAY, 1992). Homegardens generally serve as a complement to staple crop fields by producing mainly fruits, vegetables, spices, and many non-food products (ALBUQUERQUE et al., 2005; KARYONO, 1990; KEHLENBECK & MAASS, 2004; KUMAR & NAIR, 2004; MICHON & MARY, 1994; PEYRE et al., 2006). However, homegardens may also provide large portions of staple food, for example for poor families and in densely populated or heavily degraded areas without sufficient staple crop fields (SOEMARWOTO & CONWAY, 1992; TESFAYE ABEBE et al., 2006). Homegarden products, including those from animals reared in the gardens, have a relatively high nutritional value in terms of protein, minerals, and vitamins (SOEMARWOTO & CONWAY, 1992), thus, being important for the nutritional security of the gardeners' families (NAIR, 2006). As these diverse products are available year-round, homegardens also contribute to food security in times or seasons of scarcity (CHRISTANTY, 1990; FERNANDES & NAIR, 1986; KARYONO, 1990). Therefore, the importance of homegardens for combatting malnutrition and food insecurity has attracted increasing attention (KUMAR & NAIR, 2004). This, for example, has resulted in several manuals for the promotion of growing vegetables in tropical homegardens, as compiled by FAO (2001) and HELEN KELLER INTERNATIONAL (2004).

The second important function of homegardens is the generation of cash income, particularly in regions with good market access (Figure 1.1) (CHRISTANTY et al., 1986; MICHON & MARY, 1994; TESFAYE ABEBE, 2006; TRINH et al., 2003). Most of the income is said to be derived from perennials such as fruit and spice trees, cacao, and coffee, but in peri-urban areas or tourist centres as well as in tropical highlands, also vegetables and/or ornamentals are frequently grown as cash crops (ABDOELLAH et al., 2002; SOEMARWOTO & CONWAY, 1992). However, gardeners often do not cultivate certain crops exclusively for sale, but rather sell any marketable surplus of their subsistence crops (FERNANDES & NAIR, 1986). Thus, the portion of income from a homegarden may vary from 0% (GEBAUER, 2005; MÉNDEZ et al., 2001) to more than 50% of the household's total cash income (TRINH et al., 2003), depending on market access, among other factors.

In addition to the productive functions, homegardens have important social and cultural functions (Figure 1.1) (ABDOELLAH et al., 2002; CHRISTANTY, 1990; KARYONO, 2000; SOEMARWOTO & CONWAY, 1992). They are mostly 'open' for everyone, thus, providing a place for children to play and for the neighbourhood to meet and chat. The exchange of homegarden products and planting material is common in many traditional societies. Homegardens also serve as status symbol and the aesthetic purpose partly might outweigh the productive function, especially in urban areas and better-off households (ARIFIN et al., 1998; KARYONO, 1990). Some plant species in homegardens are believed to have a magical value (ABDOELLAH et al., 2002), others are necessary for religious ceremonies, e.g., Hindu Balinese families need their homegardens as source and place for making sacrifices (pers. obs.).

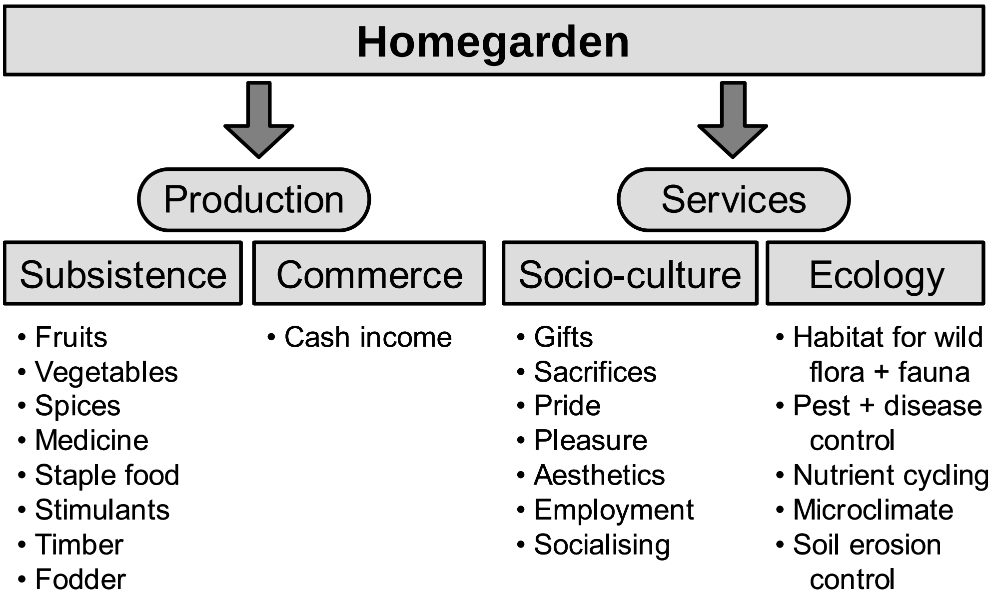

Figure 1.1. Main functions of homegardens and selected products/outputs (modified after KEHLENBECK *et al., 2007).*

Homegardens also fulfil ecological functions (Figure 1.1), particularly in those landscapes where large, monotonous, and monofunctional agricultural fields dominate (CHRISTANTY, 1990). The multi-layered vegetation structure of homegardens is said to resemble natural forests and offers a habitat for a diverse community of wild plants and animals (ALBUQUERQUE et al., 2005; HEMP, 2006; KARYONO, 1990; MICHON & MARY, 1994). This structure appears to contribute substantially to the sustainability of homegarden systems, presented in detail in the following.

1.2 Sustainability of homegardens

1.2.1 Definitions and characteristics of sustainability

Traditional agricultural systems, including homegardens and other multi-species agroforestry systems, are frequently mentioned as a time-tested example for sustainable production systems. Many definitions of sustainable agriculture have been developed; HUXLEY'S (1999) may serve as a baseline:

> 'Sustainable landuse is that, which achieves production sufficient to meet the needs of present and future populations, while conserving or enhancing the land resources on which that production depends' (HUXLEY, 1999).

Similar, rather general definitions were also given by GLIESSMAN (1990b) and TORQUEBIAU (1992), whereas others include more details such as efficient use of resources, integration of natural biological cycles, restoration after disturbances, reduced risk of environment pollution, maintenance of economic viability of farm operations, enhancement of life quality for farmers and the whole society, and/or social acceptability (HARTEMINK, 2003; HUXLEY, 1999; USDA, 2006). The concept of sustainability has, therefore, not only ecological, but also social dimensions (PEYRE et al., 2006). According to WIERSUM (2004), the term sustainability is often used only referring to present and stable conditions, but the changing needs of future generations and social dynamics should also be considered. Consequently, a sustainable agro-ecosystem should, in addition, be able to respond/adjust to changes in environmental and socio-economic conditions (GLIESSMAN, 1990b).

Typical characteristics/attributes of traditional multi-species agro-ecosystems, contributing to their ecological, economic, and social sustainability are, for example (ALTIERI, 2002; GLIESSMAN, 1990a; TORQUEBIAU & PENOT, 2006):

- Utilisation of locally available, renewable resources instead of external, purchased inputs.
- Long-term maintenance of productive capacity, for example related to soil fertility, together with positive on- and off-farm environmental impact.
- Adaptation to local conditions rather than dependence on the control of the environment.
- Maintenance of a high level of biodiversity, including intra- and inter-specific diversity of wild and domesticated plants and animals.
- Efficient resource use by horizontal and vertical stratification.
- Stable production of adequate domestic and exportable crops.
- Utilisation and maintenance of local knowledge and culture.

Homegardens are frequently regarded as sustainable, sometimes simply because they have been successfully practised for many centuries (CHRISTANTY, 1990; FERNANDES et al., 1984), or because they are associated with the same ecological functions and processes as natural forests (HOCHEGGER, 1998; JOSE & SHANMUGARATNAM, 1993; WICKRAMASINGHE, 1995). The forest-like character of homegardens is related to certain sustainability attributes such as close nutrient cycling as well as efficient use of resources such as water, nutrients, space, and light by a dynamic, multi-layered vegetation structure, which not only harbours a high species diversity, but also favors biological interactions and reduces soil erosion (ALVAREZ-BUYLLA ROCHES et al., 1989; HOCHEGGER, 1998; SOEMARWOTO & CONWAY, 1992). Another characteristic for sustainability of homegardens, recognised only recently, might be their promising capacity for carbon sequestration (KUMAR & NAIR, 2004), however, there is not yet much data available on the exact determination of this potential (KUMAR, 2006; ROSHETKO et al., 2002).

Besides such ecological attributes of sustainability, homegardens are said to fulfil also many economic and social requirements of sustainable agro-ecosystems. For example, homegardens provide the gardeners' families with year-round available, diverse products for subsistence, sale, and exchange (MÉNDEZ, 2001). For homegardening, only simple tools and low labour, cash, and external inputs are needed (ALVAREZ-BUYLLA ROCHES et al., 1989; BLANCKAERT et al., 2004). However, due to low inputs, productivity may be relatively low and, thus, could be subject of improvement in part of the homegardens (KARYONO, 1990; RUGALEMA et al., 1994; SOEMARWOTO, 1987). Homegardens are also able to easily react to changing socio-economic conditions and increasing inputs (SOEMARWOTO & CONWAY, 1992), e.g. by integrating cash crops. Commercialisation and modernisation can, on the other hand, substantially reduce the ecological and socio-economic sustainability of homegardens (ABDOELLAH et al., 2006; JOSE & SHANMUGARATNAM, 1993) as described under 1.4.

Most of the statements concerning the sustainability of homegardens are only based on qualitative and descriptive data (BLANCKAERT et al., 2004; MÉNDEZ, 2001), whereas quantitative studies are rare (e.g. see GAJASENI & GAJASENI, 1999). In addition, no long-term quantitative study of the same homegardens has been reported. Assessing sustainable land management is as difficult as defining it (HARTEMINK, 2003; IZAC & SWIFT, 1994), and the question arises if it is possible to assess sustainability *per se* by one single parameter (PIEPHO, 1996). This may be solved by selecting suitable descriptors and indicators of sustainability that cover its different dimensions (TORQUEBIAU, 1992; HUXLEY, 1999). Some of such indicators, partly applied in this study, are presented in the following.

1.2.2 Sustainability indicators

To assess sustainability of agro-ecosystems, suitable descriptors (i.e. attributes of sustainability) and indicators (i.e. precise, measurable variables of the descriptor) must be identified (HUXLEY, 1999; TORQUEBIAU, 1992). Sustainability indicators should be simply to define, easy to measure, and reproducible in time and space. They can be related to different spatial levels such as plot, farm, or village/regional level, thus, requiring clearly defined spatial boundaries (IZAC & SWIFT, 1994). In this study, assessing sustainability was restricted only to the plot level of the agro-ecosystem ‘homegarden’.

A suitable set of indicators should cover the ecological, economic, and socio-cultural dimensions of sustainability. For each agro-ecosystem, not only the set of suitable indicators, but also their desired specific rates, levels, or values may differ (GLIESSMAN, 2001). As a consequence, variable sets of indicators are provided in the literature (see e.g. IZAC & SWIFT, 1994; KUMAR & NAIR, 2004; TORQUEBIAU & PENOT, 2006). GLIESSMAN (2001), for example, suggested to assess parameters related to the soil resource, hydrogeological factors, biotic factors, ecosystem characteristics, ecological economics, and the socio-cultural environment. For agroforestry systems, HUXLEY (1999) considered descriptors based on biology (e.g. yields, biomass, soil biota), physical resources (e.g. soil fertility, water availability), economics (e.g. inputs, labour, outputs), and social aspects (e.g. food security, welfare). TORQUEBIAU (1992) suggested several indicators for assessing sustainability of homegardens that are related to the resource base (e.g. soil, light, water, biodiversity), the system’s socio-economic performance (e.g. labour, inputs, outputs), and its impact on other systems (e.g. forests, wildlife). In this study, a subset of the indicators recommended by TORQUEBIAU (1992) that were also used in other homegarden studies (e.g. GAJASENI & GAJASENI, 1999) were applied. The selected indicators, described below, focus on socio-economic and resource-based aspects, particularly on plant species diversity that is said to be a key factor towards sustainability (ALTIERI, 2002; BENJAMIN et al., 2001; HODEL et al., 1999; IZAC & SWIFT, 1994; NAIR, 2006).

Indicators related to socio-economic sustainability

To assess the management and performance of homegardens, TORQUEBIAU (1992) recommended to measure the amounts of endogenous and external inputs, labour requirements, and outputs. In a sustainable systems, mostly endogenous, locally available inputs such as manure, compost, or alternative pest and weed control measures are applied instead of exogenous, cash-demanding ones, e.g. industrial fertilisers, pesticides, or purchased planting material. In addition, labour requirements are relatively low and allocated in a flexible manner throughout the whole year. No hired, but family labour of both males and females is used, often those of weaker household members such as children, elderly, or women caring for small children. Produce meets the diverse needs of the household, including food, medicine, wood, fodder, cash, or exchange. It is of high nutritional value and available year-round (TORQUEBIAU, 1992).

Indicators related to ecological sustainability: Resources soil and light

To evaluate sustainability concerning the resource base of homegardens, TORQUEBIAU (1992) suggested to assess parameters of soil quality and its maintenance such as rates of soil erosion, soil organic matter content and bulk density, as well as soil moisture status and temperature. The immense importance of the soil component towards sustainability of agro-ecosystems has frequently been mentioned in the literature (e.g. HARTEMINK, 2003; HUXLEY, 1999; KUMAR & NAIR, 2004). In general, homegarden soil keeps its moisture and has low temperatures due to the dense layers of litter and undergrowth that contributes also to low rates of soil erosion, close nutrient cycling, and high soil organic matter contents. However, studies on soil quality usually refer to a single ‘snapshot’ of the status quo without any further consideration for variation over space and time.

Concerning the resource light, TORQUEBIAU (1992) stated that it is used efficiently by the multi-layered vegetation structure of homegardens. For its assessment, understorey temperature and photosynthetic active radiation (PAR) should be measured, among others.

Indicators related to ecological sustainability: Biodiversity

Biodiversity, particularly plant species diversity, is the aspect/criterion probably most frequently assessed in homegarden research (e.g. ALBUQUERQUE et al., 2005; HEMP, 2006; PEYRE et al., 2006; WEZEL & BENDER, 2003). The wide spectrum of plant species creates the multi-layered vegetation structure in homegardens, which is responsible for many benefits and advantages of the system and, thus, for its sustainability (see 1.3). Animals also contribute to different aspects of sustainability, e.g. for food, sale, traction, or manure (KUMAR & NAIR, 2004; TESFAYE ABEBE et al., 2006). Consequently, plant and animal diversity is considered as a sustainability indicator (TORQUEBIAU, 1992). An extensive assessment of plant diversity should include not only species numbers and frequencies, but also variety numbers as well as species abundances, expressed by different diversity indices (HUSTON, 1994; LUDWIG & REYNOLDS, 1988; NAIR, 2006; PEET, 1974; PIEPHO, 1996). In addition to species diversity as such, also particular species compositions and/or the diversity of functional groups (e.g. staples, vegetables, fruits) may be important for the sustainability of homegardens (ALTIERI & NICHOLLS, 1999; TESFAYE ABEBE et al., 2006).

1.3 Functions of biodiversity towards sustainability

The multi-layered vegetation structure in homegardens, created by a wide spectrum of cultivated and wild plants, appears to be responsible for many benefits/advantages of this system. Both the complex structure and the high plant diversity usually found in homegardens contribute substantially to their sustainability concerning ecological aspects (BENJAMIN et al., 2001; NAIR, 2006; SOEMARWOTO & CONWAY, 1992; TORQUEBIAU, 1992), e.g. by creating a favourable microclimate or by enabling efficient use of nutrients and other resources. FERNANDES et al. (1984) and GAJASENI & GAJASENI (1999) particularly emphasised the positive aspects of the relatively lower air and soil temperatures as well as the higher humidity in homegardens with a complex vegetation structure. However, the latter may also favour fungal diseases; the diverse structure may harbour injurious birds and insects (NAIR & SREEDHARAN, 1986 in MATHIAS-MUNDY et al., 1992), but severe attacks have rarely been reported from homegardens (see below).

The positive influence of (agro-)biodiversity on (agro-)ecosystem functioning and sustainable production is more and more recognised both for man-made and natural systems (ALTIERI, 2002; ATTA-KRAH et al., 2004; CARDINALE et al., 2006; CLERGUE et al., 2005; MAIN, 1999; SCHWARTZ et al., 2000). Theoretically, different species successfully coexist in the same system due to niche differentiation. Consequently, a diverse polyculture produces more biomass by exploiting more of the limited resources as compared to a monoculture (CARDINALE et al., 2006). Additionally, even without ecological complementarity, polycultures are more likely to include highly productive species under a given environmental situation, a mechanism known as the sampling or selection effect (LOREAU & HECTOR, 2001). Most of the experimental studies available, including two meta-analyses (BALVANERA et al., 2006; CARDINALE et al., 2006), supported the theory of a positive response of ecosystem properties to increasing biodiversity, although some did not reveal such influence, possibly due to the relatively small spatial and temporal scale of the experiments (BALVANERA et al., 2006; CARDINALE et al., 2006; LOREAU et al., 2001; MAIN, 1999). However, many studies concluded that not so much biodiversity or species numbers *per se* contribute to ecosystem functioning and stability, but rather the occurrence of certain functional groups or keystone species such as leguminous plants with nitrogen-fixing symbionts (CARDINALE et al., 2006; HOOPER & VITOUSEK, 1997; MCCANN, 2000), as postulated also for agro-ecosystems (ALTIERI & NICHOLLS, 1999; CLERGUE et al., 2005; IZAC & SWIFT, 1994; NAIR, 2006).

Both genetic and species diversity play important roles towards (agro-)ecosystem processes and services. On the one hand, intra-specific diversity is not only a key source for breeding, but also essential for sustainability because it enables individual species to adapt to a changing environment and, therefore, ensures their long-term survival (ATTA-KRAH et al., 2004; MAIN, 1999). Inter-specific diversity, on the other hand, leads to important synergistic ecological processes and enables ecosystem functioning. This refers to efficient, complementary resource utilisation, efficient nutrient recycling, reduced invader abundance, and a low risk of soil erosion, but also to performance of ecosystem services such as regulation of local hydrological processes or detoxification of harmful chemicals (BALVANERA et al., 2006; CLERGUE et al., 2005; GLIESSMAN, 2000; MAIN, 1999; KUMAR & NAIR, 2004; POWER & KENMORE, 2002; SOEMARWOTO & CONWAY, 1992; TORQUEBIAU, 1992; WIERSUM, 2004).

In agro-ecosystems, biodiversity not only contributes to ecological, but also to socio-economic aspects of sustainability. Productivity of a species-rich agro-ecosystem is generally higher and more stable as compared to a monocropping system because the multi-species system exploits available resources efficiently and forms a buffer against biotic (pests and diseases) as well as abiotic (storms and droughts) stresses (ATTA-KRAH et al., 2004; CLERGUE et al., 2005; POWER & KENMORE, 2002; SWIFT et al., 1996; WIERSUM, 2004). In more detail, a diverse system provides a favourable microclimate and several micro-environments suitable for different crop species (GLIESSMAN, 2000). Resources such as water, nutrients, and light are utilised complementarily and more efficiently by a combination of annual and perennial species, where, for example, tree roots may capture nutrients not reached or not exploited by the roots of annual plants (SCHROTH et al., 2001). Pests may be better controlled in multi-species systems by providing habitat, alternative food sources, and nesting sites to predators and other beneficial organisms, not only on a spatial, but also on a temporal scale (ALTIERI & NICHOLLS, 1999; GLIESSMAN, 2000; POWER & KENMORE, 2002; SWIFT el al., 1996). Besides, pest attacks have been said to be constrained in multi-species systems by effects of protection, camouflage, trapping, deterrence, or disrupting the searching behaviour of the pest (ALTIERI & NICHOLLS, 1999). In relatively diverse homegardens, for example, DRESCHER (1996) reported a higher abundance of aphid predators; whereas NAIR (2006) supposed increasing frequencies of invader species in simplified gardens. For agroforestry systems, recent studies demonstrate the importance and monetary value of plant diversity for pollination services and pest control, e.g. by offering a habitat to bees or insectivorous birds (KLEIN et al., 2006; SCHULZE et al., 2004). A diverse, multi-species production system reduces the risk of total crop failure and provides year-round available products of high nutritional value (GLIESSMAN, 2000; MAIN, 1999). For homegardens, MARTEN & ABDOELLAH (1988) postulated a positive influence of crop species number on nutrient production per m^2 garden size. Thus, plant diversity contributes to sustainability in the aspect of household food and nutritional security (ATTA-KRAH et al., 2004; HUXLEY, 1999; KUMAR & NAIR, 2004; MAIN, 1999).

WIERSUM (2004) stressed a further potential of multi-species agroforestry systems towards sustainability: a diverse range of useful plant species in a system enables its effective adjustment to changing socio-economic conditions and demands of future generations. In addition, biodiversity has ‘heritage’ functions, e.g. due to its aesthetic value on the landscape scale, or its heritage value on the habitat, species, or even genetic scale (CLERGUE et al., 2005). Highly diverse agro-ecosystems such as homegardens are, therefore, also regarded as an ideal production system for *in situ* conservation of plant genetic resources (WATSON & EYZAGUIRRE, 2002), crucial for long-term sustainability (see 1.5). Nevertheless, the suitability of biodiversity as an indicator to assess sustainability might be critically examined because there is no threshold value for an ideal number of species in a sustainable system (MAIN, 1999). Biodiversity also seems to be highly variable over time, while homegarden research has, so far, neglected to quantify such changes. Chapter 1.4 deals with major known factors influencing crop diversity in homegardens and, thus, possibly causing some changes.

1.4 Influence of different factors on crop diversity in homegardens

Crop diversity of homegardens in space and time varies depending on a combination of external and intrinsic factors that are mainly related to the categories agro-ecology (including garden features) and socio-economics (CHRISTANTY et al., 1986; HODEL et al., 1999; HOOGERBRUGGE & FRESCO, 1993; SOEMARWOTO, 1987). However, intrinsic characteristics of the gardener, like individual preferences, practices, and culture, may play an overriding role for determining crop species composition and diversity (ABDOELLAH et al., 2002; CASTIÑEIRAS et al., 2002, HODEL et al. 1999). The manifold, complex interactions existing among these factors are not yet fully understood and make the analysis of their influences on crop diversity more difficult. In addition, these factors may vary in their relative importance over time (Figure 1.2). A better understanding of the interrelationships and the processes leading to them would help to assess the sustainability of the system as well as its suitability for *in situ* conservation of plant genetic resources. In the following, the influence of selected factors on crop diversity in homegardens is described in more detail.

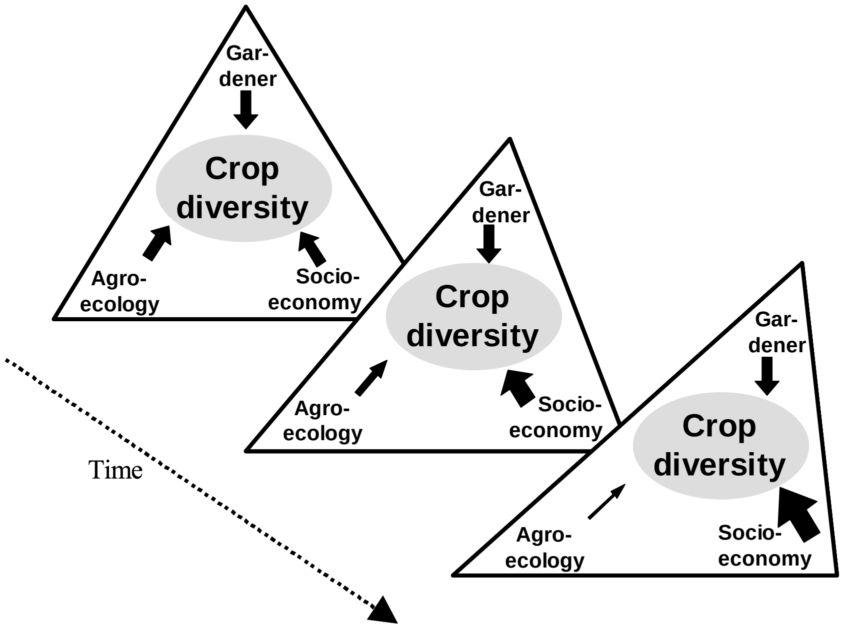

Figure 1.2. Schematic illustration of the relative importance of different factors on crop diversity in homegardens and their temporal changes (modified after KEHLENBECK et al., 2007). Here, the importance of socio-economic factors (e.g. commercialisation) increases over time, while that of agro-ecological characteristics (e.g. infertile soil) decreases, for example due to the use of industrial fertiliser.

Agro-ecological factors

Agro-ecological factors such as elevation, climate, or soil quality may limit crop diversity in homegardens (Figure 1.3). Many studies have highlighted the effect of elevation on crop diversity. Species richness is generally said to decrease with increasing elevation (0–1500 m) due to decreasing mean temperature (HODEL et al., 1999; KARYONO, 1990). However, decreasing species richness in homegardens along the elevation gradient often overlap with also decreasing garden sizes (HODEL et al., 1999; KEHLENBECK et al., 2007; KHOSHBAKHT, 2005), thus, making a clear differentiation of the driving factors impossible. Other studies reported highest species richness at intermediate elevation of 600–1700 m asl., where gardeners have the opportunity to cultivate both tropical and subtropical crops (JOHN & NAIR, 1999; QUIROZ et al., 2004; SUNWAR et al., 2006). On the other hand, no influence of elevation on species number was recorded for homegardens in Cuba (CASTIÑEIRAS et al., 2002) and in Ethiopia at 1500–2000 m asl. (TESFAYE ABEBE et al., 2006). Along the elevation gradient, however, structural complexity of homegardens decreases due to changes of crop species composition. Less fruit tree species, but more vegetables and medicinal plants were cultivated in homegardens of higher elevations (CASTIÑEIRAS et al., 2002; SHRESTHA et al., 2002; SOEMARWOTO & CONWAY, 1992). For the natural flora, highest diversity is also noted at intermediate elevation between 1000 m and 1300 m asl. (HEMP, 2006) or at about 1500–1700 m for certain plant groups (KESSLER, 2002; KLUGE et al., 2006) due to overlapping of different vegetation communities and advantageous climatic conditions at this elevation in the tropics (e.g. high humidity, intermediate temperatures).

Not only temperature, but also precipitation influences crop diversity. Homegardens in West Java harbour higher crop diversity in the wet than in the dry season (SOEMARWOTO & CONWAY, 1992). Crop diversity of Ghanaian homegardens is higher in the humid forest ecozone than in the hot and dry savannah zone (BENNETT-LARTEY et al., 2004). Similar results have been described for the comparison between rather dry and humid environments in Guatemala (AZURDIA & LEIVA, 2004; GILLESPIE et al., 1993), Bangladesh (MILLAT-E-MUSTAFA et al., 1996), and Martinique (KIMBER, 1966). An absent or only short dry period can promote high species richness (HOOGERBRUGGE & FRESCO, 1993; ZALDIVAR et al., 2002), not only in homegardens, but also in natural environments (CLINEBELL II et al., 1995; HAWKINS et al., 2003; KESSLER, 2002). A generally rather low diversity is reported in homegardens of semiarid environments, e.g. in Sudan (GEBAUER, 2005). In contrast, Cuban homegardens harbour higher crop diversity under semiarid as compared to humid conditions due to irrigation (WEZEL & BENDER, 2003). However, variation in crop diversity may occur also due to small-scale climatic variation, like flooding or droughts caused, for example, by El Niño events (Figure 1.3).

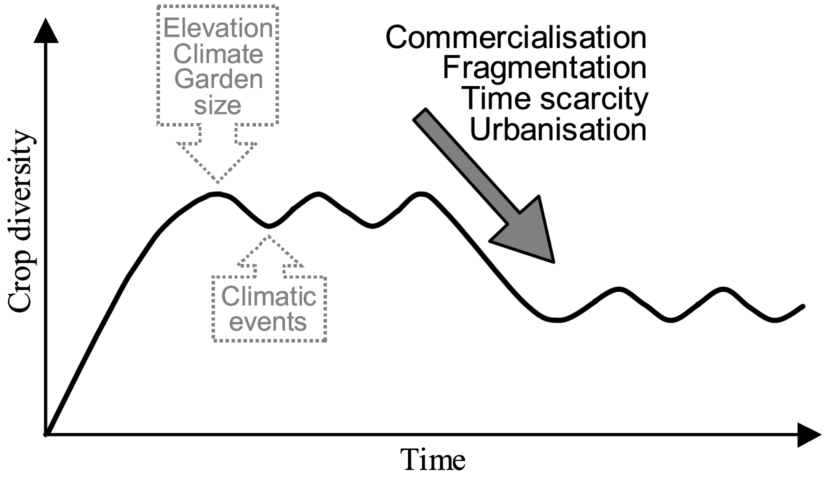

Figure 1.3. Schematic development of crop diversity (except ornamentals) in homegardens over time under the influence of changing socio-economic conditions (modified after KEHLENBECK et al., 2007). Agro-ecological factors (e.g. elevation) may limit plant diversity, while short-term/small-scale climatic events may cause a certain fluctuation around a mean level.

Soil quality is another agro-ecological factor that generates variation of crop diversity in homegardens, but its influence has not yet been studied in detail. HODEL et al. (1999) simply assumed an influence of soil factors on diversity without quantifying this. A general low crop diversity is said to occur on rather marginal, harsh environments having only poor soil quality, e.g. sandy or shallow soils (CECCOLINI, 2002; KIMBER, 1966; MILLAT-E-MUSTAFA et al., 1996; OKUBO et al., 2003; WIERSUM, 2006). In forest gardens, KAYA et al. (2002) reported lower species diversity on marginal soils as compared to more fertile soils. Many cultivated plant species, particularly vegetables and spices, do not give adequate yields under unfavourable soil conditions characterised by, for example, low pH value or plant available P content. Due to high competition on poor homegardens soils, tree density is said to be rather low, too (WIERSUM, 2006). Therefore, gardeners may stop cultivating unsuitable species while switching to a reduced set of crops that can cope with poor soil quality (HVOSLEF, 1994).

Garden features

Within the major factors influencing crop diversity, garden size is one of those frequently analysed. A positive relationship between garden size and species richness has been documented in many countries, e.g. Indonesia (ABDOELLAH et al., 2002; ARIFIN et al., 1997 and 1998), India (DAS & DAS, 2005), Nepal (SUNWAR et al., 2006), Bangladesh (MILLAT-E-MUSTAFA et al., 1996), and Venezuela (QUIROZ et al., 2004). However, its influence on species richness was found to be rather weak in other studies (HODEL et al., 1999; RICO-GRAY et al., 1990) or not even existing (ABDOELLAH et al., 2006; ALBUQUERQUE et al., 2005; BLANCKAERT et al., 2004; HOCHEGGER, 1998; KUMAR et al., 1994). In small homegardens, particularly tree species richness decreases, resulting in a poor vertical vegetation structure. However, an increasing number of annual crops like vegetables and spices partly may compensate the decrease of perennial crops in small gardens. Consequently, crop species density may decrease with increasing garden size (HOCHEGGER, 1998). In addition, diversity expressed by indices (e.g. Shannon index) is said to decrease with increasing garden size, probably due to more uniform planting patterns and the dominance of a few species in larger gardens (KUMAR et al., 1994; PEYRE et al., 2006).

Homegarden age is thought to influence crop species richness positively (BAN & COOMES, 2004; QUIROZ et al., 2004; WEZEL & OHL, 2005; WIERSUM, 2006). When setting up a new homegarden, gardeners start planting with a rather small set of crops, particularly staples as an initial source for subsistence (COOMES & BAN, 2004). Over time, more and more species may be introduced by gardeners or resprout from the former vegetation, while established, reliable species remain (Figure 1.3). Particularly tree species richness and abundance in homegardens may increase over time (BACKES, 2001; WEZEL & OHL, 2005). However, BLANCKAERT et al. (2004) and HODEL et al. (1999) did not find any relationship between crop diversity and age when surveying homegardens of Mexico and Vietnam, respectively.

Socio-economic factors

Among socio-economic factors, the negative influence of market proximity and intensive market-oriented production on crop diversity in homegardens has frequently been recorded (Figure 1.3) (ABDOELLAH et al., 2002; ALI, 2005; CASTIÑEIRAS et al., 2002; CECCOLINI, 2002; CHRISTANTY, 1990; HOOGERBRUGGE & FRESCO, 1993; MICHON & MARY, 1994; SHRESTHA et al. 2004; SOEMARWOTO & CONWAY, 1992; TESFAYE ABEBE et al., 2006). In remote areas, traditional subsistence homegardens provide the owner families with a wide spectrum of products to meet their daily needs, resulting in high crop diversity (ABDOELLAH & MARTEN, 1986; MILLAT-E-MUSTAFA et al., 1996). Good market access, on the other hand, may drive gardeners from subsistence to semi-commercial or commercial production. The cultivation of cash crops, particularly of annual vegetables or ornamentals, leads to both genetic erosion of traditional vegetables and decreasing numbers of perennials such as fruit and timber trees (PEYRE et al., 2006; SHRESTHA et al., 2004). As a consequence, commercial homegardens often lack a complex vegetation structure. The focus of development agencies on improving cash income generation and nutrition through the promotion of mostly exotic, annual vegetables can lead to such negative effects, associated with the loss of indigenous knowledge and cultural erosion (KARYONO, 2000; SHRESTHA et al., 2004). In addition, the nutritional value of exotic vegetables often is markedly lower as compared to traditional ones, thereby, affecting the important role of homegardens for family nutrition (ABDOELLAH et al., 2006). Commercialisation with perennial cash crops, partly also supported by development projects, often was accompanied by a marked decrease in forest trees, vegetables, medicinal plants, and traditional fruit tree species and varieties (BELACHEW WASSIHUN et al., 2003; DAS & DAS, 2005; MICHON & MARY, 1994; SOEMARWOTO, 1987; VOGL et al., 2002).

Market proximity and commercialisation, on the other hand, could also have no (LAMONT et al., 1999; TRINH et al., 2003) or even a positive influence on crop diversity in homegardens (HODEL et al., 1999; KIMBER, 1966). The slightly positive effect could be explained by a higher amount of cash income generated in semi-commercialised homegardens accompanied by higher labour investment, from which also subsistence crops could profit. GONZALES (1985, cited in GLIESSMAN, 1990b) as well as QUIROZ et al. (2004) argued that a well-balanced mix of subsistence and cash crop production can lead to higher plant diversity in homegardens with an intermediate market access, particularly if there is a demand for traditional crops in urban centres (SUNWAR et al., 2006). In contrast, WEZEL & OHL (2005) reported a rather low diversity in very remote and isolated homegardens, where gardeners had only little contact to other ethnic groups and were still much engaged in gathering food from the forests instead of cultivating it.

Besides commercialisation, the scarcity of land and high population density generally also reduce homegarden biodiversity. Families with insufficient crop fields are forced to grow high proportions of staples in their homegardens (SOEMARWOTO & CONWAY, 1992). As many staple food crops are light-demanding, perennials like fruit or timber trees disappear from such homegardens (KARYONO, 1990). High population density is often accompanied by fragmentation of homegardens, thus, causing a decrease of crop diversity due to decreased garden sizes (ARIFIN et al., 1997; HOOGERBRUGGE & FRESCO, 1993; TESFAYE ABEBE et al., 2006). Urbanisation is also said to reduce crop species diversity (Figure 1.3) (MICHON & MARY, 1994). Along the urbanisation gradient, more and more crop species are replaced by ornamentals (KARYONO, 1990; KEHLENBECK et al., 2007; RICO-GRAY et al., 1990). In peri-urban regions with good access to large markets in the city, traditional homegardens may be completely converted into commercial fruit tree or vegetable gardens, thereby, losing not only their potential for subsistence production, but also much of their ecological and social functions (SOEMARWOTO & SOEMARWOTO, 1982). At the highest urbanisation level, homegardens are generally rather small and dominated by ornamentals, giving priority to the aesthetic function instead of subsistence production (ARIFIN et al., 1998). These effects of modernisation and urbanisation may even reach rural areas (SOEMARWOTO & SOEMARWOTO, 1982).

Gardeners' characteristics

Certain characteristics of the gardener and his/her household are known to influence crop diversity in homegardens. A gardener's age can influence crop diversity positively (QUIROZ et al., 2004), possibly because, over the years, gardeners try to cultivate new crops while they continue to plant well-tried species. In addition, older gardeners often have more time for homegardening and are supported by their grown-up children. Consequently, higher time allocation to homegardening leads to higher crop diversity (HODEL et al., 1999). Large, rather 'old' households with large labour force generally maintain a higher species richness in their homegardens as compared to small and rather 'young', labour force-constrained households (see Figure 1.3) (COOMES & BAN, 2004; HOOGERBRUGGE & FRESCO, 1993; QUIROZ et al., 2004; STOLER, 1981 (cited in CHRISTANTY et al., 1986); TESFAYE ABEBE et al., 2006). Farmers as compared to gardeners with off-farm employment may cultivate more crop species in their homegardens due to higher time allocation and experience of the farmers (ARIFIN et al., 1997; CARON, 1995; LAMONT et al., 1999; QUIROZ et al., 2004).

How formal education or sex of the gardener influence crop diversity in homegardens is still uncertain. CASTIÑEIRAS et al. (2002) reported a slightly positive correlation between gardener's formal education and species richness that was, however, not confirmed by QUIROZ et al. (2004). In homegardens of higher educated gardeners, KARYONO (1990) noted a higher importance of ornamentals. Some studies indicated a higher species richness and diversity in homegardens managed mainly by females as compared to males (BAN & COOMES, 2004; DRESCHER, 1996 for rural gardens; WILSON, 2003), whereas other did not find any influence (HODEL et al., 1999). Similarly, the influence of a household's wealth status on crop diversity is debated controversially. In general, homegardens of well-off households are said to harbour fewer food-producing plant species because such households purchase food and prefer ornamentals (HODEL et al., 1999; KARYONO, 1990). In other cases, higher crop diversity found in homegardens of wealthy families was related to larger garden sizes, larger landholdings suitable for staple crop production, or to their more pronounced mobility and social contacts used for gathering planting material (ABDOELLAH & MARTEN, 1986; COOMES & BAN, 2004; DAS & DAS, 2005; SHRESTHA et al., 2004). A positive influence of household's wealth status concerning crop diversity at farm level was also postulated by PERZ (2005) due primarily to larger labour forces.

Ethnicity of the gardener may also be a factor explaining variation in crop diversity of homegardens (HODEL et al., 1999). Ethnic and cultural influences are particularly important for species composition (WIERSUM, 2006). Different ethnic groups prefer different plant products and, therefore, cultivate for example more vegetables or more medicinal plants in their homegardens (ABDOELLAH, 1980 in SOEMARWOTO & CONWAY, 1992; AZURDIA & LEIVA, 2004; SHRESTHA et al., 2004; TRINH et al., 2003). Migration and mobility can, thus, have a positive effect on crop diversity in homegardens (SHRESTHA et al., 2004; SOEMARWOTO, 1987). The positive influence will occur as long as plant species brought from the migrants' home regions establish successfully in the new environment and, on the other hand, migrants also adopt useful plants from indigenous gardeners. However, plant diversity in migrant homegardens and those of minorities could also be rather low due to poverty and discrimination (HODEL et al., 1999), e.g., by assigning land of poor soil quality for settlement to such groups (HOLDEN & HVOSLEF, 1995). Besides, shortage of labour for homegarden management and poor access to suitable agricultural land for staple food crops may further decrease crop diversity in migrant homegardens. Rather low crop diversity was reported not only from homegardens of migrant families, but in the initial years also overall for their farms (PERZ, 2005) or for their mixed plantations (KUSUMANINGTYAS et al., 2006).

In conclusion, no individual factor alone determines the crop diversity found in homegardens, but rather a complex combination of agro-ecological, socio-economic, cultural, and political factors causes spatial and temporal variation of crop species.

1.5 Homegardens as places for *in situ* conservation of plant genetic resources

The maintenance of both species and genetic diversity is commonly accepted as an important feature towards long-term sustainability of agro-ecosystems (ALTIERI, 2002; GLIESSMAN, 2001; HODEL et al., 1999; PIEPHO, 1996; TORQUEBIAU, 1992). High inter- and intra-specific diversity enables the adaptation of agro-ecosystems to changing environmental and socio-economic conditions (ATTA-KRAH et al., 2004; MAIN, 1999). Agro-biodiversity (here, in the sense of plant genetic resources), including traditional crop varieties and landraces as well as wild ancestors of crop species, is a valuable asset for breeding activities and the development of ‘new’ crops, among others (BROOKFIELD, 2001; POWER & KENMORE, 2002; TORQUEBIAU, 1992).

Scientific activities for a systematic conservation of plant genetic resources (PGR) initially amost exclusively focussed on *ex situ* techniques (i.e. conservation of species and varieties outside their natural habitats), whereas the importance of *in situ* techniques has been emphasised only since the 1980s (MAXTED et al., 1997). *In situ* conservation refers in general to the conservation of whole (agro-)ecosystems that provide the habitats of target species and varieties (MAXTED et al., 1997). Concerning *in situ* conservation of agro-biodiversity, it is commonly performed on traditional farms or parts of farms such as homegardens, leading to the term ‘on-farm conservation’. Such a conservation technique allows for further crop evolution and adaptation to changing environments, while genetic diversity is regarded ‘frozen’ in *ex situ* approaches (BROOKFIELD, 2001; MAXTED et al., 1997). On the other hand, on-farm conserved materials are highly vulnerable to loss caused by changes in farming practices, e.g. commercialisation or modernisation, particularly if farmers do not earn any compensation or economic benefit by maintaining PGR (MAXTED et al., 1997; RHOADES & NAZAREA, 1999). Thus, complementary strategies including both *ex situ* and *in situ* approaches are regarded most appropriate to insure against the erosion of agro-biodiversity (DAMANIA, 1996; MAXTED et al., 1997).

Homegardens are said to harbour a very high agro-biodiversity, possibly the highest of all agro-ecosystems (SWIFT & ANDERSON, 1993 in NAIR, 2006; SWIFT et al., 1996). Therefore, homegardens are regarded as an ideal production system for *in situ* conservation of PGR, particularly of crop species and their varieties (BENNETT-LARTEY et al., 2004; ESQUIVEL & HAMMER, 1992; MAXTED et al., 1997; WATSON & EYZAGUIRRE, 2002). However, the overall impact of homegardens towards PGR conservation may be rather low because homegardens generally only occupy a small portion of the total agricultural area (ALVAREZ-BUYLLA ROCHES et al., 1989). Besides, the mostly low genetic diversity (i.e. small populations, few varieties) of species in individual homegardens can further reduce this impact (DAMANIA, 1996). Consequently, not single, but all homegardens of the same or even several regions should be combined to one conservation unit and, in addition, exchange of planting material between these gardens should be promoted (DAMANIA, 1996; GUARINO & HOOGENDIJK, 2004; OAKLEY, 2004). To address the increasing problem of crop species and variety loss caused by changes of environmental, cultural, and socio-economic conditions, further approaches should be considered such as developing market opportunities for traditional crop products, improving seed supply, or even paying subsidies for PGR conservation (BRUSH, 1995; DAMANIA, 1996; RHOADES & NAZAREA, 1999; SMALE et al., 2004; SMITH et al., 1992).

Homegardens do not only play an important role for *in situ* conservation of domesticated plants, but they can also contribute substantially to the conservation of wild plants, particularly where natural ecosystems like forests have largely been replaced by agricultural fields (ALBUQUERQUE et al., 2005; HEMP, 2006; SCHROTH et al., 2004). In Indonesia, the conversion of primary forest to frequently unsustainable agricultural lands has increased dramatically, contributing to a tremendous PGR loss. Forest margins are particularly concerned due to easy access, even in protected areas, e.g. national parks. Sustainable and productive agricultural systems urgently need to be promoted in such agricultural frontier areas to reduce the pressure on further forest conversion. Traditional agro-ecosystems such as homegardens and forest gardens could help to protect valuable forest resources, and they could serve as a model for the design of sustainable agroforestry systems (DE CLERCK & NEGREROS-CASTILLO, 2000; SCHROTH et al., 2004). However, despite an increasing body of literature, even partly summarised in two recent reviews (KUMAR & NAIR, 2006; EYZAGUIRRE & LINARES, 2004), neither the functioning nor the potential of homegardens have been satisfactorily studied. Research is needed, particularly, concerning nutrient and water balances, the value of non-conventional products and services, system productivity, and sustainability, including temporal changes and factors driving them (KUMAR & NAIR, 2004).

1.6 Objectives of the study

The principal objective of this study was to assess the sustainability of homegardens with the help of selected sustainability indicators. Rural homegardens in Central Sulawesi, Indonesia, were targeted for the investigation because a data set from 2001 was available (KEHLENBECK, 2002; KEHLENBECK & MAASS, 2004). The study aimed at determining spatial differences and temporal changes of resource quality in homegardens and the underlying driving forces, focussing especially on crop diversity, but also on soil quality, microclimate, and management of homegardens.

Specifically, the following research questions were addressed:

- Are the homegardens socio-economically sustainable?
- Is the resource ‘soil’ managed in a sustainable manner in homegardens?
- Is the resource ‘light’ used efficiently in homegardens?

- Are there systematic spatial differences of the resource ‘crop diversity’ in homegardens?
- Can crop diversity in homegardens be maintained over time?
- Which factors are responsible for spatial and temporal differences of crop diversity in homegardens?

Finally, potentials for improving homegarden productivity and their suitability for *in situ* conservation of plant genetic resources were assessed. This study was associated to the interdisciplinary German-Indonesian collaborative research program STORMA (Stability of Rainforest Margins in Indonesia, SFB 552; STORMA, 2007).

2 Material and Methods

Homegardens in the highlands of Central Sulawesi were studied from March to November 2001 and re-visited in 2003/2004 to evaluate changes in homegarden management, soil quality, and crop diversity over time. For the in-depth study from June 2003 to June 2004, the sample size was expanded to reveal more details about the influence of agro-ecological and socio-economic factors on crop diversity. Methods in this study mainly focussed on determining certain indicators for the assessment of sustainability with regard to socio-economic and biophysical aspects, as suggested by GLIESSMAN (1990a), HUXLEY (1999), and TORQUEBIAU (1992) (see 1.2.2).

2.1 Research area

2.1.1 Geographical and ecological conditions

The research was carried out in the Napu valley, subdistricts Lore Utara and Lore Tengah, district Poso, province Central Sulawesi (Figure 2.1). The valley is located at the eastern margins of the Lore Lindu National Park (latitude 1°23'–37' South, longitude 120°18'–20' East) at an altitude of about 1,100 m asl. Small asphalt roads lead to the province capital, Palu, situated northwest of the valley (approx. 100 km away) and to the district capital, Poso, east of the valley (approx. 50 km away).

The Lore Lindu National Park was founded in 1993 and covers an area of about 220,000 ha. The park provides a habitat for highly diverse flora and fauna, including many endemic and endangered species. Therefore, it has been assigned as a Man and Biosphere Reserve by UNESCO already in 1977 (UNESCO, 2006). Concerning the Napu valley, the natural vegetation is classified as lower montane rain forest (WHITTEN et al., 1987).

2.1.2 Climate and soils

In the research area, temperature is rather constant throughout the year. Mean temperature is 21 °C with a range of about 13–32 °C (STORMA climatic measurements from December 2001 to September 2004, subproject Z2). Annual mean precipitation is about 1800 mm with a slightly dryer season from June to August. Mean annual relative atmospheric humidity is about 83%, being slightly lower in the dryer season, when temperature is mostly lower as well.

In the valleys of the research area, mainly colluvial, alluvial, and lacustrine sediments are covering crystalline and metamorphic parent material (DECHERT et al., 2004). Soils of the Napu valley are mainly Fluvic Cambisols, Fluvisols, and Gleysols (FAO classification, revision of 1988), many of which have been transformed into Anthrosols (paddy soils) by wet rice cultivation; whereas those of the adjacent slopes are Eutric or Dystric Cambisols and Leptosoles, depending on parent material and topographic position (MACKENSEN et al., 1999; unpublished report).

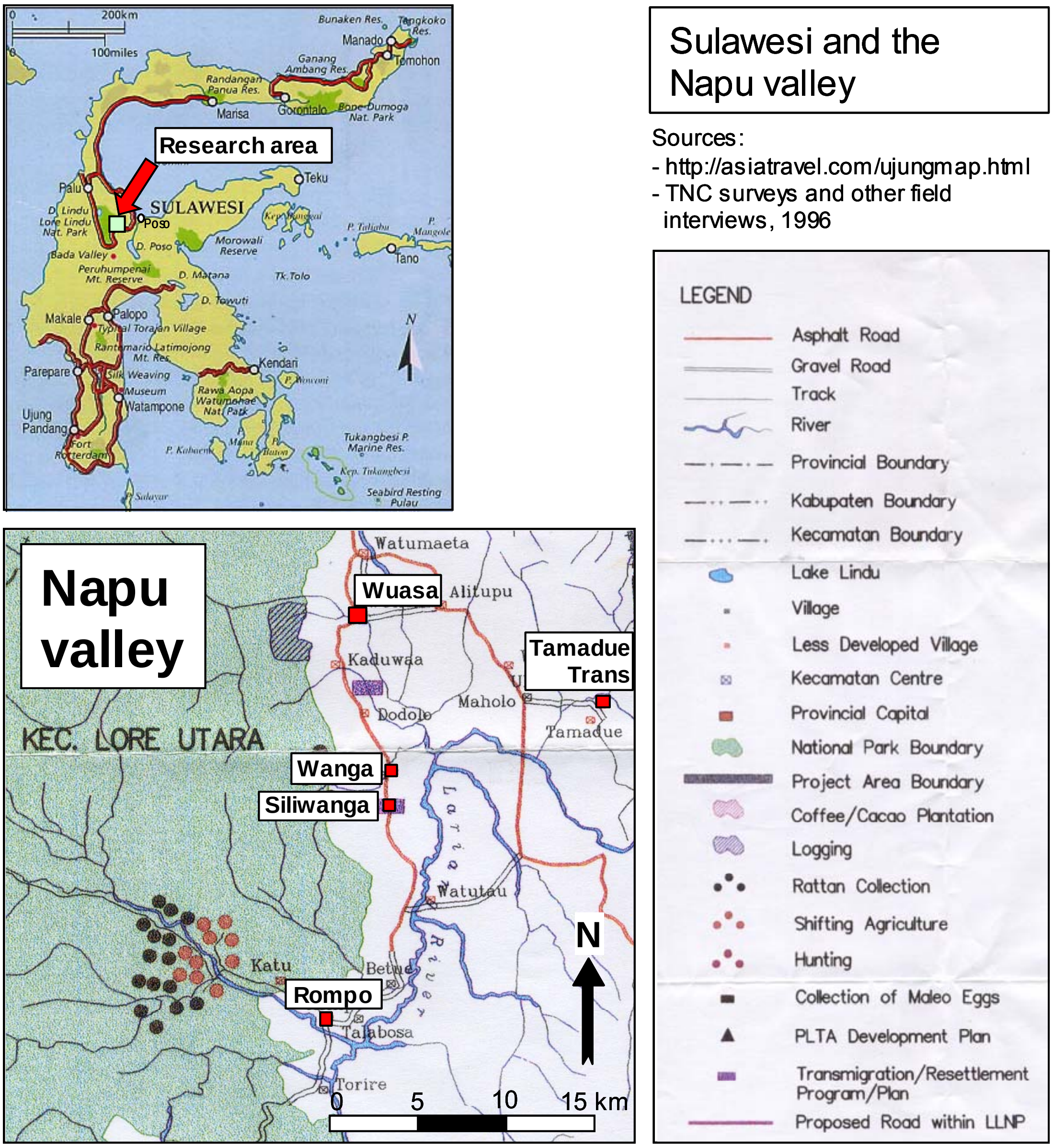

Figure 2.1. Location of the research area in Central Sulawesi and the five study villages in the Napu valley.

2.1.3 Historical and socio-cultural background

The Napu valley came under European influence in 1907, after the Dutch colonialists had defeated the local inhabitants in the 'Peore war' (WEBER, 2005). The local ethnic group called itself 'Pekurehua', derived from the similar sounding call of a common bird in this valley (WEBER, 2005). The inhabitants were feared head hunters, frequently attacking villages in neighbouring valleys and in the Poso plain, where they were named 'Napu', i.e. manslaughterer in the Poso language. The pre-colonial subsistence agriculture in the Napu valley was based mainly on shifting cultivation with the main crops being upland rice, maize, tuber crops, and some vegetables (SUNITO, 2004). The extended grasslands in the South of the valley were used for raising water buffaloes and horses. Paddy rice cultivation was limited to some small suitable plots only. One of the first scientists visiting the Napu valley in 1911, GRUBAUER (1923), reported well-tended and fenced homegardens for growing vegetables and ornamentals around the houses.

The Dutch promoted cultivation of paddy rice in the Napu valley, and they introduced improved agricultural techniques as well as new crops such as robusta coffee[1] that was planted in cleared forest plots (SUNITO, 2004). The colonial administration forced the locals to move from their scattered semi-permanent huts in the mountains to newly founded villages in the valley, where they could be controlled/monitored and converted by missionary work. However, many villagers preferred to live in huts on their upland fields, guarding crops against wild pigs, monkeys, and birds. According to WEBER et al. (2003), people in the village of Wanga returned to their village houses for school and church service only on weekends until the 1980s.

The next major changes in the study region occurred when the asphalt roads to Palu and Poso were completed in the early 1990s. The earlier small influx of migrants into the Napu valley increased drastically, resulting in a population growth of 166% from 1980 to 2001 (MAERTENS et al., 2002). However, population density is still low with 8 inhabitants/km^2. In 2001, about 30% of all inhabitants in the Napu village were migrants (MAERTENS et al., 2002), but their share differed markedly among the villages (see below). On the one hand, migration took place spontaneously, particularly from other parts of Sulawesi, driven by the availability of large flat and fertile land areas (BURKARD, 2002a). On the other hand, the Indonesian government founded three transmigration resettlement projects in the Napu valley, mainly for Javanese and Balinese migrants (HOPPE & FAUST, 2004). The migrants introduced cacao and arabica coffee cultivation as well as large-scale vegetable growing. Many migrants were rather successful both in agriculture and trading or other entrepreneurships, thus, arousing envy by the locals. Social integration of the migrants is still very limited and many prejudices against the other groups exist (e.g. migrants think that locals are lazy, locals feel that migrants want to ‘master’/dominate them) (ABDULKADIR-SUNITO, 2004; HOPPE & FAUST, 2004).

Since 2000, a recent increase of the population in the Napu valley occurs because of the influx of refugees from the district capital Poso (FAUST et al., 2003). Due to the inter-religious struggles that already claimed more than 1000 lives, Christian families fled the city and took refuge in the Napu valley, among other regions. The refugees were distributed over the villages; houses and fields were given to them. Although the situation in Poso gradually got safer in 2004, many refugees decided to stay in the Napu valley, as they already got settled there and lost their economic basis in Poso (ABDULKADIR-SUNITO, 2004).

The present agriculture in the Napu valley is based on paddy rice production (about 20% of the agricultural area) in the bottom of the valley and agroforestry systems (about 30% of the agricultural area) with mixed or sole cash crops cacao, coffee, and/or fruit trees on the slopes (RHEENEN et al., 2004). Besides, rainfed crops such as maize and french beans or groundnuts are cultivated, both for self consumption and sale. Some migrant farmers specialised on vegetable production (mainly spring onions, carrots, cabbages, tomatoes, and potatoes) to service the market in Palu. Large parts of the valley are covered by unutilised grasslands

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[1] For scientific plant species names see Appendix 12.

(partly infested by *Imperata cylindrica*), smaller parts by fallow or secondary forests. Most of the inhabitants in the research area are self-employed small-scale farmers, off-farm employment opportunities, mainly as government officials, being scarce (MAERTENS et al., 2002).

2.2 Selection of study sites

To assess differences in the homegardens' resource quality and factors causing these differences, five villages out of 15 within the Napu valley were chosen for this study. The selected villages differ in their market access, origin of inhabitants, and soil quality, among others (Table 2.1). The selection procedure of the five villages was partly carried out by STORMA, subproject A4 (Socio-economic analysis of farm households and their enterprises). STORMA randomly selected four villages in the Napu valley (Wuasa, Watumaeta, Wanga, and Rompo) with mainly indigenous inhabitants (ZELLER et al., 2001). For the basic homegarden study in 2001, two of these STORMA-selected villages (Wuasa and Rompo) and the village Siliwanga, inhabited by migrants, were chosen to allow comparisons between local and migrant homegardens (KEHLENBECK & MAASS, 2004). To further clarify the specific influence of soil quality and ethnic group of the gardener towards crop diversity, the sample size was extended in 2003 by two suitable villages. Out of the STORMA-selected villages, Wanga was chosen because of its indigenous inhabitants, whereas Tamadue-Trans was selected as a further migrant village. In the following, the five research villages are described in more detail.

Wuasa is the administrative centre of the sub-district 'Lore Utara' (Napu valley) since the 1960s. Many government offices are located in this village. There is also a small hospital, a police station, a small military base, and junior and senior high schools. Many shops and small restaurants as well as garages and petrol stations can be found. Therefore, many of the inhabitants are employed in the service sector.

Rompo is a small, remote village about 35 km south of Wuasa. The village is surrounded by forest, most of the inhabitants are locals and still rooted in their traditions. There are only two small shops and a primary school. Market access is rather poor, but has been recently improved due to road construction. In 2001, about 10 km of the road to Rompo were a small dirt road. Many of the wooden bridges between Wuasa and Rompo were broken, therefore, rivers had to be crossed via fords that where hardly passable after heavy rains. This situation changed in 2004, when all bridges were rebuilt and the road was asphalted, except the last 5 km.

The third village chosen was Wanga, a small village around 12 km south of Wuasa, located directly at the paved road to Rompo. Until the 1960s, Wanga was the administrative centre of the sub-district because it was the residence of the last king of Napu (WEBER et al., 2003). The inhabitants are mostly locals, engaged in agriculture and fishing in the nearby Wanga lake. Some migrants from South Sulawesi and the western margins of the Lore Lindu National Park arrived in the 1990s. Soil quality was said to be poor in Wanga (DECHERT, 2003).

Siliwanga was founded only recently for settling transmigrant families mostly from Bali (60%) and East Java (20%) (Table 2.1). As usual for transmigrant programmes, each household was provided with 1 ha land for paddy rice cultivation, 0.75 ha dry-land, and 0.25 ha homegarden, including a small, wooden house. Allotted by lottery, some households received one head of Bali cattle in addition. The village Siliwanga is located about 20 km south of Wuasa along the road Wuasa–Rompo, surrounded by rather infertile grasslands that were formerly used for buffalo grazing only. Due to the low soil quality of the assigned land and the lack of a irrigation system for paddy rice cultivation, about 70% of the 300 transmigrant families have already left Siliwanga (HOPPE & FAUST, 2004). The remaining families try to cope with the poor conditions by raising cattle and clearing forest plots for maize and cacao cultivation. However, the depopulated village with its empty houses and its overgrown gardens and paths is a pathetic sight. Most of the remaining households would leave Siliwanga as soon as possible, if they had the means.

Another transmigrant village selected for this study was Tamadue-Trans, called also Merkasari, which is part of the old village Tamadue-Kampung. This village is located in the eastern part of the Napu valley, about 30 km south-east of Wuasa, near the road Wuasa–Poso. The last 5 km leading from this road to the village are not yet asphalted. Due to poor road and bridge conditions, access to Tamadue is difficult after heavy rains. Before the foundation of Tamadue-Trans in 1991, the area was covered with forest, growing on rather fertile soil. This migrant village was initially settled exclusively by about 200 Moslem transmigrant families from Java and Lombok (HOPPE & FAUST, 2004). However, 75% of the transmigrant families left Tamadue-Trans soon after arrival because the agricultural land allotted to them was mostly still covered by forest. These out-migrated households were replaced by about 170 ‘spontaneous’ migrant families of Javanese or Balinese origin that bought the deserted houses and fields. Most of the Balinese migrants were descendants of transmigrants already settled in other parts of Central Sulawesi in the 1960s (HOPPE & FAUST, 2004). Today, about 50% of the 250 households are of Javanese and 30% of Balinese origin. Despite the poor access to their village, the migrants of Tamadue-Trans are successful in paddy rice, cacao and vegetable production.

Table 2.1. Characteristics of five villages studied in the Napu valley, Central Sulawesi (2003/2004).

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue-Trans
Year of foundation	1892	1915	1923	1992	1991
Inhabitants (no.)	2,600	400	350	600	700
Ethnicity	90% locals	90% locals	75% locals	95% migrants	99% migrants
Distance to paved road	0 km	5 km	0 km	0 km	5 km
Market access	Good	Poor	Medium	Medium	Poor

Sources: ZELLER et al. (2001) and own data.

In each of the five research villages, 10 households with homegardens were randomly selected. In Wuasa, Rompo, and Wanga, these households were selected out of the sample chosen by subproject A4 (ZELLER et al., 2001), and in Siliwanga and Tamadue-Trans from the village household lists. For comparability among the migrant villages, in Tamadue-Trans only households of Balinese origin were included into the sample. In 2003, two homegardens selected for the 2001-survey in Siliwanga had been abandoned. To replace these gardens, two ‘new’ households were randomly selected in 2004 in the same village. Two other selected homegardens in the village Rompo that had been abandoned in 2004, however, were not replaced.

2.3 Socio-economic characteristics of sample households and farms

For gathering basic socio-economic data of the households surveyed, a standardised, formal questionnaire was used, designed by subproject A4 of STORMA, but shortened for the purpose of this study. Included questions concerned household composition and characteristics (number, age, origin, ethnic group, religion, formal education, and occupation of the household members), possession of land and livestock, plot-specific use and amounts of inputs and outputs, and wealth status (food, dwelling, other assets) of the household (see

Appendix 1). The complete STORMA-questionnaire is available from the internet: <www.gwdg.de./~uare/research/projects/storma_a4/activities.php>. In 2001, relevant data of the selected households in the villages Wuasa and Rompo were made available through subproject A4 (S. SCHWARZE, personal communication, 2002). Because the village Siliwanga was not covered by the STORMA-survey, a translator assisted the author to conduct the interviews without asking questions concerning the wealth status. In 2004, the author herself completely carried out all interviews in the five villages.

2.3.1 Household-specific characteristics

Household sizes ranged from 1 to 14 persons, being rather small in the migrant villages Siliwanga and Tamadue (Table 2.2, for complete data see Appendix 3). Whereas median number of children per household was more or less similar among the villages, the number of adults was rather high in Wuasa and low in the migrant villages. This is reflected in differences of the median number of men able to work between 15 and 67 years per household that was 2–3 in the local villages, but only 1 in the migrant villages. Families in the migrant villages were rather young, particularly in Siliwanga (Table 2.2). In Wuasa, the percentage of households with small children and old people (mostly parents or parents-in-law of the household head) as well as median ages of household heads and their wives were rather high. However, medians of the mean age of adults per household did not differ significantly.

Table 2.2. Composition and characteristics of 50 households (HH) in five villages of the Napu valley, Central Sulawesi, 2004 (medians, ranges in brackets). N = 10 per village, apart from age of household head in Rompo and Wanga (N = 9).

	Wuasa		Rompo		Wanga		Siliwanga		Tamadue	
HH members total	8.0a	(3–14)	5.0ab	(1–11)	5.5ab	(3–8)	4.0ab	(3–6)	3.5b	(2–6)
Children (0–14)	2.0a	(0–5)	1.5a	(0–5)	1.0a	(0–3)	2.0a	(1–3)	1.0a	(0–2)
Adults (> 14)	5.0a	(3–10)	3.0ab	(1–6)	4.0ab	(2–7)	2.0b	(2–3)	2.0ab	(2–7)
Men (15-67)	2.0a	(1–6)	2.0ab	(0–4)	3.0ab	(1–4)	1.0b	(1–2)	1.0ab	(1–2)
HH with small children (< 5)	80%		60%		20%		50%		20%	
HH with old people (> 67)	40%		10%		20%		10%		0%	
Age of household head	55a	(34–69)	50ab	(25–89)	47a	(43–71)	36b	(30–50)	42ab	(32–65)
Age of HH head's wife	53a	(32–71)	40ab	(20–60)	47ab	(33–55)	33b	(28–45)	36ab	(31–55)
Mean age of adults/HH	37a	(30–54)	31a	(22–45)	36a	(26–54)	35a	(29–49)	39a	(26–58)
Christian HH	100%		100%		100%		20%		10%	

Medians are given because variables were not normally distributed.

Medians in a row followed by different letters are significantly different at P≤0.05.

In the three local villages Wuasa, Rompo, and Wanga, all households belonged to the Christian religion (Table 2.2), mainly to the Protestant church, except some families that were members of the Catholic, Pentecost, or Salvation Army church. Most of the heads of Christian households and their wives were of Napu origin, some had migrated from some other provinces of Sulawesi (Figure 2.2). In the migrant villages Siliwanga and Tamadue, most of the households surveyed were of Hindu religion and Balinese origin. However, in Tamadue, one Balinese family had recently converted to Protestant religion (Table 2.2). In Siliwanga, two Christian households came from North or Central Sulawesi, one Muslim household was of mixed Javanese origin.

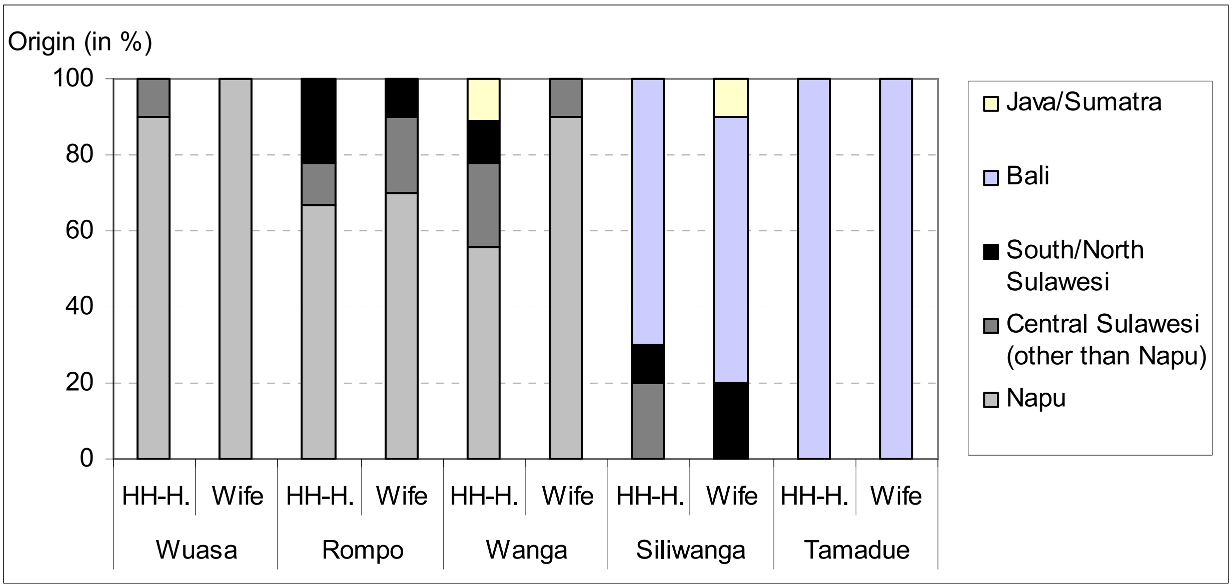

Figure 2.2. Origin of household heads (HH-H.) and their wives in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from HH-heads in Rompo and Wanga, where N = 9.

Formal education differed not only among the five villages, but also among males and females. In all five villages, household heads generally had a higher education grade than their wives (Table 2.3). The percentage of respondents, who did not complete primary school or never attended school was high in the migrant villages, particularly in Tamadue. However, some male and/or female respondents with an academic degree or diploma (e.g. teacher, pastor) were contained in the sample in all villages, except for Wanga. In the local villages Wuasa, Rompo, and Wanga, about half of the household heads already attended some agricultural training courses, whereas in the migrant village Siliwanga, even 80% of household heads attended such training, mostly in the frame of the transmigrant programme. In contrast, only few household heads in Tamadue ever attended some training, although all households were engaged in agriculture. Women’s attendance in agricultural training courses was conspicuously low.

Table 2.3. Formal education and attendance at agricultural training in percentages of household heads (of wives in brackets) in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from HH-heads in Rompo and Wanga, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Not completed primary school	0 (20)	0 (0)	0 (20)	20 (50)	50 (60)
Only completed primary school	30 (30)	33 (50)	44 (50)	20 (30)	20 (20)
Only completed secondary school	60 (40)	56 (40)	56 (30)	40 (10)	20 (20)
Completed Academy/University	10 (10)	11 (10)	0 (0)	20 (10)	10 (0)
Attended agricultural training	50 (20)	56 (20)	56 (0)	80 (20)	30 (0)

Most household heads worked mainly as farmers, ranging from 60% in Wuasa to 100% in the remote village Rompo (Table 2.4). The second important field of occupation was the civil service sector, particularly in the village Wuasa with its offices, schools and the small hospital. However, in the villages Rompo and Tamadue, no respondent worked mainly as a civil servant. Instead, in Tamadue some household heads employed themselves as tradesmen in own kiosks. This was a sideline also in the other villages, apart from Rompo. Popular second occupations of household heads were farming for all those not being a farmer as main occupation, or handicrafts (particularly carpenter) for those being mainly farmers. As wage labour opportunities were rare, only few household heads in the migrant village Siliwanga occasionally searched for such work besides farming their own land.

Table 2.4. Main occupation in percentages of household heads (of wives in brackets) in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from household heads in Rompo and Wanga, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Farmer	60 (30)	100 (70)	67 (40)	80 (70)	80 (40)
Civil servant/pensioner	40 (0)	0 (10)	33 (0)	10 (0)	0 (10)
Self-employed (trade/transport)	0 (10)	0 (0)	0 (0)	0 (0)	20 (10)
Housewife	– (60)	– (20)	– (60)	– (30)	– (40)

Wives of the household heads selected for this study were mainly engaged either in agriculture or housework, only very few female respondents were civil servants (e.g. teacher, nurse) or tradeswomen (Table 2.4). However, marked differences existed between villages. In Wuasa and Wanga, the majority of wives were occupied mainly with housework, with farming only as a sideline, whereas in Rompo and Siliwanga 70% worked mainly as farmers, although 50–60% of these women had to care for small children (Table 2.2).

To reveal, if the 50 sample households surveyed in this study were representativ for the whole study region, selected basic socio-economic data (i.e. household size, formal education, and occupation of household members) were compared with results of the STORMA household survey concerning the subdistrict Lore Utara or the whole STORMA research area, as given in SCHWARZE (2004). The average overall household size of 5.2 in this study (see Table 2.2) corresponded quite well with the respective STORMA data of 5.8 for Lore Utara. Even the median numbers of adults and children per household in this study (2–5 and 1–2, respectively) were rather similar to the respective means as given by SCHWARZE (2004) (4.1 and 1.7, respectively). However, marked differences in household size and composition existed among the local and migrant villages in this study. Households in the two migrant villages Siliwanga and Tamadue were clearly smaller than those in the local villages (median total sizes: 4.0 vs. 5.5, adults: 2.0 vs. 4.0). Thus, the households in the local villages were more representative for the overall subdistrict than those in the migrant villages.

A similar trend is obvious concerning levels of education. For Lore Utara, SCHWARZE (2004) reported 91% of the adults having at least completed primary school, which is much more than in total Indonesia (about 76%, survey data from 2004, BPS, 2004). In the present homegarden study, 100% of the household heads in the three local villages and 80–100% of their wives did at least complete primary school (Table 2.3). However, in the migrant villages only 50–80% of household heads and 40–50% of their wives did so. The slightly lower education level of women, particularly for higher education, was already stated by SCHWARZE (2004) for the whole STORMA research area. As reported by SCHWARZE (2004), 96% of the households in the whole STORMA research area were engaged in agriculture. This statement corresponded well with the results of the present research, where 100% of the households were fully or partly engaged in agricultural tasks (Table 2.4).

2.3.2 Farm-specific data

Farm sizes were highly variable and did not differ significantly among the villages (Table 2.5, for complete data see Appendix 4). Because fallow areas contributed markedly to large farm sizes, particularly in Rompo, Wanga, and Siliwanga (Figure 2.3), the size of the cropped farm area was calculated additionally. Median cropped area was highest in Tamadue and lowest in Rompo and Wanga, but differences were not significant (Table 2.5). However, the cropped farm area per household member differed significantly between villages, being rather large in Tamadue and small in Wuasa. Homegardens as part of the whole farming system were owned by nearly all households. Only in Rompo, two homegardens were rented together with the houses. Total homegarden sizes, as given by the respondents, varied from 350–2500 m^2 (Table 2.5). Median homegarden sizes were significantly larger in the migrant than in the local villages. Sizes of cultivated/cropped areas in homegardens (i.e. total size minus fallow areas and such occupied by houses and yards) were mostly slightly smaller than total homegarden sizes, apart from Siliwanga, where gardeners mentioned the poor soil quality as a reason for large uncultivated areas inside their homegardens. Proportions of the total homegarden size to the total farm area were higher in the migrant villages, particularly in Siliwanga, as compared to the local villages. This indicated that the living of many migrant families depended considerably on their homegardens.

Most households divided their farm area into several plots planted either to paddy rice, upland annual crops, or perennials, according to the suitability of the land, needs of the household, and its capability to work the land. However, proportion and sizes of these plots were highly variable among farms and villages (Figure 2.3). Perennials, mostly coffee and cacao, usually occupied the largest part of the cropped farm area and were mainly sold as cash crops. The majority of households owned such plots, varying from 100% in Rompo and Tamadue, 90% in Wuasa and Rompo, to 80% in Siliwanga, where farmers assessed the surrounding grasslands as unsuitable for growing perennials. The median size of plots planted to perennials was particularly high in Tamadue and rather low in Wanga and Siliwanga (Figure 2.3), but differences were not significant. Paddy rice was grown mainly for subsistence, although not all households owned such plots. In the local villages, Wuasa, Rompo and

Wanga, 70–80% of the sampled households possessed paddy rice plots with median plot sizes between 3000 and 5400 m^2 (Figure 2.3). Fewer households in the migrant villages, Siliwanga and Tamadue, owned paddy rice plots (50–60%), however, median sizes were markedly, but not significantly different between these villages. In Siliwanga, lacking an irrigation system, paddy rice plots were rather small, whereas in Tamadue, they were extremely large (up to 4 ha per household).

Table 2.5. Median characteristics in sizes (ranges in brackets) of 50 farms with homegardens investigated in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9 for total and cropped farm size as well as for proportion HG/farm.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Total farm size (ha)	2.6a (0.9–8.8)	5.9a (1.7–11.5)	3.9a (2.1–19.5)	3.1a (1.9–8.8)	4.0a (1.8–29.3)
Cropped area (ha)	2.3a (0.6–3.3)	1.8a (0.5–4.2)	1.6a (0.3–10.5)	2.0a (0.3–3.6)	3.1a (1.1–6.2)
Cropped area/ HH member (ha)	0.2b (0.2–0.5)	0.4b (0.1–0.7)	0.4ab (0.1–1.7)	0.4ab (0.1–0.9)	0.9a (0.3–1.6)
Total HG size (in 1000 m^2)	1.0b (0.4–1.8)	0.8b (0.4–2.0)	0.7b (0.4–2.0)	2.5a (2.5)	2.5a (2.0–2.5)
Cropped HG area (in 1000 m^2)	0.7b (0.3–1.1)	0.6b (0.3–1.4)	0.6b (0.3–1.4)	0.9ab (0.5–2.4)	2.3a (0.7–2.4)
Proportion total HG/ farm (%)	2.4ab (0.7–16.7)	1.7b (0.6–4.3)	1.7b (0.2–6.5)	8.3a (2.9–13.2)	6.3ab (0.9–14.3)

Note: HH = Household, HG = Homegarden.
Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

Annual crops, such as maize, french beans, or groundnuts, were usually grown on upland plots and used both for sale and self-consumption. Such plots were common in the local villages, where frequency of ownership as well as median plot sizes were similar to the data of paddy rice plots. In the migrant villages, fewer households owned upland plots (60% in Siliwanga, 20% in Tamadue) and median sizes were rather small (Figure 2.3). Fallows (i.e. abandoned fields owned by the household, but currently not being worked; covered mostly by herbs, shrubs, and small trees) occurred commonly in most of the villages, apart from Tamadue (only 60% instead of 80–100% households owning fallow plots). Fallow plot sizes were highly variable, resulting in no significant differences of medians among villages. However, in the remote village Rompo with its surrounding forests, fallow sizes were extremely large (up to 7.2 ha per household), whereas in the more densely populated village Wuasa, households owned rather small fallow plots.

As for basic socio-economic data, also selected farm-specific data of the sample households were compared with the results of the STORMA household survey (SCHWARZE, 2004). In the subdistrict Lore Utara, mean farm size was 2.7 ha (SCHWARZE, 2004). As mean household size was stated as 5.8, mean farm area per capita was 0.47 ha. Following SCHWARZE (2004), mean size of homesteads (i.e. homegardens) in Lore Utara was 780 m^2 per household, that of irrigated paddy rice fields 0.5 ha, and that of all upland, rainfed fields (including annual and perennial crops) 1.8 ha. Similar to the basic socio-economic household characteristics (see

2.3.1), some of these results corresponded much better with the three local villages of the present study than with the migrant villages. In the migrant villages, median total homegarden size was as much as 2500 m^2, whereas in the local villages, it varied from 700–1000 m^2 (Table 2.5). However, median sizes of paddy rice as well as of upland fields (annual crops plus perennials) were mostly lower in all villages (except Tamadue) of the present study (Figure 2.3) as compared to the subdistrict Lore Utara. Due to rather large fallow plots, median total farm sizes were mostly larger in the present study, but farm area per capita smaller than in the whole subdistrict (Table 2.5). In summary, sample households of the present study could be considered as representative for the subdistrict Lore Utara, both for household as well as farm characteristics.

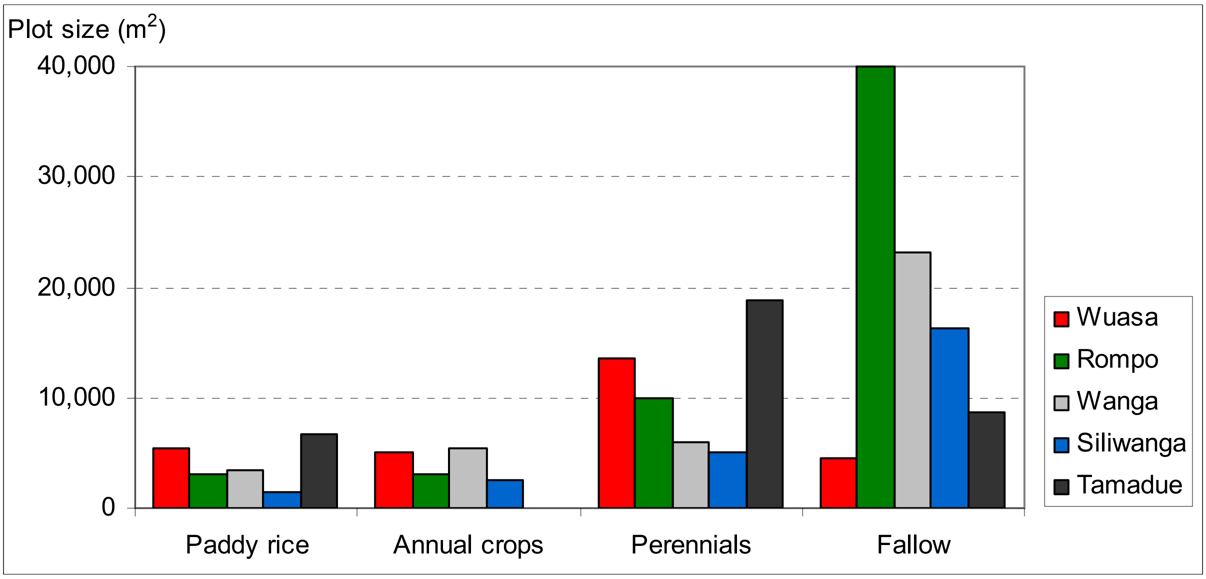

Figure 2.3. Median farm area allocated to different crop types in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

All sample households in the Napu valley owned some livestock with summed values from 45,000 IR (Indonesian Rupiah) to 26,600,000 IR per household (exchange rate in 2004: 10,000 IR ≈ 1 Euro). In the local villages Wuasa, Rompo, and Wanga, households owned in median 1.1–1.3 TLU[2] (Tropical Livestock Units) (Table 2.6), having a median value of 1,300,000–1,500,000 IR. In the migrant village Siliwanga, both median TLU per household and value of livestock was rather high (median value = 7,200,000 IR), but in Tamadue only low (median value = 700,000 IR). However, differences among villages were not significant. Overall, horses and buffaloes were rarely reared and mostly for prestige. Only three households in Wuasa and Rompo reared buffaloes and one household each in Wuasa and Tamadue owned horses. Cattle were also seldomly reared (Table 2.6), apart from Wanga, where communal grazing areas were available in the uplands, and from the migrant village Siliwanga, where cattle was distributed initially by the transmigrant programme and extensive grasslands surrounded the village. In Wanga, cattle were mostly kept for prestige outside of

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[2] TLU were calculated based on SCHWARZE (2004).

the homegarden. In Siliwanga, cattle were indispensable for the rather poor families, who could not afford to rent a tractor for ploughing their small paddy rice plots. Additionally, cattle offspring was the sole important source of cash income for many households in Siliwanga. Most of them kept their cattle in small stables in their back yard gardens over night. Raising pigs in the homegardens was very common, particularly in the local villages and in Tamadue, where most households owned 1–3 heads. Pigs were used for sale (e.g. for yearly payment of school fees), for exchange (e.g. for land or for other kinds of livestock), for gift (e.g. for bride price), and/or for self-consumption, served only on important private or religious celebrations such as Christmas, baptism, weddings, or funerals.

Table 2.6. Proportion of households per village owning cattle, pig, dog, duck, and chicken (heads per households in brackets) as well as median TLU per household (range in brackets) in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village.

Possession of	Wuasa		Rompo		Wanga		Siliwanga		Tamadue	
Cattle	10%	(0–5)	0%	(0)	40%	(0–4)	70%	(0–7)	10%	(0–2)
Pig	100%	(1–6)	70%	(0–4)	100%	(1–8)	40%	(0–1)	90%	(0–13)
Dog	60%	(0–4)	50%	(0–8)	80%	(0–8)	70%	(0–4)	40%	(0–10)
Duck	80%	(0–20)	20%	(0–7)	10%	(0–2)	10%	(0–2)	50%	(0–13)
Chicken	70%	(0–23)	90%	(0–27)	80%	(0–11)	100%	(1–19)	70%	(0–50)
TLU	1.3	(0.4–8.7)	1.3	(0.1–2.7)	1.1	(0.4–4.7)	2.3	(0.1–5.3)	0.9	(0.2–6.4)

Note: TLU = Tropical Livestock Units.
Medians are given because variables were not normally distributed.

Dogs were raised by the majority of respondent households, except for Tamadue (Table 2.6). Besides guarding the houses, dogs were used for assisting in hunting and, frequently, also for self-consumption, being served at minor festivities or at the weekly private Bible and praying meetings of neighbourhoods. Occasionally, dogs were sold for this purpose as well. Raising poultry in homegardens was very popular among the respondent households. However, ducks were common only in Wuasa and Tamadue, whereas chicken were raised by 70–100% of the households in all villages (Table 2.6). Households without chicken lost their flock only recently by the 2004 raged Asian bird flu that caused many losses. Both ducks and chicken were raised for their eggs and meat, for sale and, by the Hindu respondents, also for making sacrifices. Rabbits occurred only recently in the Napu valley, being distributed by an NGO to only two respondent households in Wuasa. Fish were raised in large ponds only by one gardener each in Wuasa, Siliwanga, and Tamadue.

2.3.3 Households' wealth status and assets

Size, condition, and equipment of houses differed among the villages (see Appendix 5 for complete data). Houses were largest in Wuasa (median: 135 m^2), medium-sized in Rompo, Wanga, and Tamadue (about 100 m^2), and smallest in Siliwanga (only 69 m^2). Most of the houses were roofed with corrugated iron, apart from Rompo, where bamboo roofs still existed. Cement floors were common in nearly all houses, only in Siliwanga some houses had only earth flooring. Wooden planks were the usual wall material, however, in Wuasa wood was already replaced by bricks and cement in many cases. Most households were connected to electricity, apart from the remote village Rompo, where electricity was available, but households could not afford the connection costs. In Wuasa, Wanga, and Siliwanga, 70% of respondents' houses were equipped with private water pipes, although water supply often broke down and water quality was far away from drinking quality. In Rompo, water was available only from public wells or taps, whereas in Tamadue public water supply did not exist anymore. Households drew their muddy water from self-dug holes behind their houses, often located very close to latrines and stables. Improved latrines were common only in the local villages, whereas more than 50% of the migrant families used their homegardens as a toilet.

Private-owned motorised vehicles were rare in the research area, particularly cars and tractors, possessed by only one household in Tamadue. Motorcycles were slightly more common in the villages Wuasa and Tamadue, where 30–40% of respondents owned one. All migrant households in Siliwanga and Tamadue owned at least one bicycle, used mainly for transport of the harvest. In the local villages, this was done by rented carts or, in some cases, by own handcarts. Frequency of pesticide sprayer possession was highest in Tamadue and Wuasa (100 and 80%, respectively), medium in Rompo and Siliwanga (50–60%), and low in Wanga (40%). Chain saws were owned by only few respondents in Wuasa, Wanga, and Tamadue.

Common electronic assets were radio-tapes, particularly in Wuasa and the migrant villages. Televisions with satellites (and sometimes also video players) were owned by some respondents in Wuasa and Tamadue, whereas in Rompo, Wanga, and Siliwanga such appliances were still very rare. Concerning household appliances, kerosene cookers were the most frequent one, owned by 70–80% of the respondents in Wuasa, Wanga, and Tamadue, but only 20–30% in Rompo and Siliwanga. Some wives had mechanical sewing machines, but not in Siliwanga. In Tamadue, few households owned a small rice mill or water pump.

2.3.4 Households' poverty index

Households were each assigned to one of three wealth status levels (i.e. poor, medium, well-off) by characterising their welfare situation with a poverty index. To generate this index, Principal Component Analysis (PCA) of all assessed wealth indicators was carried out to select in an iterative process the most important ones. The methodology of this complex procedure is described in detail by Henry et al. (2003). For the 50 households studied, the final PCA was only performed on the basis of 10 selected wealth indicators (see Appendix 6). The scores of the resulting first factor (accounting for nearly 34% of the variability) were taken as poverty index. Households were then divided into terciles according to the index. As a result, 16–17 households each were assigned to the groups of poor, medium, or well-off households (see Appendix 5). In Siliwanga, most of the households were characterised as poor, in Rompo as medium, whereas in Wanga as well-off (Table 2.7). In Wuasa and Tamadue, wealth status of households was mixed.

Table 2.7. Proportion of households (in %) belonging to different wealth status groups in five villages of the Napu valley, Central Sulawesi. N = 10 per village.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Poor	30	10	20	80	20
Intermediate	20	60	20	20	50
Well-off	50	30	60	0	30

2.4 Interviews

Each household was visited three times for individual interviews. First, the interview on basic socio-economic data (see 2.3) was carried out with the head of the household and/or his wife. At a second visit, homegarden-specific data were gathered. Questions on plant species use and yield were asked at a third visit. Questions on homegarden and plant species were asked to the person mainly responsible for the homegarden, if possible. Otherwise, the head of the household and/or his wife were interviewed. Every interview lasted between one and two hours and was conducted in the homestead. However, gardeners that were exceptionally busy on their paddy rice fields or plantations were visited on their plots as well.

2.4.1 Homegarden data

For gathering homegarden-specific data, a semi-structured questionnaire was developed (see Appendix 2). This questionnaire included questions on age, history and function of the homegardens, soil quality and its changes, inputs and outputs, management patterns, and problems with homegarden management such as crop pests and diseases, weed infestation, shortage of time, among others. A translator assisted in all interviews and translated the answers in 2001, whereas in 2004, the interviews were conducted by the author herself. In 2004, some questions were added or asked in more detail as compared to 2001 (see Appendix 2).

2.4.2 Plant species data

Cultivated plant species were completely listed for each homegarden (see 2.5). Gardeners' appreciation of each single species grown in their homegardens was assessed using the plant lists as a kind of questionnaire (Table 2.8). In 2004, question no. 4 was added and question no. 7 emphasised more details than in 2001. To monitor changes in crop diversity, gardeners already interviewed in 2001 were asked additionally, why they had stopped to grow any plant species that previously occurred in their homegarden but was not located in the 2003-survey. The interviews were carried out by the author herself in both survey rounds.

Table 2.8. Questionnaire for plant species data (checked for each species).

1. How do you use this plant species (e.g. staple food, fruit, vegetable, spice, medicine, fodder, ornamental, construction, fuel wood, fence, shade, green manure, cash-crop, ...)? If used as medicine, what part is used, for what kind of illness?
2. Are there different varieties of this plant? Please list the local names and describe the varieties!
3. From where did you get the seeds/seedlings of this plant species (e.g. own reproduced seeds, neighbour, market/shop, gathered, occurred spontaneously, project, ...)?
4. What is the yield of this plant species per week/month/year?
5. When did you harvest this plant species the last time?
6. How do you use the products of this plant species (self consumption, sale, gift, ...)?
7. If you already sold products of this plant species, how much per week/year, and what was the price?

2.5 Plant inventory

Before starting the plant inventory, the borders of each homegarden were identified together with the gardener. In most homegardens, borders were clearly defined by fences, hedges, ditches, or marking trees. In few cases, borders were rather indistinct because the homegarden gradually turned into a plantation of the same owner. Areas only dominated by a sole crop like coffee were then excluded from the homegarden area. In the same way, larger areas within the homegarden not cultivated at all or used as paddy rice fields were excluded. The size of each homegarden was measured with a tape, excluding the area occupied by the house. Rough sketches of the homegardens were drawn, including arrangements of houses, sheds, stables, paths, yards, wells, toilets, and the different production zones. In 2003/2004, the sizes of both cultivated and uncultivated zones (e.g. yards, stables, ponds) were roughly estimated. Production zones were classified visually according to the plants dominantly cultivated in a particular zone, i.e. vegetable zone, ornamental zone, coffee/cacao zone, fruit tree zone, and mixed zone. Mixed zones were characterised by a close mixture of different crop types. Parts of the homegardens not planted for a while and covered only by grasses and small herbs were classified as fallow zone. The occurrence of tree nurseries was recorded. Seedlings were included in the plant species inventory if they were planted in the soil, but not if they were planted into small plastic bags. The latter were mostly not intended to be planted in the homegarden where they were raised, but to be transplanted to plantations of the household.

Complete plant species inventories, initially together with the gardener, were carried out to assess number of species and abundance of crops and ornamentals. For assessing the dynamics of crop diversity, homegardens visited in 2001 (July–October) were re-inventoried in 2003 (July–August) as well as in 2004 (June), whereas the ‘new’ homegardens (in the villages Wanga and Tamadue) were inventoried only once in 2004 (January and February). In this study, the term ‘crop’ is applied to all useful plant species except ornamentals. Therefore, a ‘crop’ includes both planted species as well as those spontaneously occurring and additionally promoted. For trees, the height was estimated. For vertical structure analysis, all individual plants were assigned to one of five strata (0–1 m, 1–2 m, 2–5 m, 5–10 m, > 10 m), as suggested by KARYONO (1990) and ABDOELLAH et al. (2002). The occurrence of weeds, defined as undesired plants from the gardener’s view, was documented, but not quantified. Plants were recorded with local, Indonesian and/or scientific names. For identification of crop and weed species, the following literature was used:

PROSEA-series (Plant Resources of South-East Asia):

> FARIDAH HANUM et al., 1997; FLACH & RUMAWAS (1996); GUZMAN & SIEMONSMA (1999); LEMMENS (2003); MAESEN & SOMAATMADJA (1992); PADUA et al. (1999); SIEMONSMA & KASEM PILUEK (1994); VALKENBURG & BUNYAPRAPHATSARA (2001); VERHEIJ & CORONEL (1992); VOSSEN & WESSEL (2000).

Further literature:

> BÄRTELS (1993); BURKILL (1966); FRANKE (1992); HENDRIAN & TRI HADIAH (1999); HEYNE (1927); LEVANG & FORESTA (1991); OOMEN & GRUBBEN (1977); PERRY (1980); REHM & ESPIG (1991).

As some of the ornamental species have medicinal properties, a few ornamentals were identified by the literature mentioned above. The more frequently planted ornamentals were mostly well known and/or mentioned by BÄRTELS (1993). However, as the focus of this study was on crop diversity, many of the ornamentals were not identified.

Nomenclature was basically taken from the Mansfeld database of agricultural and horticultural crops (online: <http://mansfeld.ipk-gatersleben.de/mansfeld/>), if a species name was available, or otherwise after ZANDER & ERHARD (2002). Of unidentifiable plant species, specimens were taken and sent for identification to Herbarium Celebense (*Index Herbariorum* CEB) in the 2001-survey or to Herbarium Bogoriense (BO) in the 2003/2004-survey. Crop species were classified into the following 9 use categories, according to the literature mentioned above or the gardener's statement about the main utilisation: Fruits, vegetables, sweets and stimulants, spices, medicines, staple food, construction and fuel wood, multi purpose use, and others (e.g. wrapping, fodder, toys).

Besides crop species number, also crop species density per 1000 m^2 homegarden area and several similarity coefficients as well as diversity indices were calculated (see 2.9.2). To assess, if the sampled area was large enough for collecting a representative proportion of all species present, a species-area curve was drawn by plotting the cumulative species number against the cumulative garden area sampled. In general, this curve has a relatively steep slope at first, but it flattens out when the accumulated area of the sample plots is sufficient to represent the total species number in a homogeneous (agro-)ecosystem (EVANS et al., 1955). DIERßEN (1990) suggested an area as sufficient, if 95% of the total species number were included in the sample. To investigate community structure pattern of the homegardens studied, the species abundance model was graphically assessed by plotting the number of individuals per species (in log scale) against the species in rank order, beginning with the most abundant species (KREBS, 1999). For a logarithmic series, the species-abundance curve should follow a nearly straight line, whereas for a lognormal distribution, it follows a reverse S-shaped curve. According to PIEPHO (1996), the lognormal distribution characterises very diverse and complex ecosystems. The logarithmic distribution is typical for more simple ecosystems that are dominated by relatively few factors.

2.6 Soil investigation

2.6.1 Soil sampling

Samples of the litter-free top soil (0–15 cm depth) were taken from 30 homegardens in 2001 and from 50 homegardens in 2003. The sampling methods were slightly different in the two years. In 2001, a short, T-handled soil auger with an inner diameter of about 1.5 cm was used. From each homegarden 20 soil samples were randomly taken and bulked, avoiding disturbed areas, such as yards, paths, stable areas, or rubbish pits. In four rather large homegardens with two clearly distinct production zones, 20 soil samples were taken separately in each zone.

In 2003, a soil corer with an inner diameter of 3.9 cm was used for sampling. If the garden was small (< 350 m^2) or planted rather uniformly, five soil samples per garden were randomly collected and bulked. In large gardens with distinct zones for vegetables, coffee/cacao or fruit production and/or with fallow areas, five samples per zone were randomly collected and bulked separately. To determine overall means for soil quality parameters in these large gardens, weighted means were calculated according to the proportions in sizes of particular production zones to the total homegarden sizes. Despite the general use of the term ‘soil fertility’ in the literature and when interviewing gardeners about their rating/management of garden soils, in this study ‘soil quality’ is mainly applied because the former term strongly refers to crop yields.

2.6.2 Sample treatment

After sorting out stones and roots, the field-moist samples were weighed and crushed. Samples were air-dried and stored in cardboard boxes. In STORMA’s laboratory at University of Palu, the soil samples were dried at 80 °C for about 8 hours, weighed again and passed through a 2 mm sieve.

2.6.3 Soil chemical and physical analysis

Soil analyses were conducted in different laboratories of the universities of Palu (STORMA laboratory), Bogor (IPB, Dept. of Soil Sciences) and Göttingen (Table 2.9). Bulk density was determined in 2004 only by assessing the dry weight of soil samples with known field volume (determined by the soil corer). Sand, silt, and clay contents were measured using the pipette method in both years. According to the texture, soil was classified following the German System DIN 4220 (SCHEFFER, 1998). For assessing pH values, soil was mixed with distilled water or 0.01 M $CaCl_2$, respectively, at a ratio of 1: 2.5. Sub samples were powdered with a ballmill for determination of total C- and N-contents, using a C/N-Analyser (in Göttingen: Carlo Erba, ANA 1400; in Palu: Vario EL, Elementar).

Table 2.9. Physical and chemical analyses of the soil samples from homegardens in the Napu valley, carried out in 2001 and 2004 in different laboratories.

Parameter	Method (Reference)	Analysed in 2001	Analysed in 2004	Laboratory 2001	Laboratory 2004
Bulk density		No	Yes	–	STORMA Palu
Texture	Pipette	Yes	Yes	Göttingen [a]	IPB Bogor
pH H_2O	1 : 2.5	Yes	Yes	Göttingen [b]	STORMA Palu
pH $CaCl_2$	1 : 2.5	Yes	Yes	Göttingen [b]	STORMA Palu
C and N $_{total}$	C/N-Analyser	Yes	Yes	Göttingen [a]	STORMA Palu
Available P	Olsen (OLSEN & SOMMERS, 1982)	Yes	Yes	Göttingen [b]	STORMA Palu
- “ -	Bray I (ANONYMOUS, 1979)	No	Yes	–	Göttingen [c]
Exchange. K	CAL (SCHÜLLER, 1969)	Yes	No	Göttingen [b]	–
CEC $_{effective}$	Extraction (LÜER & BÖHMER, 2000)	No	Yes	–	Göttingen [d]
BS	- “ -	No	Yes	–	Göttingen [d]

Göttingen [a] = Institute of Agricultural Soil Sciences.
Göttingen [b] = Institute of Agricultural Chemistry.
Göttingen [c] = Institute for Crop and Animal Production in the Tropics.
Göttingen [d] = Geographical Institute, Dept. of Landscape Ecology.
Note: Exchange. = Exchangeable; CEC = Cation exchange capacity; BS = Base saturation.

Plant available phosphorus was determined using the methods of Olsen and/or Bray I (Table 2.9) by spectrometer (Göttingen) or Continous Flow Analyser AA3/Bran & Luebbe (Palu). The P-Bray method was applied in 2004 because the P-Olsen method, used in 2001, is not recommended for acid soils (LANDON, 1991). However, the latter was additionally applied in

2004 to enable the determination of changes in available P contents over time. In 2001, exchangeable K was assessed following the CAL method and determined from the extract by flame photometer. In 2004, exchangeable cations (Al, Ca, Mg, K, Na, Mn, Fe) were determined after extraction with 1 M NH_4Cl using ICP-OES (Inductive Coupled Plasma – Optical Emission Spectrometry) (Optima 4300 DV, Perkin Elmer). Effective cation exchange capacity ($CEC_{eff.}$) and base saturation (BS) were calculated from the amount of exchangeable cations and pH value before and after extraction (LÜER & BÖHMER, 2000).

2.6.4 Rating/assessment of soil quality

LANDON (1991) suggested that soil bulk density should not exceed 1.7 g/cm^3. Soils with a pH value under 5.5 (measured in H_2O) were rated as 'acid' (LANDON, 1991), while WHITTEN et al. (1987) assessed a value under 4.5 as 'very acid'. Table 2.10 shows the rating of other soil nutrients and characteristics according to different authors.

Table 2.10. Rating of several soil characteristics according to different authors.

	N content (%)†	C content (%)†	P content Olsen (ppm)†	P content Bray I (ppm)‡	$CEC_{eff.}$ (cmol/kg) †	BS (%)§
Very Low	< 0.1	< 2		< 3	< 5	< 20
Low	0.1–0.2	2–4	< 5	3–7	5–15	20–40
Medium	0.2–0.5	4–10	5–15	7–20	15–25	40–60
High	0.5–1.0	10–20	> 15	> 20	25–40	60–80
Very High	> 1.0	> 20			> 40	> 80

† LANDON (1991).
‡ OLSEN & SOMMERS (1982).
§ WHITTEN et al. (1987).

For successful production of cacao, top soil (0–15 cm) should meet the following requirements (HARDY, 1958):

N > 0.22%
C > 2% (or organic matter > 3,5%)
C/N ratio > 9
pH > 6.0
K > 0.24 cmol/kg
Ca > 8.0 cmol/kg
Mg > 2.0 cmol/kg
P (Truog) > 18 ppm (corresponding to 'low level' according to LANDON (1991))

In addition, WOOD & LASS (1985) recommended a cation exchange capacity of more than 12 cmol/kg and a base saturation of more than 35% for suitable cacao soils. They also emphasised that cacao roots are very sensitive to waterlogging and suggested a sand content of at least 50% for good drainage and aeration. Concerning contents of Al, HALLIDAY & TRENKEL (1992) mentioned a level of more than 3% of total CEC as harmful for cacao.

2.7 Leaf investigation

To relate soil nutrient content with the nutrient supply to selected crops, cacao leaves were sampled for analysis of relevant plant nutrients. Cacao was chosen as a perennial crop because of its high frequency in homegardens and its importance for income generation of gardeners.

2.7.1 Leaf sampling

Within each homegarden with cacao trees (N = 40), 10 leaves of randomly selected trees were taken. As recommended by ACQUAYE (1964), the most recently matured leaf of a twig (usually the third leaf from the tip) was picked with its petiole, excluding damaged leaves or those with abnormal sizes.

2.7.2 Sample treatment and analysis

The samples were packed in plastic bags, weighed, air-dried, and transported to the STORMA laboratory in Palu. After final oven-drying (about 4 hours at 80 °C), samples were ground to powder and stored in plastic bags. All analyses were carried out in the STORMA laboratory. N content of the leaf material was analysed by a C/N-Analyser (Vario EL, Elementar). For analysis of P, K, Mg, Fe, and Ca, plant material was completely digested by HNO_3 under pressure. Nutrient contents were detected by ICP-OES (Optima 2000 DV, Perkin Elmer).

2.7.3 Rating of leaf nutrient contents

Following the suggestions of HALLIDAY & TRENKEL (1992) for cacao production in Trinidad, near-mature cacao leaves with nutrient contents less than 1.8% N, 0.13% P, 1.2% K, 0.3% Ca, 0.2% Mg, and 50 ppm Fe should be rated as severely deficient. Normal nutrient contents should be higher than 2.0% N, 0.2% P, 2.0% K, 0.4% Ca, 0.45% Mg, and 65 ppm Fe.

2.8 Case studies

To shed more light on sustainability issues, three homegardens in Wuasa and Siliwanga were chosen for a detailed case study of soil quality and erosion, microclimate and management patterns in March, April and June 2004. The homegardens selected represented the three main garden types found in the research area (KEHLENBECK & MAASS, 2004). In Wuasa, one homegarden of ‘type 1’ (small spice garden) and one of ‘type 2’ (large, species-rich fruit tree garden) were selected. In Siliwanga, one garden of ‘type 3’ (very large, species-poor migrant garden) was chosen. The selected households had similar sizes (2–4 adults and 1–2 children per household) and were exclusively engaged in agriculture.

2.8.1 Case study interviews

For a period of two weeks, households chosen were visited every evening when at least the household head and his wife were available for daily interview, lasting about 30 min. The purpose of these interviews was to study in detail time and work allocation of the household concerning homegarden management, including other homegarden-related inputs and outputs. In a 24-hour recall, the following questions were asked:

1. What kind of work did each household member perform today in the homegarden or somewhere else (except housework such as cooking, washing, cleaning)? How long did it take?
2. What was harvested today from the homegarden? What was the amount per item? For what purpose each item was harvested? What and how much was harvested from other farm plots?

2.8.2 Soil quality and erosion

In the selected homegardens, topsoil samples (0–15 cm) were taken again from the different production zones (2–3 zones per garden) to estimate small-scale variation of soil quality and soil erosion. Therefore, samples were not bulked, but analysed separately. Soil treatment after sampling was the same as described under 2.6.2. Texture analysis was carried out in Bogor, pH-value (in H_2O) as well as C and N contents were analysed in Palu. In Göttingen, plant available P (Bray I), CEC $_{\text{effective}}$ and base saturation were determined (for methodology see 2.6.3).

For assessment of soil erosion, the content of Caesium-137 was analysed according to WU & TIESSEN (2002) in the same topsoil samples as described above. To serve as reference samples, three undisturbed topsoil samples (0–15 cm) were taken each from forest near Wuasa and grassland in Siliwanga. To obtain the required amount for Caesium-137 analysis (minimum 250 ml dry soil), each sample was combined from three cores, taken in immediate vicinity. Dried and sieved subsamples were transported to Göttingen. Analysis of Caesium-137 was carried out by gamma spectroscopy in the LARI-laboratory of the Institute for Forest Botany, University of Göttingen. Caesium-137 activity was measured 24 to 70 hours per 250 ml soil sample.

2.8.3 Microclimate and PAR (photosynthetic active radiation)

Microclimate and PAR (photosynthetic active radiation) measurements were conducted in different production zones of the three selected homegardens. Microclimate (i.e. soil temperature and air temperature) was measured by HOBO™ Pro RH/Temp-data loggers over a period of two weeks. Three data loggers were each fitted on a wooden pole of 1.3 m length, provided with a wooden board on its top for data logger's protection from direct sunlight and rain (see Figure 3.29 as an example). These poles were hammered into the soil to such depth that the data loggers sensors were exactly 1 m above soil surface. Per garden, one data logger each was installed between cacao trees in the cacao production zone, and either in the vegetable, fruit tree or (in Siliwanga) cassava production zone, while a third data logger served as a reference at a bare place. Three further data loggers, protected in plastic bags, were buried at the base of each pole in 5 cm depth for recording soil temperature. Data loggers were adjusted to measure and store temperature every hour. After finishing two weeks' measurements, stored data were transferred to a notebook computer for further processing. For every daily course, the minimum, the maximum, and the mean temperatures of air and soil, as well as the amplitudes were used to calculate overall means of the whole measurement period per zone and garden. Besides, mean daily courses of air and soil temperatures were calculated per zone and garden.

PAR (photosynthetic active radiation, wavelength 380–710 nm) was measured to describe light regimes in different production zones of homegardens, using three data loggers 'Ecotec DL-424'. To allow comparison with data already generated in the area, measurement was conducted following BRODBECK (2004) with slight adaptations. Four sensors were fitted on each of two bamboo poles, at heights of 0.3, 1.3, 3.0, and 4.5 m. The sensors of each pole were connected to a data logger. For reference measurement, only one sensor, connected to a third data logger, was fitted on a third pole at 3.0 m height. The three poles were planted in the different production zones of each homegarden, just beside the position of the microclimate measurement units (see above). Measurement was carried out in May 2004 for a period of five days per homegarden and was adjusted to one measurement every ten seconds and saved as an integrated value every minute. Stored data were transferred to a notebook computer after finishing each measurement of five days. Mean daily courses of PAR were calculated for each zone and stratum as well as for the bare space per garden. In addition, the mean duration of direct solar radiation (defined as periods of time with PAR ≥ 250 $\mu E/m^2s$) per day as well as mean relative light intensity (i.e. PAR measured in the stand in relation to PAR at bare space of the same garden) were calculated per zone and stratum for each of the three gardens (BRODBECK, 2004).

The layout of one selected case study homegarden was measured in detail. Position and size of the house, toilette, stable, and pathways were determined using a measuring tape and drawn on a map of the particular garden. In addition, the position of all trees, shrubs, and single herbs were included into this map. Herbs occurring in clumps were not marked individually in the maps. Instead, their production area was drawn. Both crops and ornamentals were considered for mapping. Heights and crown diameters of all trees and banana plants taller than 2 m were determined using a measuring stick. Each crown diameter was measured twice, forming a right angle, for calculating the mean diameter and canopy area of the respective tree. For trees and bananas planted exactly at the border of the garden, only half of the canopy area was considered for calculating the total canopy cover; for those individuals planted in less than 1 m distance to the garden border, only 67% of the canopy area was considered.

2.9 Data processing and statistical analysis

Raw data were arranged in MS Excel 2000 spreadsheets and statistically analysed using SPSS software (version 11.0). For each metric variable, normal distribution and homogeneity of variances were tested by Shapiro-Wilk and Levene test, respectively (JANSSEN & LAATZ, 2003). If test conditions were fulfilled, differences between group means were determined by t-test (for comparing two groups) or one-way ANOVA (for comparing more than two groups), followed by *post-hoc* Tukey's HSD test. Concerning not normally distributed variables, medians were presented in the tables and differences between groups were identified by non-parametric Mann-Whitney's U-test (for comparing two groups) or Kruskall-Wallis' H-test (for comparing more than two groups), followed by Nemenyi test for revealing the significantly different groups (TIMISCHL, 2000). Spatial differences of soil quality parameters between production zones within homegardens were analysed as 'paired samples' using the Wilcoxon signed-rank test. To analyse changes in related variables over time (e.g. crop species richness per garden in the years 2001, 2003, and 2004), Friedman test was used. Linear bivariate relations between variables were analysed using Pearson's correlation coefficients for metric variables and Spearman's correlation coefficients for ordinal variables (JANSSEN & LAATZ, 2003).

2.9.1 Multiple regression analysis

To identify factors that influence crop diversity, multiple linear regression analysis was performed. The dependent variables were crop species richness, Margalef index, crop species density, crop individual density, diversity expressed by the Shannon index, and Shannon evenness index. The explanatory, independent variables belonged to four different categories: garden features (i.e. age and size), characteristics of the gardener and his/her household (e.g. gardeners age, origin, and sex, profession of household head, household size), socio-economic features including farm characteristics and wealth status of the household (e.g. market access, farm area per household member, poverty index, cash oriented production), and soil characteristics (e.g. C, N, and available P content, pH value). These independent variables were selected mainly according to the available literature, presented in detail in 1.4. After checking the influence of all variables per single category each, a final multiple regression analysis was carried out using only the most important explanatory variables out of the four categories. Some highly correlated pairs of independent variables such as soil N and C contents or pH value and available P content were converted to dummy variables to avoid multicollinearity. Nominal variables, e.g. origin of the gardener or market access, were included into the model as dummy variables. After running the analysis with non-transformed independent variables only, non-linear variables were transformed to their natural logarithm to check a possible improvement of the model.

Regression analysis was performed using the stepwise method, including only variables with an F-probability of their partial correlation coefficient $P \leq 0.05$ and excluding such with $P \geq 0.1$ (BACKHAUS et al., 2006). Auto-correlation among independent variables was examined by the Durbin-Watson test, provided by SPSS. The result of this test should be in certain limits around the value 2.0, depending on the number of cases and number of explanatory variables in the model (e.g. limits for 50 cases and three explanatory variables: 1.59–2.41; for five explanatory variables: 1.69–2.31) (BACKHAUS et al., 2006). To detect multicollinearity, the ‘condition index’ was calculated by SPSS. Following BELSLEY et al. (1980), an index higher than 15-30 indicates multicollinearity. In this study, regression models with an index of more than 16 were rejected. To test for heteroscedasticity, an analysis of the residuals was performed visually by plotting standardised predicted values against standardised residuals (BACKHAUS et al., 2006). No relation between these two variables indicates the required non-heteroscedasticity.

2.9.2 Specific analyses of vegetation and diversity data

Species density

To calculate species density per 1000 m^2 garden area, two methods were used. One measure was based on regression analysis of all cases and calculation of residuals for each single case, followed by estimation of species number in a standard plot according to the percentage difference between counted and predicted species number for the measured plot size, but extrapolated to a standard 1000 m^2 plot. Before regression analysis, garden size was ln-transformed to ensure linearity of its influence on species number.

The second measure for species density was calculated for a standard plot size of 1000 m^2 according to the modified Arrhenius equation, as suggested by EVANS et al. (1955):

$$S = \frac{s}{\log(x+1)} \times \log(X+1)$$

where S = Estimated number of species in a standard plot

s = Number of species counted in the plot

x = Measured size of the plot

X = Standard plot size

Diversity indices

Alpha diversity is commonly measured as species richness of an individual sample unit. However, sample sizes might not be equal in a study and, thus, influencing species richness per sample. Besides, equitability or evenness of abundance is not included in the measure of species richness, although it is an essential component of diversity. In addition to species richness, this study presents different diversity indices as suggested by KREBS (1999), MAGURRAN (1988), and MCCUNE et al. (2002), among others.

1. The **Margalef index** counts for the positive relationship between number of individuals (i.e. size) of a sample and its number of species. It is calculated as follows (LUDWIG & REYNOLDS, 1988):

$$M = \frac{S-1}{\ln N}$$

where M = Margalef's index

S = Number of species

N = Total number of individuals

As suggested by PIEPHO (1996), an index such as the Margalef index should be provided beside the pure species richness for comparing diversity among samples of different sizes.

2. The **Shannon index** is probably the most common diversity index based on heterogeneity, calculated as follows (MAGURRAN,1988):

$$H' = -\sum_{i=1}^{S} p_i \times \ln p_i$$

where H' = Shannon index of diversity

S = Number of species

p_i = Abundance of the *i*th species

The measure H' increases with the number of species and evenness of their abundance. It is sensitive to changes rather in the rare species than in the dominant species of a community (PEET, 1974).

3. The first nonparametric heterogeneity measure of diversity used in ecology was **Simpson's index** (KREBS, 1999), given by:

$$\lambda = \sum_{i=1}^{S} p_i^{\ 2}$$

where λ = Simpson's index of diversity
S = Number of species
p_i = Abundance of the *i*th species

Simpson's index ranges from 0 to 1 and describes the probability that two individuals randomly picked from one plot belong to the same species. The higher the index the lower the diversity. According to PEET (1974), Simpson's index is more sensitive to changes in the dominant than in the rare species.

4. The reciprocal of Simpson's index, called also **Hill's N_2**, is calculated as follows (LUDWIG & REYNOLDS, 1988):

$$D = \frac{1}{\lambda}$$

where D = Hill's N_2
λ = Simpson's index

Hill's N_2 ranges between 0 and S (number of species), pointing towards the number of very abundant species. Therefore, a high value indicates a high diversity.

5. One of the measures of evenness is the **Shannon evenness index** or Pielou's J (PEET, 1974) that is:

$$E = \frac{H'}{H'_{max}} = \frac{H'}{\ln S}$$

where E = Shannon evenness index
H' = Shannon index of diversity
H'_{max} = Maximum possible value for Shannon index, given S species

Shannon evenness index ranges from 0 to 1, giving the percentage of H' obtained when all species are evenly distributed. Increasing values indicate more equally abundant species (LUDWIG & REYNOLDS, 1988).

Similarity measures

Floristic similarity between crop plant communities among samples (i.e. beta diversity) was estimated by calculating **Sørensen's coefficient** as follows (modified after MAGURRAN, 1988):

$$S_S = \frac{2c}{a + b}$$

where S_S = Sørensen's similarity coefficient

a = Number of species present in sample A

b = Number of species present in sample B

c = Number of species present in both samples

The higher S_S, ranging from 0 to 1, the more similar are the plant communities among the two samples. Species common in both samples are weighed double. However, only presence-absence data are included in this measure, information on species abundance is ignored.

As an index that includes species abundance data, the **Renkonen index** or 'percentage similarity' was calculated as follows (KREBS, 1999):

$$P_S = \sum_{i=1}^{S} \min\left(p_{1i}, p_{2i}\right)$$

where P_S = Renkonen index

S = Number of species

min = Minimum when comparing two samples, 1 and 2

p_{1i} = Abundance of the *i*th species in sample 1

p_{2i} = Abundance of the *i*th species in sample 2

As the abundance of a few species was extremely high in some cases, all individual counts were transformed in the same way as for the principal component analysis (see 2.9.4) before the Renkonen index was calculated, following the suggestions of KREBS (1999).

Importance value

Importance values are averages of at least two of the parameters relative dominance, relative density/abundance, and relative frequency (MCCUNE et al., 2002). These measures have the advantage to level out the bias of single variables such as high absolute abundance. In this study, the importance value Summed Dominance Ratio (SDR) was analysed on village level to compare the importance or dominance of different crop use categories among the villages. First, the relative densities and relative frequencies per village were calculated for each species as follows (MCCUNE et al., 2002):

$$\mathrm{RD_j}\ (\%) = \frac{\mathrm{Indiv._j}}{\text{Sum of all individuals}} \times 100$$

and $$\mathrm{RF_j}\ (\%) = \frac{\text{No. of plots}_\mathrm{j}}{\text{Sum of all plots}} \times 100$$

where RD $_j$ = Relative density of the species j in a village
RF $_j$ = Relative frequency of the species j in a village
Indiv. $_j$ = Number of individuals of the species j in a village
No. of plots $_j$ = Number of plots in a village, where species j occurred

Second, the SDR per species and village was calculated by:

$$\mathrm{SDR} = \frac{\mathrm{RD} + \mathrm{RF}}{2}$$

Third, the single SDR values of all species per use category (e.g. of all fruit species) and per village were summed up.

2.9.3 Hierarchical cluster analysis

Cluster analysis was performed to detect patterns of similarity and, hence, separate different homegarden types based on their plant composition. In 2001, presence-absence data of plant species were used for analysis, applying squared Euclidean distances as a measure of dissimilarity and the average linkage method (KEHLENBECK & MAASS, 2004). Disadvantages of this method were its tendency for chaining and the loss of all information on species abundance data. Consequently, data of the 2003/2004-survey were analysed as abundance data using squared Euclidean distances and the 'Ward' or 'minimum variance' method that is space-conserving and tends to generate homogenous clusters (BACKHAUS et al., 2006; MCCUNE et al., 2002). Species abundance data were transformed before analysis as recommended by MCCUNE et al. (2002) because of the high degree of variation within variables (i.e. abundance data). Transformation of the original data was calculated as follows:

$$x = \ln(y + 1)$$

where x = transformed value
y = original value

To detect outliers that influence the final cluster analysis, BACKHAUS et al. (2006) suggested to perform first a cluster analysis using the 'nearest neighbour' (single linkage) method. The final analysis was then performed without the outliers. Cluster analysis was carried out using MVSP (Multi-Variate Statistical Package), version 3.13m, Kovach Computing Services (2006). For the decision, where to 'cut' the resulting dendrogram and, thus, defining the correct number of different clusters in the final solution, the 'elbow' criterion was used

(BACKHAUS et al., 2006). ‘Sum of squares’ were plotted against the respective number of clusters. The resulting curve shows an ‘elbow’ point at the optimal number of clusters, indicating that heterogeneity among clusters increases is markedly ‘before’, but only little ‘behind’ this point. Stepwise discriminant analysis was carried out using SPSS to prove if cluster groups differed significantly from each other and to determine variables/species that contributed most to the separation of groups (MCCUNE et al., 2002).

2.9.4 Principal component analysis

Principal component analysis (PCA) was performed using MVSP to detect and visualize changes of plant composition over time. Species abundance data were transformed (see 2.9.3) and centred to assess normality of the variables and to reduce the bias from very dominant species in the analysis (MCCUNE et al., 2002; LEPŠ & ŠMILAUER, 2003). PCA axes to be extracted were determined following Kaiser’s rule (MCCUNE et al., 2002). For analysing changes over time, the mean abundance per village was calculated for each species and each year. PCA was then performed with the transformed and centred mean abundance data. As suggested by MCCUNE et al. (2002), rare species (i.e. species that occurred in less than 5% of the sample plots) were not deleted before analysis because the focus of this study was on species diversity, thus, all species were regarded as important for characterisation of the homegardens.

3 Results

3.1 Age of homegardens and their former land use

The homegardens surveyed were cultivated for periods between 2 and 40 years (see Appendix 8). However, some gardeners were uncertain, in which year they initially planted their homegardens. On avarage, the oldest homegardens were found in Wuasa with a median of 26 years, while in Rompo and Wanga they were of intermediate age (13.5 and 14 years, respectively), and in the migrant villages Siliwanga and Tamadue they were youngest (9.5 and 10 years, respectively). However, differences among medians were significant between Wuasa and the migrant villages only. The areas of most of the homegardens in the migrant villages had never been planted before, thus, were forest (in Tamadue) or grassland (in Siliwanga) until first cultivation. Only one garden in Siliwanga and three in Tamadue were already used as homegardens by previous owners, however, had been planted only sparsely. In the local villages, the present area of most of the homegardens had already been cultivated before, mostly planted with upland crops (20–50%) or robusta coffee (10–20%). Some gardens had already been used as homegardens by previous owners (0–30%). Only 20–40% of the homegardens in the local villages had not been cultivated for an unknown long time, covered mostly by herbs, shrubs, and small trees.

3.2 Function and role of homegardens

The primary function of homegardens was subsistence-oriented crop production for supplying the gardeners' families with non-staple food, such as fruits, vegetables, and spices (see Appendix 8). However, some gardens served mainly as sources of cash income or for ornamental purposes. The proportions of these functions differed among the villages surveyed. In the remote village Rompo, all gardeners used their homegarden products mainly for self-consumption, in Wanga 80%, and in the migrant villages 60–70%. In Wuasa, only 50% of the gardeners mentioned subsistence production, but 40% decoration as a main function. In the migrant villages, 20–30% of the gardeners rated their gardens mainly as source for additional cash income that was important for only 10% of the gardeners in Wuasa or Wanga. Secondary functions of homegardens were mainly decoration (particularly in Rompo and Wanga) or generation of cash income (particularly in Tamadue). Although the general importance of homegardens for daily life was rated as high to very high by 67% of the gardeners (N = 49), their contributions to cash income and subsistence were assessed to be low. No gardener mentioned the homegarden as main source for daily food supply (N = 47), apart from one gardener in Tamadue, who harvested many fruits from his homegarden. For all gardeners, paddy rice fields or plantations served as main cash sources, homegardens were said to contribute nothing or only little. On average, homegardens were said to contribute only about 6% of the total household's cash income (range 0–33%, given by 30 respondents, see Appendix 8). However, portions differed according to the function of homegardens. Gardeners, who mentioned that a main or second function of their homegarden was generation of additional cash income (N = 12) obtained a mean income portion of 10% from them. In contrast, gardeners managing a rather subsistence-oriented homegarden (N = 18) stated to gain on average only less than 3% of their total cash income from homegarden products. However, instead of the productive function many gardeners stressed particularly the important social functions of their gardens as meeting point, place for relaxing and children's playground.

3.3 Micro-zonation

In the homegardens studied, 11 different management zones were identified, six cultivated and five non-cultivated zones. Cultivated zones were dominated either by ornamentals, tree seedlings, vegetables and spices, cacao and coffee trees, or by fruit trees. In mixed vegetation zones, no functional plant species group dominated. Non-cultivated zones were fallows, residential areas (including house, yard, toilets, and wells), stables, ponds and ditches, or other zones (e.g. kiosks, sheds, sites for constructions, or, in the case of Balinese households, the shrine area). In most homegardens, seven different micro-zones were found, ranging from 2–10 zones per garden (for details and sizes of zones see Appendix 7). Besides the residential zone that was found in all homegardens, ornamental and cacao/coffee zones were found most frequently both in local (i.e. Wuasa, Rompo, and Wanga) and migrant villages (Figure 3.1). Vegetable zones and tree nurseries were more common in local than in migrant villages. The occurrence of fruit tree and mixed zones varied markedly among villages. Fallow zones were found in all homegardens of Siliwanga, but in only 30–50% of those in the other four villages. In the migrant villages, zones for stables and other such as kiosks or shrine areas were generally found more often (60–100%) than in local villages (30–60%). Fish ponds occurred only in the villages Wuasa, Siliwanga, and Tamadue (30–40% of the homegardens).

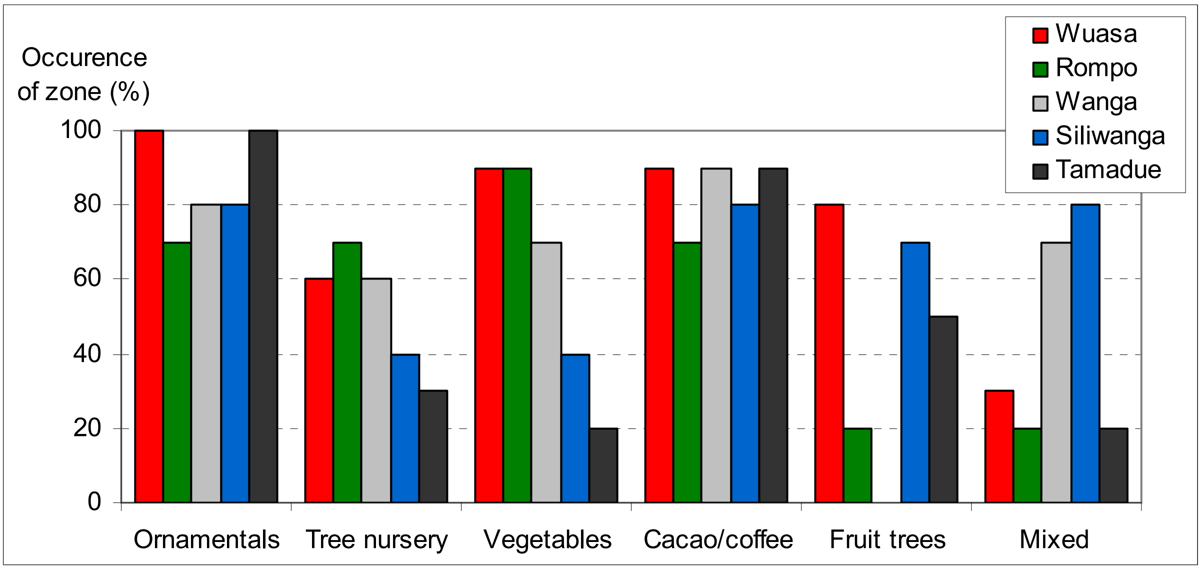

Figure 3.1. Occurrence (in %) of different cultivated micro-zones in homegardens of five villages in the Napu valley, Central Sulawesi, 2004. N = 10 per village.

The location of the different zones within homegardens was clearly fixed, based on practical considerations as well as traditions. Ornamentals were planted exclusively in front and/or at the sides of houses as well as along the front fence. Balinese gardeners cultivated ornamentals additionally around the shrine area in their front garden. Nurseries for trees and/or vanilla (Figure 3.2) were found mostly at a shady place in the back yard very close to the house, where they could be watered regularly and protected from thieves. Zones for vegetables were laid out mostly close to the house in the front or side garden, often fenced to protect them from livestock and children. In many vegetable zones, also spicy, medicinal, and ornamental plants were cultivated, whereas trees occurred very rarely.

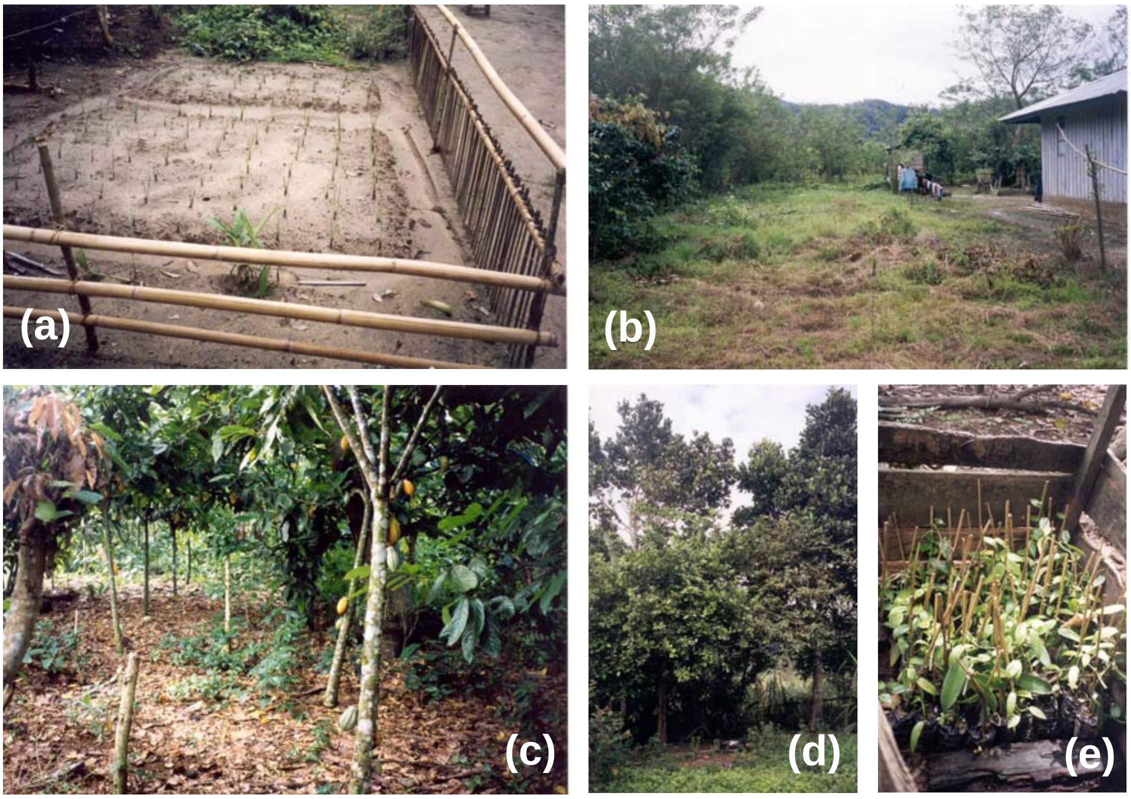

Figure 3.2. Different vegetation zones in homegardens of the Napu valley, Central Sulawesi. (a) Vegetable zone in a garden in Rompo; (b) Fallow zone in a garden in Tamadue; (c) Cacao/coffee zone in a garden in Tamadue; (d) Fruit tree zone in a garden in Wuasa; (e) Nursery for vanilla in a garden in Tamadue.

The cacao and coffee zone was mostly located beside or in the back of houses (Figure 3.2). Most cacao/coffee zones were shaded by fruit or multipurpose trees. If planted not too densely, staple food crops such as cassava, taro, or sweet potato were commonly grown under cacao and coffee trees. Fruit trees were often planted along homegarden borders, sometimes also in groups beside or behind the houses. They occurred only rarely in the front garden because this place was occasionally used as a temporary roofed party place in cases of weddings or funerals when existing trees would have to be felled. Fallow zones were found mostly in the back part of gardens, where unfavourable conditions hindered cultivation, e.g. due to water logging (Figure 3.2). Temporary fallows, caused by lack of time for hoeing and planting after harvesting the last crop, were sometimes found beside or in front of houses. Stables and ponds were laid out mainly in the back edges of homegardens to avoid unpleasant smell. However, in very large gardens, stables were found not too far away from houses in the back garden.

The sizes of micro-zones and their proportions of total homegarden areas differed among villages. Ornamental zones occupied, on average, only about 1–5% of the total homegarden area. They were important in proportion in the local villages Wuasa and Wanga, but their sizes were largest in Wuasa and the migrant village Tamadue (Figure 3.3). Median sizes of ornamental zones differed significantly only between Wuasa and Rompo. Vegetable zones were largest in the local villages Wuasa and Rompo, where they occupied about 4% and 10% (median) of the total homegarden area, respectively. In Tamadue, both median size and median proportion of vegetable zones were significantly lower than in Wuasa or Rompo. Cacao and coffee zones occupied 20–30% (medians) of the homegarden area in the local villages. In Siliwanga, cacao and coffee zones were very small (5%), whereas in Tamadue, they were the most important zones, occupying nearly 70% of the total homegarden area. However, apparent differences among villages were not significant due to the large variability. Fruit tree zones were rather small, occupying only up to 4% of the total garden area. However, single fruit trees were often integrated in the mixed vegetation zone that was small in Wuasa, Rompo, and Tamadue, but rather large in Wanga and Siliwanga (about 16% of total garden area). Fallow zones within homegardens were of importance in size and proportion mainly in Siliwanga (median: 33% of the total garden area), caused by unfavourable soil conditions.

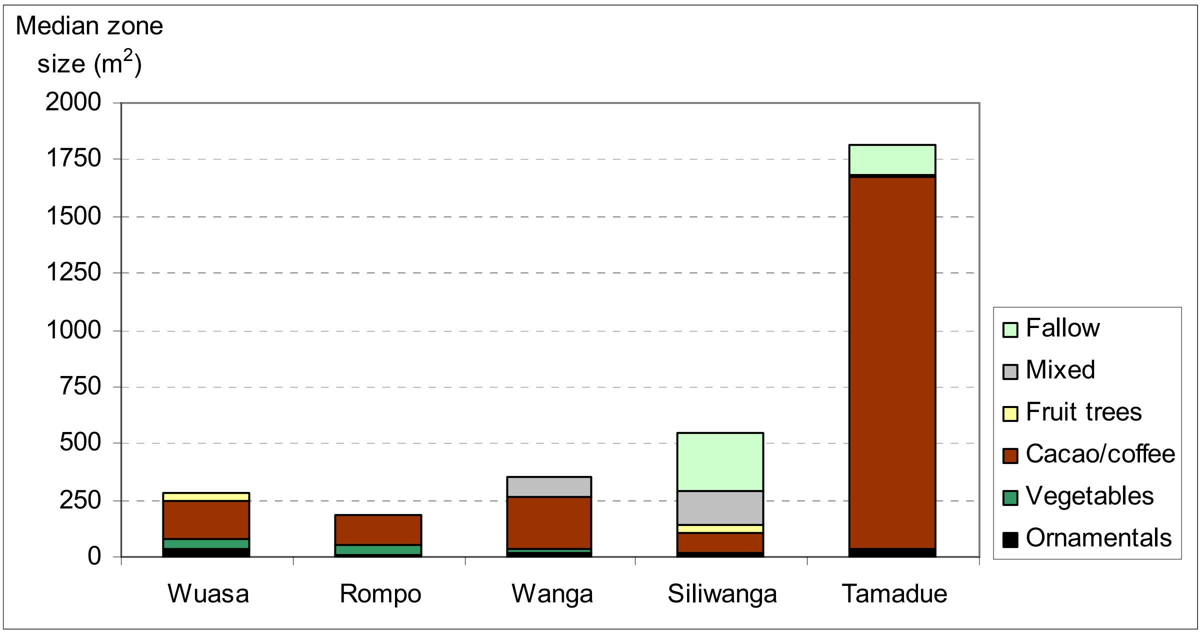

Figure 3.3. Median sizes of cultivated zones and fallows in homegardens of five villages in the Napu valley, Central Sulwesi, 2004. N = 10 per village.

Residential areas occupied about 26–36% (medians) of the homegarden area in the local villages, but in Siliwanga and Tamadue only 19% and 15%, respectively. Differences of median proportion were significant between Wanga and Tamadue only, whereas median sizes of residential areas did not differ markedly, being rather small in Rompo and Siliwanga (medians 210–220 m^2), medium in Wuasa and Wanga (about 240 m^2), and large in Tamadue (about 300 m^2). Ponds, stables, and other buildings such as shelters occupied only 2–6% of total garden area, being rather large in the migrant villages, where many pigs and cattle were raised in the homegardens. In the local villages, ponds were not common (apart from Wuasa) and pigs were often not stabled, but tethered. Ponds and ditches were dug for better drainage exclusively in Wuasa, Siliwanga, and Tamadue. Only larger ponds (50–400 m^2) were used for raising fish, whereas smaller ones were used in some cases for cultivation of semi-aquatic plants such as water spinach. However, many gardeners used their ponds mainly as a place for their household rubbish.

3.4 Homegarden management and inputs/outputs

3.4.1 Sources of planting material

Gardeners mentioned several different sources of planting material. About one third of the planting material was supplied by family members, friends, or neighbours, another third had already been planted by previous garden owners or was self-established from seeds of wild or previously cultivated plants. About 10% of the planting material each was harvested from own plots, supplied by alien people, purchased, or received by development projects. However, differences in the sources of planting material existed among the villages. Own plots as a source of planting material were more important in the local villages (particularly in Wanga) than in the migrant villages Siliwanga and Tamadue, where gardeners often asked friends and neighbours for new planting materials (Figure 3.4). In the recently founded migrant village Siliwanga, rather large portions of the planting material were requested from alien people (i.e. mostly inhabitants of the nearby local village Wanga), received by projects (i.e. mostly from the governmental transmigrant programme) or brought from the home region Bali. Self-establishment of plants seemed to play a larger role in the local than in the migrant villages. Purchasing of planting material was more important in Wuasa and Tamadue than in the other three villages.

Sources of planting material did not only differ among villages, but also among crop use categories. Both fruit and vegetable species were most often self-established or requested from friends and neighbours. In the migrant villages, gardeners received about 20% of their fruit species from projects. For both local and migrant gardeners, such projects were also the main sources for planting material (about 22% and 27%, respectively) of stimulant species (e.g. cacao, tea, and arabica coffee). Planting material of spices, medicinal plants, and multi purpose trees (MPT) was mostly requested from friends and neighbours (about 35–40% each). However, in the local villages own plots were an important source for MPT species, too. Large parts of staple crop species were already planted by former garden owners. For local gardeners, own fields were another important source for staple crops, whereas migrants mostly requested planting material of such crops from their friends and neighbours.

For wood and timber species, the most important source of planting material was simply self-establishment from the natural vegetation nearby (about 70%), but some species were also transplanted by the gardeners from the wild (about 7%). Gathering from the wild was a rather important source also for some medicinal species, particularly in the local villages (nearly 10%). Migrant gardeners brought nearly 20% of their medicinal plants from their home region Bali. Purchasing of planting material was important only for the use categories ‘fruits’ and ‘spices’ (local gardeners about 14% and 8%, migrant gardeners about 13% and 14%, respectively). However, gardeners mostly did not purchase seeds or plantlets in shops or markets. Instead, they bought fruits and spices for consumption and planted some of the seeds or remnants of rhizomes in their homegarden. Planting material could sometimes be transported even over rather large distances. Most of the mentioned fruits were bought by the gardeners in the markets of urban centres such as Poso or Palu up to 100 km away from the Napu valley. Also visits of relatives living farther away were often used as an opportunity to request new planting material, even from alien people living in the village visited.

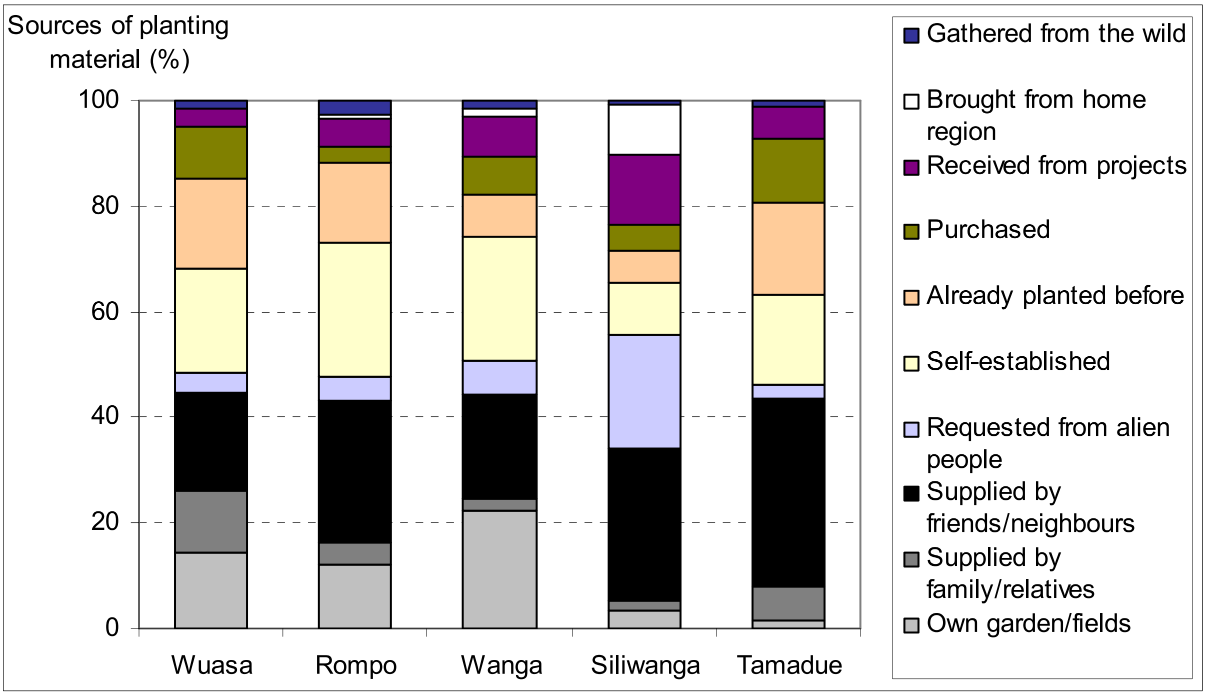

Figure 3.4. Sources of planting material as mentioned by the owners of 50 homegardens in five villages of the Napu valley, Central Sulawesi, 2003. N = 10 per village.

Many gardeners also have given away planting material. However, no quantitative data about recipients or the frequency and amount of material flow were recorded. A few gardeners even mentioned that sometimes too many people asked for planting material. One female gardener in Wuasa complained that some of her homegarden crops already were reduced to very small numbers due to repeated requests by neighbours and relatives. She explained that rejecting the requests only would led to the stealing of desired plants. Stealing of planting material occurred rarely in homegardens, but it was mentioned by the gardeners as a severe problem in the more remote upland fields and plantations, particularly in cacao and vanilla plantations.

3.4.2 Labour

Main homegarden work was carried out mostly by household heads or their wives, but marked differences existed among villages. In the interviews, respondents in the more traditional local villages Rompo and Wanga stated that in about 90% of the homegardens main gardeners were females (see Appendix 8). In Wuasa and Siliwanga, however, 60% of the gardens were said to be managed mainly by males, in Tamadue with its coffee- and cacao-dominated homegardens even about 90%. According to calculations of the detailed working time schedules for males and females, however, the portion of mainly female-managed homegardens shifted slightly (Rompo and Wanga about 80%, Wuasa and Siliwanga 60%). Median monthly working hours of household heads and their wives, given in Table 3.1, partly reflect these results (for details see Appendix 9). In Rompo and Wanga, wives worked 5–10 times more than their husbands, but in Siliwanga, household heads worked slightly more than their wives. However, differences between males and females were not significant because of extremely high variation. The village Tamadue was excluded from the detailed analysis as data were incomplete. Children and children-in-law mostly only assisted in homegarden work, although in some households, children contributed markedly to homegarden management, particularly in Wuasa and Siliwanga (see range in Table 3.1). In few cases, also friends, neighbours, or relatives were involved in homegarden management. In the local villages, female household members carried out most of the total homegarden work (median Wuasa 57%, Rompo 90%, Wanga 93%), whereas in the migrant village Siliwanga, females carried out less than half of the work (median 47%).

Summed monthly working time varied from about 3–52 hours per household, village medians were fairly similar with a range of about 9–12 hours per month (Table 3.1). As homegarden size varied markedly, monthly working hours per 100 m^2 cultivated garden area were also calculated. In Wuasa, Rompo, and Wanga, median working time/100 m^2 was about 2 hours per month, in Siliwanga, it was only 0.9 hours. Calculated on a daily basis, median daily working time was about 4 min./100 m^2 garden area in the three local villages, but less than 2 min./100 m^2 in the migrant village (range 0.4–20 min./100 m^2). However, differences among villages were not significant.

Table 3.1. Median monthly homegardening working hours (ranges in brackets) of the household head (HH-H.), his wife, his children, or his friends and relatives as well as median working hours in total per month, and per 100 m^2 garden area as given by respondents interviewed in 39 households in four villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	Wuasa		Rompo		Wanga		Siliwanga	
Working hours HH-H.	1.8a	(0.0–23.1)	1.0a	(0.0–22.0)	0.7a	(0.0–19.0)	3.9a	(0.0–20.0)
Working hours wife	2.5a	(0.0–32.0)	5.7a	(0.2–19.3)	7.1a	(0.0–20.9)	3.4a	(0.2–22.9)
Working hours children	1.1a	(0.0–20.3)	0.0a	(0.0–12.0)	0.1a	(0.0–8.0)	0.0a	(0.0–28.0)
Working hours friends and relatives	0.0a	(0.0–2.1)	0.0a	(0.0–6.0)	0.0a	(0.0–0.1)	0.0a	(0.0–0.04)
Working hours total	12.3a	(3.4–47.4)	10.1a	(4.6–36.6)	9.3a	(2.8–27.6)	8.6a	(4.8–51.9)
Working hours/100 m^2	2.0a	(0.3–10.1)	2.0a	(0.3–5.7)	2.2a	(0.2–5.9)	0.9a	(0.4–2.8)

Note: As medians are given, total working hours are not equal to the overall sum of the three worker categories. Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

Hoeing and pulling up/mowing weeds were carried out regularly by more than 80% of the gardeners. These kinds of work consumed most of gardener's working time, particularly in the local villages Wuasa, Rompo, and Wanga (Table 3.2, for details see Appendix 9). Harvesting was carried out regularly by 96% of the gardeners, who spent 2.4 hours per month (median) with harvesting in all villages. In the villages Wanga, Siliwanga and Tamadue, all gardeners sprayed their gardens regularly, whereas in Wuasa and Rompo only 70% and 56% did so, respectively. Time spent on spraying was significantly higher in Siliwanga than in Rompo, but it was generally rather low (Table 3.2). Fertilising of homegardens was more common in the migrant villages Siliwanga and Tamadue (> 90% of the gardeners) than in the local villages (60–80%). Accordingly, time used for fertilising was markedly higher in Siliwanga than in the local villages. Planting and pruning trees consumed only 0.1–0.3 hours per month (median) in all villages (Table 3.2). Planting was carried out regularly by more than 90% of the gardeners in all villages, apart from Tamadue, where only 30% did so. Pruning trees was performed only if trees, particularly cacao trees, were cultivated in the homegarden. In Tamadue, 90% of the gardeners pruned their trees regularly, in Wuasa and Rompo 70–80%, and in Wanga and Siliwanga only 50–60%.

Table 3.2. Median monthly homegardening working hours (ranges in brackets) allocated to different kinds of work, as given by respondents interviewed in 39 households in four villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga
Hoeing	6.0a (0.0–36.0)	4.0a (1.0–24.0)	5.0a (0.0–12.0)	0.7a (0.0–9.0)
Weeding/mowing weeds	1.3a (0.0–30.0)	1.2a (0.3–24.0)	1.0a (0.1–15.0)	2.5a (0.1–45.0)
Harvesting	2.4a (0.3–3.0)	2.4a (2.4–4.0)	2.4a (0.5–4.0)	2.4a (0.0–3.0)
Spraying	0.1ab (0.0–1.8)	0.0b (0.0–0.2)	0.3ab (0.1–0.5)	0.5a (0.0–1.0)
Fertilising	0.1ab (0.0–2.0)	0.2ab (0.0–0.7)	0.0b (0.0–2.4)	0.7a (0.2–3.0)
Planting	0.3a (0.0–6.1)	0.2a (0.0–1.0)	0.1a (0.0–1.0)	0.2a (0.0–0.9)
Pruning trees	0.2a (0.0–0.5)	0.1a (0.0–4.0)	0.3a (0.0–1.4)	0.1a (0.0–1.0)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

Most of the different kinds of work were clearly assigned either to male or female workers. However, Table 3.3 shows some differences among migrant and local households. Hoeing was carried out mainly by women (i.e. wives and daughters/daughters-in-law of the household head) in the local villages Wuasa, Rompo, and Wanga, but by men (i.e. household heads and their sons/sons-in-law) in the migrant villages. Weeding was performed by both males and females in the villages Rompo and Siliwanga, whereas in Wuasa and Wanga more females and in Tamadue more males were involved in it. A clear female task was harvesting; only in Tamadue, where mainly cacao and coffee was harvested, 40% male household members took part in this kind of work. Spraying was almost always done by males, not exclusively by household members, but also by friends or neighbours. Only in the villages Wuasa and Tamadue, a few women joined the spraying activities. Fertilising was mostly a female task in the local villages and Siliwanga, but a male one in Tamadue. Planting was carried out mainly by women in the local villages, but by men in the migrant villages. In all villages, males mainly performed pruning of trees.

In the interviews, 27 gardeners mentioned also sweeping the yard and some of the bordering zones as a typical homegarden work. This activity was said to take mostly between 5 and 15 min., carried out daily (by 78% of the 27 gardeners) or every second day. In most of the cases (63%), only females swept, in only 15% exclusively male household members did so. However, as not all gardeners mentioned this activity that could also be classified as part of the housework, it was excluded from the analysis.

Table 3.3. Proportion of female workers (%) performing the different kinds of homegarden work as given by respondents interviewed in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Hoeing	63	62	91	36	20
Weeding	60	46	83	50	33
Harvesting	78	75	80	92	60
Spraying	13	0	0	0	18
Fertilising	56	100	100	75	29
Planting	67	89	89	44	0
Pruning trees	12	12	7	7	19

The specific work allocation between men and women was reflected by different responsibilities for the various homegarden plant types as shown in Table 3.4 (for details see Appendix 8). In the local villages Wuasa, Rompo, and Wanga, in most cases women were responsible for ornamentals, medicinal plants, spices, and vegetables. In these production zones, the typical female tasks of hoeing, planting, fertilising, and harvesting were performed frequently. In the migrant villages, more women than men were responsible for ornamentals and medicinal plants, whereas men mainly took care of spices in Siliwanga and of vegetables in Tamadue. In all villages, mostly men were responsible for fruit and cacao/coffee trees, corresponding to their main tasks pruning and spraying that both was carried out mainly in the fruit and cacao/coffee production zone of homegardens. In Tamadue, exclusively fruit trees and the cacao/coffee zones were fertilised, thus, men were mainly involved in fertilising activities only in this particular village (Table 3.3).

Table 3.4. Proportion of female household members (%) responsible for different homegarden plant types as given by respondents interviewed in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Ornamentals	92	100	100	76	75
Medicinal plants	100	100	91	91	64
Spices	100	67	100	0	70
Vegetables	90	100	90	67	0
Fruit trees	9	10	23	11	17
Cacao/coffee trees	20	17	14	0	17

In summary, the quantity of time allocated for homegarden management was rather small. When compared with the time needed for cultivation of paddy rice fields and plantations, homegarden management was rated as less time-consuming by 90% of the gardeners. Concerning the quality of work, 96% of the gardeners stated that working their paddy rice fields and plantations was very heavy, but homegarden work was an easy task.

3.4.3 Soil fertility rating and management

Most of the gardeners assessed soil fertility of their homegardens as medium to high, apart from Siliwanga, where 70% of the gardeners rated the soil as poor and complained about it as a main constraint for successful homegarden production (Table 3.5, for details see Appendix 10). Low soil fertility was rated as a serious problem not only in Siliwanga, but also in Rompo and Wanga. Concerning changes of soil fertility over time, many gardeners perceived deterioration, particularly in Wuasa. However, in Siliwanga, most gardeners mentioned some improvement of soil fertility over time. Nearly all gardeners stated that fertilising (besides hoeing) was the best method for improving soil fertility. Nevertheless, 20–40% of gardeners in the local villages Wuasa, Rompo, and Wanga did not fertilise their homegardens (Figure 3.5). Reasons for not fertilising at all given by the gardeners were mostly lack of means (for industrial fertiliser) or knowledge (for manure and ash), sometimes also lack of time, laziness, and revulsion (for manure).

Table 3.5. Rating (in %) of soil fertility, its changes over time, and its role in hindering successful homegarden management by 49 gardeners in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Soil fertility low	30	10	30	70	20
Low soil fertility is a serious problem	30	78	80	70	0
Fertility deteriorated	80	56	40	0	50
Fertility unchanged	0	44	30	10	10
Fertility improved	20	0	30	90	40

The most frequently used fertiliser in homegardens was kitchen ash that was available daily to virtually all gardeners (for details see Appendix 10). Figure 3.5, however, shows obvious differences among villages. Whereas only 20% of the gardeners in Tamadue used ash as a fertiliser, in Siliwanga 90% did so. In the local villages Wuasa, Rompo, and Wanga, 50–60% of gardeners fertilised with ash. Applying ash was mostly carried out weekly or monthly, however, also daily application existed. In the local villages, about 90% of gardeners applied ash exclusively to vegetables and spices, whereas in the migrant villages, it was used mainly for fruit trees and cash crops such as cacao and coffee. Applied amounts were only 0.25–4 small buckets (i.e. about 5 l volume) per month, however, mainly spread on a rather small area such as the vegetable zone.

Industrial fertiliser such as urea, triple-super-phosphate, potassium chloride or NPK-fertiliser was less commonly used, apart from the migrant villages (Figure 3.5). In Tamadue and Siliwanga, 60% and 40% of gardeners, respectively, applied industrial fertiliser, whereas in the local villages, no one or only few gardeners in Wuasa did so. If industrial fertiliser was used, it was applied 1–4 times a year nearly exclusively to fruit trees and cash crops such as cacao and coffee. In most cases, extremely small amounts were applied such as 1–6 kg per year and garden, however, in Tamadue the migrant gardeners used 30–100 kg/year, particularly in the commercialised homegardens. Concerning the villages surveyed over time, use of industrial fertiliser increased markedly only in Siliwanga (see 3.10.2).

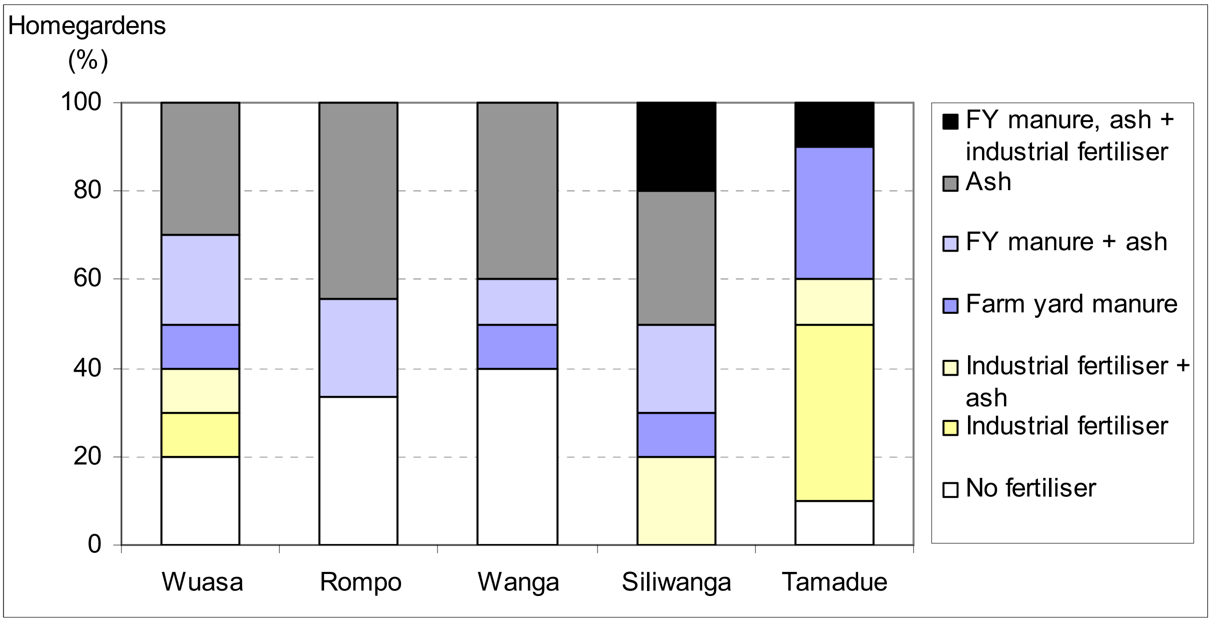

Figure 3.5. Use of different fertilisers in 49 homegardens according to gardeners' responses in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

Farm yard manure was available to 80% of gardeners that reared pigs and/or cattle in their homegardens. However, it was used as a fertiliser only by 20–50% of the gardeners in each village, due to unawareness, revulsion, or time scarcity of gardeners. In the migrant villages Siliwanga and Tamadue, the proportions of manure utilization were slightly higher than in the local villages (Figure 3.5). Cash crops and fruit trees were almost exclusively fertilised with manure in the migrant villages, whereas gardeners in the local villages mostly fertilised vegetables and spices with manure. The applied amount ranged mainly around 2–10 large buckets (i.e. about 10 l volume) per year and garden, distributed in some cases to up to 80 cacao, coffee, and fruit trees. Only three gardeners in Siliwanga and Tamadue applied more manure (40–180 large buckets per year) to their trees. For all kinds of fertilisers, the applied amount per year was rather small in relation to the sizes of homegardens.

Figure 3.6 shows the use of industrial fertiliser in farm plots according to different crops. Farmers stated to use industrial fertiliser mainly for their paddy rice fields, particularly in the migrant villages. In Tamadue, more than 50% of the farmers fertilised also perennial and annual crops as well as their homegardens with industrial fertiliser, whereas in the other villages, comparably few or even no farmers mentioned to do so. Besides ethnicity of the gardeners, also wealth status of households influenced fertiliser use. Only 13% of the poor households reported to use industrial fertiliser or farm yard manure as a main fertiliser in their homegardens, whereas 41% of the intermediate and 53% of the well-off households did so. On the other hand, 69% of poor gardeners, but only 35% of the rich used ash as a main fertiliser in their homegardens.

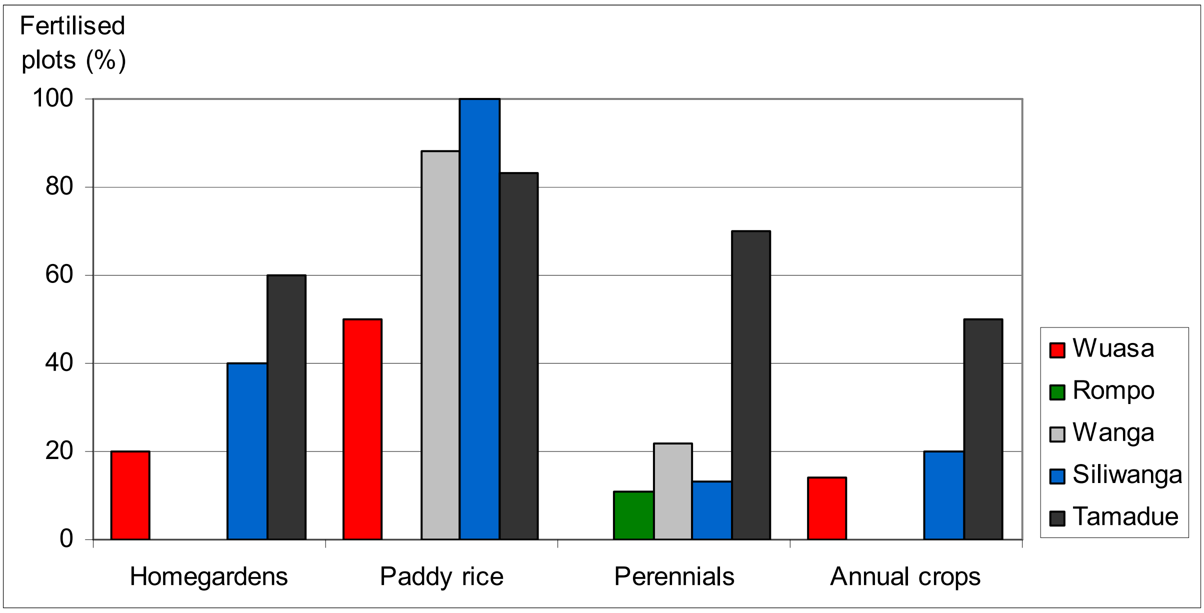

Figure 3.6. Use of industrial fertiliser in homegardens and in plots planted to paddy rice, perennials, or annuals, as given by 49 respondent households in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

3.4.4 Control of weeds, crop pests, and diseases

Weeds were rated as a very serious or at least as a ‘normal’ problem in homegardens by 96% of the gardeners interviewed. This was reflected by the high share of working time needed for weed control (see 3.4.1), carried out mainly by spraying herbicides about 1–4 times per year (see Appendix 11). However, in the remote village Rompo, only 50% of the gardeners applied herbicides, whereas in the other villages, 70–100% did so (Figure 3.7). Alternative methods for weed control were said to be carried out by 96% of the gardeners, mostly by hoeing (80%), by weeding/pulling out the weeds (61%), and by mowing (57%). In all villages surveyed over time, the use of herbicides increased markedly (see 3.10.2).

Most important crop pests according to gardeners were leaf-feeding caterpillars (86%), black and red ants (59%), and aphids (39%) (see Appendix 11). These pests were said to damage mainly cash crops such as cacao and spring onion, besides other leafy vegetables and spices. Spraying insecticides in homegardens was common only in the migrant village Tamadue (Figure 3.8), where exclusively cacao trees that dominated many homegardens were regularly treated 4–12 times per year. In the other villages, in most cases insecticides were applied only occasionally in the past, but not regularly. Instead, in the local villages Wuasa, Rompo, and Wanga, 70–90% of the gardeners stated to carry out alternative methods for crop pest control, such as cutting off infested plant parts, collecting and killing of the insects, dusting with ash, and spraying soap-suds. However, in the migrant villages, only 20–30% of gardeners mentioned to apply such alternative methods.

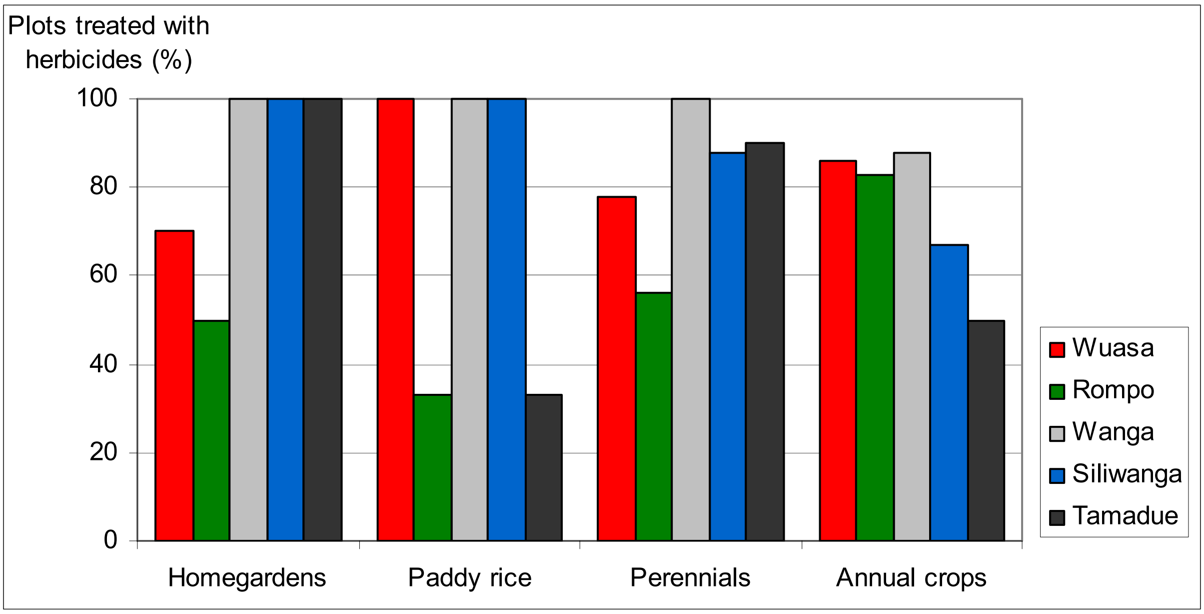

Figure 3.7. Use of herbicides in homegardens and in plots planted to paddy rice, perennials, or annuals, as given by 49 respondent households in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

Crop diseases were recognised by the gardeners only rarely and almost exclusively on cacao trees. Gardeners described these diseases mostly as ‘die-back’, first of the branches and later of the whole cacao tree, often accompanied by a white coating on the infested bark surface. Besides, gardeners mentioned another important and problematic disease of cacao fruits, which they named ‘cancer’. Only few gardeners distinguished three different kinds of ‘cancer’ on cacao fruits, i.e. ‘stone cancer’, ‘black cancer’, and ‘spotted cancer’. Of these, only ‘black cancer’ is a fungal disease, namely the black pod rot, caused by *Phytophthora* spp. The other two ‘cancers’ were caused by insects that were not recognised by the gardeners. ‘Stone cancer’ is caused by the cacao pod borer *Conopomorpha cramerella*, a common cacao pest in Southeast Asia. Caterpillars of the pod borer feed inside the unripe fruits only, thus, not being visible any more at harvest time. ‘Spotted cancer’ is caused by the bites of nocturnal *Helopeltis* bugs. Spraying fungicides against the mentioned diseases (or even pests) in homegardens was mentioned exclusively by one gardener in Siliwanga and six gardeners in Tamadue, where many households depended on additional cash income from sales of cocoa. In the three local villages, most of the gardeners did nothing against crop diseases or they applied some alternative control methods, e.g. removing infested cacao fruits/branches or general pruning of cacao trees. About 30% of the gardeners rated problems with pests and diseases as ‘very severe’ and 60% as ‘normal’.

Spraying herbicides was common not only in homegardens, but also in other plots planted to paddy rice, perennials, and annual crops (Figure 3.7). In the local villages, the portion of herbicide use was mostly lower in homegardens than in other plots, whereas in the migrant villages, it was higher in homegardens. Insecticides were used mainly in the migrant villages, particularly for paddy rice fields (Figure 3.8). In homegardens, insecticides were mostly used less often than in the rice fields, but more often than in perennial or annual crops. As compared to the migrant villages, farmers in the local villages used insecticides in a markedly lower proportion, but also mainly for spraying rice fields and homegardens.

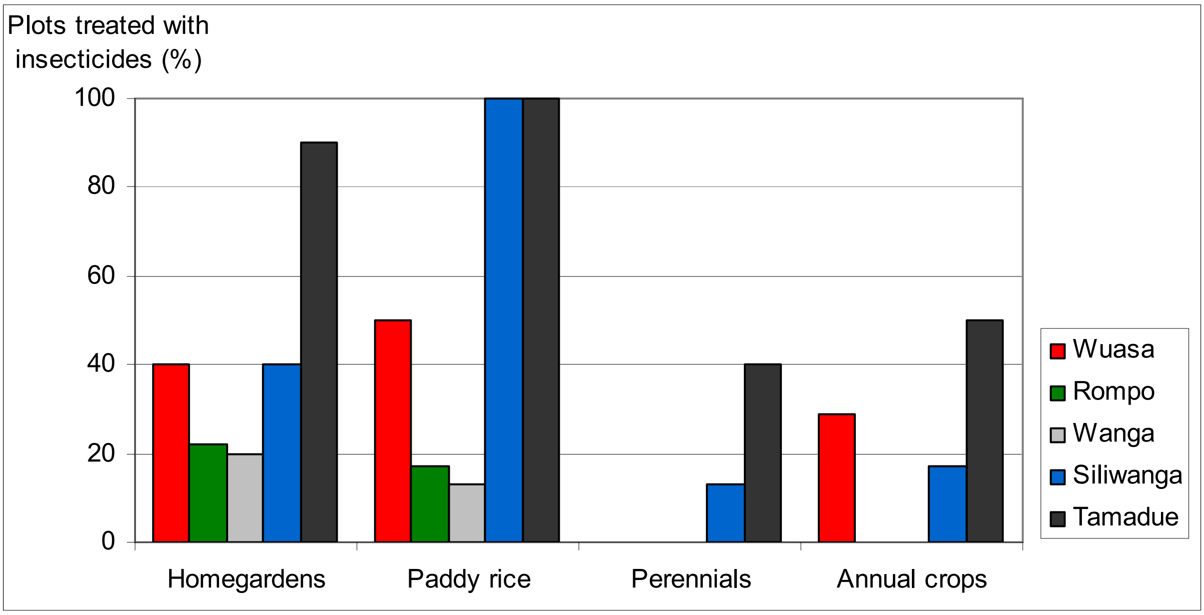

Figure 3.8. Use of insecticides in homegardens and in plots planted to paddy rice, perennials, or annuals, as given by 49 respondent households in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

3.4.5 Other limitations of homegarden management

Besides problems with soil fertility, weeds, and pests and diseases, crop production in homegardens was further constrained. Gardeners mentioned particularly their lack of time, which was stressed as a very serious problem in the local villages Rompo and Wanga, whereas in Wuasa and Tamadue it was mostly no or only a ‘normal’ problem (see Appendix 11). Instead, 60% of the gardeners in Tamadue complained very much about bad crop varieties that did not give adequate yields. Although this problem did not seem as severe in the other villages, most gardeners appeared to be unsatisfied with their traditional varieties. If available, 88% of all gardeners would like to cultivate high-yielding varieties, particularly cacao and fruit trees. Nearly 50% of them would even cut down their mature cacao and fruit trees to replace them with improved varieties.

Many gardeners complained about limitations of successful homegarden production due to damage by small children and free-roaming livestock. Homegardens in the Napu valley were generally not completely closed by fences or hedges. For socio-cultural reasons, at least the main entrance must not have a gate. As a result, children used homegardens as playing and football ground, thus damaging many crops and ornamentals. Besides, small children liked very much to climb even young trees for harvesting mostly unripe fruits, breaking branches and trampling down the herbal undergrowth. Poultry was said to be another severe problem in homegardens, particularly in the rather traditional villages Rompo and Wanga. Scraping chicken in seed beds, and ducks feeding on small leafy crops were an everyday sight in the villages and caused heavy damages, particularly on vegetables and spices, but also on ornamentals and recently planted trees. Sometimes also escaped pigs, cattle, buffaloes, or horses entered homegardens at night and destroyed the crops. Many gardeners already stopped growing vegetables and spices, due to constant damages by livestock; but only 16% of the gardeners mentioned better fencing as a method for improving homegarden production.

About 25% of such gardeners that sold some homegarden produce (N = 38) complained about very serious problems with sale. Nearly all of them mentioned the low prices they got for coffee and cacao. Some gardeners complained also about low number of and bad access to trustworthy middleman, particularly in Wanga.

3.4.6 Outputs

The homegardens surveyed served mostly for subsistence production, some also for income generation. Only two of 206 species found in homegardens (see 3.5.1) were cultivated exclusively for sale (cacao and vanilla). On average, gardeners used only less than one species grown in their homegarden for sale in the villages Wanga and Siliwanga, but 2.5–3 species in the villages Wuasa, Rompo, and Tamadue. Of the 49 gardeners asked for species uses, only about 18% did not sell any produce of their homegarden, 33% sold produce of one species, 20% that of two species, and nearly 30% that of three or more species. The most common produce was cacao, traded by about 75% of the gardeners, followed by coffee (mostly arabica, but also some robusta coffee), sold by about 30%, and by the spicy fruits of the candlenut tree, sold by nearly 20% of the gardeners. A few gardeners also traded surplus of fruits, such as avocados, mandarins, pineapples, or water apples. Vegetables such as tomatoes or pumpkins were sold only by single gardeners. However, the contribution of sold produce from homegardens to the total household income was mostly less than 10% (see 3.2). No detailed information on amounts of cash income generated in the homegardens surveyed was available.

Concerning the produce for family consumption, yield estimates of gardeners seemed to be very difficult and not reliable. Most often, gardeners estimated amounts of harvest only as ‘much’, ‘enough’, or ‘little’. When gardeners mentioned quantities, they often used ‘a handful’, ‘a small bowl’, or ‘one meal’. Some were even not able to state anything about the yield, particularly for continuously harvested fruit trees. Consequently, only the occurrence of a harvest within the preceding year, but not its frequency or amount was analysed for each crop species. On average, only 54% of the species cultivated in the homegardens surveyed were used by the gardeners in the preceding year. However, large differences of the used portions existed according to different crop use categories. The most exploited use categories were spices (on average, 75% of the species were harvested by the gardeners), and stimulants as well as staple crops (73% harvested each), followed by vegetables (60%) and fruits (54%). A typical reason for not harvesting any produce from a species cultivated in the homegarden was simply that the plant had not yet reached its productive stage. Besides, certain crops were neglected by the gardener, other species did not fruit because of insufficient management or unsuitable climate. Concerning medicinal plant species, only a small portion (25%) was harvested and used by the gardeners to cure illness. Respondents mentioned that they rather preferred the modern medicaments available in the shops instead of time-consuming preparation of traditional medicine. Some young gardeners stated that they still recognised the function of a medicinal plant, but they lacked the knowledge on how to prepare a medicine from it. However, single gardeners also highly regarded the value of traditional medicine and used up to 100% of the medicinal plant species in their homegardens. Many gardeners also mentioned that they sometimes gave away medicinal plant parts to their friends and neighbours. Out of the species used mainly for fuel wood and timber as well as such for multipurpose use, only 5% and 2% were said to be harvested, respectively.

In summary, the production potential of homegardens was not fully exploited, both for subsistence and cash income generation.

3.5 Floristic composition and vegetation structure in the year 2004

3.5.1 Plant species richness and use

In the 2004-survey, a combined total of 206 crop species belonging to 71 plant families were cultivated in the 48 homegardens studied. Complete lists of these crop species, their occurrence in the homegardens, and information on their utilisations are given in Appendix 12 and Appendix 13. Fifty of the 206 crop species were considered to be wild species, mostly from the surrounding natural vegetation. They were used particularly as fuel wood and timber (28 species), but several species were also utilised as a medicine or vegetable (10 or 8, respectively). The species-area curve shown in Figure 3.9 indicates that the overall sampled garden area of about 5.2 ha can be regarded as representative for the set of crop species occurring in homegardens of the research region. A further increase in sample area would not add a considerable number of new crop species. About 90% (i.e. 187 spp.) of the total crop species number were already reached with 30 gardens covering an area of 3.45 ha.

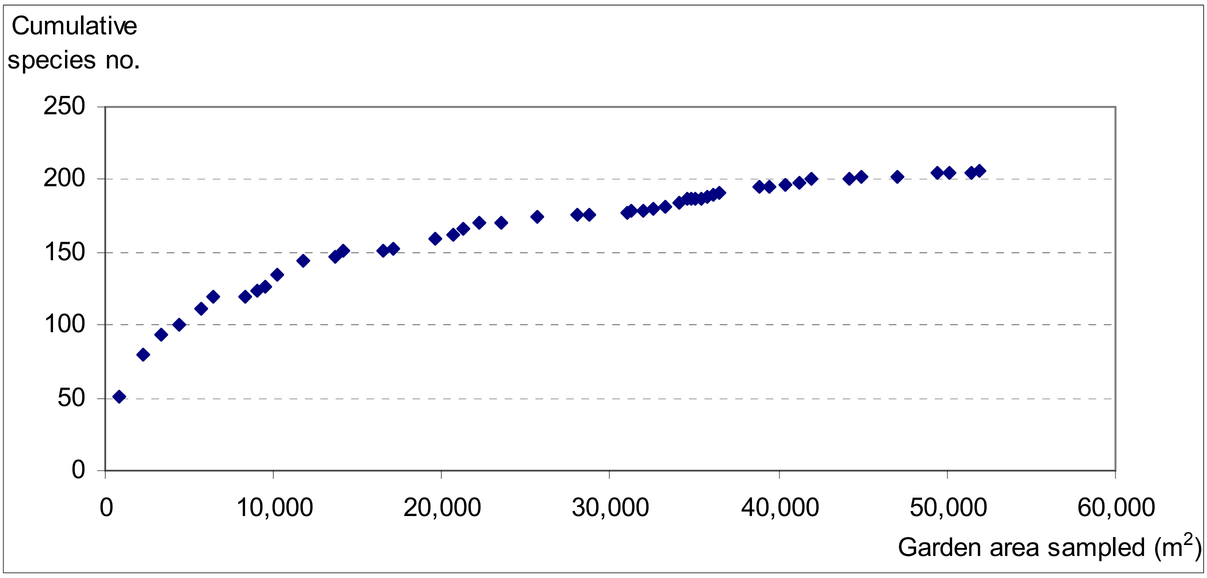

Figure 3.9. Species-area curve for 206 crop species cultivated in 48 homegardens of five villages in the Napu valley, Central Sulawesi, 2004. Total garden area sampled was 51,972 m^2, homegardens were ordered randomly. N = 10 per village, apart from Rompo, where N = 8.

According to their predominant use, about 20% of the 206 crop species were classified each as vegetables or medicinal plants, and about 15% each as fuel wood/timber plants, fruits, or spices (Table 3.6). Less than 5% were grown each for their sweet and stimulant properties, as staple food, as multiple-purpose-trees (MPT) or for other utilization such as wrapping, fodder, handicraft, or toys. However, for most of the crop species not only one single utilization was given by the gardener, but two, three or even more (see Appendix 12). All fruit trees, for example, were said to yield good fuel wood beside fruits; some were used additionally as medicinal plants. Also for many spices, gardeners mentioned an additional medicinal value. Most of the staple food crops were predominantly used for feeding pigs, although gardeners still mentioned their value for human nutrition and as famine food. Among villages, the highest number of crop species was cultivated in Rompo, followed by Wuasa and Wanga (Table 3.6). Homegardens in the migrant villages harboured less crop species, mainly due to smaller numbers of medicinal and fuel wood/timber plants.

Table 3.6. Crop species numbers in total, per village, and per functional group of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	All villages	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Species total	206	117	124	105	98	99
Fruits	30	24	21	22	19	19
Vegetables	40	17	24	18	20	19
Stimulants/sweets	10	7	9	5	6	7
Spices	28	20	16	18	15	19
Medicinals	39	24	21	17	12	10
Staple foods	10	6	6	7	7	7
Fuel wood/timber	34	14	20	14	6	9
MPT	8	2	4	2	8	4
Other	7	3	3	2	5	5

Five crop species were grown in more than 90% of the homegardens studied, i.e. cacao, arabica coffee, the shade tree *Gliricidia sepium*, the fruit tree guava, and the spice chilli (for scientific names see Appendix 12). Additionally, the staple food crops tannia and cassava as well as the fruits banana and mango were cultivated in more than 80% of the homegardens. In summary, only 29 crop species were grown rather frequently, occurring in at least 50% of the gardens. On the other hand, 86 crop species were found only very rarely, being cultivated in less than 5% of the homegardens.

Concerning their abundance, many of the crop species found in homegardens were represented only by very few individuals, whereas the majority of the individuals belonged to only few crop species. In more detail, 30 species were represented by only one single individual each, nearly half of the species were represented by less than ten individuals each (Figure 3.10). On the other hand, only seven very abundant species (i.e. 3.4% of total species) contained more than 50% of all individuals, as these species were represented by more than 1,000 individuals each. Therefore, the community structure pattern followed a logarithmic distribution model.

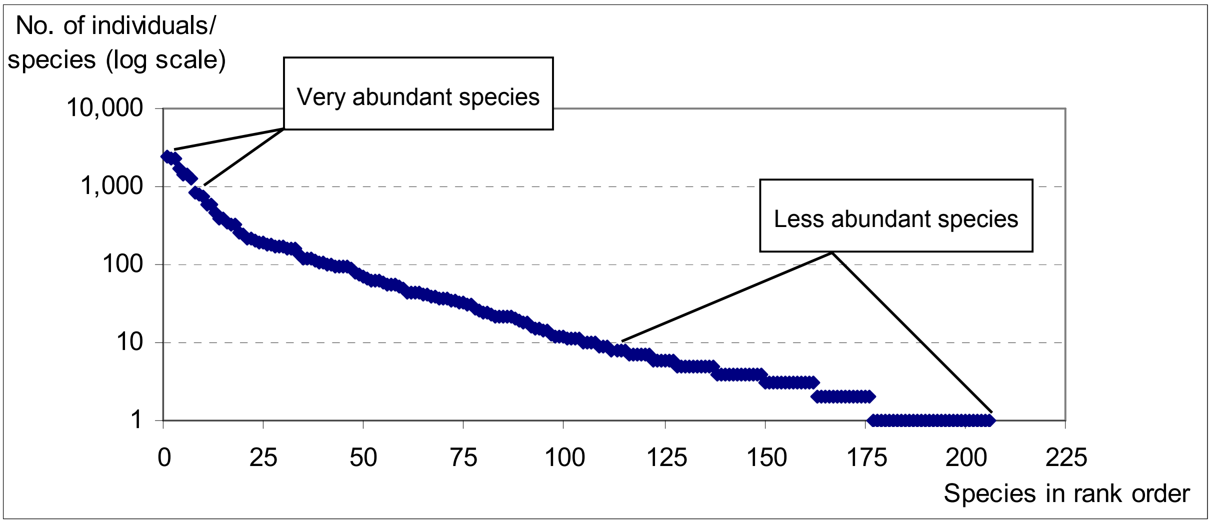

Figure 3.10. Abundance of 206 crop species cultivated in 48 homegardens of five villages in the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

The analysis of the species distribution pattern per village revealed clear differences between portions of less abundant and very abundant species (Table 3.7). The portion of less abundant species (i.e. species represented each by less than 0.1% of the total individuals) was rather low in Wanga as compared to the other four villages. On the other hand, the portion of very abundant species (i.e. species represented each by more than 5% of the total individuals) was relatively low in Wuasa. In addition, the portion of individuals included in the two most abundant species differed among villages. In Tamadue and Wuasa, homegardens were characterised by a high share of individuals belonging to only two most dominant species (cash crops cacao and arabica coffee or groundnut and spring onion, respectively).

Table 3.7. Total homegarden area sampled per village, total species and individual number, as well as selected community structure parameter of crop species cultivated in homegardens of five villages in the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Total garden area sampled (m^2)	7,009	6,186	7,395	12,138	19,244
Total species (no.)	117	124	105	98	99
Total individuals (no.)	8,196	4,171	3,086	5,328	4,612
Less abundant species[†] (%)	43.6	46.8	27.6	38.8	46.5
Very abundant species[‡] (%)	2.6	4.0	4.8	5.1	5.1
Individuals represented by the two most abundant species (%)[§]	38.0	24.2	19.1	28.1	41.6

[†] Species represented each by less than 0.1% of total individuals.
[‡] Species represented each by more than 5% of total individuals.
[§] Different according to village.

When varieties or landraces were included into the analysis as additional units, crop diversity in the 50 homegardens surveyed in 2003 was as high as 329 species and/or varieties/landraces. The highest varietal diversity was found in the use category 'fruit species', where more than 50% of the species were represented by more than only one variety/landrace (Figure 3.12, for detailed data see Appendix 12). Following the gardeners, banana and mango had the highest varietal diversity with 28 and 11 varieties/landraces, respectively (for bananas see Figure 3.11). However, sometimes the same variety/landrace might have been named differently by the gardeners due to their different ethnic background and native languages, thus, causing a certain double counting.

A high varietal diversity was also found in the use categories ‘stimulant species’ and ‘staple crops’, where 40 and 50% of the species were represented by more than one variety/landrace, respectively (Figure 3.12). Cacao with seven and cassava with four different varieties/landraces showed the highest varietal diversity in these two use categories. In the categories ‘vegetables’ and ‘spices’, about 25% and 15% of the species had more than one variety/landrace, respectively, with common eggplant (8) and chilli (10) having the highest numbers of varieties/landraces. In the categories ‘medicine’, ‘wood’, ‘MPT’, and ‘other’, no or only few species (two medicinal plants) were said to be represented by more than one variety/landrace (Figure 3.12).

Figure 3.11. Some of the banana varieties cultivated in homegardens of the Napu valley, Central Sulawesi. The scale of the photos is similar.

For some of the crop species, the spectrum of cultivated varieties differed substantially among villages. For example, only one of the 28 banana varieties/landraces was cultivated in all five villages. On the other hand, 2–4 different banana varieties/landraces were planted exclusively in every village, except Tamadue. Similarly, only two out of 11 mango and two out of seven cacao varieties/landraces were grown in all five villages. In the local villages (particularly in Wuasa), a higher varietal diversity of some crop species was found as compared to the migrant villages Siliwanga and Tamadue. In Wuasa and Rompo, 6–7 different varieties/ landraces of common eggplant were grown, whereas in the migrant villages only 1–2. For avocado, pummelo, and squash, three varieties/landraces were cultivated in the local, but only one in the migrant villages each. On the other hand, varietal diversity of durian, malay apple, and rambutan was higher in the migrant (particularly Tamadue) than in the local villages.

Names of the varieties/landraces as given by the gardeners mostly reflected the morphological appearance of a particular variety/landrace. Very often, the colours of seeds, fruits, or stems and leaves were used for naming, e.g. varieties/landraces ‘white’, ‘red’ and ‘green’ for yard long beans (following their seed colours). Shape or size of the fruits were commonly used also for naming, e.g. for banana varieties/landraces ‘horn’, ‘sickle’, ‘candle’, and ‘shoe’. Fruit taste was sometimes used as a variety name also, e.g. ‘sweet’ and ‘sour’, or variety/landrace ‘milk’ for both avocado and banana. Gardeners mentioned only 18 crop species with modern varieties, mostly fruit and cash crop species, e.g. durian, mandarin, coconut, pineapple, rambutan, jackfruit, cacao, spring onion, and tomato. Modern varieties were often named ‘hybrid’, ‘agriculture’, or after the region, where the variety was said to have originated, e.g. ‘Ambon’, ‘Bogor’, ‘Jember’, ‘the South’.

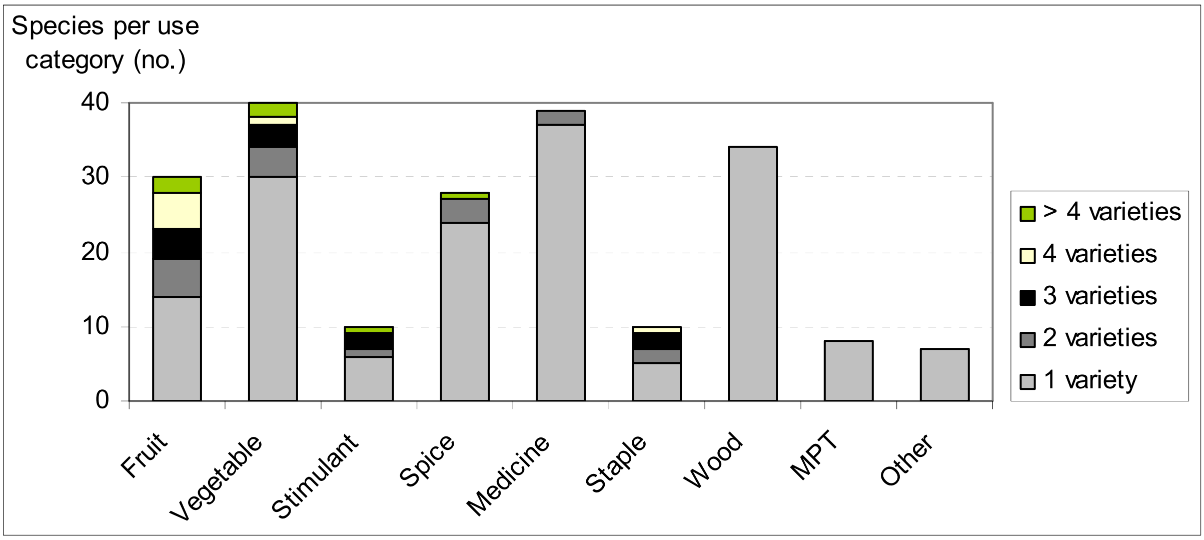

Figure 3.12. Number of varieties/landraces per crop species in different use categories. Results of inventories of 50 homegardens and of interviews of 50 gardeners in five villages of the Napu valley, Central Sulawesi, 2003.

The mean number of crop species per garden differed markedly among villages, although values varied strongly (13–68 species per garden). Homegardens in Wuasa harboured significantly more crop species than in Tamadue (Table 3.8), mainly due to differences in the mean number of vegetables, spices, and medicinal plants (Figure 3.13). In contrast, the number of fruit species, stimulants, staple food crops, and species for other uses did not differ among the villages.

Not only the mean number of crops per use category may characterise homegardens and differentiate villages, but also the number of cultivated individuals per species and frequency of occurrence per village. Calculation of the summed dominance ratio (SDR) that included both number of individuals and frequency of cultivation resulted in marked differences for some of the use categories among villages (Figure 3.14). Similarly to the mean number of fruit species (Figure 3.13), also SDR of fruit species did not differ among villages. In Rompo, the rather high mean number of vegetable species was reflected by a just as high SDR.

Although mean numbers of stimulant species were similar among villages, the SDR of stimulants was markedly higher in Tamadue than in the other villages. For Wuasa, the high importance of both spices and medicinal plants (Figure 3.13) was supported by the SDR. Staple crops were rather similar in mean species number among villages, but the SDR indicated their high dominance in Siliwanga. Higher mean numbers of wood species, but lower numbers of MPT species in the local villages Wuasa, Rompo, and Wanga as compared to Siliwanga and Tamadue were similarly reflected by the respective SDR values.

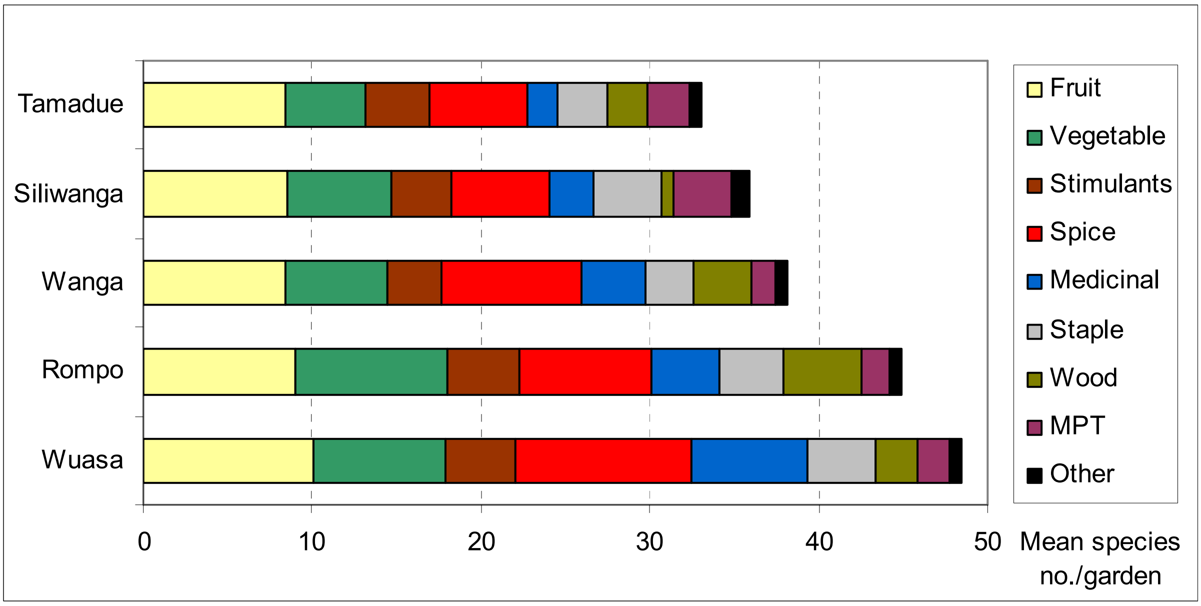

Figure 3.13. Mean number of crop species in different use categories of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

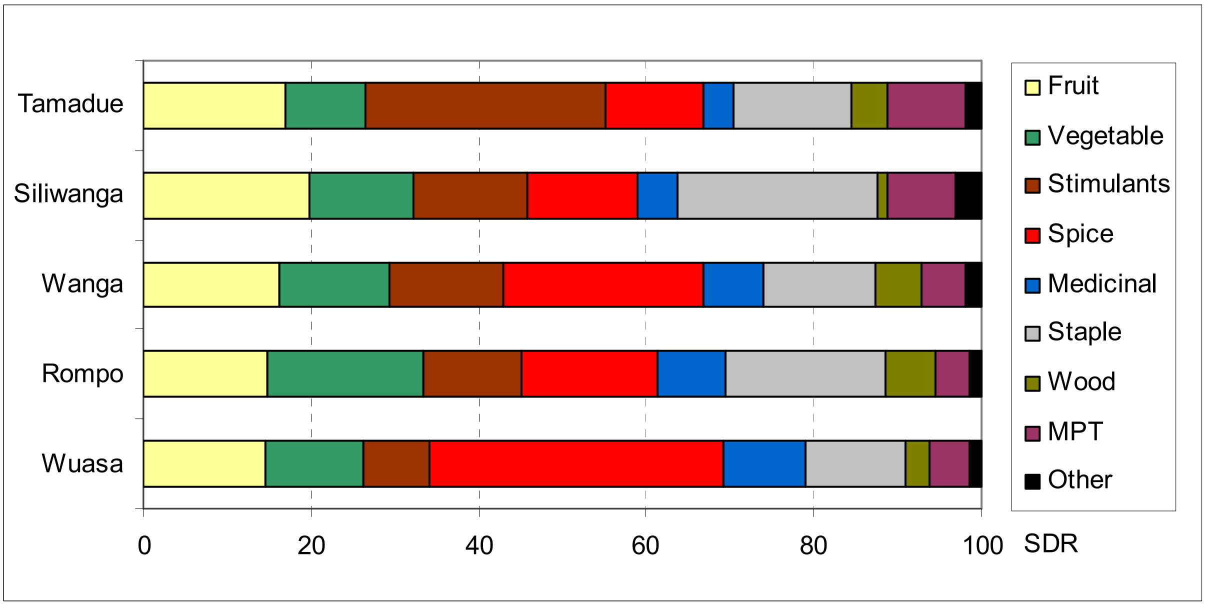

Figure 3.14. Summed dominance ratio (SDR) of crop species in different use categories of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

As homegarden size and density of crop individuals might influence the number of crop species per garden, Margalef index as well as crop species density per 1000 m^2 garden area were calculated additionally to compare the homegardens. However, Margalef index values followed the same pattern as crop species number (Table 3.8), being highest in Wuasa and lowest in Tamadue. To calculate species density, garden sizes (ln-transformed) were plotted against crop species numbers and a regression was calculated (see 2.9.2). When all homegardens studied were included in the calculation, there was no significant influence of homegarden size on crop species number ($R^2 = 0.028$). However, Figure 3.15 highlights marked differences between gardens managed by local or migrant gardeners. The latter harboured less crop species than those of locals. Concerning the homegardens with comparable sizes ('overlapping area' in Figure 3.15), these differences were even significant (T-test, $P \leq 0.001$). Crop species number was influenced by garden size only in homegardens managed by locals, but not in those managed by migrants. As a consequence, regression analysis was only carried out for homegardens managed by local gardeners, including almost all gardeners in the local villages Wuasa, Rompo, and Wanga (except garden no. 50) as well as two gardeners living in Siliwanga, but originating from Sulawesi (gardens no. 22 and 25). Thus, species density based on residuals of regression analysis could only be calculated for the villages Wuasa, Rompo, Wanga, and the two gardens of Siliwanga. However, means did not differ among the villages (Table 3.8).

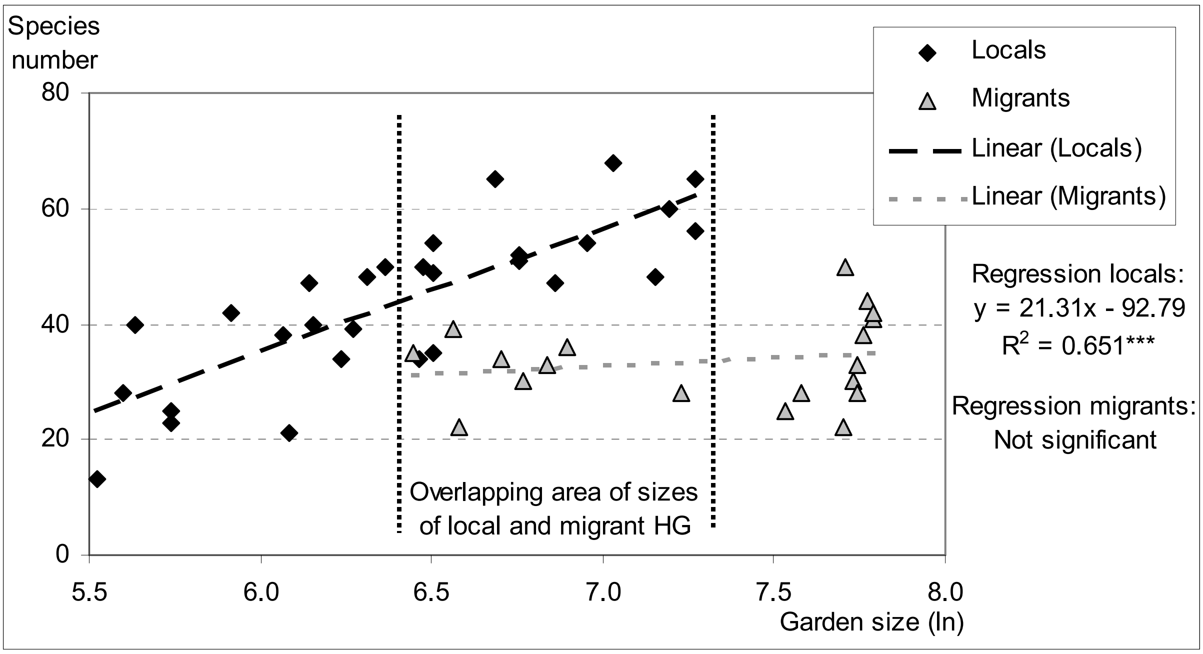

Figure 3.15. Relations between garden size and crop species number in homegardens managed by local (N=29) and migrant (N=19) gardeners studied in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8. Broken lines indicate trend lines, however, only the regression of the variable 'Locals' is significant. Between the dotted lines, homegardens used for comparison of mean species number in gardens of local and migrant gardeners were grouped together.

To evaluate all villages with homegardens managed by both local and migrant gardeners, species density was additionally calculated following the Arrhenius formula (see 2.9.2), results of which are presented in the following chapters, when species density is concerned. Again, no differences were found among the local villages. However, existing differences were confirmed regarding local and migrant villages, as already revealed concerning species number and Margalef index (Table 3.8).

Table 3.8. Mean crop species numbers per homegarden, mean Margalef index, and mean crop species density per 1000 m^2 calculated by regression residuals method (R)† and by the Arrhenius formula (A) (ranges in brackets) of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	Mean crop species number	Mean Margalef index	Mean crop species density/1000 m^2 (R)†	Mean crop species density/1000 m^2 (A)
Wuasa	48.5a (23–68)	7.5a (4.9–10.2)	59.3a (41.5–79.8)	51.4a (27.7–67.1)
Rompo	44.9ab (28–65)	7.1ab (4.9–9.8)	53.8a (41.2–68.8)	47.0ab (34.5–61.7)
Wanga	38.1ab (13–56)	6.5ab (2.8–9.0)	49.1a (28.4–64.0)	40.3abc (16.3–57.3)
Siliwanga	35.9a (22–44)	5.7ab (3.7–6.4)	54.4a (52.0–56.8)	36.2bc (19.7–44.9)
Tamadue	33.0 (22–50)	5.4b (4.1–7.1)	n.a.	30.4c (22.9–44.8)

Means in a column followed by different letters are significantly different at $P \leq 0.05$.

† Calculated only for homegardens managed by local gardeners, N = 10 in Wuasa, N = 8 in Rompo, N = 9 in Wanga, N = 2 in Siliwanga.

In summary, homegardens in Wuasa had very high crop species richness and density; they were dominated mainly by spice crops. In the remote village Rompo, homegardens harboured high species richness in a rather balanced mixture of different crop use categories. Mixed cultivation was found also in Wanga, where homegardens had intermediate species richness. Homegardeners in the migrant village Siliwanga focussed more on producing staple crops, their gardens harboured intermediate to low species richness. In Tamadue, where homegardens were dominated by stimulant crops, species richness and density were low.

Ornamentals

In addition to the 206 crop species, 162 ornamental species were cultivated in the homegardens studied in the 2004-survey. The most frequently grown ornamentals, cultivated in more than 50% of all homegardens, were african marigolds (*Tagetes* spp.), bougainvillea (*Bougainvillea* sp.), garden kroton (*Codiaeum variegatum*), caladium (*Caladium bicolor*), and chrysanthemum (*Dendranthema x grandiflorum*). In the local villages, gardeners frequently also cultivated zinnia (*Zinnia elegans*) and garden balsamine (*Impatiens balsamina*), whereas also allamanda (*Allamanda cathartica*), rose (*Rosa* sp.), and hibiscus (*Hibiscus rosa-sinensis*) were grown frequently in the migrant villages. Nearly 50% of the ornamental species were cultivated only very rarely, i.e. in less than 5% of the homegardens. Marked differences in diversity of ornamental plants existed among the villages. Both total and median numbers of ornamentals were quite high in Wuasa, but low in Rompo and Siliwanga (Table 3.9). Besides, also the number of common ornamental species (grown in at least 50% of the homegardens) was rather high in Wuasa as compared to the other villages.

Table 3.9. Diversity of ornamentals (total number per village, median number per garden, range per village, and number of frequently grown ornamentals per village) of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	Total number of ornamental species	Median species no. per garden	Range	No. of common ornamental species[†]
Wuasa	115	25.5a	11–60	20
Rompo	48	11.5b	1–19	6
Wanga	79	14.5ab	2–33	8
Siliwanga	61	12.0b	4–22	7
Tamadue	68	18.5ab	9–27	11

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.
† Species cultivated in more than 50% of the homegardens in the particular village.

Weeds

Besides 206 crop and 162 ornamental species, 57 weed species were found in the homegardens. The weed species belonged to 22 plant families, however, 19 of the species were grasses (for the complete list with scientific names and potential uses see Appendix 14). Despite their denomination as weeds, gardeners mentioned several potential uses for most of these species, e.g. 60% of them were said to have some medicinal value, 40% were used as fodder, and about 20% for handicraft. For only 15% of the weed species, no gardener mentioned any utility. However, knowledge about weeds and their uses differed markedly among villages. Both the number of named and used weed species were significantly higher in the local villages Wuasa, Rompo, and Wanga than in the migrant villages (Table 3.10), where many gardeners did not know a single weed name or any utilisation. Knowledge about weed names and their uses was positively correlated with the age of the interviewed gardener ($r = 0.5$ for names ($P < 0.001$); $r = 0.4$ for uses ($P = 0.006$)). Most of the gardeners who were able to name at least 20 different weed species, were about 60 years old.

Table 3.10. Knowledge of weed species and their use (median numbers of named and used weed species, given by the gardeners, ranges in brackets) of 49 gardeners interviewed in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 9.

	No. of named weed species		No. of used weed species	
Wuasa	15.0a	(6–27)	8.0a	(2–15)
Rompo	12.0a	(3–29)	6.0a	(3–27)
Wanga	9.0ab	(4–19)	5.5a	(2–14)
Siliwanga	2.5bc	(0–4)	2.0ab	(2–4)
Tamadue	2.0c	(0–3)	0.0b	(0–3)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

3.5.2 Vegetation structure

For vertical structure analysis, vegetation of homegardens was assigned to five strata. In the first stratum (< 1 m), mostly annual spices and vegetables or tuber crops such as spring onion, chilli, tomato, sweet potato, or taro were found. Species reaching the second layer (1–2 m) were both larger annual and perennial, bushy plants, e.g. tobacco, cotton, or cassava. In the third stratum (2–5 m), mostly woody perennials such as cacao, coffee, and mandarin, but also the non-woody banana and some climbers, e.g. chayote, passion fruit, and vanilla, occurred.

The fourth stratum (5–10 m) was reached only by larger trees such as guava, pummelo, durian, or pine. Only few plants, e.g. bamboo or coconut, grew higher than 10 m and formed the fifth layer (see Figure 3.16).

Figure 3.16. Example for a typical multi-layered vegetation structure in homegarden no. 10 in Wuasa, Napu valley, Central Sulawesi, 2004.

Figure 3.17 indicates marked differences of the vegetation structure among local and migrant homegardens. In homegardens of the local villages Wuasa, Rompo, and Wanga, crop species number decreased continuously from the lower to the higher strata. However, in the migrant villages (particularly in Tamadue), also most species occurred in the first stratum, but the second most important stratum was the third, dominated by the cash crops coffee and cacao and shade trees. Only small proportions of crop species were found in the fourth and fifth layers in all villages, particularly in Siliwanga.

Similar differences were revealed when analysing the proportions of crop individuals per stratum. In the local villages, the proportions of individuals decreased continuously from lower to higher strata (i.e. 55–70% of individuals occurred in the first, 20–32% in the second, and 9–13% in the third layer). Concerning the migrant villages, homegardens in Siliwanga followed the same pattern as the local homegardens, whereas in Tamadue, the highest proportion of individuals was found in the second layer (36%), followed by the third and the first layers (32 and 30%, respectively). Proportions of individuals in the fourth and fifth layers were rather small (i.e. 0.5–2.0 and 0–0.3%, respectively) in all villages, particularly in Siliwanga.

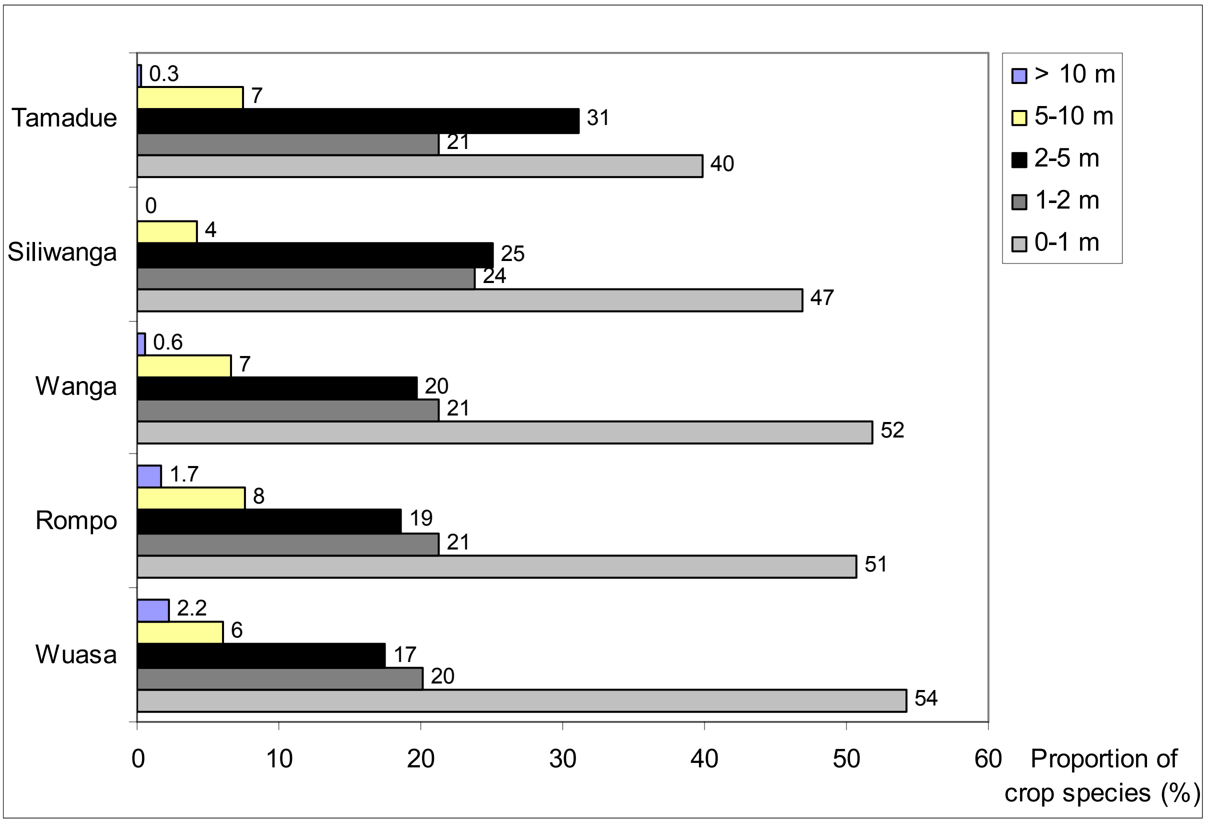

Figure 3.17. Mean proportion of crop species occurring in different strata of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

3.5.3 Crop diversity indices based on heterogeneity and equitability

Median crop species diversity and evenness showed high variation (Table 3.11, for detailed data see Appendix 16). Shannon diversity and evenness indices were high in the local, but low in the migrant villages, particularly in Tamadue with its cacao- and coffee-dominated homegardens. Simpson's index was fairly low in the local and slightly higher in the migrant villages, also indicating a higher diversity in the local villages (note: Simpson's index describes the probability that two individual plants picked from one plot belonged to the same species. This probability was only 8–9% in the local, but 12-18% in the migrant villages). The same tendency was shown by Hill's N_2. Diversity was high in the local villages with a number of about 12 very abundant species as compared to only about 6–8 in the migrant villages. Differences among all diversity indices (apart from Shannon evenness) were significant only between Rompo and the migrant village Tamadue.

Table 3.11. Median diversity and evenness indices (ranges in brackets) of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	Shannon index H'	Shannon evenness	Simpson's index λ	Hill's N_2
Wuasa	3.0ab (1.5–3.5)	0.78a (0.37–0.88)	0.09ab (0.04–0.50)	11.0ab (2.0–23.8)
Rompo	3.0a (2.4–3.3)	0.80a (0.67–0.87)	0.09b (0.05–0.17)	12.0a (6.0–18.9)
Wanga	3.1ab (1.5–3.3)	0.81a (0.46–0.88)	0.08ab (0.05–0.48)	12.9ab (2.1–18.9)
Siliwanga	2.6ab (2.3–3.0)	0.74a (0.66–0.86)	0.12ab (0.06–0.17)	8.2ab (5.7–15.4)
Tamadue	2.3b (2.1–2.9)	0.66a (0.58–0.83)	0.18a (0.08–0.23)	5.6b (4.3–12.0)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

3.5.4 Similarities and classification

For comparison among villages, Sørensen's coefficient and Renkonen index were calculated based on crop species occurance at village-level. For both indices, Table 3.12 indicates markedly higher similarity among the three local villages Wuasa, Rompo, and Wanga, (numbers in bold) than among these and the migrant villages, or between these latter two.

Table 3.12. Sørensen's coefficient and Renkonen index of crop species composition and abundance of 48 homegardens at village-level in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8. Comparisons among local villages are bolded.

	Sørensen's coefficient S_S				Renkonen index P_S			
	Wuasa	Rompo	Wanga	Siliwanga	Wuasa	Rompo	Wanga	Siliwanga
Rompo	**0.73**	–			**70.9**	–		
Wanga	**0.76**	**0.72**	–		**70.4**	**67.8**	–	
Siliwanga	0.61	0.58	0.62	–	59.4	58.8	61.6	–
Tamadue	0.61	0.60	0.63	0.64	59.0	60.3	58.8	61.5

In general, the same tendency was found in similarities of the different functional crop species groups. Similarities among local villages were higher than when comparing these and the migrant villages or between the two migrant villages, apart from the group 'sweets and stimulants', where highest similarity existed among the migrant villages. However, the values of similarity indices differed markedly among functional groups. 'Sweets and stimulants' as well as 'staple food crops' showed the highest values for similarity among villages (range S_S: 0.71–0.92 and 0.57–1.00; range P_S: 74.7–90.2% and 65.2–88.9%, respectively), due to small species numbers in these two functional groups and their high cultivation frequency. The use category 'fruits' also showed rather high similarity (range S_S: 0.73–0.88; P_S: 66.9–82.8%), followed by 'spices' (range S_S: 0.71–0.88; P_S: 58.4–81.4%). Lowest similarities among villages were found in the two groups 'medicinal plants' and 'fuel wood and timber plants' (range S_S: 0.33–0.64 and 0.13–0.59; P_S: 27.8–51.0% and 7.3–44.8%, respectively). In the groups of vegetables and plants for multi-purpose-use or other uses, similarities were intermediate.

Table 3.13 shows mean similarities of crop species composition and abundance, calculated on the basis of similarity indices of single homegardens. As compared to Table 3.12, mean similarities among the local villages were rather low. Among local and migrant villages, similarities were slightly lower than among local villages only. Within a village, mostly crop species composition of homegardens was more similar than among the villages. Particularly homegardens in the migrant villages Siliwanga and Tamadue shared many crop species. Homegardens in Tamadue, however, shared only few crops with homegardens of the other four villages.

Table 3.13. Mean similarity indices (based on data of single homegardens and calculated both within and among villages) of crop species composition and abundance of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8. Comparisons among local villages are bolded.

	Mean Sørensen's coefficient S_S					Mean Renkonen index P_S				
	Wuasa	Rompo	Wanga	Siliw.	Tamad.	Wuasa	Rompo	Wanga	Siliw.	Tamad.
Within	0.54	0.47	0.49	0.56	0.53	30.0	29.0	29.2	37.4	34.2
Rompo	**0.51**	–				**29.1**	–			
Wanga	**0.48**	**0.45**	–			**26.5**	**25.0**	–		
Siliwanga	0.48	0.45	0.50	–		24.5	28.3	28.5	–	
Tamadue	0.45	0.42	0.42	0.44	–	21.5	22.0	23.4	25.3	–

Note: Siliw. = Siliwanga; Tamad. = Tamadue.

Classification was carried out by hierarchical cluster analysis on the basis of transformed crop species abundance data of each single homegarden. The homegardens no. 1, 2, and 9 in Wuasa as well as no. 14 in Rompo were identified as outliers (see Appendix 17) and were excluded from further analysis. Three of these outliers, namely gardens no. 1, 2, and 14, belonged to the most species-rich gardens of the survey (i.e. 60–68 species per garden) and were characterised by special combinations of rare crop species (e.g. up to four 'endemic' species per garden). Homegarden no. 9 was predominated by the cash crop groundnut (70% of all individuals belonged to this species). Figure 3.18 presents the results of the cluster analysis of crop species abundance data in the remaining 44 homegardens. A final number of four clusters was chosen according to graphical detection by the 'elbow' criterion (see Appendix 18).

The first principal division into two large groups clearly separated homegardens into migrant and local gardens with only few exceptions (Figure 3.18). In the next major division, resulting in four clusters, the location in a village was partly reflected in cluster patterns. In cluster 1, almost exclusively homegardens were found of the village Tamadue and in cluster 2 of Siliwanga. In contrast, homegardens of clusters 3 and 4 were mainly located in the local villages Wuasa, Rompo, and Wanga. Results of the cluster analysis, thus, partly reflected those of the similarity analysis (Table 3.12 and Table 3.13). Both analyses showed a high degree of homogeneity of crop species composition of homegardens within each migrant village, resulting in clearly separated clusters 1 and 2. Among migrant and local villages, homegardens were more heterogeneous, only few migrant homegardens were included into clusters 3 or 4. On the other hand, the separation among the three local villages was rather poor. The relatively high similarity indices among these villages were reflected by the mixtures of homegardens from Wuasa, Rompo, and Wanga in clusters 3 and 4.

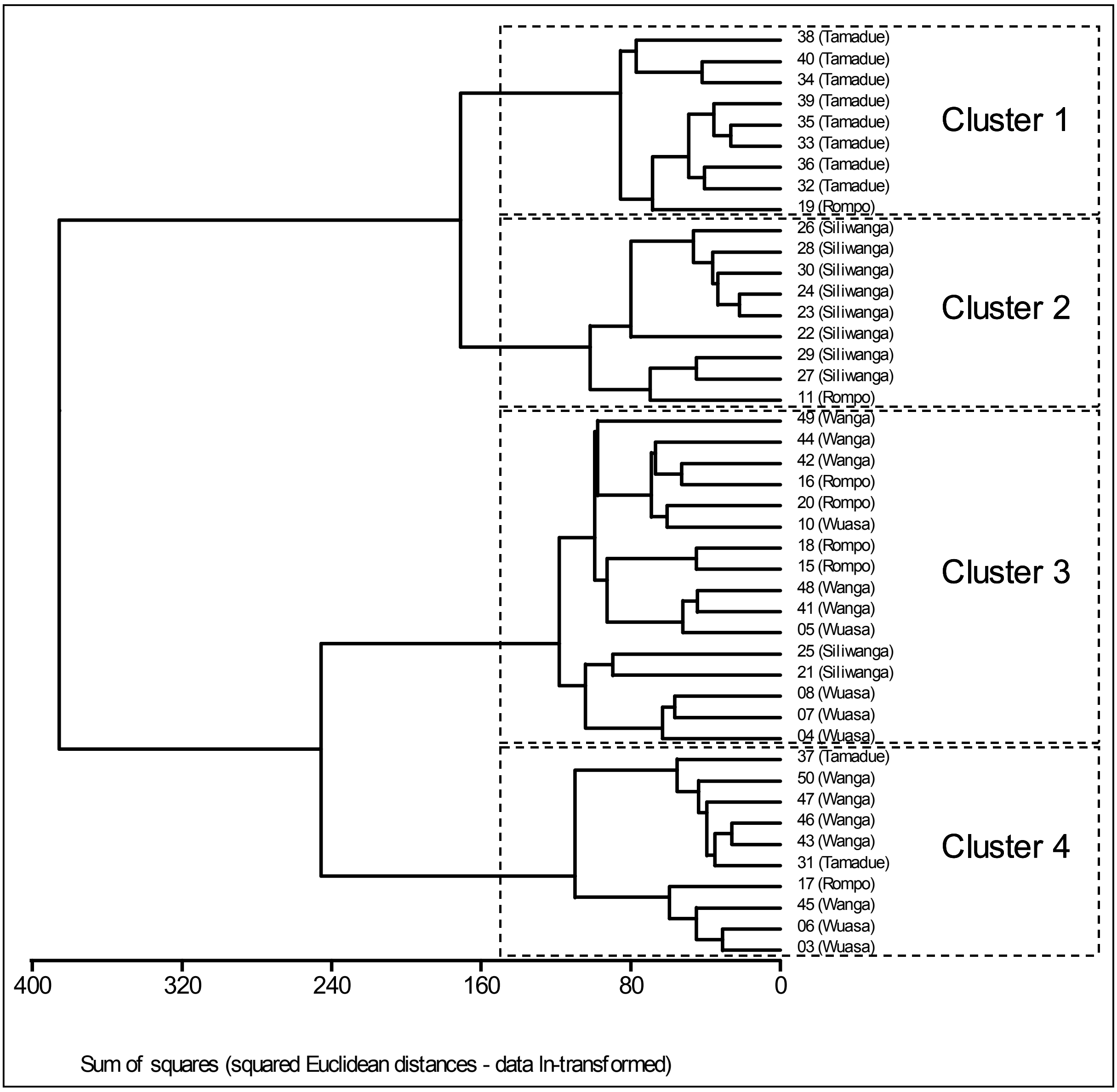

Figure 3.18. Dendrogram as result of hierarchical cluster analysis on the basis of ln-transformed crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004, using Ward's method and squared Euclidian distances. Homegardens no. 1, 2, 9, and 14 were identified as outliers before and were, therefore, excluded from this cluster analysis.

The four clusters identified were tested for significant differences by discriminant analysis that confirmed the correct classification of all 44 homegardens included in the final analysis (see Appendix 19 and Appendix 20). In addition, discriminant analysis revealed the 13 most important crop species responsible for the separation of clusters, i.e. spring onion, napier grass, coconut, tree cassava, cacao, soybean, pineapple, *Sauropus androgynus*, *Glochidion* sp., sweet potato, chilli, bitter gourd, and potato (given in order of inclusion by SPSS to stepwise analysis). Homegardens classified in cluster 1 were, thus, characterised by many individuals of coconut, cacao, and sweet potato, but few or no individuals of spring onion, chilli, and pineapple (Table 3.14). Consequently, also homegarden no. 19, located in Rompo, was grouped into this cluster. Differently from nearly all other local homegardens, no single spring onion, chilli, or pineapple plant was cultivated in garden no. 19. Cluster 2 grouped homegardens with many individuals of pineapple, sweet potato, and cacao, but very few spring onion plants. Besides, tree cassava was frequently grown in these gardens. Homegarden no. 11, located in Rompo, but grouped into cluster 2, was the only garden managed by locals having tree cassava plants. Homegardens in cluster 3 harboured many spring onions and chilli plants, but only few coconut palms. The two gardens located in Siliwanga, but included in cluster 3 (i.e. gardens no. 21 and 25), were the only ones in Siliwanga with spring onion. Besides, at least part of the household members managing these two gardens originated from Sulawesi. In cluster 4, homegardens with no or only few individuals of pineapple, coconut, cacao, and sweet potato were found. The homegardens no. 31 and 37 located in Tamadue, but included in cluster 4, were the only ones in the village Tamadue having no single coconut palm and only very few (1–4) cacao trees.

Table 3.14. Median number of individuals (ranges in brackets) of selected crop species per homegarden causing separation of clusters among 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004, selected by discriminant analysis (method: stepwise inclusion of variables).

	Cluster 1 N = 9	Cluster 2 N = 9	Cluster 3 N = 16	Cluster 4 N = 10
Spring onion	0b (0–7)	0b (0–1)	48a (0–195)	6ab (0–50)
Coconut	3a (1–16)	1b (0–4)	1ab (0–6)	0b (0–1)
Cacao	105a (11–227)	29a (4–135)	30ab (4–89)	2b (1–34)
Pineapple	0c –	14a (0–118)	4ab (0–24)	0bc (0–2)
Sweet potato	10a (0–142)	14a (6–90)	2ab (0–38)	0b (0–10)
Chilli	1b (0–5)	6a (2–39)	10a (1–33)	7ab (0–26)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

Clusters differed significantly not only in number of individuals of the 6 crop species shown in Table 3.14, but also in median numbers of species and individuals in the different use categories. Cluster 1 tied homegardens with only few vegetable species, but rather high numbers of fruit, stimulant, and staple food species (Table 3.15). In these gardens, stimulants were found in very high individual numbers, particularly cacao and arabica coffee (Figure 3.19). Homegardens of cluster 2 were characterised by low species and individual numbers of spices, but high to very high numbers of fruit as well as staple food crop species and individuals. In cluster 3, homegardens with many species and individuals of vegetables, spices, and medicinal plants were found. Homegardens of cluster 4 harboured only small numbers of species and individuals of fruits, vegetables, medicinal plants, and staple food crops. Additionally, the total number of individuals in homegardens belonging to cluster 4 was significantly lower than in the other clusters. Further differences among clusters existed comparing woody and herbal crop plants. In homegardens of cluster 3, significantly more herbal species and individuals were cultivated than in cluster 4 (median species number 24.0 and 10.5, median individual number 258 and 76, respectively). Woody crop plant species and individuals were found in significantly higher numbers in homegardens of cluster 1 as compared to cluster 4 (median species number 20.0 and 12.5, median individual number 392 and 53, respectively).

Table 3.15. Median number of crop species per use category (ranges in brackets) of clusters among 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004.

	Cluster 1 N = 9	Cluster 2 N = 9	Cluster 3 N = 16	Cluster 4 N = 10
Fruit	8ab (4–12)	9a (4–13)	10a (4–16)	5b (1–9)
Vegetable	5b (3–6)	6ab (3–10)	8a (5–10)	5b (1–9)
Stimulant	4a (2–5)	4a (2–5)	4a (2–6)	3a (1–5)
Spice	6ab (3–9)	5b (2–9)	10a (3–15)	6ab (1–10)
Medicinal	3ab (0–4)	3ab (1–5)	5a (0–13)	2b (0–6)
Staple food	4a (2–5)	4a (3–5)	4a (2–5)	2b (0–4)
Wood	2a (0–14)	1a (0–15)	2a (0–7)	1a (0–5)
MPT	3ab (2–4)	4a (2–5)	2b (1–2)	2b (1–3)
Other	1a (0–2)	1a (0–2)	1a (0–2)	1a (0–1)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at P≤0.05.

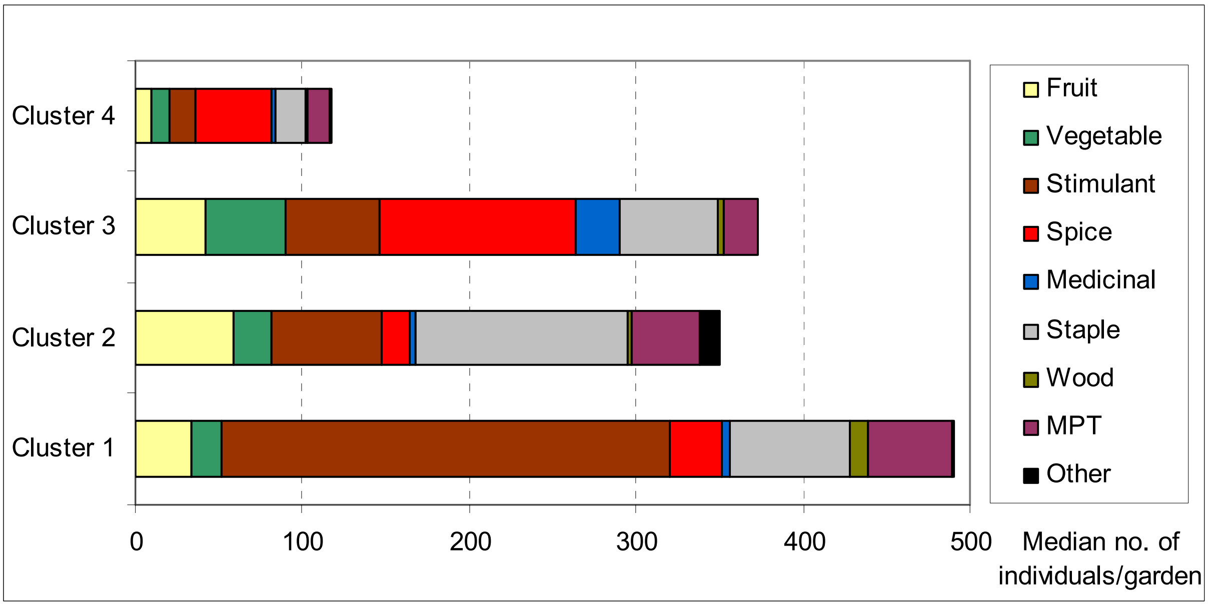

Figure 3.19. Median number of crop individuals in different use categories per cluster based on crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. Cluster 1, N = 9; Cluster 2, N = 9; Cluster 3, N = 16; Cluster 4, N = 10.

Not only crop species composition, but also vegetation structure showed marked differences among clusters (Figure 3.20). The highest proportions of crop species were found in the first stratum (i.e. 0–1 m height) in homegardens of all four clusters. In homegardens of clusters 1 and 2, the second largest proportion of species occurred in the third stratum (i.e. 2–5 m height), followed by the second stratum (i.e. 1–2 m height). In contrast, proportions of crop species decreased continuously from the first to the fifth strata in homegardens of clusters 3 and 4. The upper stratum of trees taller than 10 m was absent in homegardens of cluster 4.

Proportions of crop individuals per stratum also differed among clusters. Homegardens of cluster 1 with their clear dominance of coffee and cacao trees harboured nearly 33% of all crop individuals in each of the first, second, and third strata. In contrast to cluster 1, proportions of crop species in homegardens of clusters 2, 3, and 4 decreased continuously from the first to the fifth strata. Homegardens grouped in clusters 3 and 4 were additionally characterised by a very high share of individuals in the first stratum (i.e. 62% and 63%, respectively), confirming the importance of mostly annual vegetables and spices in these gardens (Figure 3.19). However, in homegardens of cluster 4 no individual plant reached the fifth stratum, in those of cluster 2 only very few did so.

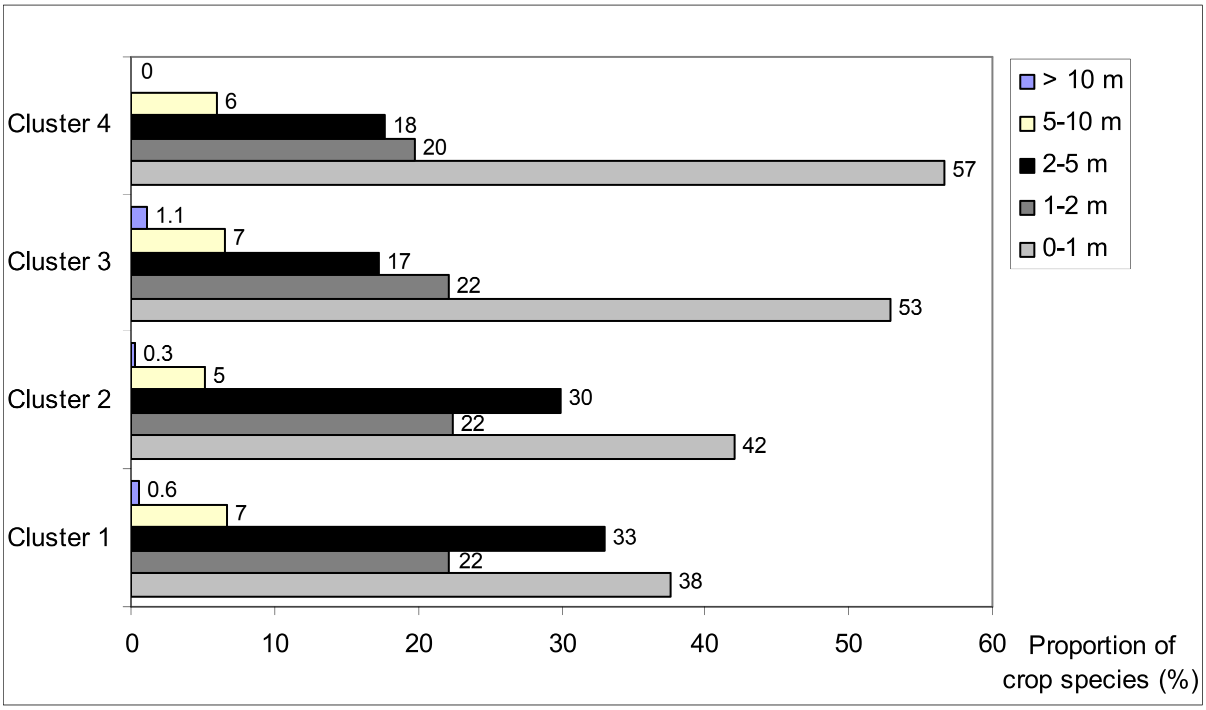

Figure 3.20. Mean proportion of crop species occurring in different strata per cluster based on crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. Cluster 1, N = 9; Cluster 2, N = 9; Cluster 3, N = 16; Cluster 4, N = 10.

Besides numbers of species and individuals per use category as well as vegetation structure, also crop species richness, density, and diversity indices differed significantly among clusters (Table 3.16). For clusters 1 and 2, these characteristics mainly followed the same patterns as for the villages Tamadue and Siliwanga, respectively (i.e. being comparably low or intermediate), already described in 3.5.1 (Table 3.8), and 3.5.3 (Table 3.11). Homegardens of cluster 3 stand for significantly highest diversity parameter. Cluster 4 tied homegardens with very low species number, Margalef index, and species density as well as low to intermediate diversity indices.

Table 3.16. Mean crop species richness, density (dens.) per 1000m^2, and diversity (ranges in brackets) per cluster based on crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
	N = 9		N = 9		N = 16		N = 10	
Richness	36.3ab	(25–50)	38.4ab	(22–65)	45.7a	(34–56)	26.6b	(13–40)
Margalef index	5.8ab	(4.1–7.8)	6.1ab	(3.7–9.8)	7.7a	(5.3–9.0)	5.0b	(2.8–7.4)
Dens./1000 m^2	33.6b	(22.9–47.3)	37.7b	(19.7–61.7)	48.3a	(36.3–57.3)	30.0b	(16.3–49.0)
Shannon H'	2.4b	(2.1–3.0)	2.7ab	(2.3–3.0)	3.0a	(2.4–3.5)	2.4b	(1.5–3.2)
H' evenness	0.68b	(0.58–0.83)	0.75ab	(0.68–0.86)	0.79a	(0.66–0.88)	0.75ab	(0.46–0.88)
Simpson λ	0.17a	(0.07–0.23)	0.12ab	(0.06–0.17)	0.09b	(0.04–0.17)	0.17ab	(0.06–0.48)

Means in a row followed by different letters are significantly different at $P \leq 0.05$.

Although the cluster analysis was performed only on the basis of crop species abundance, marked differences of some other garden characteristics among clusters were also found (Table 3.17). Median sizes of homegardens in cluster 1 were rather large as opposed to clusters 3 and 4. Cluster 2 grouped homegardens with a high proportion of the garden to the whole farm area cultivated. At the same time, homegardens of cluster 2 harboured a high number of staple food crops (Figure 3.19). Families not owning large fields apart from the homegarden seemed to rely a lot on obtaining their daily food from their homegardens. Additionally, owners of the homegardens in cluster 2 were rated rather poor (lowest poverty index) as compared to the other families of the sample (Table 3.17). Cultivation of homegardens grouped in cluster 1 was largely cash-oriented (being correct also for garden no. 19), indicated by the high share of cash crop individuals (i.e. cacao, arabica coffee, vanilla, and mandarin). Homegardens of cluster 1 were mostly managed by male gardeners, whereas those of the other three cluster by female gardeners.

Table 3.17. Median garden size and its proportion of the whole cultivated farm area, share of cash crop individuals, share of female gardeners, and median poverty index per cluster performed on crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004 (ranges in brackets).

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
	N = 9		N = 9		N = 16		N = 10	
Garden size (m^2)	2280a	(930–2450)	1000ab	(470–2420)	645b	(370–1400)	370bc	(250–1900)
Prop. garden/farm cultivated (%)	6ab	(2–13)	12a	(2–30)	4ab	(2–11)	3b	(0.2–12)
Share of cash crop individuals (%)	49a	(10–69)	22ab	(10–33)	15ab	(5–41)	7b	(1–63)
Share of female gardeners (%)	13		67		69		60	
Poverty index	-0.11a	(-1.0–2.9)	-1.0b	(-1.4–-0.5)	-0.5ab	(-1.4–2.3)	0.4a	(-1.1–1.4)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

When analysing chemical and physical soil parameters, additional differences among clusters were revealed. For clusters 1 and 2, soil characteristics mainly followed the same patterns as for the villages Tamadue and Siliwanga, respectively (i.e. low available P contents; in Tamadue high, but in Siliwanga low $\text{CEC}_{\text{eff.}}$ and base saturation), as described in more detail in 3.6 (Table 3.21 and Table 3.23). Soil of the homegarden no. 11, which was located in Rompo, but grouped in cluster 2, had very similar characteristics like many gardens of the village Siliwanga (i.e. low pH value, available P content, and base saturation, see Appendix 21). In cluster 3, homegardens with slightly acid soils of rather low C and available P contents as well as low CEC$_{eff.}$, were tied together. However, the base saturation of these homegardens was rather high. Soils of homegardens in cluster 4 resemble those of cluster 3, but in cluster 4, soils were less acid than in cluster 3. Besides pH value, also the other soil parameters were rather high in homegardens of cluster 4.

Table 3.18. Medians of selected physical and chemical soil parameters (ranges in brackets) per cluster performed on crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004.

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
	N = 9		N = 9		N = 16		N = 10	
Clay content (%)	32.0a	(27–45)	20.0b	(15–47)	18.5b	(5–26)	22.5ab	(14–38)
pH (CaCl$_2$)	5.4ab	(4.9–5.8)	4.6c	(4.0–5.2)	5.0bc	(4.3–5.5)	5.6a	(5.0–6.2)
C content (%)	3.9a	(3.2–5.1)	2.8b	(1.6–4.7)	2.1b	(1.1–4.8)	2.8b	(1.6–4.5)
P-Bray (ppm)	44.0c	(26–75)	52.0bc	(29–188)	194.0ab	(45–338)	278.0a	(52–440)
CEC$_{eff.}$ (me/100 g)	29.9a	(18.0–37.9)	5.0c	(4.0–9.5)	9.8bc	(4.7–17.7)	16.1ab	(9.9–25.4)
Base saturation (%)	98.3a	(95.6–99.3)	85.9b	(39.8–96.4)	97.9ab	(58.4–99.5)	99.8a	(97.5–100)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

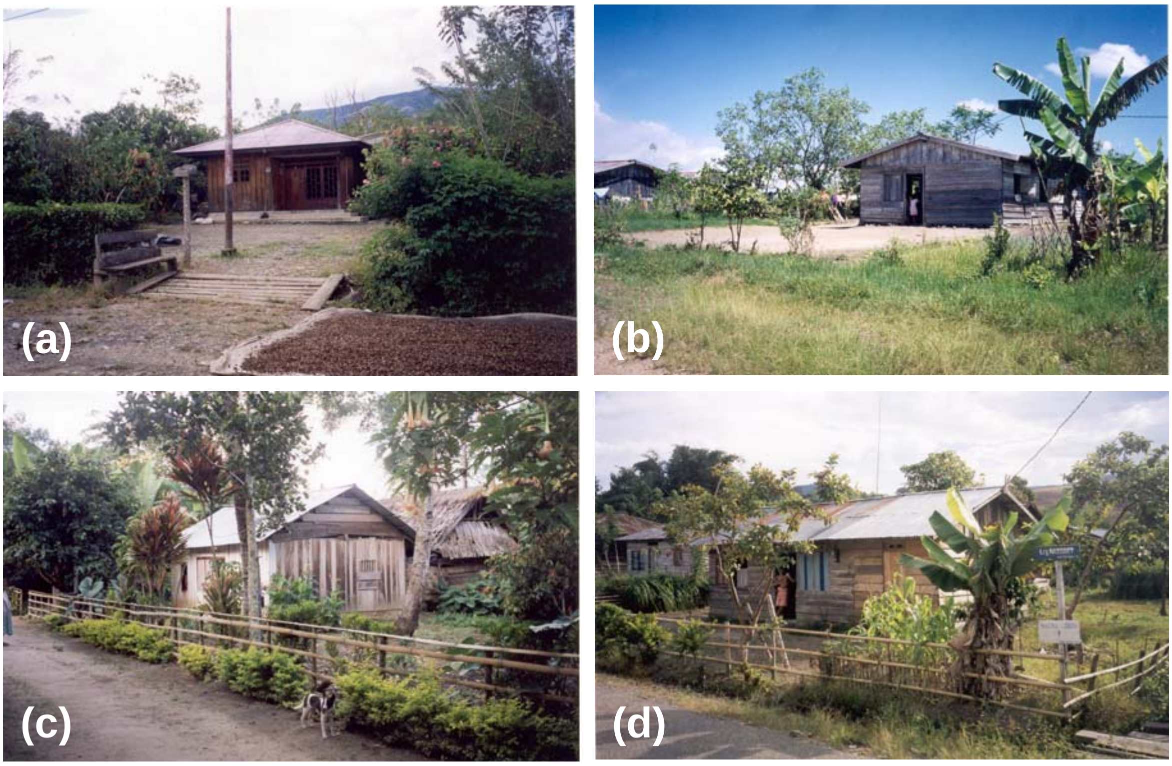

Figure 3.21. Examples of homegardens in the Napu valley, Central Sulawesi, grouped in different clusters. (a) A large cash crop homegarden of cluster 1 in the migrant village Tamadue; (b) A homegarden of cluster 2 in the migrant village Siliwanga with a poorly developed vegetation structure; (c) A species-rich homegarden of cluster 3, located in Rompo; (d) A small, species-poor homegarden of cluster 4 in Wanga.

In summary, in cluster 1 very large cash crop gardens with a rather low diversity and owned mostly by migrants were found (Figure 3.21). Soils of these homegardens were fertile, but of low available P content. Homegardens of cluster 2 were of intermediate size and diversity. They were mostly managed by poor migrant families that cultivated many staple food crops, but nearly no tall trees. Soil quality in homegardens of cluster 2 was very poor. In cluster 3, homegardens of medium size that harbour a very high diversity, particularly of spices, vegetables, and medicinal plants were grouped together. Soils of these homegardens were rather fertile, but of low pH and $CEC_{eff.}$. Cluster 4 tied small homegardens with rather low diversity, few woody plants and no trees taller than 10 m, but with the most fertile soils.

In addition to the cluster analysis, Principal Component Analysis (PCA) of species abundance data was carried out to further differentiate homegardens based on their crop species composition. Axis 1 explains about 15% of the total variability (Table 3.19) and is positively correlated with spring onion, yard-long bean, and *Heliconia indica*. Axis 2, explaining about 13% of the total variability, is positively correlated with spring onion, but negatively with cacao, arabica and robusta coffee, banana, pineapple, cassava, cocoyam, and sweet potato. Four of these species (spring onion, cacao, pineapple, and sweet potato) were also detected as being important for the cluster analysis (see Table 3.14).

Table 3.19. Summary table and variable loadings for the first two axes of the 11 most important crops (variable loadings > 0.2 for at least one of the axes) as a result of Principal Component Analysis, based on abundance data of 206 crop species cultivated in 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8. Species abundance data ln- transformed and centred before analysis.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	12.49	10.62	5.85	4.28
Percentage	14.97	12.73	7.01	5.13
Cumulative Percentage	14.97	27.70	34.71	39.83
Variable loadings:				
Spring onion	0.432	0.266		
Yard-long bean	0.244	0.042		
Heliconia indica	0.215	-0.031		
Cassava	0.134	-0.388		
Cacao	-0.002	-0.301		
Banana	0.117	-0.263		
Cocoyam	0.097	-0.261		
Sweet potato	0.065	-0.254		
Pineapple	0.167	-0.232		
Arabica coffee	-0.176	-0.219		
Robusta coffee	0.076	-0.217		

PCA confirmed parts of the cluster analysis, although the four homegarden types were not clearly separated. Homegardens of cluster 4 appear in the upper left part of Figure 3.22. In the upper right part of the figure, mostly homegardens tied in cluster 3 were found that were characterised (as in the cluster analysis) by large numbers of spring onions. In the lower left part of Figure 3.22, a mixture of homegardens belonging to the clusters 1 and 2 appear. These gardens were characterised by many individuals of arabica coffee (negative loadings of axis 1, Table 3.19). The four homegardens excluded as outliers from cluster analysis (i.e. gardens no. 1, 2, 9, and 14) were also clearly separated by PCA.

When applying PCA, migrant homegardens (marked by the dotted line) were not as distinct from local gardens as revealed by cluster analysis (Figure 3.22). Interestingly, species composition of the three local gardens (no. 5, 19, and 22), which interfere with the migrant garden group, was similar to the migrant gardens (dominance of cash crops like cacao and coffee). In contrast to cluster analysis, PCA revealed that garden no. 5 (cluster 3) also resembled gardens of clusters 1 or 2. On the other hand, the local garden no. 22, but also no. 11 (both cluster 2), showed a certain proximity to gardens of cluster 3.

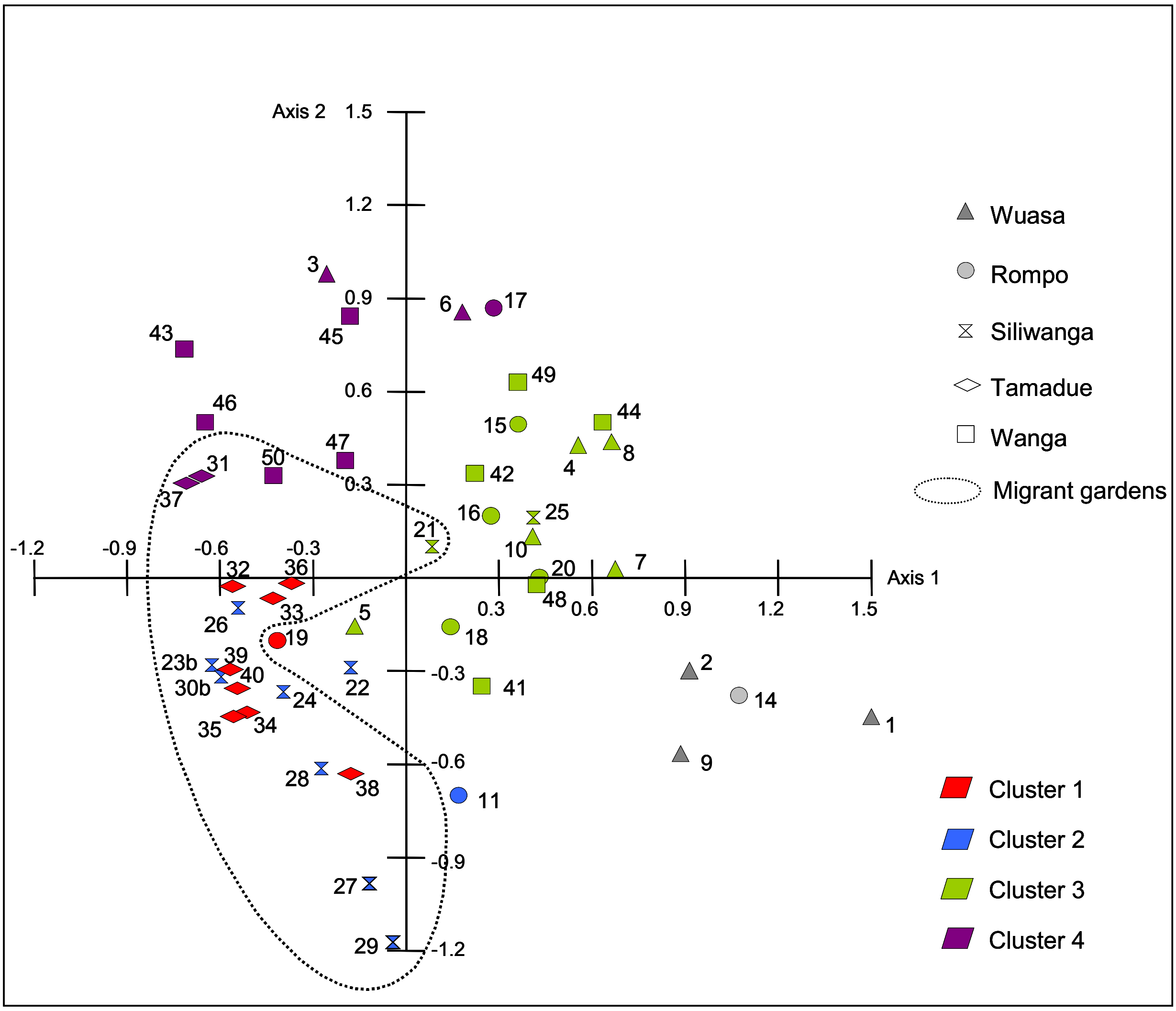

Figure 3.22. Result of Principal Component Analysis (cases scores of axis 1 and 2), based on ln-transformed and centred abundance data of 206 crop species cultivated in 48 homegardens of five villages in the Napu valley, Central Sulawesi, 2004.

3.6 Soil characteristics

Soil physical and chemical characteristics were highly variable, both among homegardens in the same villages and among different production zones of single homegardens (see Appendix 21 and Appendix 22). However, soil quality parameters showed different patterns in the five villages studied, suggesting different soil types. At first, these differences among villages are presented in detail below. Secondly, differences among production zones and possible reasons causing them are emphasised.

3.6.1 Texture and bulk density

Median sand content was highest in Wuasa and lowest in Tamadue, whereas medians of silt and clay contents were lowest in Wuasa and highest in Tamadue (Table 3.20). Consequently, most of the homegarden soils in Wuasa were classified as loamy or clay sand, only 20% as sandy loam. In Rompo, 70% of the soils were loam, in Wanga 100%. Soil was rather heterogeneous in Siliwanga, were 50% of the samples were grouped as loamy or clay sand, 40% as sandy loam, and 10% as loamy clay. In Tamadue, 80% of the soils were classified as loam (mostly silt loam or silty clay loam) and 20% as silty clay. Bulk density was rather low and did not differ among the villages, apart from Tamadue, where it was significantly lower than in Wuasa, Rompo, and Siliwanga (Table 3.20).

Table 3.20. Medians of physical top soil properties (ranges in brackets) in 50 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village.

	Sand content (%)		Silt content (%)		Clay content (%)		Bulk density (g/cm^3)	
Wuasa	67a	(48–86)	14b	(8–35)	16b	(5–24)	1.0a	(0.8–1.2)
Rompo	47ab	(31–71)	28ab	(14–47)	23ab	(10–32)	0.9a	(0.7–1.3)
Wanga	44b	(33–55)	33ab	(26–41)	23ab	(19–30)	0.9ab	(0.7–1.1)
Siliwanga	51ab	(22–67)	32ab	(10–41)	19b	(12–47)	1.0a	(0.6–1.1)
Tamadue	11b	(9–51)	46a	(24–58)	34a	(22–45)	0.6b	(0.5–1.0)

Medians are given because variables were not normally distributed.

Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Note: As medians are given, sums of sand, silt, and clay contents are not equal to 100.

3.6.2 pH value and available P content

Medians of pH values measured in water were similar in all five villages (Table 3.21). However, in all villages single gardens suffered from soil with a pH value under 5.5 that was rated as ‘acid’ (see 2.6.4). Such low pH values occurred in 40% of the homegardens in Siliwanga, 30% in Wuasa and Rompo, but only 20% in Wanga and Tamadue. When production zones were analysed separately, even 50% of the homegardens in Wuasa, Rompo, and Siliwanga suffered at least in one zone from acid soil, in Wanga 40%, and in Tamadue only 20%. Median pH values measured in $CaCl_2$ differed among villages, being high in Tamadue, but low in Siliwanga.

Table 3.21. Medians of pH values and available P contents of top soil (ranges in brackets) in 50 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village.

	pH (H_2O)		pH ($CaCl_2$)		P-Olsen (ppm)		P-Bray (ppm)	
Wuasa	5.7a	(5.3–6.8)	5.2ab	(4.8–6.2)	56a	(24–118)	262a	(73–440)
Rompo	5.7a	(5.0–6.3)	5.1ab	(4.5–6.1)	39ab	(11–106)	117ab	(30–247)
Wanga	5.6a	(5.4–6.2)	5.1ab	(4.9–5.8)	11bc	(1–19)	237a	(45–393)
Siliwanga	5.6a	(4.6–5.8)	4.7b	(4.0–5.2)	11abc	(5–34)	65ab	(29–188)
Tamadue	5.8a	(5.2–6.1)	5.3a	(4.9–5.8)	2c	(1–3)	47b	(26–65)

Medians are given because variables were not normally distributed.

Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Median P-Olsen contents were high in Wuasa, but very low in Tamadue (Table 3.21). In the latter village, all soils were rated as very low (see 2.6.4). Even in the villages Wanga and Siliwanga, some homegarden soils had only low to very low P-Olsen contents, whereas in Wuasa and Rompo, all soils were rated as medium or high. Concerning P-Bray contents, medians were highest in Wuasa and Wanga, intermediate in Rompo and Siliwanga, and lowest in Tamadue (Table 3.21). Similarly to pH values, single gardens in all five villages had rather low P-Bray contents. However, P-Bray contents were rated as ‘high’ in all homegardens and even in all production zones apart from one fallow zone in Rompo, where available P content was rated as ‘medium’ only (see 2.6.4). P-Bray content was correlated slightly positively to pH (H_2O) value ($r = 0.382$; $P = 0.006$).

3.6.3 N and C contents

As N and C contents were highly correlated ($r = 0.976$, $P < 0.001$), both values showed the same patterns among villages. Soil in Tamadue had the highest median N and C contents, that in Wuasa and Rompo the lowest (Table 3.22). In Wuasa, N content of soil was rated as ‘low’ in all homegardens, C content as ‘very low’ in 80% of them. In homegardens of Rompo, both N and C contents were mostly rated as ‘low’, although soil of single gardens had ‘very low’ N (30% of the gardens) and C (50%) contents. In Wanga and Siliwanga, homegarden soil was mostly rated as ‘medium’ concerning N content and as ‘low’ concerning C content. Soil of homegardens in Tamadue had ‘medium’ N and C contents. C/N ratios were highest in Siliwanga and lowest in Tamadue.

Table 3.22. Medians of N and C contents as well as C/N ratios of top soil (ranges in brackets) in 50 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village.

	N content (%)		C content (%)		C/N ratio	
Wuasa	0.13b	(0.11–0.19)	1.7b	(1.3–2.7)	12.3ab	(10.7–15.0)
Rompo	0.17b	(0.07–0.26)	2.2b	(0.9–3.2)	12.8ab	(11.1–13.6)
Wanga	0.22ab	(0.14–0.38)	2.8ab	(1.8–4.8)	12.2ab	(11.7–14.0)
Siliwanga	0.21ab	(0.13–0.34)	2.9ab	(2.0–4.7)	14.2a	(11.6–15.6)
Tamadue	0.34a	(0.20–0.46)	4.0a	(2.8–5.1)	11.9b	(11.0–13.6)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

3.6.4 Cation exchange capacity and base saturation

Median effective cation exchange capacity (CEC $_{\text{eff.}}$) of homegarden soils was highest in Tamadue and lowest in Siliwanga (Table 3.23). It could be rated as ‘very low’ in Siliwanga, ‘low’ in Wuasa and Rompo, ‘medium’ in Wanga, and ‘high’ in Tamadue. These differences in CEC $_{\text{eff.}}$ were mainly caused by differences in amounts of exchangeable Ca and Mg (not shown in Table 3.23). In Tamadue, amounts of both Ca and Mg were high (median for Ca = 19.0 cmol/kg, for Mg = 7.4 cmol/kg), whereas in Siliwanga they were low (median for Ca = 2.6 cmol/kg, for Mg = 1.3 cmol/kg). However, amounts of exchangeable K showed a quite different pattern: They were lowest in Tamadue and highest in Wuasa (Table 3.23). Consequently, soils in Tamadue, Siliwanga, and Rompo were rated as ‘low’ concerning the amount of exchangeable K, that in Wanga and Wuasa as ‘medium’.

Table 3.23. Medians of effective cation exchange capacity (CEC), exchangeable K and Al, as well as base saturation of top soil (ranges in brackets) in 50 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village.

	CEC $_{eff.}$ (cmol/kg)		Exchangeable K (cmol/kg)		Exchangeable Al (cmol/kg)		Base saturation (%)	
Wuasa	9.8bc	(5.7–15.8)	0.54a	(0.43–0.95)	0.02b	(0.00–0.26)	97.2a	(92.4–99.8)
Rompo	11.2bc	(5.5–19.5)	0.38abc	(0.16–0.84)	0.01ab	(0.00–0.82)	97.8ab	(85.9–99.8)
Wanga	15.9ab	(12.6–17.7)	0.51ab	(0.20–0.78)	0.02b	(0.00–0.06)	99.2a	(96.1–100)
Siliwanga	4.9c	(4.0–8.2)	0.24bc	(0.11–0.45)	0.39a	(0.15–1.88)	85.6b	(39.8–96.4)
Tamadue	28.3a	(17.8–37.9)	0.17c	(0.09–0.34)	0.00b	(0.00–0.06)	98.2a	(95.6–99.3)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Median amounts of exchangeable Al were low in all villages apart from Siliwanga (Table 3.23). However, total amounts did not exceed the critical absolute value of about 2–3 cmol/kg. However, in two homegardens in Siliwanga the portion of Al from CEC $_{eff.}$ went above the critical portion of 30% (see 2.6.4). Base saturation of soils was more than 97% in Wuasa, Rompo, Wanga, and Tamadue, where it was rated as ‘very high’. Only in Siliwanga, base saturation was slightly lower, but still rated as ‘very high’ in 80% of the homegardens surveyed.

3.6.5 Differences of physico-chemical soil characteristics among production zones

All soil characteristics studied showed high variability among the different production zones within a single homegarden. As vegetable and cacao/coffee production zones were the most frequent, only these zones were compared here. Out of the 50 homegardens studied, 17 had both vegetable and cacao/coffee production zones. Seven of them were located in Wuasa, four in Rompo, four in Wanga, and two in Siliwanga. Patterns of differences in several soil quality parameters among zones were identified according to the fertilising habits of the gardeners. Only few cacao/coffee zones were fertilised occasionally (29%), but more than 50% of the vegetable zones were fertilised regularly, mostly with ash. Therefore, homegardens formed two groups: in one group, vegetable zones were regularly fertilised (N = 9), in the other group, no fertiliser was used for vegetables (N = 8). For the parameters pH value, available P content, CEC, exchangeable Ca and K contents, and base saturation, differences among production zones were analysed separately in these two subgroups. For water content, bulk density and N and C contents, no differences between subgroups were found, hence, only differences between production zones were compared.

Table 3.24. Median water content, bulk density, and N and C contents of top soil in vegetable and cacao/coffee zones (ranges in brackets) of 17 homegardens in four villages of the Napu valley, Central Sulawesi, 2004.

Soil parameter	Vegetable zone		Cacao/coffee zone	
Water content w/w (%)	25.00b	(16–43)	33.00a	(24–66)
Bulk density (g/cm^3)	0.99a	(0.79–1.37)	0.97b	(0.71–1.08)
N content (%)	0.18b	(0.06–0.30)	0.20a	(0.10–0.27)
C content (%)	2.00b	(0.90–4.30)	2.60a	(1.40–3.40)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$ (Wilcoxon test).

In all 17 homegardens studied, soil water content (w/w) was significantly higher in the cacao/coffee zones than in the vegetable zones (Table 3.24). Bulk density was lower in most of the cacao/coffee zones as compared to vegetable zones. In most of the homegardens, N and C contents were higher in cacao/coffee than in vegetable zones.

If vegetable zones were not fertilised with ash, pH values in vegetable and cacao/coffee zones were similar (Table 3.25). In fertilised vegetable zones, pH values were significantly higher than in the adjacent cacao/coffee zones. Available P contents were much lower in vegetable zones than in cacao/coffee zones, if vegetables zones were not fertilised, but higher, if they were fertilised. The same pattern was found by analysing relative available P content in soil of vegetable zones by defining available P content in the adjacent cacao/coffee zone as 100%. In a median, soil of unfertilised vegetable zones contained only 38% of the available P in cacao/coffee zones, whereas that of fertilised vegetable zones as much as 139%.

Table 3.25. Medians (ranges in brackets) of pH value, available P content, effective cation exchange capacity (CEC), exchangeable (exch.) Ca and K, and base saturation of top soil in fertilised (N = 9) and unfertilised (N = 8) vegetable zones as compared to adjacent cacao/coffee zones of the same 17 homegardens in four villages of the Napu valley, Central Sulawesi, 2004.

	Vegetable zone fertilised	Vegetable zone	Cacao/coffee zone
pH (H_2O)	No	5.5a (4.7–6.3)	5.7a (5.2–5.8)
	Yes	6.2a (5.3–6.9)	5.7b (5.2–5.8)
P-Bray (ppm)	No	97b (24–343)	253a (109–512)
	Yes	240a (66–463)	164b (57–395)
CEC $_{eff.}$ (cmol/kg)	No	8.0b (3.9–14.2)	11.7a (9.0–16.5)
	Yes	12.1a (7.5–25.1)	12.4a (4.5–19.4)
Exch. Ca (cmol/kg)	No	6.4b (1.3–11.0)	8.6a (5.8–12.2)
	Yes	8.8a (5.8–19.9)	8.9a (2.4–14.1)
Exch. K (cmol/kg)	No	0.3b (0.1–0.6)	0.6a (0.4–1.0)
	Yes	0.4a (0.3–0.9)	0.5a (0.2–0.8)
Base saturation (%)	No	97.0a (49.9–100.0)	98.7a (96.8–99.6)
	Yes	99.7a (96.8–100.0)	97.7a (81.7–99.9)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$ (Wilcoxon test).

Effective cation exchange capacity (CEC) as well as exchangeable Ca and K were significantly lower in unfertilised vegetable zones than in the adjacent cacao/coffee zones (Table 3.25). However, fertilised vegetable zones had similar values as cacao/coffee zones. Fertilising vegetable zones with ash did not cause significant differences between zones in absolute values of base saturation, but in relative values. Unfertilised vegetable zones had only 98.5% of the base saturation of the adjacent cacao/coffee zone, whereas fertilised vegetable zones had 102%. In summary, fertilising had raised pH value and available P content in soil of vegetable zones as compared to adjacent, mostly unfertilised cacao/coffee zones. Reduction of effective cation exchange capacity as well as exchangeable Ca and K in vegetable zones was prevented by fertilising. As the most used fertiliser in vegetable zones was ash, no positive effects on N and C contents of the soil were detected.

3.6.6 Suitability of the soil in cacao/coffee zones for production of cacao

Cacao and/or coffee were produced in particular planting zones or in the main part of the garden in 38 from 50 homegardens studied. Due to the growing importance of cacao production for cash income generation, soil quality of these zones is rated in more detail in the following, according to the minimum requirements given in 2.6.4. As patterns of soil quality in cacao/coffee zones mostly were quite similar to the differences in overall soil quality among villages already presented in 3.6.2, 3.6.3, and 3.6.4, detailed data concerning the medians of cacao/coffee zones per village were given only in Appendix 23.

In all villages, pH value of most soils from cacao production zones were slightly too low for high production levels of cacao (Table 3.26). Available P contents were rated as ‘sufficient’ in all cacao zones concerning P-Bray. However, P-Olsen soil contents were considered as ‘too low’ in Tamadue and in one garden in Wanga. Concerning N contents, soils of cacao zones in homegardens of Wuasa, Rompo, and Siliwanga were mostly rated as ‘too low’. In Wanga and Tamadue, most or all soils had sufficient N levels, respectively. About 50% of garden soils used for cacao production in Wuasa and Rompo did not contain sufficient C, whereas in the other three villages no soil was rated as ‘too low’ in C. C/N ratios did all meet the minimum requirements for cacao production. Concerning exchangeable K in cacao soils, a severe shortage was detected only in Tamadue, but also in Siliwanga, some soils did not contain sufficient K. Amounts of Ca as well as CEC $_{\text{eff.}}$ were rated as ‘too low’ in all cacao soils of Siliwanga and some to many of them, respectively, in Wuasa and Rompo. Base saturation was sufficient in all cacao zones of the homegardens studied.

Table 3.26. Portion of soils (%) fulfilling the minimum requirements for successful cacao production concerning different soil parameters in cacao production zones of 38 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 8 in Wuasa; N = 7 each in Rompo, Wanga, and Siliwanga; N = 9 in Tamadue.

Soil parameter	Wuasa	Rompo	Wanga	Siliwanga	Tamadue
Sand ≥ 50%	75	43	14	57	0
pH (H_2O) ≥ 6.0	0	0	14	0	33
P-Olsen ≥ 5 ppm	100	100	86	100	0
P-Bray ≥ 7 ppm	100	100	100	100	100
N ≥ 0.22%	0	29	71	29	100
C ≥ 0.20%	50	57	100	100	100
C/N ratio ≥ 9	100	100	100	100	100
K ≥ 0.24 cmol/kg	100	86	86	57	22
Ca ≥ 8 cmol/kg	50	57	100	0	100
CEC $_{\text{eff.}}$ ≥ 12 cmol/kg	38	29	100	0	100
Base saturation ≥ 35%	100	100	100	100	100

In summary, soil of homegardens in Wanga was more suitable for cacao production as compared to the other villages. Only few garden soils in Wanga had too low levels of N, P-Olsen, or K. In Tamadue, soils were generally suitable for cacao production, apart from too low P-Olsen and K levels. In addition, the quite low sand contents of soils (Table 3.26, mostly below 15%) might have caused problems with aeration of the soil. In Wuasa and Rompo, cacao trees might suffer mainly from N deficiencies, but also levels of Ca, Mg, and K were partly too low. The worst situation for cacao production was detected in Siliwanga, where most of the soils did not have sufficient amounts of N, Ca, Mg, and K, but too high levels of

Al (data not shown). Besides, cacao production in Siliwanga suffered from imperfect drainage caused by high and fluctuating water tables, as indicated by orange-coloured iron-oxide concretions in about 20 cm depth, giving the soil a mottled appearance (Figure 3.23).

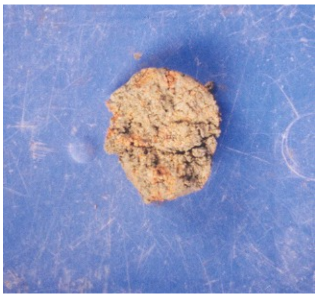

Figure 3.23. Soil sample with orange-coloured iron-oxide concretions, taken from about 20 cm depth in a homegarden of the migrant village Siliwanga, Napu valley, Central Sulawesi.

3.7 Cacao leaf analysis

Median dry matter contents varied between 36–41%, being highest in Wuasa, Siliwanga, and Tamadue and lowest in Rompo (Table 3.27). N and C contents of cacao leaves did not differ among villages (Table 3.27). Concerning N contents, 80% of the analysed cacao leaf samples could be rated as severely deficient (see 2.7.3).

Table 3.27. Median dry weight, water content, as well as N and C contents of cacao leaves sampled in 40 homegardens of five villages of the Napu valley, Central Sulawesi, 2004. N = 9 each in Wuasa and Tamadue; N = 8 each in Rompo and Siliwanga; N = 6 in Wanga.

	Dry matter content (% of fresh weight)		N content (%)		C content (%)	
Wuasa	41.2a	(36.1–43.0)	1.6a	(1.4–1.9)	45.5a	(41.9–50.1)
Rompo	36.1b	(34.2–39.2)	1.7a	(1.5–1.9)	45.5a	(42.5–48.9)
Wanga	39.0ab	(37.4–42.3)	1.6a	(1.3–1.8)	47.0a	(43.6–49.9)
Siliwanga	41.2a	(35.6–47.7)	1.5a	(1.4–2.0)	47.1a	(42.2–51.0)
Tamadue	40.4a	(39.0–44.4)	1.6a	(1.3–2.4)	45.6a	(42.4–48.9)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Median P and Mg contents of cacao leaves did not differ among villages (Table 3.28). In Siliwanga, cacao leaves had markedly higher K contents than those in Tamadue, but lower Ca contents than those of Wuasa and Wanga. Median Fe contents did not differ among villages (data not shown, see Appendix 25). Although P contents of leaf samples were never rated as severely deficient, 50% of the samples did not reach the 'normal' P level (see 2.7.3). Concerning K contents, no sample reached the 'normal' K level, and nearly 70% were rated as severely deficient. K deficiency differed in the villages surveyed: in Wanga and Siliwanga, only less than 50% of the samples were rated as severely deficient, in Wuasa and Rompo about 60% and in Tamadue 100%. However, Ca contents of all samples exceeded the 'normal' level. This applied also for Mg contents of most of the samples. Only about 13% of the leaf samples did not reach the 'normal' level of Mg. Concerning Fe contents, 55% of the samples were rated as deficient, nearly 40% as severely deficient.

Table 3.28. Median P, K, Ca, and Mg contents of cacao leaves sampled in 40 homegardens of five villages of the Napu valley, Central Sulawesi, 2004. N = 9 each in Wuasa and Tamadue; N = 8 each in Rompo and Siliwanga; N = 6 in Wanga.

	P content (%)	K content (%)	Ca content (%)	Mg content (%)
Wuasa	0.20a (0.15–0.25)	1.04ab (0.69–1.42)	1.66a (1.07–2.06)	0.58a (0.46–0.76)
Rompo	0.20a (0.17–0.24)	1.08ab (0.67–1.34)	1.48ab (0.92–1.89)	0.54a (0.45–0.74)
Wanga	0.18a (0.15–0.34)	1.21ab (0.61–1.68)	1.72a (1.20–2.34)	0.59a (0.43–0.79)
Siliwanga	0.22a (0.13–0.28)	1.29a (0.77–1.83)	1.08b (0.78–1.71)	0.59a (0.44–0.86)
Tamadue	0.22a (0.17–0.27)	0.75b (0.42–1.18)	1.42ab (1.04–1.80)	0.63a (0.41–0.81)

Medians are given because variables were not normally distributed.
Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Nutrient contents in cacao leaves and in the corresponding soils correlated only for some nutrients. K contents in the leaves were related strongly and positively to K contents ($r = 0.57$; $P < 0.001$) and P-Bray contents ($r = 0.57$; $P < 0.001$) of the soil, but negatively to soil Mg contents ($r = -0.34$; $P = 0.039$). Mg contents of the leaves were not influenced by soil Mg contents, but were related negatively to soil P-Bray ($r = -0.43$; $P = 0.008$) and K contents ($r = -0.48$; $P = 0.003$). N, P, Fe, and Ca contents of cacao leaves were not influenced by any soil parameter studied.

3.8 Case studies

3.8.1 Management details

In the three homegardens studied in detail for a time period of 15 days each, the most frequent management activities carried out were sweeping and harvesting. Both activities were done almost daily, mostly by the wives, and lasted about 25 min. every day on average (Figure 3.24). However, the migrant garden was swept only once in this period. In this garden, nearly every day some fodder for cattle and pig was cut and chopped. For the migrant family, cutting fodder was the most time-consuming activity, lasting more than one hour per day. Hoeing was a rather frequent task in all homegardens, carried out 2–3 times per week. Wives spent about 10–20 min. per day on hoeing, sometimes supported by their husbands or sons (Figure 3.24). Pruning cacao and fencing the garden were rather seasonal activities, carried out mostly by the household heads.

Overall daily time investment in homegardening was 13 min./100 m^2 on average in the small spice garden and about 5 min./100 m^2 in the large fruit tree and the very large migrant garden each. Wives conducted 54–74% of the total homegarden work, household heads 12–46%. Children helped only in the migrant garden, contributing 27% of the work. Instead, the already adult children of the two local families were engaged in cultivating paddy rice fields or doing cooperative and wage labour (Figure 3.25). Regarding the agricultural work activities of the whole family, homegardening accounted for only about 7% of the local families' time, but 15% of the migrant family's time. The family managing the spice garden was mostly engaged in paddy rice cultivation (62% of total time) and tending its plantation (30%). For the family owning the fruit garden, paddy rice cultivation was only a minor task in the time period documented, accounting for only about 13% of the total active time. Instead, this family spent about 33% of its time in the plantation and for cooperative work, each. The migrant family was mainly engaged in paddy rice cultivation that consumed 68% of the working time. Besides, cattle husbandry and cooperative work accounted for 8–10% of the family's total working time.

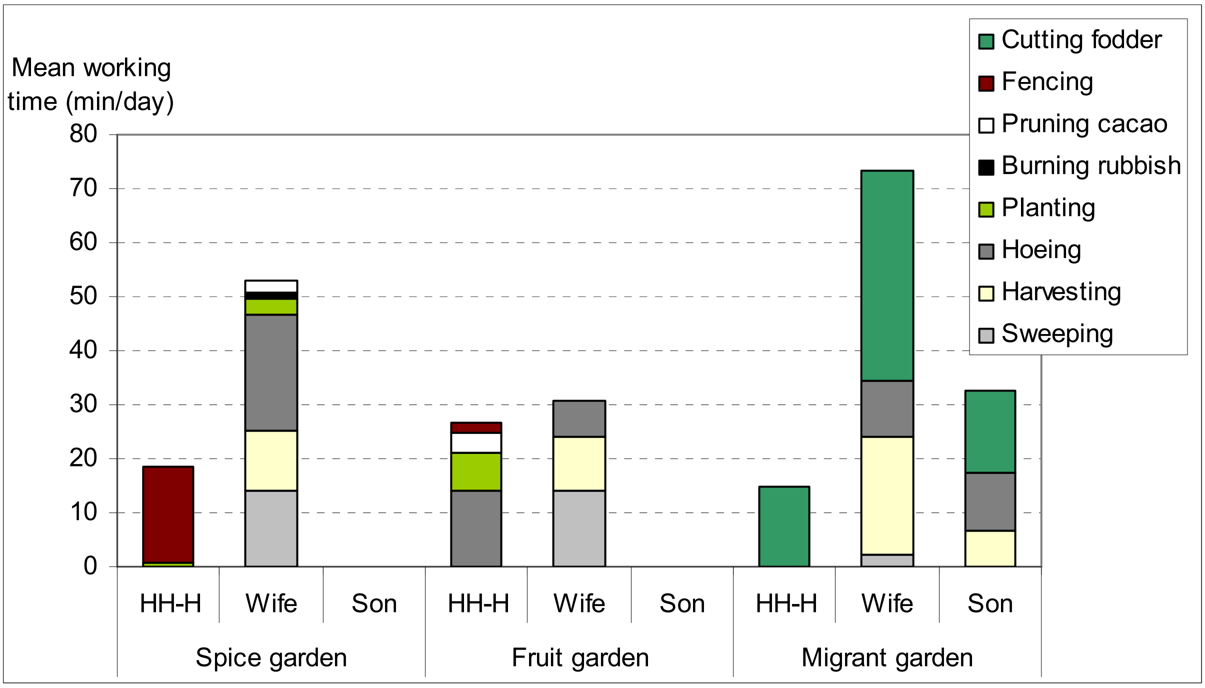

Figure 3.24. Mean daily time and work allocation among family members in homegarden management studied during 15 days in three different homegarden types in the Napu valley, Central Sulawesi, in 2004 (HH-H = Household head). Homegarden sizes: Spice garden = 580 m^2; Fruit garden = 1050 m^2; migrant garden = 2420 m^2.

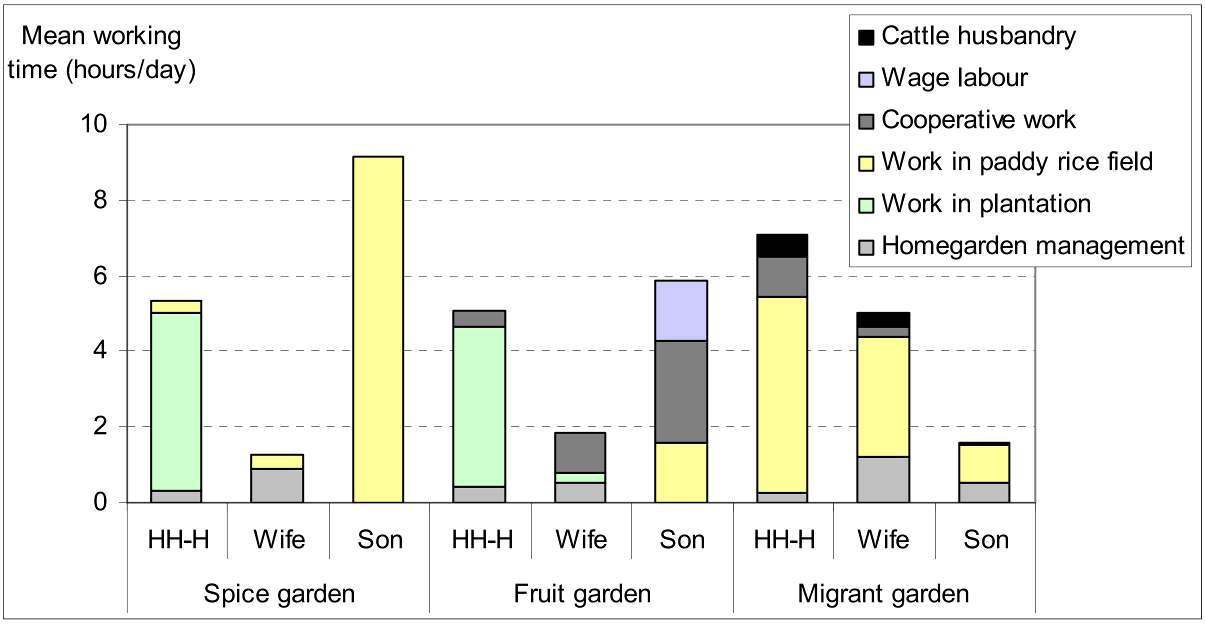

Figure 3.25. Mean daily time allocation to different farm operations among family members studied during 15 days in three different homegarden types in the Napu valley, Central Sulawesi, in 2004 (HH-H = Household head).

In the spice and fruit gardens, the most frequently harvested crops were different spices such as spring onion or lemon grass. Spices were harvested by the local families every day in rather small amounts, i.e. one mixed portion per day with a monetary value of about 500 IR (10,000 IR ≈ 1 Euro in March 2004) (Figure 3.26). The migrant family only harvested 7 portions of spices in the same time period. Vegetables such as cassava or *Vigna* leaves were harvested 3–5 times during the 15 days studied only in the spice and migrant gardens. The value of the harvested vegetables also was about 500 IR per portion. In all three families interviewed, 50% (fruit garden) to 76% (migrant garden) of the value of vegetables, spices, and fruits consumed in the 15 days surveyed was covered by products from their homegardens, the remainder was obtained from their plantations, by gifts, or, in the case of the migrants, from the shop. For the family managing the spice garden, cash income derived from sales of cacao cultivated in their homegardens was the only cash income source during the observed time period, whereas for the family managing the fruit garden, it accounted for only 28% of the total income. Cacao was harvested 6 times in the spice garden (4.5 kg dry seeds) and 2 times in the fruit garden (2 kg dry seeds) during the study period, fetching a price of 8,700 IR/kg.

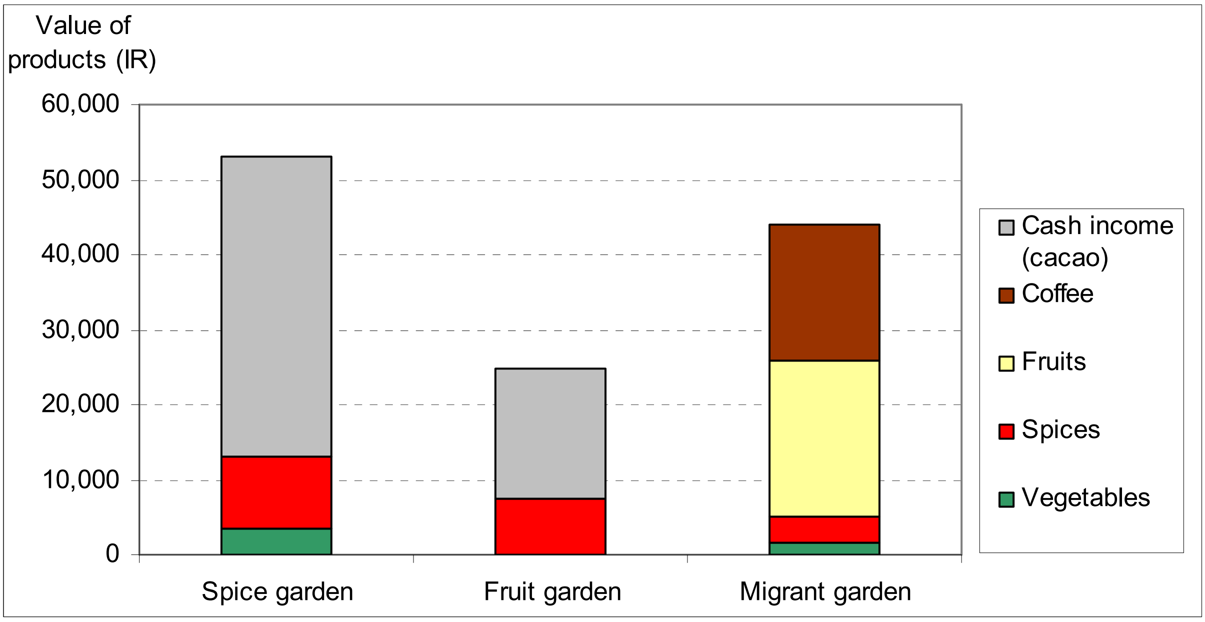

Figure 3.26. Monetary value of homegarden products harvested for sale and for home consumption during 15 days in three different homegarden types in the Napu valley, Central Sulawesi, in 2004. 10,000 IR ≈ 1 Euro (March 2004).

The migrant family did not gain any cash income from their homegarden (Figure 3.26). They harvested 4.5 kg dry coffee seeds with a value of 4,000 IR/kg, but only for their own consumption. The most important products from the migrant garden were fruits and fodder, harvested nearly every day. As fodder was not sold at markets in the region, no monetary value could be assessed. For all the fruits harvested, mainly mandarins and guavas, a total value of 21,000 IR was calculated. The two local families did not harvest any fruits during the 15 days studied because they mainly cultivated seasonal fruit species in their homegardens, e.g. mango and avocado. In the migrant garden, banana leaves for wrapping were harvested once, and flowers as well as fragrant screw pine leaves for sacrifices several times. The staple crop rice was obtained from own paddy rice fields in sufficient amount by all three families. Therefore, no staple crops were harvested in the homegardens during the observation period. Besides, neither medicinal plants nor fuel wood or timber were harvested in the same time.

In summary, homegarden management was a rather small part of the overall activities in the three families studied. Homegardens were worked in only 1–2 hours per day, mainly by women who spent much time on harvesting and hoeing. Men were rather engaged in cultivating plantations or paddy rice fields. The main function of homegardens was different among the families studied. The spice and fruit gardens, managed by local families, served both for subsistence and income generation, whereas all products of the migrant garden were consumed by the family.

3.8.2 Map and tree canopy cover

A detailed map of garden no. 8 (spice garden, Wuasa) is given in Appendix 26. Canopy cover of tree species and bananas higher than 2 m was calculated as 21.3% of the cultivated garden area for the stratum 2–5 m, 3.5% for the stratum 5–10 m, and 4.1% for the stratum > 10 m.

3.8.3 Soil quality and erosion

Soil quality varied largely among the three homegarden case studies as well as among different production zones of the same garden (Table 3.29, Table 3.30, and Table 3.31). In general, soil quality was higher in the spice and the fruit gardens than in the migrant garden. Particularly available P content was rather low in the migrant homegarden. The spice garden was never fertilised according to the gardener. Soil quality was markedly lower in the vegetable zone of this garden than in the cacao zone (Table 3.29). Large differences between production zones were present particularly in available P and exchangeable Al contents. Low nutrient contents in the vegetable zone might be related to the habit of daily sweeping there. On the other hand, litter was collected in garbage pits in the back yard, e.g. under the cacao trees, and occasionally burned, causing probably the higher soil nutrient contents in the cacao zone.

Table 3.29. Median chemical and physical soil quality parameters (ranges in brackets) in the vegetable and cacao production zones of homegarden no. 8, belonging to the type 'small spice garden' and located in Wuasa, Napu valley, Central Sulawesi. Significantly higher values are given in bold.

Spice garden	Vegetable zone (N = 5)		Cacao zone (N = 5)	
pH (H_2O)	5.8a	(5.2–6.0)	6.1a	(5.6–6.2)
N (%)	0.10b	(0.04–0.13)	**0.13a**	(0.11–0.17)
P-Bray (ppm)	18.8b	(17.9–36.3)	**171.5a**	(88.4–250.5)
Exchangeable Al (cmol/kg)	**0.35a**	(0.25–0.58)	0.10b	(0.09–0.16)
Exchangeable Ca (cmol/kg)	5.83b	(3.52–6.57)	**8.18a**	(7.45–8.55)
Exchangeable K (cmol/kg)	0.18b	(0.16–0.20)	**0.44a**	(0.25–0.57)
$CEC_{eff.}$ (cmol/kg)	7.95b	(4.76–8.32)	**11.88a**	(10.73–12.18)
Base saturation (%)	91.9b	(88.6–94.5)	**97.4a**	(95.3–97.7)
Sand (%)	61.2a	(52.2–81.5)	52.1a	(46.6–54.1)
Clay (%)	19.9a	(10.4–22.9)	18.6a	(18.6–22.8)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at $P \leq 0.05$.

The fruit tree garden was occasionally fertilised with ash in the vegetable zone and with farm yard manure in the cacao zone, according to the gardener. In this garden, soil quality did not differ very much among the production zones (Table 3.30). However, pH value and base saturation were significantly higher, but N and exchangeable Al contents lower in the vegetable than in the cacao zone. All other chemical soil properties showed slightly higher values in the vegetable than in the cacao zone. Occasional fertilising of the rather small vegetable zone with ash might have caused its higher soil quality.

Table 3.30. Median chemical and physical soil quality parameters (ranges in brackets) in the vegetable and cacao production zones of homegarden no. 10, belonging to the type 'large fruit tree garden' and located in Wuasa, Napu valley, Central Sulawesi. Significantly higher values are given in bold.

Fruit garden	Vegetable zone (N = 4)		Cacao zone (N = 5)	
pH (H_2O)	**7.1a**	(7.1–7.2)	5.7b	(5.5–5.9)
N (%)	0.12b	(0.06–0.12)	**0.14a**	(0.13–0.19)
P-Bray (ppm)	435.8a	(419.9–733.8)	328.8a	(174.0–470.8)
Exchangeable Al (cmol/kg)	0.09b	(0.089–0.092)	**0.14a**	(0.12–0.31)
Exchangeable Ca (cmol/kg)	9.30a	(5.18–14.82)	5.68a	(5.31–7.72)
Exchangeable K (cmol/kg)	0.85a	(0.52–1.00)	0.57a	(0.33–0.63)
CEC $_{eff.}$ (cmol/kg)	12.32a	(7.09–17.22)	8.33a	(7.78–11.25)
Base saturation (%)	**99.1a**	(98.7–99.3)	96.7b	(93.1–97.1)
Sand (%)	79.6a	(76.4–88.9)	66.2a	(60.6–78.5)
Clay (%)	11.2a	(6.8–12.0)	11.0a	(7.7–17.3)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at P≤0.05.

In the large migrant garden, the gardeners regularly fertilised nearly exclusively the cacao production zone near the house with ash and farm yard manure. This has probably caused the markedly higher values of most of the soil quality parameters in the cacao than in the cassava zone (Table 3.31). High patchiness of soil quality in the cacao zone, e.g. in available P content, might be related to raising pigs in a small part of this zone in the past. The soil in the back yard garden, covered mainly by weeds and used only extensively for cassava and fodder production, was characterised by rather poor soil quality.

Table 3.31. Median chemical and physical soil quality parameters (ranges in brackets) in the vegetable and cacao production zones of homegarden no. 29, belonging to the type 'very large migrant garden' and located in the migrant village Siliwanga, Napu valley, Central Sulawesi. Significantly higher values are given in bold.

Migrant garden	Cassava zone (N = 5)		Cacao zone (N = 5)	
pH (H_2O)	5.9b	(5.3–6.0)	**6.2a**	(6.0–7.0)
N (%)	0.20a	(0.15–0.23)	0.20a	(0.19–0.23)
P-Bray (ppm)	25.8a	(11.3–30.2)	38.6a	(23.4–313.2)
Exchangeable Al (cmol/kg)	**0.20a**	(0.14–1.50)	0.12b	(0.10–0.14)
Exchangeable Ca (cmol/kg)	3.72b	(1.66–4.86)	**6.30a**	(4.92–9.44)
Exchangeable K (cmol/kg)	0.15b	(0.08–0.20)	**0.61a**	(0.28–1.07)
CEC $_{eff.}$ (cmol/kg)	6.47b	(4.36–8.12)	**10.61a**	(9.72–15.37)
Base saturation (%)	96.0b	(60.6–97.0)	**98.3a**	(96.2–99.3)
Sand (%)	45.4a	(36.7–47.6)	49.3a	(29.6–55.1)
Clay (%)	11.9a	(9.9–19.7)	21.5a	(12.4–24.7)

Medians are given because variables were not normally distributed.
Medians in a row followed by different letters are significantly different at P≤0.05.

The analysis of Caesium-137 for assessing soil erosion did not yield useful results because in all soil samples content of Caesium-137 was rather low (Table 3.32). In many samples, particularly of the fruit garden, Caesium-137 content even was below the limit of detection. Results given in Table 3.32 were, therefore, tainted with much uncertainty. However, soil erosion was an obvious and severe problem in some homegardens of the research area, as shown in Figure 3.27.

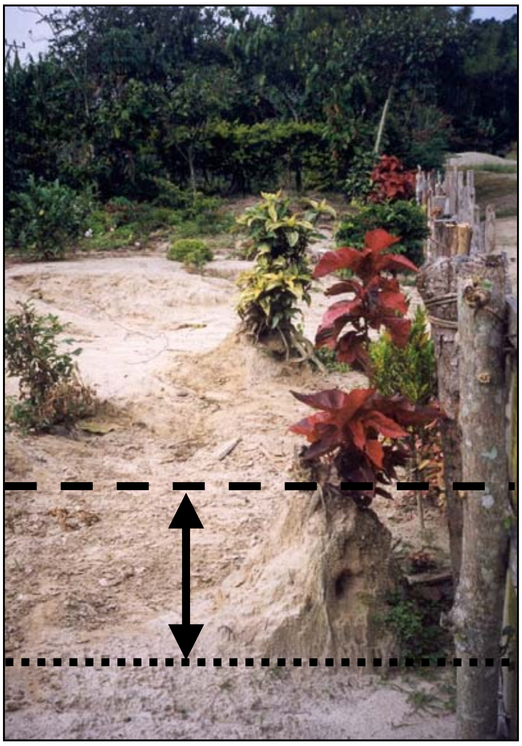

Figure 3.27. An example of soil erosion in the front yard of a homegarden in Rompo, Napu valley, Central Sulawesi, 2004. The broken line indicates soil surface during planting of the ornamentals along the fence; the dotted line shows the present surface. Difference was about 30 cm.

Table 3.32. Mean activity of Caesium-137 (range in brackets) in top soil of vegetable and cacao zones of the spice and fruit gardens, and of cassava and cacao zones in the migrant garden as well as in soil of two undisturbed reference zones (forest and grassland), Napu valley, Central Sulawesi, in 2004.

	Cs-137 activities (Bq/kg)								
	Vegetable/cassava zone			Cacao zone			Reference zone		
Spice garden	N = 2	0.7	(0.59–0.74)	N = 2	1.7	(1.78–1.59)			
Fruit garden		n.a.			n.a.				
Migrant garden	N = 3	1.3	(1.08–1.49)	N = 4	1.4	(1.31–1.46)			
Forest Wuasa							N = 3	1.4	(0.99–1.79)
Grassland Siliwanga							N = 3	0.8	(0.73–0.84)

Note: n.a. = not available.

Comparing sand and clay contents of different production zones within single homegardens might serve as a substitute for a rough assessment of soil erosion. This seemed to be meaningful because mainly the frequently swept and hoed vegetable zones were affected by laminar soil erosion. Probably, clay particles might first be washed out from the soil, thus, leading to decreasing clay, but increasing sand contents. For the two homegardens with a vegetable zone (i.e. the spice and fruit gardens), texture analysis showed a slightly, but not significantly higher sand content in the vegetable than in the cacao zones (Table 3.29 and Table 3.30). However, clay contents did not differ among production zones.

To prove such differences for a larger sample size, all homegardens with a distinct vegetable and cacao zone were included into the analysis (N = 17) (see 3.6.5). For homegardens cultivated for more than 20 years (N = 9), texture analysis showed a markedly higher mean sand and lower mean clay content in vegetable (sand 63.1%, clay 16.6%) than in adjacent cacao zones (sand 55.9%, clay 20.5%). Differences were significant only for the clay contents. No differences in sand and clay contents between vegetable and cacao zones were detected in homegardens cultivated for less than 20 years (N = 8).

3.8.4 Microclimate and Photosynthetic Active Radiation (PAR)

Besides soil quality, also microclimate and insolation might differ among production zones in the three case study homegardens (Figure 3.28, Figure 3.29, and Figure 3.31), thus, offering suitable micro-environments for several production tasks. Mean temperatures of air and soil decreased significantly from bare space to vegetable/cassava zones and from these to cacao/tree zones in all three homegardens, except for the migrant garden, where mean air temperatures of cassava and cacao zones were similar (Table 3.33, Table 3.34). Maximum soil and air temperatures were highest at bare space, intermediate in the vegetable or cassava production zones, and lowest in the cacao or tree zones of all three homegardens investigated (Table 3.33, Table 3.34). During the day time, temperature differences among production zones were markedly higher in the soil than in the air, especially around midday (Figure 3.30). Mean amplitudes of soil and air temperatures were highest at bare spaces and lowest in cacao/tree zones (Table 3.33, Table 3.34). Comparisons among the three homegardens were difficult, due to different weather conditions during the three time periods of measurement. Besides, partial shading slightly reduced maximum temperature at the bare place in the fruit garden, where no totally ‘bare’ place could be found for reference measurement.

Table 3.33. Mean overall soil temperatures (ranges in brackets), mean minimum, maximum, and amplitudes (all values in °C) in different production zones of three different homegarden types in the Napu valley, Central Sulawesi, in 2004. For the different time periods of measurement, see Figure 3.30.

Garden type	Production zone	Overall mean	Mean minimum	Mean maximum	Mean amplitude
Spice garden	Bare space	25.3a (21.0–36.6)	21.8a	31.8a	10.1a
	Cacao zone	22.9b (19.8–27.1)	20.9b	25.6b	4.6b
	Tree zone	21.4c (19.8–22.9)	20.6c	22.4c	1.8c
Fruit garden	Bare space	24.1a (18.3–32.8)	20.8b	29.7a	8.9a
	Vegetable zone	23.3b (19.8–27.1)	21.6a	25.6b	3.9b
	Cacao zone	22.0c (20.2–23.6)	21.1b	23.0c	1.9c
Migrant garden	Bare space	25.2a (20.2–35.7)	21.5a	31.7a	10.3a
	Cassava zone	23.5b (20.6–27.5)	21.5a	26.3b	4.8b
	Cacao zone	21.1c (19.8–22.5)	20.5b	21.8c	1.3c

Means in a column followed by different letters within one garden type are significantly different at P≤0.05.

Table 3.34. Mean overall air temperatures (ranges in brackets), mean minimum, maximum, and amplitudes (all values in °C) in different production zones of three different homegarden types in the Napu valley, Central Sulawesi, in 2004. For the different time periods of measurement, see Figure 3.30.

Garden type	Production zone	Overall mean	Mean minimum	Mean maximum	Mean amplitude
Spice garden	Bare space	22.3a (15.2–35.7)	18.1a	31.9a	13.8a
	Cacao zone	21.8b (15.6–32.8)	18.0a	29.8b	11.8b
	Tree zone	21.3c (15.2–30.7)	18.0a	28.2c	10.2c
Fruit garden	Bare space	22.2a (14.5–32.8)	18.0b	29.9a	11.9a
	Vegetable zone	21.7b (14.9–30.7)	18.2a	28.2b	10.0b
	Cacao zone	21.3c (14.9–29.1)	18.2a	26.8c	8.6c
Migrant garden	Bare space	20.8a (14.1–32.3)	15.7b	29.6a	14.0a
	Cassava zone	20.5b (14.1–31.1)	15.7b	28.6b	12.9b
	Cacao zone	20.5b (14.5–30.7)	16.4a	27.8c	11.4c

Means in a column followed by different letters within one garden type are significantly different at $P \leq 0.05$.

Soil temperature in the different production zones was directly related to the duration of direct radiation near the soil surface (Figure 3.34). The longer the soil was exposed to direct sunlight, the higher was the soil temperature ($R^2 = 0.851$). These differences in radiation were responsible for different soil and air temperatures in cacao zones among the homegardens. In the spice garden, where cacao was planted rather sparsely and direct radiation reached the stratum of 0.3 m height for more than three hours a day (Figure 3.33), the daily maximum for soil temperature in the cacao zone was about 25 °C (Figure 3.30). In the fruit and migrant gardens, where cacao was planted either under shade trees or rather densely, maximum temperatures were only about 23 and 22 °C, respectively. Air temperature followed similar patterns: In the spice garden, the maximum in the cacao zone was about 29 °C, whereas in the fruit and migrant gardens only 26 and 27 °C, respectively. However, as measurements were not carried out simultaneously, influences of different weather conditions could have influenced the results. During temperature measurement periods, project weather stations in about 5 km distance from the homegardens investigated determined a mean air temperature of 21.1 °C, 21.3 °C, and 20.3 °C in the spice, fruit, and migrant gardens, respectively.

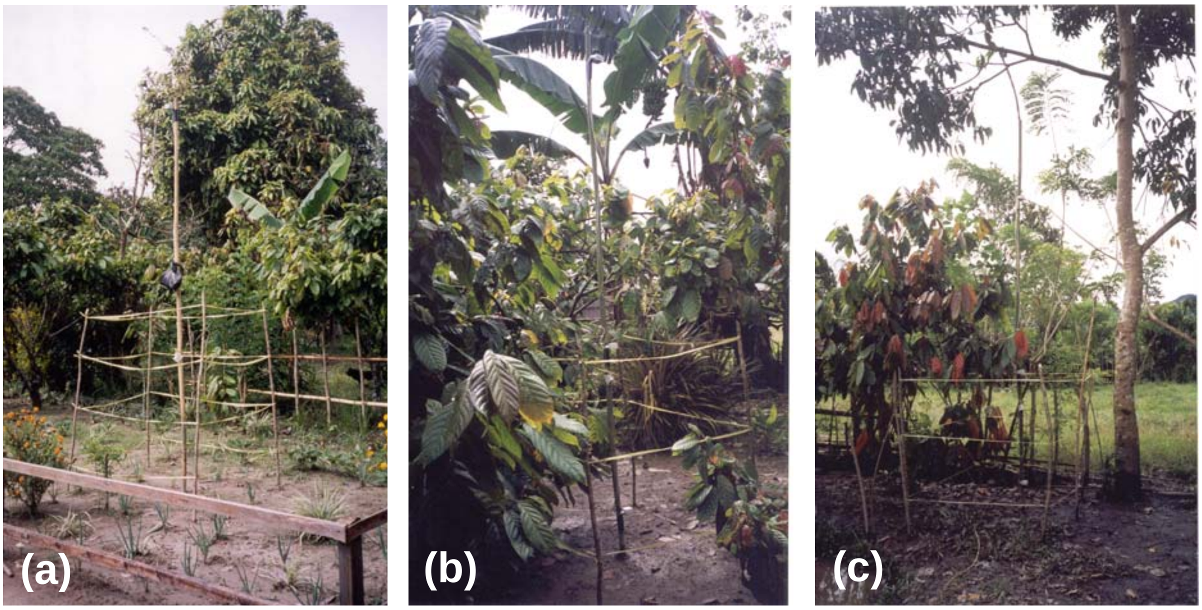

Figure 3.28. PAR measurement units in the small spice garden in Wuasa, Napu valley, Central Sulawesi. (a) The reference zone; (b) The cacao zone; (c) The tree zone.

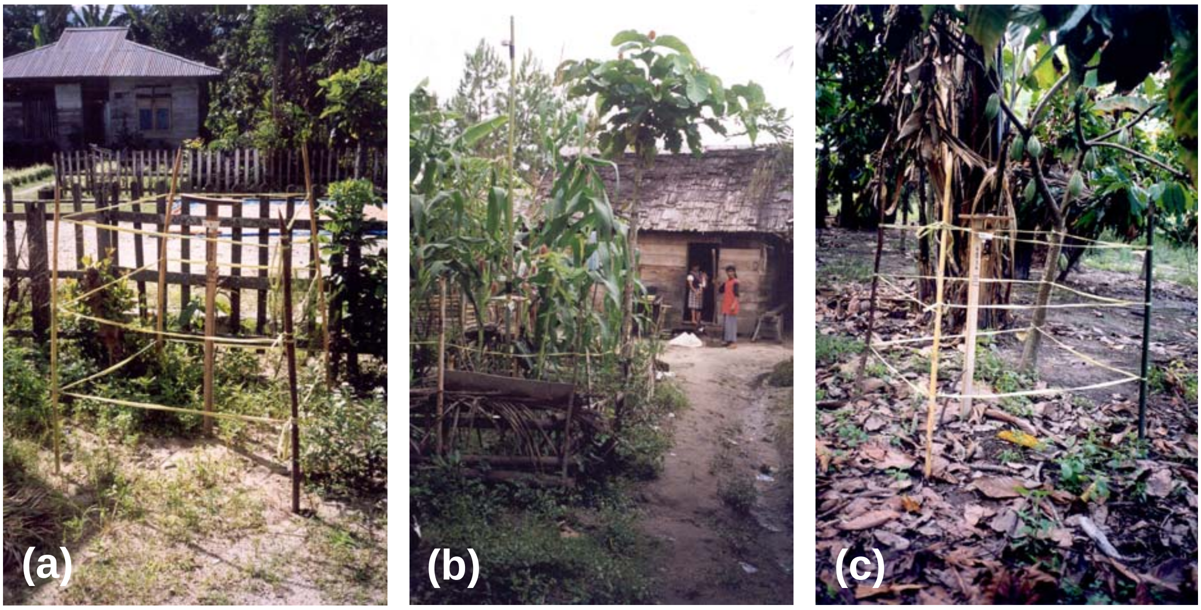

Figure 3.29. Temperature and PAR measurement units in the large fruit garden in Wuasa, Napu valley, Central Sulawesi. (a) The reference zone; (b) The vegetable zone; (c) The cacao zone.

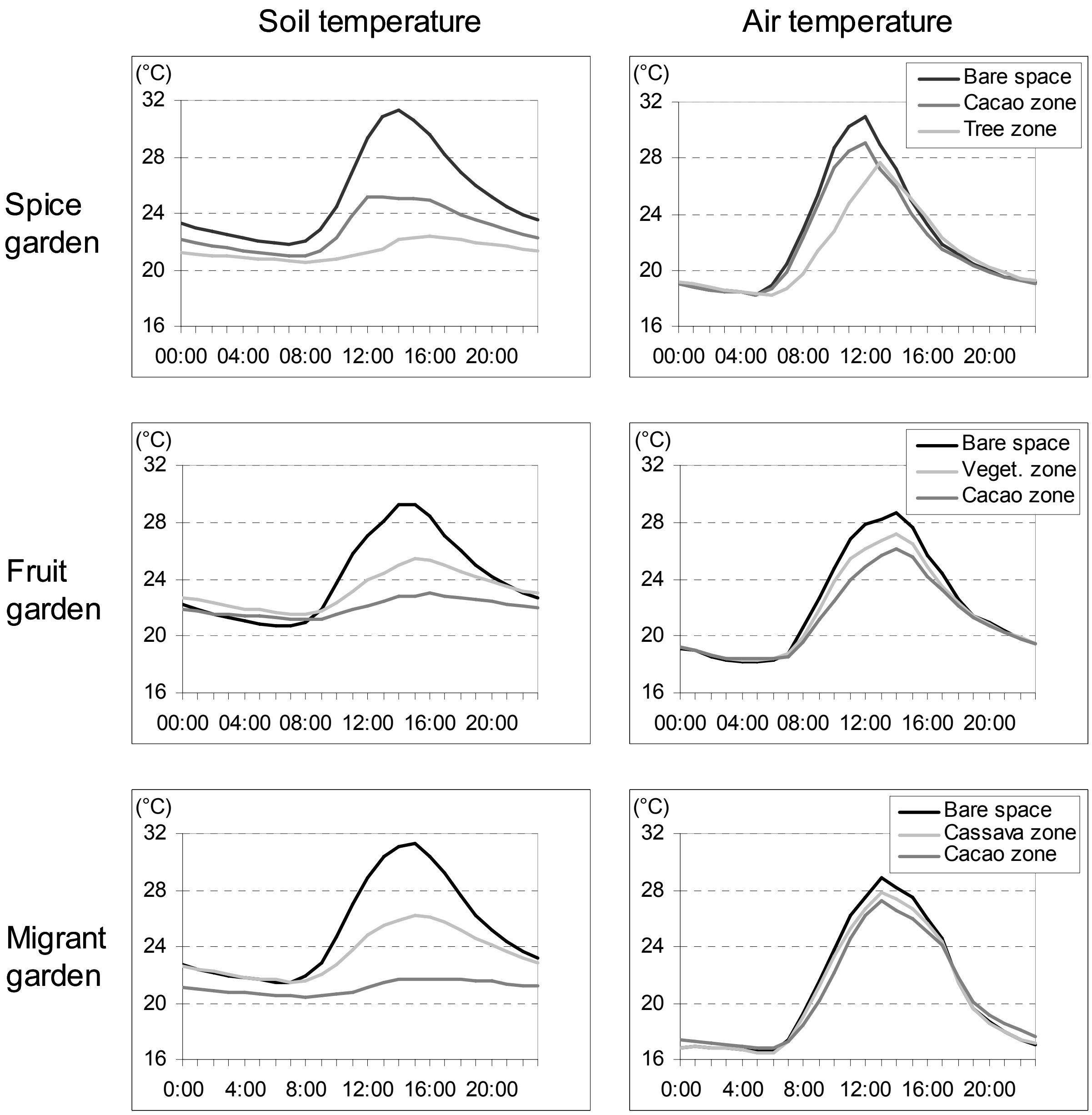

Figure 3.30. Mean daily courses of soil and air temperatures in different production zones of three different homegarden types in the Napu valley, Central Sulawesi, in 2004. Measurement periods: Spice garden = 27.03.–13.04.2004; Fruit garden = 02.05.–14.05.2004; Migrant garden = 21.05.–02.06.2004.

Photosynthetic Active Radiation (PAR) decreased markedly from higher to lower vegetation strata. Although variability was rather high, Figure 3.32 clearly shows different patterns among gardens. In the small spice garden (Figure 3.28), the cacao zone still received some direct radiation at 0.3 m, namely 30% of the radiation at bare space (Table 3.35). Under the fruit trees, relative light intensity at 0.3 m and 1.3 m was less than 20% of the radiation in the open. At 3.0 m, radiation under the fruit trees was also low, but in the cacao zone radiation was similar to that of the bare space, because cacao trees were rarely higher than 3.0 m.

Table 3.35. Mean relative light intensity in % of bare space light intensity (ranges in brackets) in different strata and production zones of three homegardens in the Napu valley, Central Sulawesi, referring to diurnal sums (05:45–18:14 h). Duration of measurement was five days each (for exact time period see Figure 3.32).

Garden type	Strata in cacao zone				Strata in: Tree zone (spice garden)/ Vegetable zone (fruit garden)/ Cassava zone (migrant garden)		
	0.3 m	1.3 m	3.0 m	4.5 m	0.3 m	1.3 m	3.0 m
Spice garden	30 (26–32)	49 (43–54)	96 (94–98)	n.a.	17 (12–23)	16 (11–21)	26 (22–30)
Fruit garden	15 (13–19)	24 (19–30)	40 (37–49)	58 (52–65)	25 (20–28)	44 (41–47)	58 (52–62)
Migrant garden	2 (1–2)	3 (2–3)	62 (51–63)	88 (84–91)	54 (52–57)	54 (50–59)	41 (31–47)

Note: n.a. = not available.

In the large fruit garden (Figure 3.29), radiation in the cacao zone was less than in the spice garden (Figure 3.32 and Table 3.35). Even in strata above 3.0 m height, relative light intensity in the cacao zone was less than 60% of the ambient radiation because cacao trees in this garden were shaded by bananas and large fruit and timber trees. The vegetable zone received only 25% of the ambient radiation at a height of 0.3 m, where most of the leaves of small herbaceous spices occurred. However, higher strata in the vegetable zone received markedly more direct radiation than that the corresponding cacao zone in the same garden.

In the large migrant garden (Figure 3.31), only very small portions of the bare space radiation reached the two lowest strata in the cacao production zone (Figure 3.32 and Table 3.35). Almost no vegetation covered the soil under the densely planted cacao trees. In the cassava production zone, 41–54% of the ambient radiation reached all three strata measured. Cassava was planted only sparsely and the soil was densely covered with weeds.

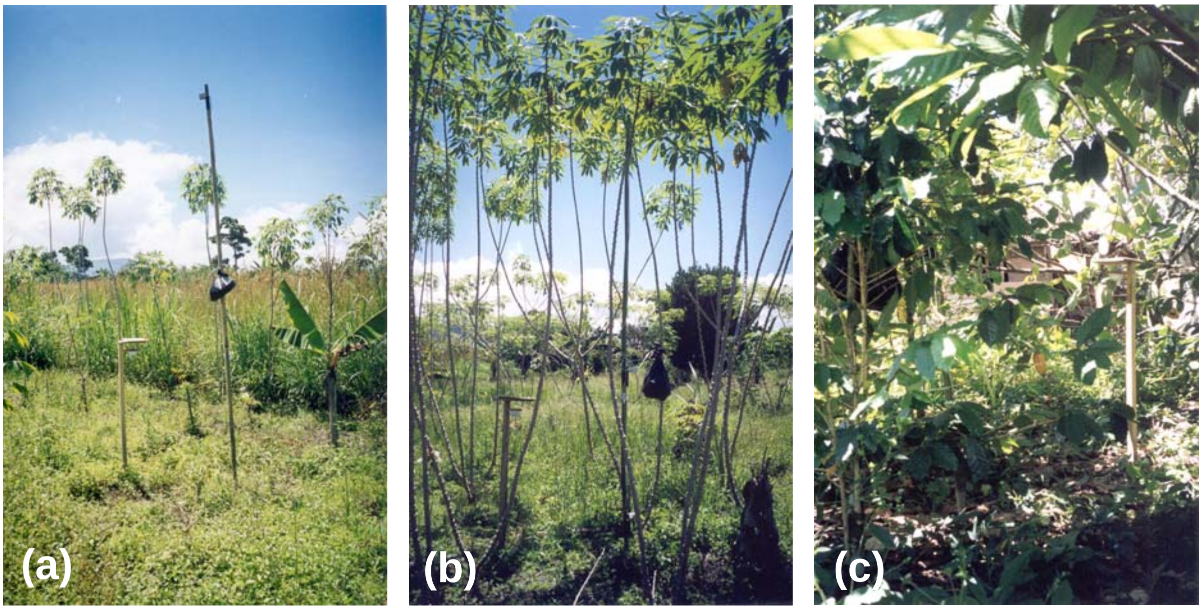

Figure 3.31. Temperature and PAR measurement units in the migrant garden in Siliwanga, Napu valley, Central Sulawesi. (a) The reference zone; (b) The cassava zone; (c) The cacao zone.

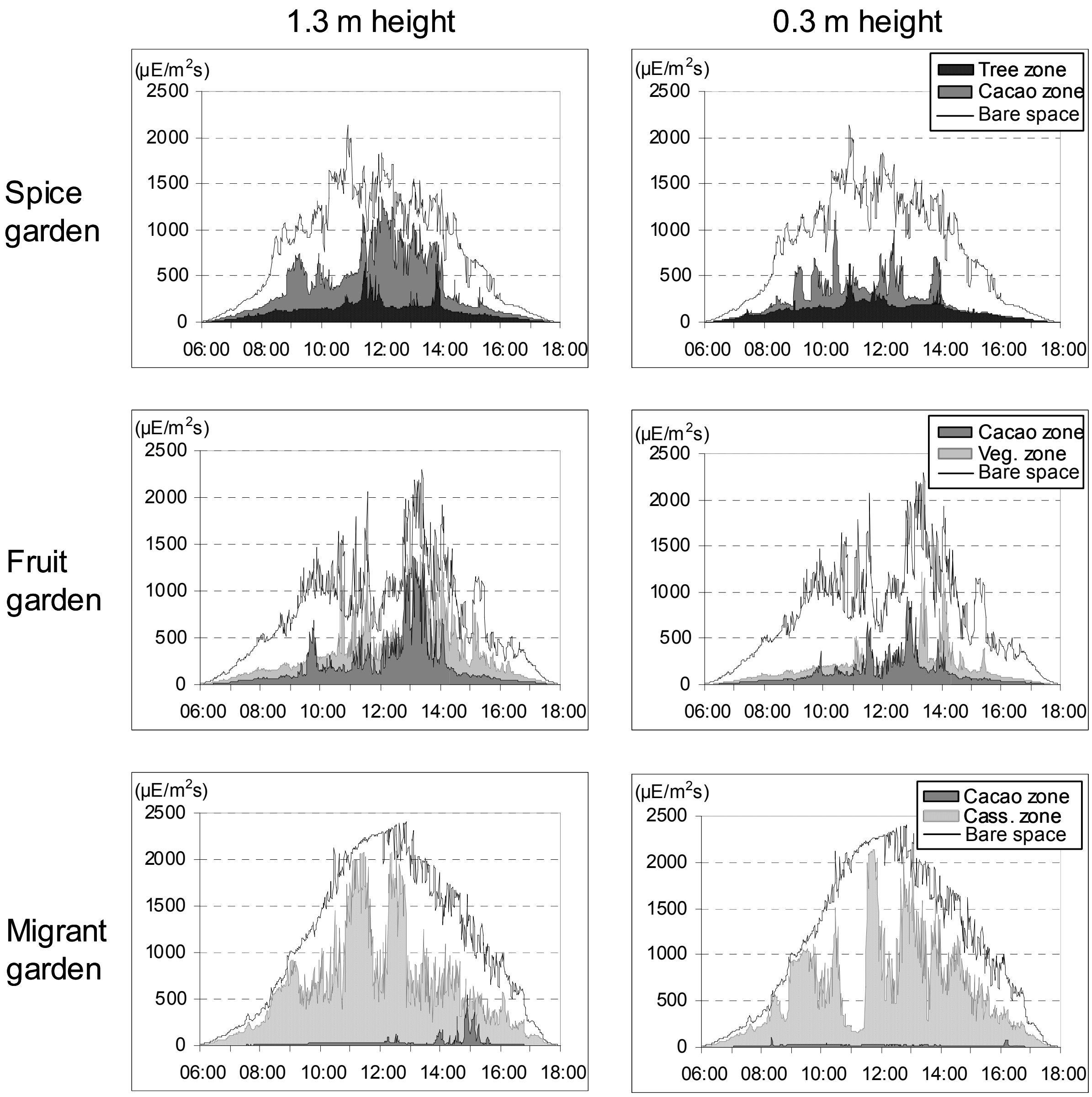

Figure 3.32. Mean daily courses of PAR (Photosynthetic Active Radiation) in different production zones and strata (heights in m) of three different homegarden types in the Napu valley, Central Sulawesi, in May 2004. Time periods of measurement: spice garden 6-10 May, fruit garden 11-15 May, migrant garden 22-26 May. (Veg. zone = Vegetable zone; Cass. zone = Cassava zone).

The duration of direct radiation in the different homegardens followed similar patterns as the amount of radiation. Time periods of direct radiation decreased from higher to lower vegetation strata and from sparsely planted to densely planted zones (Figure 3.33). The duration of direct radiation was very low under the fruit trees of the spice garden. However, leaves of cacao trees received direct radiation for 3–8 hours a day. In the fruit garden, direct radiation reached the top leaves of cacao trees only for 4 hours a day, whereas leaves at 1.3 m height obtained only 2 hours of direct radiation. In the migrant garden, the lowest stratum in the cacao zone received direct radiation for only 1 min. per day, that at 1.3 m height for only 17 min. However, direct radiation reached the top cacao leaves for 7 hours a day. Also the cassava production zone obtained long periods of direct radiation, i.e. 5 to nearly 7 hours per day in all strata (Figure 3.33).

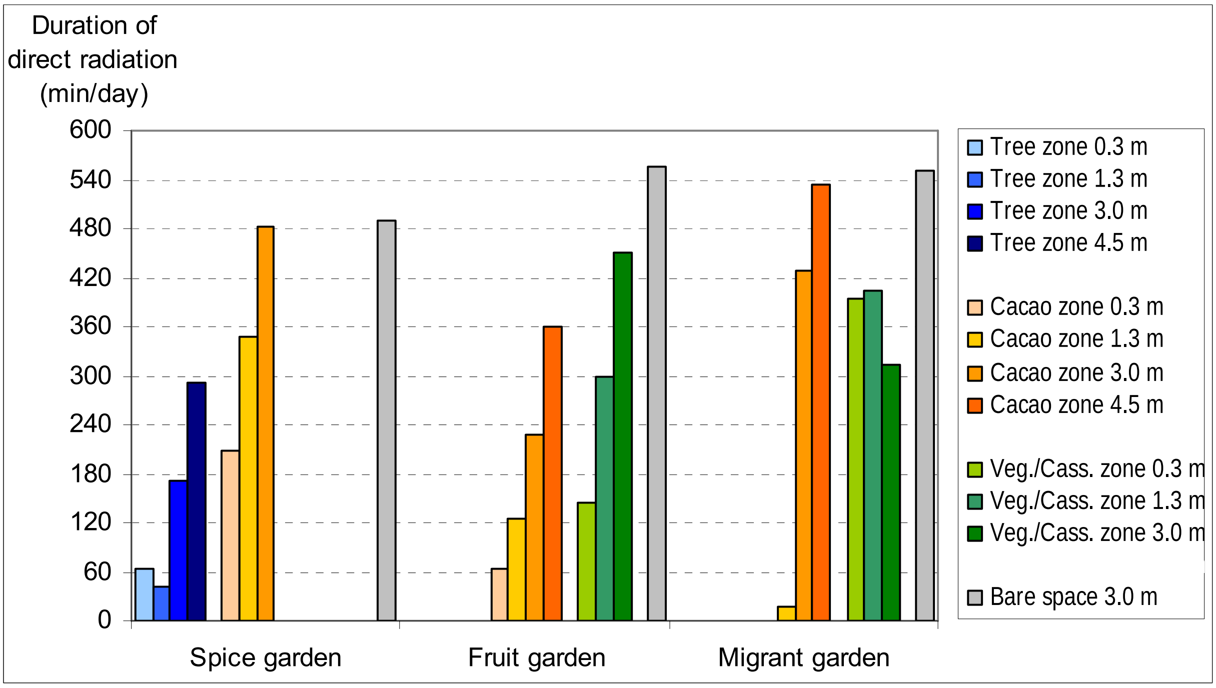

Figure 3.33. Mean duration (in minutes per day) of direct radiation ($\geq 250\ \mu E/m^2s$) in different vegetation strata and zones of three different homegarden types in the Napu valley, Central Sulawesi, in 2004. Veg. = Vegetable; Cass. = Cassava.

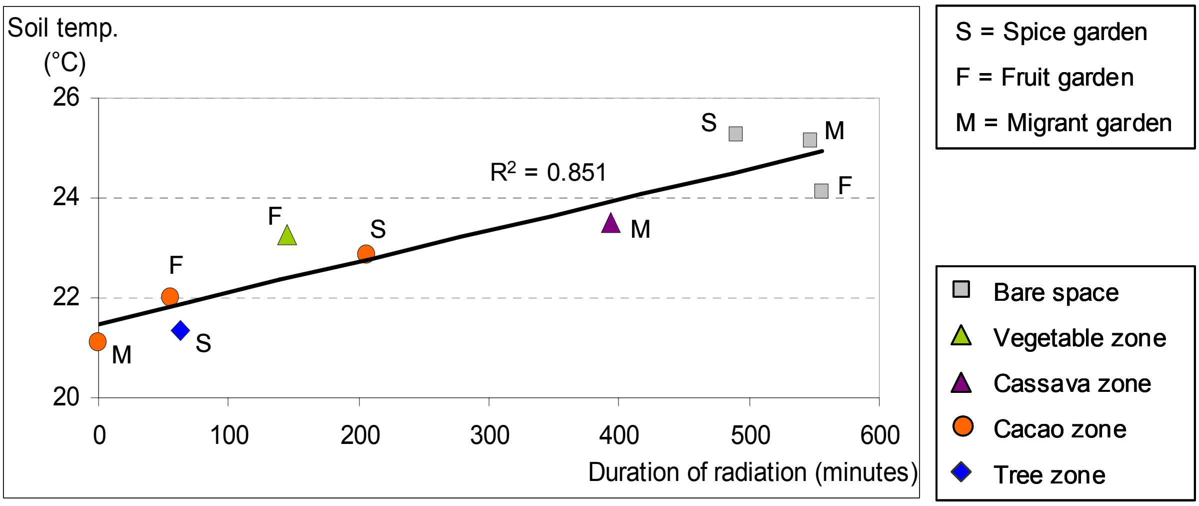

Figure 3.34. Relation between mean daily duration of direct radiation near the soil surface and mean soil temperature in different production zones of three different homegarden types in the Napu valley, Central Sulawesi, in 2004. Note: Time periods of measurement were different for radiation and temperature in the three homegardens.

3.9 Factors influencing plant diversity

To reveal the main factors that probably were responsible for the detected spatial differences in crop diversity parameters among homegardens (see 3.5), multiple regression analyses were performed. Firstly, only variables of the four categories garden characteristics, gardener/household features, socio-economics, and soil were included in the analyses. Table 3.36 lists the names, units, and ranges of six dependent and 26 independent variables belonging to four different categories. For the first regression model, only garden age and size were selected. The second analysis included nine characteristics of the gardener and his/her household (Table 3.36). For the third and fourth analyses, seven socio-economic characteristics and soil quality parameter each were selected. For the final regression model, only those variables were selected out of the four factor categories that were proved to influence crop diversity significantly or nearly significantly.

Table 3.36. Categories, names, units, and ranges of variables used for multiple regression analysis on crop diversity of 48 homegardens of five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

Category	Variable name and unit	Minimum-Maximum
Dependent variables:		
Crop diversity	Species richness (spp. no.)	13–68
	Margalef diversity index	2.8–10.2
	Species density (spp. no./1000 m^2)	16–67
	Individual density (individual no./100 m^2)	7–394
	Shannon index	1.46–3.49
	Shannon evenness index	0.37–0.88
Independent variables:		
Garden	Garden age (years)	2–40
	Garden size (m^2)	250–2,420
Gardener and household	Age of the gardener (years)	20–68
	Origin of the gardener: Outside Sulawesi (no/yes)	0–1
	Sex of the gardener: Male (no/yes)	0–1
	Duration of gardener's formal education (years)	0–17
	Occupation of the HH head: Non-farmer (no/yes)	0–1
	HH size (no. of members)	1–14
	Mean age of adults in the HH (years)	22–58
	Portion of adults without completed primary school (%)	0–100
	Dependence ratio (ratio children < 15 years/no. of total HH member in %)	0–60
Socio-economics	Market access: Good (no/yes)	0–1
	Cultivated farm area per HH member (m^2)	694–17,542
	Paddy rice field: Available (no/yes)	0–1
	Livestock units (TLU)	0.06–8.72
	Per capita expenditure on clothes per year (1000 IR)	5–350
	Poverty index: Very poor (no/yes)	0–1
	Homegarden production cash-oriented (i.e. > 25% of crop individuals were cash crops) (no/yes)	0–1
Soil	Sand content (%)	9–86
	N content < 0.2% (no/yes)	0–1
	C content (%)	0.9–5.1
	P-Olsen content < 20 ppm (no/yes)	0–1
	pH ($H_2 0$) < 5.5 (no/yes)	0–1
	K content (cmol/100 g)	0.09–0.95
	Cation exchange capacity CEC $_{eff.}$ (cmol/100 g)	4.0–37.9

Note: HH = Household, IR = Indonesian Rupiah (exchange rate in 2004: 10,000 IR ≈ 1 Euro).

3.9.1 Regression of single categories

Garden features

Garden age as one of the two garden-related features positively influenced only crop species density (Table 3.37). However, ln transformation of garden age resulted in a positive influence on crop species number and the value of the Margalef index. Garden size negatively influenced individual density and crop species evenness (i.e. Shannon evenness index), whereas diversity expressed by the Shannon index was not influenced by garden features.

Characteristics of gardeners and households

Out of the nine variables referring to gardeners' characteristics as well as structure and composition of his/her household, only four had a significant influence on all or some of the crop diversity parameters (Table 3.37). The most important variable was 'origin of the gardener from outside Sulawesi' that was the only one with a constantly strong negative influence on all crop diversity parameters. Age of the gardener had a varying influence on the diversity parameters (positive on species density, negative on evenness). Out of the household structure features, only mean age of adults and dependence ratio showed a varying influence on some diversity parameters, the latter, however, only if ln-transformed. Although the factor 'occupation of the household head' only nearly significantly influenced some diversity parameters (P = 0.078 and 0.093 for Shannon evenness index and the value of the Shannon index, respectively), it was considered for the final regression model.

Table 3.37. Simplified results of stepwise multiple regression analysis on crop diversity for single categories of variables for 48 homegardens of five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8.

	Species richness	Margalef index	Species density	Individual density	Shannon index	Shannon evenness index
Garden:						
Garden age	ns (ln+)	ns (ln+)	+	ns	ns	ns
Garden size	ns	ns	ns	–	ns	–
Gardener and household:						
Age of the gardener	ns	ns	+	ns	ns	–
Origin: Outside Sulawesi	–	–	–	–	–	–
Mean age of adults in HH	+	+	ns	ns	ns	ns
Dependence ratio	ns	ns	ns	ns (ln–)	ns (ln+)	ns (ln+)
Socio-economics:						
Market access: Good	+	+	+	+	ns	ns
Cultiv. area/HH member	–	–	–	ns	ns (ln–)	ns
Livestock units	ns	ns	ns	+	ns	ns
Production: Cash-oriented	ns	ns	ns	–	–	ns
Soil:						
N content < 0.2%	+	+	+	ns	+	ns
P-Olsen content < 20 ppm	ns	ns	ns	–	ns	ns

Note: ns = Not significant; + = Positive influence; **–** = Negative influence, HH = Household.

Socio-economic factors

In this category, not only variables describing market access, but also referring to farm characteristics and wealth status of the household were included. Among these factors, market access was the most important, having a positive influence on most of the diversity parameters (Table 3.37). In addition, size of cultivated farm area per capita negatively influenced most of the diversity parameters, partly, however, only in its ln-transformed form. A cash-oriented production had a negative influence on individual density and on crop diversity expressed by the Shannon index. The number of livestock units only positively influenced individual density of crops. Shannon evenness index was not influenced by any socio-economic factor. Variables concerning poverty index, clothing expenditures, and availability of paddy rice fields did not influence homegarden crop diversity.

Soil quality parameter

Among soil variables, N and available P contents (as dummy variables) were the only ones that tended to have a significant, but only small influence (adjusted R^2 mostly around 0.10) on crop diversity parameters. Low N content of the soil positively influenced crop species richness and density as well as the Margalef index and crop diversity expressed by the Shannon index, whereas relatively low available P content negatively influenced individual density (Table 3.37). Ln transformations of the variables did not improve the regression models.

3.9.2 Final regression model

For the final regression analysis, 13 independent variables were selected out of 25 variables tested initially (see 3.9.1). Regression analysis performed best for the models explaining variability in species richness (56%) and species density (60%) (Table 3.38). Both were influenced by exactly the same factors with similar weights (i.e. positively by garden size and mean age of adults in a household, but negatively by the variables ‘origin outside Sulawesi’, ‘production cash-oriented’, and relatively low available P content of the soil). Apart from available P content, the same variables influenced the Margalef index, explaining 45% of its variation. Concerning crop individual density, only 33% of its variability was explained by the regression model (Table 3.38). Individual density was also negatively influenced by the variable ‘production cash-oriented’, but positively by a good market access and livestock units possessed by the household.

Crop diversity expressed by the Shannon index was influenced only by the single variable ‘origin of gardener from outside Sulawesi’ (beta coefficient -0.38**, adjusted R^2 = 0.13**). Also crop species evenness was influenced only by the single variable ‘garden size’ (beta coefficient -0.33*, adjusted R^2 = 0.09*). Ln transformation of independent variables did not improve the regression models.

In summary, large gardens managed by families with rather old members harboured a higher crop diversity (i.e. species richness, species density, and Margalef index) than small gardens of young families. Concerning species evenness, large gardens tended to be dominated by only few crop species. In homegardens of migrant families, significantly lower crop diversity parameters (i.e. species richness and density, values of Shannon and Margalef indices) could be expected than in that of locals. Good market access may enhance crop individual density. In homegardens dominated by cash crops, plant diversity parameters (apart from the values of Shannon diversity and evenness indices) was markedly lower than in subsistence homegardens. Homegardens with relatively low soil available P contents tended to have low crop species richness and density.

Table 3.38. Results of stepwise multiple regression analyses on different crop diversity parameters for 48 homegardens of five villages of the Napu valley, Central Sulawesi, 2004. N = 10 per village, apart from Rompo, where N = 8. For each independent variable the standardised regression coefficient (beta coefficient) and the significance level is presented. Non-standardised regression coefficients are given in brackets.

	Species richness	Margalef index	Species density	Individual density
Adjusted R^2	0.56***	0.45***	0.60***	0.33***
Durbin-Watson statistic	1.996	2.126	2.119	1.890
Maximum condition index	15.38	14.07	15.38	3.33
Independent variables:				
Constant	(22.21**)	(4.26***)	(30.30***)	(46.34**)
Garden age	ns	ns	ns	ns
Garden size	0.79***(0.01)	0.59** (0.001)	0.55** (0.01)	ns
Age of gardener	ns	ns	ns	ns
Origin of gardener: Outside Sulawesi	-0.67*** (-17.39)	-0.73*** (-2.57)	-0.67*** (-17.40)	ns
Occupation of HH head: Non-farmer	ns	ns	ns	ns
Mean age of adults in the HH	0.27* (0.45)	0.24* (0.05)	0.24* (0.39)	ns
Dependence ratio	ns	ns	ns	ns
Market access: Good	ns	ns	ns	0.35** (50.39)
Cultivated farm area/HH member	ns	ns	ns	ns
Livestock units	ns	ns	ns	0.30* (9.50)
Homegarden production cash oriented	-0.40**(-10.66)	-0.38** (-1.38)	-0.41** (-11.00)	-0.33* (-41.62)
N content < 0.2%	ns	ns	ns	ns
P-Olsen content < 20 ppm	-0.26*(-6.80)	ns	-0.27* (-6.90)	ns

Note: ns = Not significant; *, **, *** = F-test (for the model) or T-test (for independent variables) significant at P≤0.05, ≤0.01, ≤0.001, respectively.

3.10 Changes of different homegarden features over time

In the 30 homegardens surveyed in 2001, 2003, and 2004, changes in their function, management, crop diversity, and soil quality were compared over time.

3.10.1 Function of homegardens

In all three villages, function of homegardens changed over time. Their importance for subsistence decreased markedly in Wuasa, but increased in Rompo (Figure 3.35). Simultaneously, their role for cash income generation increased in Wuasa, but decreased in Rompo. In the migrant village Siliwanga, homegardens became important for cash income generation only in 2004. The ornamental function of homegardens increased particularly in Wuasa, where 40% of the gardeners mentioned decoration as the main function of their gardens in the 2004 survey. The increasing importance of homegardens in Wuasa and

Siliwanga for the generation of cash income was also reflected by the temporal changes in crop species composition in both villages (see 3.10.3).

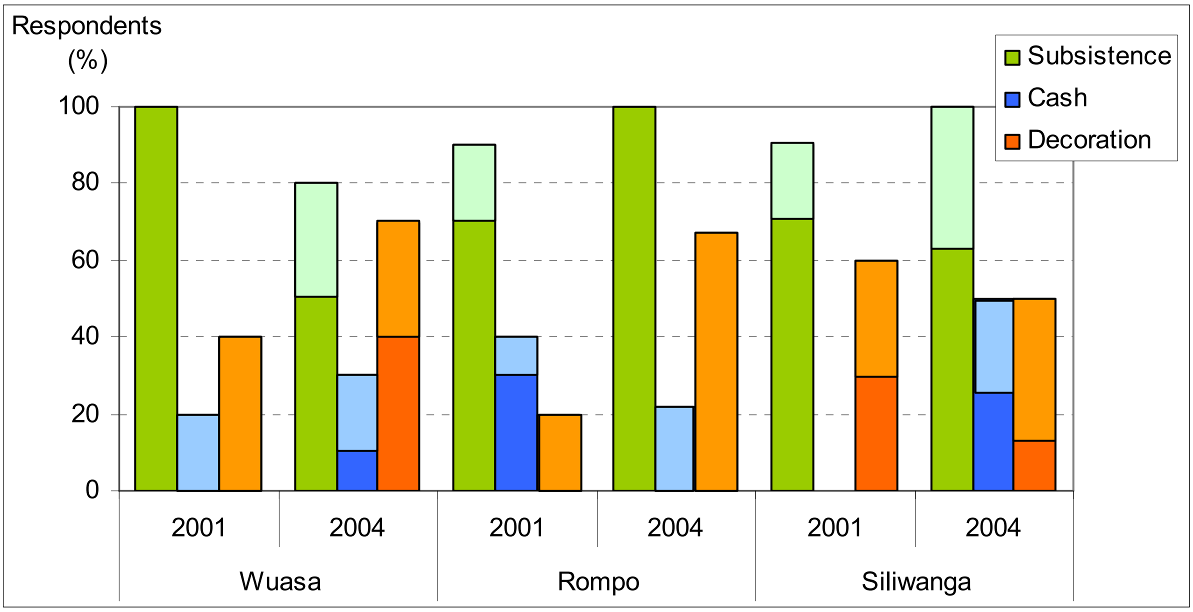

Figure 3.35. Main and secondary functions of homegardens in three villages of the Napu valley, Central Sulawesi, in 2001 and 2004, as given by the gardeners (pale-coloured bars: secondary function). N per village = 10, apart from Rompo 2004 and Siliwanga 2004, where N = 9 and N = 8, respectively.

3.10.2 Management: Use of internal and external inputs

Figure 3.36 shows different trends in the use of the internal input 'natural' fertiliser. In the local villages Wuasa and Rompo, the use of farm yard manure decreased markedly over time, whereas in the migrant village its use was mentioned by 50% of the gardeners in 2004, but none in 2001. At the same time, the importance of ash increased in all three villages.

The use of external inputs in homegardens mostly increased over time (Figure 3.37). In 2001, only 7% of the 30 gardeners interviewed regularly used industrial fertiliser (one each in Wuasa and Siliwanga), three more gardeners in Wuasa used it only once due to supply by a village development programme (KEHLENBECK, 2002) that stopped free distribution in the year 2002. In 2004, already 21% of the gardeners used industrial fertiliser regularly (two in Wuasa and four in Siliwanga). In most of the homegardens studied, however, industrial fertiliser was still used only rarely. In the homegardens of the remote village Rompo, even in 2004 no industrial fertiliser was applied. Also the use of insecticides was mentioned by some gardeners only, but its use already increased over time. Herbicide use increased markedly over time in all three villages, particularly in Siliwanga.

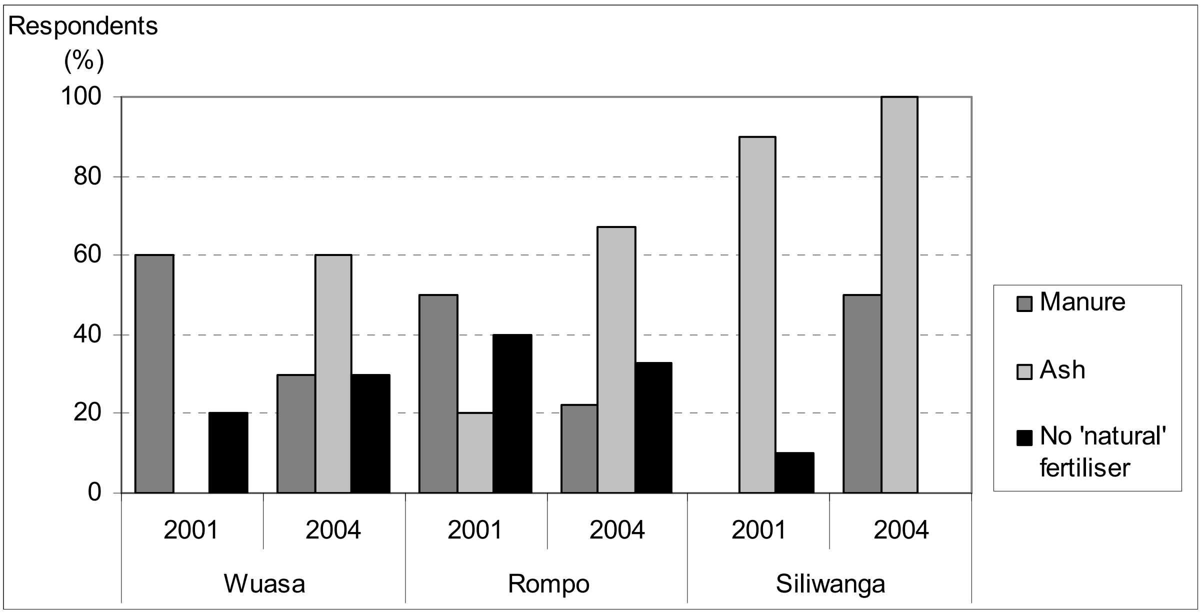

Figure 3.36. Use of natural fertilisers in homegardens in three villages of the Napu valley, Central Sulawesi, in 2001 and 2004, as given by the gardeners. N per village = 10, apart from Rompo 2004 and Siliwanga 2004, where N = 9 and N = 8, respectively.

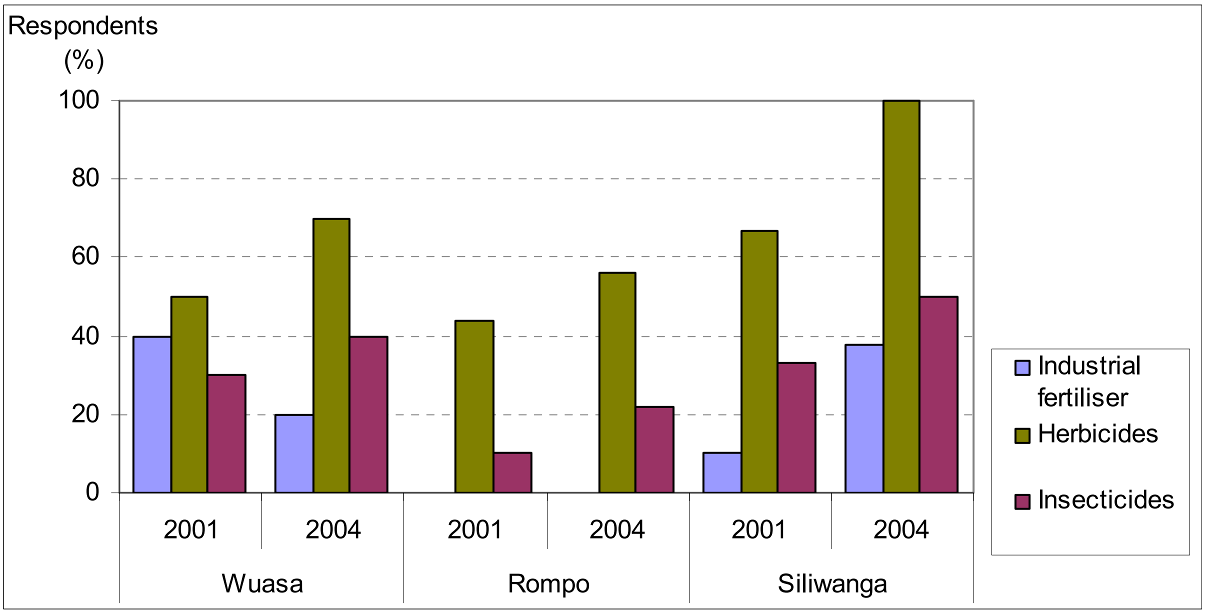

Figure 3.37. Use of external inputs in homegardens in three villages of the Napu valley, Central Sulawesi, in 2001 and 2004, as given by the gardeners. N = 10 in Wuasa; N = 9 in Rompo; N = 9 and N = 8 in Siliwanga in 2001 and 2004, respectively.

3.10.3 Crop diversity

Crop species composition

Principal Component Analysis (PCA) based on crop species composition and its changes over time (i.e. means of crop species abundance per village for the years 2001, 2003, and 2004, for detailed data on total individual numbers per village see Appendix 13) resulted in a clear distinction of the three villages along the first two ordination axes (Figure 3.38). Despite temporal changes, villages remain clearly separated in the ordination space. Axis 1 explains about 50% of the total variability (Table 3.39) and is positively correlated with tea and some staple crops, particularly paddy rice, cassava, and sweet potato. On the other hand, it is negatively correlated with some traditional fruit trees such as mango or pummelo and with certain rather modern crops, like spring onion, tomato, and vanilla, grown partly as cash crops. Therefore, axis 1 might reflect the continuum from subsistence staple crops to more diverse, mixed cultivation, used both for subsistence and income generation.

Axis 2, explaining about 20% of the total variability (Table 3.39), is negatively correlated with certain traditional crop species, such as the vegetables *Clerodendron minahassae*, and eggplants as well as the spicy fragrant screw pine (Figure 3.38). On the other hand, it is positively correlated with the cash crop species groundnut and cacao, accompanied by the shade tree *Gliricidia sepium*. Also vanilla and spring onion are slightly correlated positively with axis 2. Thus, axis 2 can be interpreted as reflecting the continuum from traditional subsistence crops towards modern cash crops. The distinct locations of the three villages in the ordination space confirm previous findings concerning importance of different crop use categories (Figure 3.14). Homegardens in Wuasa were characterised by many spices, partly used as cash crops, those in Siliwanga by staple crops, whereas those in Rompo by mixed cultivation, including many vegetables.

Table 3.39. Summary table as a result of Principal Component Analysis, based on mean abundance data per village of 196 crop species cultivated in 30 homegardens surveyed over time in the Napu valley, Central Sulawesi; species abundance data ln-transformed and centred before analysis.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	21.39	8.98	4.53	3.14
Percentage	48.74	20.45	10.31	7.14
Cumulative Percentage	48.74	69.18	79.50	86.64

Concerning temporal changes, homegardens in Wuasa were characterised by a rather small portion of staples, but a high portion of cash crops, even recently more emphasised (Figure 3.38). This pattern reflects the increasing importance of commercial crops in this particular village with its rather good market access. In the migrant village Siliwanga, a similar, but less pronounced trend was found. Its starting position was different from Wuasa, due to a markedly different crop species composition, characterised by the dominance of staple crops in Siliwanga. However, the abundance of these staples had already decreased over the short time span of this investigation. Partly, they were replaced, for example, by the cash crop cacao. In the remote village Rompo with rather poor market access, no change towards more cash crops has been detected. Homegardens in this village were still characterised, for example, by traditional vegetables, whereas abundance of cash crops was rather low. For cacao and vanilla, exclusively grown for income generation, mean portion of individuals per homegarden increased markedly over time both in Wuasa (from 7 to 11%) and in Siliwanga (from 3 to 8%), whereas in Rompo only from 7 to 8%.

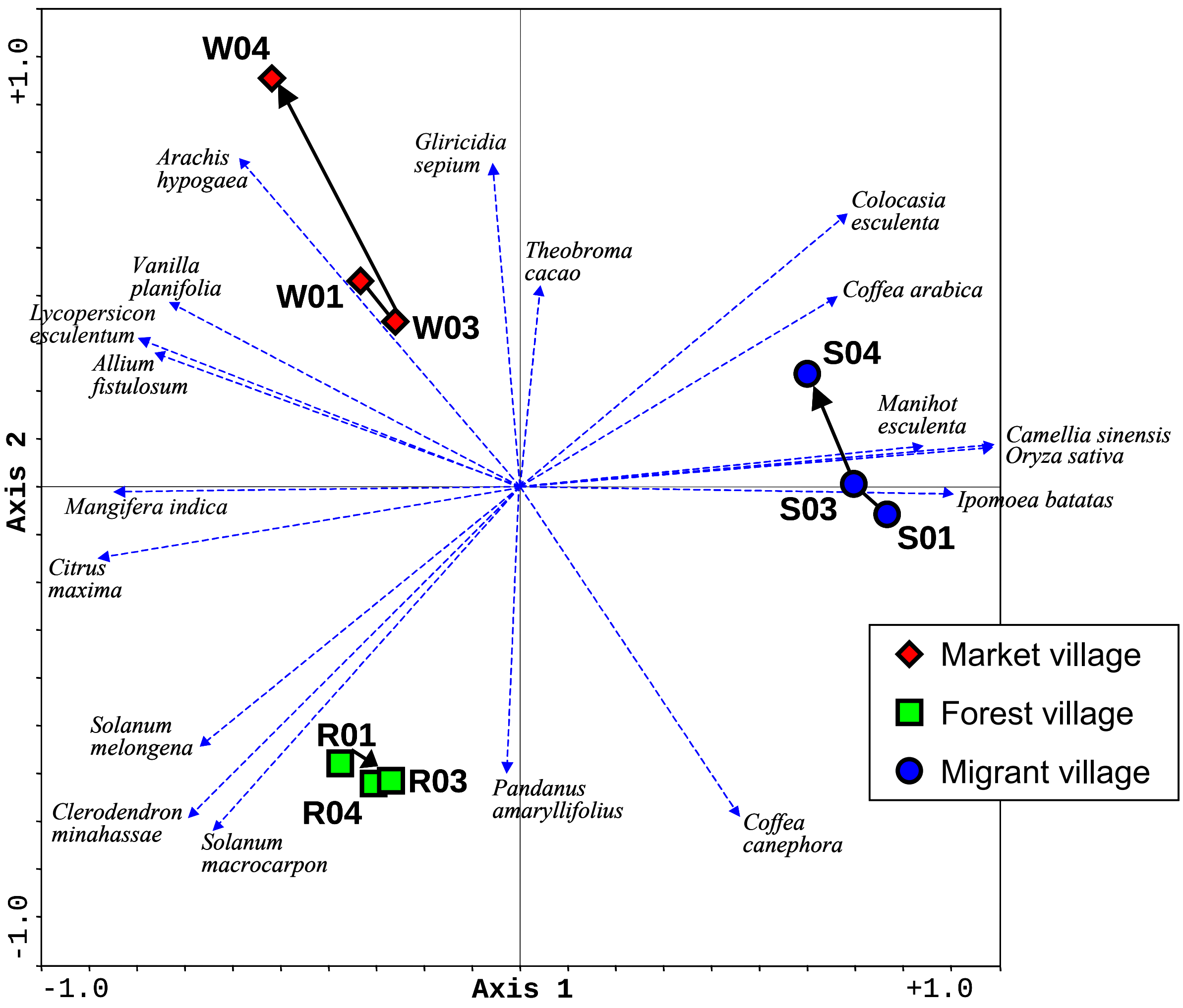

Figure 3.38. Changes of crop species composition from 2001 to 2004 in 30 homegardens of three villages (Market village = Wuasa; Forest village = Rompo; Migrant village = Siliwanga) in the Napu valley, Central Sulawesi. Biplot of cases (linked by bold arrows) and selected crop species as a result of Principal Component Analysis, based on mean abundance data per village of 196 crop species cultivated in the homegardens surveyed over time; species abundance data ln-transformed and centred before analysis.

Differences in temporal changes of overall number of individuals per use category among villages are also demonstrated by Figure 3.39. Homegardens in Wuasa were characterised by a rather constantly high portion of spices, including spring onion, groundnut, and vanilla for sale (note: Groundnut was used as spice by gardeners, not as oil crop). The other use categories were represented only by relatively small portions. Over time, portions of vegetables, medicinal plants, and multipurpose trees showed a slight increase, whereas those of fruit trees and stimulants tended to decrease. The decrease in stimulants, including the cash crop cacao, seems to be inconsistent with the results of the PCA (Figure 3.38). However, within the use category ‘stimulants’, also arabica coffee is included, whose portion decreased markedly over time in Wuasa (from 9% to 2%), causing, therefore, the overall decrease of stimulants.

Homegardens in the remote village Rompo were not dominated by any particular crop. Apart from the portions of the recently increased staple crops and decreased spices, portions of the other use categories were rather evenly distributed and remained relatively stable over time (Figure 3.39). The mixture of different crops points towards the primary subsistence role of homegardens in Rompo. PCA results (Figure 3.38) were, therefore, confirmed. This applies also for the case of Siliwanga. Homegardens in the migrant village were clearly characterised by the high, but strongly declining portion of staple crops (Figure 3.39). On the other hand, portions of spices and stimulants slightly increased over time, showing the growing importance of these homegardens for income generation.

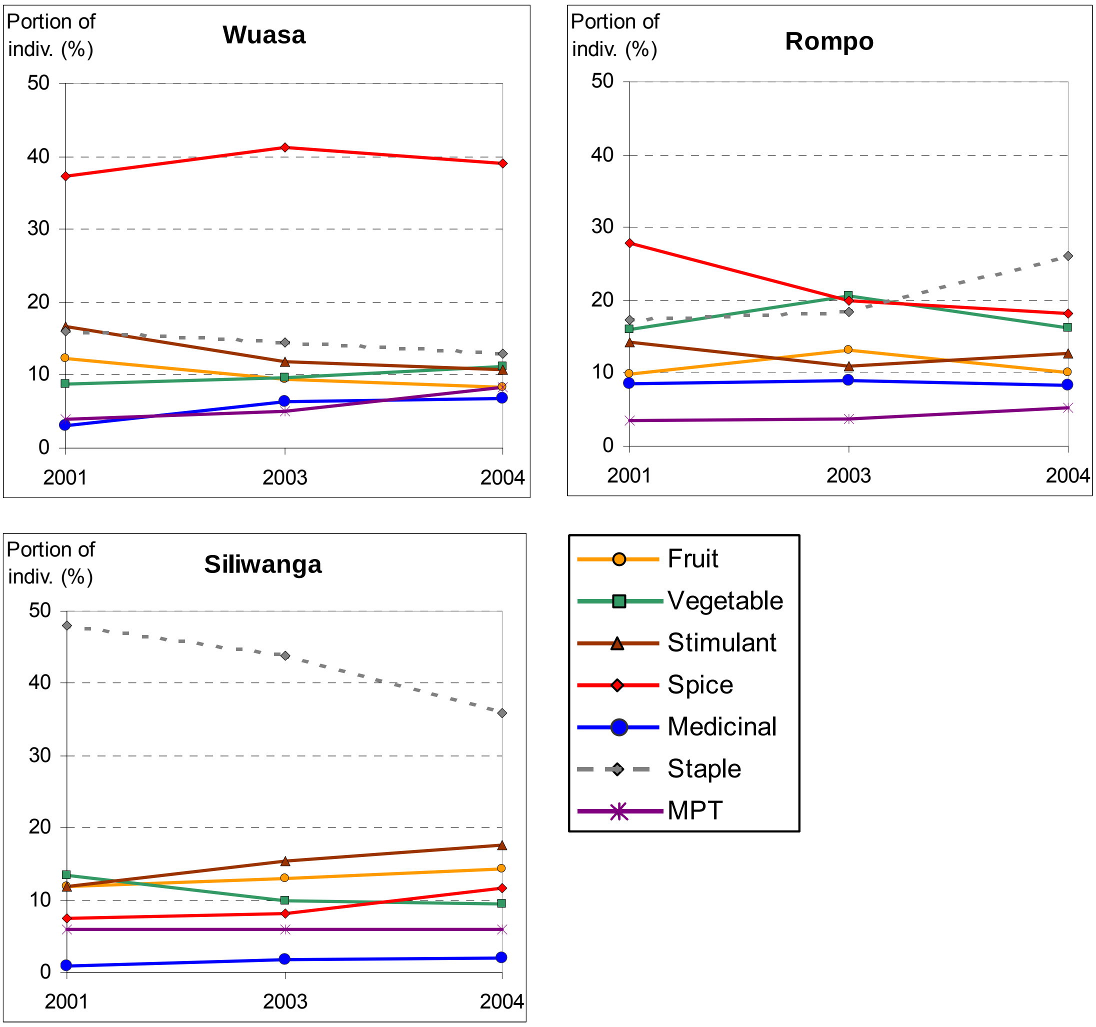

Figure 3.39. Temporal changes (means per village) in the portions of the overall number of crop individuals per use category in 30 homegardens in three villages of the Napu valley, Central Sulawesi, from 2001 to 2004. Due to very low portions, the use categories 'wood' and 'others' are not shown. Indiv. = Individuals.

Besides portions of the overall number of individuals per use category, also temporal changes in the number of species per use category differed markedly among villages (Figure 3.40). Although portions of crop individuals in some use categories markedly declined in single villages (e.g. spices in Rompo), species numbers increased over time in nearly all villages and use categories, particularly for vegetables. However, the species turnover for vegetables was found to be high, too. From 2001 to 2004, a mean of 3–5 vegetable species were introduced into the homegardens, but at the same time, the cultivation of 1–2 vegetable species was given up. Also the number of fruit crop species increased in the three villages, particularly in Wuasa. Mainly high-valuable species usable for sale such as durian, rambutan, and mandarin were introduced. In Wuasa, the number of medicinal plant species increased exceptionally by about 3.5 species per homegarden. Reasons for this are given below. In general, the increase in species number over time in the different use categories was rather high in Wuasa, intermediate in Siliwanga, and low in Rompo.

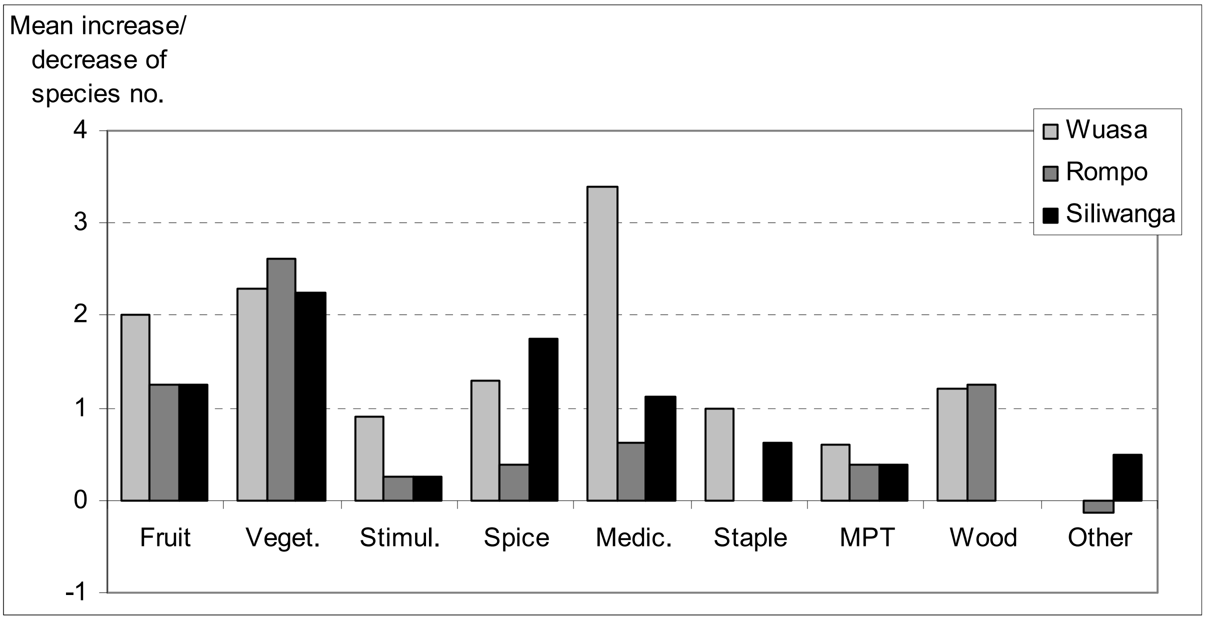

Figure 3.40. Mean temporal changes (means per village) of crop species numbers in different use categories from 2001 to 2004 in 30 homegardens in three villages of the Napu valley, Central Sulawesi. Veget. = Vegetables; Stimul. = Stimulants; Medic. = Medicinal.

Crop species richness and diversity

Crop species richness in the homegardens revisited increased markedly over time both per village and per garden (Figure 3.41, for detailed data see Appendix 15 and Appendix 16). In the three villages, a combined total of 152, 171, and 178 useful plant species were identified in 2001, 2003, and 2004, respectively. Mean density of crop species increased significantly in Wuasa and Siliwanga, whereas changes of density of individuals did not show any trend. Changes in crop diversity expressed by the Shannon index were also not clear except in the migrant village Siliwanga, where the index increased significantly. This might be due to the decreasing dominance of staple crops in the migrant gardens (Figure 3.39). In Siliwanga, however, crop diversity mostly continued to be markedly lower than in the two local villages Wuasa and Rompo.

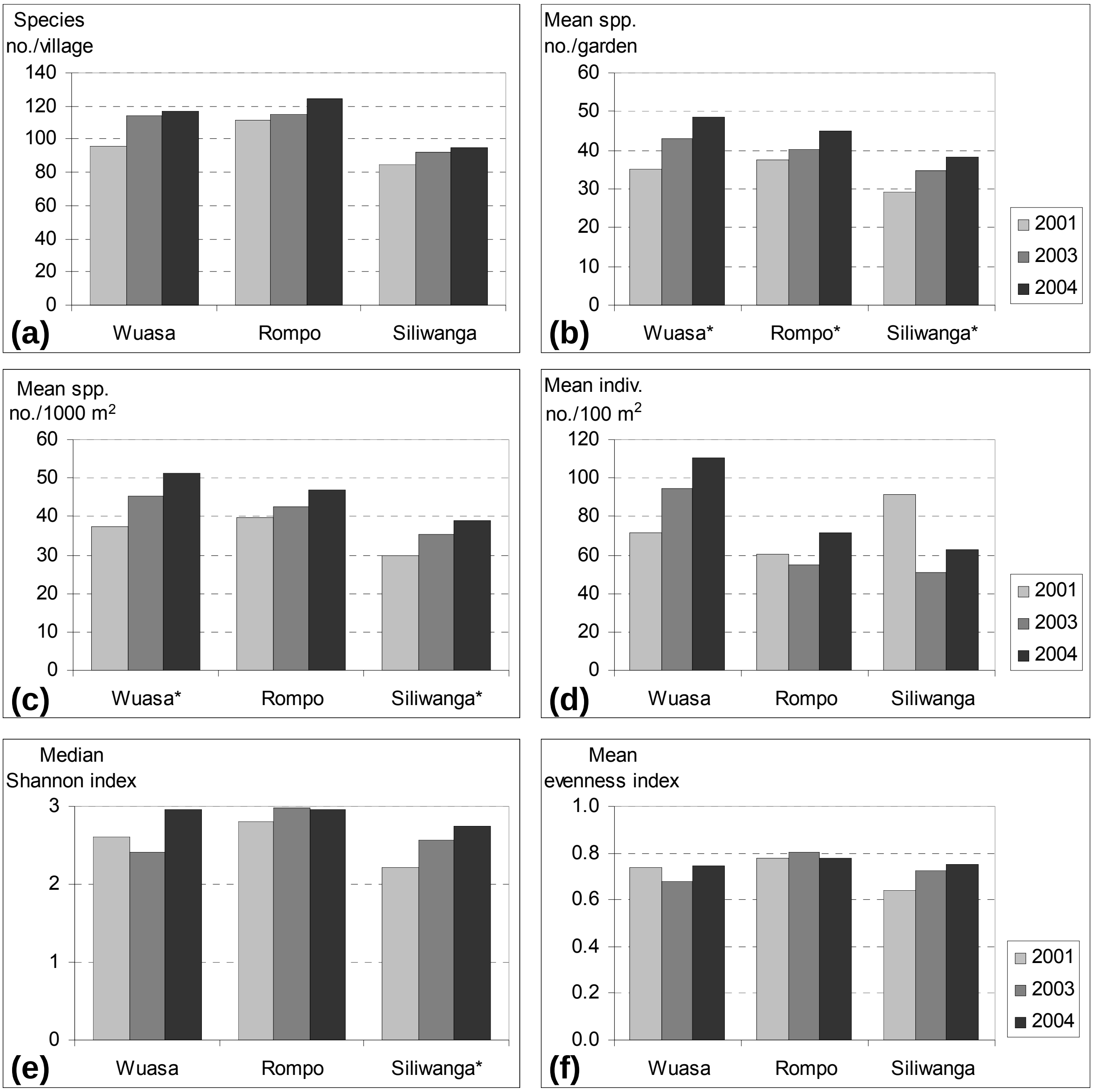

Figure 3.41. Crop diversity parameters of 30 homegardens in three villages of the Napu valley, Central Sulawesi, from 2001 to 2004. (a) Total species richness; (b) Mean species richness per garden; (c) Mean species density (according to the Arrhenius formula); (d) Mean individual density; (e) Median Shannon index; (f) Mean Shannon evenness index. (In villages followed by an asterisk, changes of the respective variable over time were significant at P≤0.05 by Friedman test).

Reasons for changes in crop diversity as given by the gardeners

Gardeners gave different reasons for starting or giving up the cultivation of certain crop species. Increase in crop species number over time might be due to experimental cultivation of new crops in the homegardens, e.g. of new cash crop species for increasing income generation. Many gardeners mentioned that they try out, firstly in small plots of their homegardens, to grow new crops, which just came into 'fashion' such as soybean, vanilla, or teak. After successfully having tested the suitability and specific demands of the new crop, they start to plant it in larger numbers in their fields or plantations. Partly, crop species number also increased due to the activities of development projects that promoted the cultivation of particular crops. One project was focussing on the cultivation of medicinal plant species in homegardens. This campaign was initiated by the governmental organisation CSIADCP (Central Sulawesi Integrated Area Development and Conservation Project, funded by the Asian Development Bank). In general, it aimed at improving the protection of the Lore Lindu National Park by rising the socio-economic welfare of the people living in the adjacent villages. The homegarden part of this project was successful particularly in Wuasa, where the increase in medicinal plant species was profound (Figure 3.40), raising in total from 17 species in 2001 to 24 in 2004 and in a mean per garden from 3.4 to 6.8, respectively. However, this success was mainly caused by the Mayor of Wuasa, who pushed gardeners to grow these recommended plants. In the other two villages studied, the impact of this project on medicinal plants seemed to be rather low, as their number increased only slightly (Figure 3.40). The same development project distributed seedlings of a modern variety of mandarin trees in the research area during 2002/2003. Many gardeners planted the received trees in their homegardens, particularly in the villages Rompo and Siliwanga. Another development project, ECML (Environmental Conservation of Marginal Lands) initiated by CARE International Indonesia, distributed seeds of modern vegetable species, such as chinese cabbage and pak choi, grown in some homegardens in Rompo. However, in some cases also the personal interests of gardeners led to an increase in crop diversity. Gardeners particularly transplanted medicinal plants from the wild to their homegardens to have them available if required (see 3.4.1). In the homegardens surveyed, seasonal effects could not be made responsible for the significant increase in crop species number over time, because in all three years species inventories were carried out in the same season.

The reason most frequently mentioned for giving up cultivation of certain crops was the disappearance of the particular species, especially for fruits, vegetables, spices, stimulants, and medicinal plants (Figure 3.42). Species were said to disappear, for example, because of accidental hoeing of the young plants, dying off, pests and diseases, or by extraordinary climatic events such as heavy rains or drought. The latter was supposed to be responsible for the disappearance of many crop species during the El Niño event in the year 2002. The second important reason for decrease of crop species was simply their total harvest. As the availability of seeds is rather limited (e.g. low own production of seeds, see 3.4.1), cultivation of the crop concerned may not be continuous. Gardeners totally harvested particularly vegetables and spices, but also some staple crops.

Species numbers of trees such as fruit trees, stimulants, or fuel wood, partly decreased, because gardeners decided to cut trees down (Figure 3.42). Gardeners mentioned that they felled trees that disturbed cultivation (i.e. shade out more valuable crops), that might damage houses in case of storm, or that gave only small, low-quality, or low-price harvest. The latter reason was often given for felling traditional fruit tree species/varieties (e.g. pummelo, mandarin, water apple) and for removing arabica coffee that was suffering from decreasing prices and was recently replaced by cacao and vanilla. In some homegardens, the crop species number decreased because gardeners moved species to their other fields and plantations. Particularly valuable crop species such as vanilla, cacao, teak, or candle nut were sown at first in the homegardens for better control, and later moved on to their intended final location.

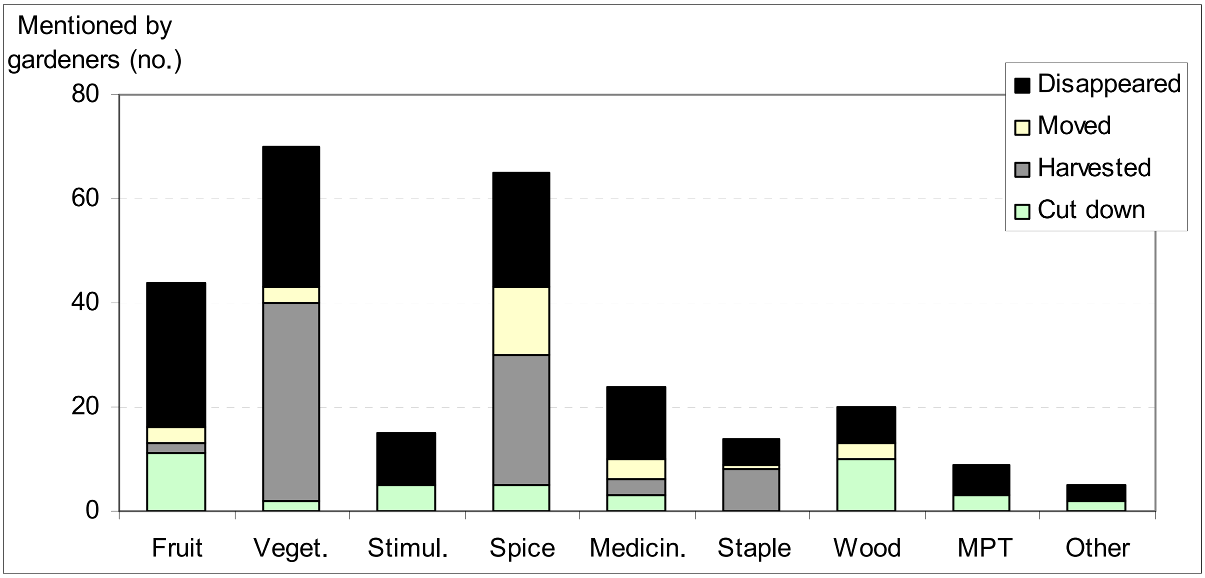

Figure 3.42. Reasons given by gardeners for the decrease of crop species number in different use categories in 30 homegardens in three villages of the Napu valley, Central Sulawesi, from 2001 to 2004.

3.10.4 Soil quality

As expected, sand contents of all homegardens did not change over time (Table 3.40), indicating that soil samples of 2001 and 2004 were comparable despite slightly different approaches for soil sampling in 2001 and 2004 (see 2.6.1). For all 26 homegarden soils analysed in 2001 and 2004, both N and C contents decreased markedly over time. When villages were analysed separately, only the N decrease in Siliwanga was significant, due to reduced sample sizes of only eight to ten homegardens per village.

Table 3.40. Changes of median sand, N, and C contents (ranges in brackets) of topsoil (0–15 cm) of 26 homegardens in three villages of the Napu valley, Central Sulawesi, from 2001 to 2004. N = 10 in Wuasa, N = 8 each in Rompo and Siliwanga.

		Sand content (%)	N content (%)	C content (%)
Wuasa	2001	68.5a (47.0–87.0)	0.16a (0.11–0.19)	2.00a (1.27–2.23)
	2004	67.0a (48.0–86.0)	0.13a (0.11–0.19)	1.72a (1.32–2.65)
Rompo	2001	50.0a (33.0–67.0)	0.20a (0.13–0.29)	2.33a (1.63–3.35)
	2004	46.5a (32.0–71.0)	0.18a (0.08–0.27)	2.24a (1.10–3.21)
Siliwanga	2001	49.5a (42.0–56.0)	0.26a (0.18–0.35)	3.07a (2.62–4.48)
	2004	50.5a (43.0–58.0)	0.22b (0.16–0.34)	3.00a (2.49–4.67)

Medians are given because variables were not normally distributed.

Medians within a column and between years per village followed by different letters are significantly different at $P \leq 0.05$.

Over time, pH (H_2O) did not change, whereas pH ($CaCl_2$) decreased significantly for all homegardens (Table 3.41). When villages were analysed separately, only in Wuasa a significant decrease of pH ($CaCl_2$) was detected. Although median available P contents decreased over time in all villages, changes were not significant, because in nearly 40% of the homegarden soils P-Olsen contents increased from 2001 to 2004 (possibly due to fertilising).

Table 3.41. Changes of median pH values and available P content (ranges in brackets) of topsoil (0–15 cm) of 26 homegardens in three villages of the Napu valley, Central Sulawesi, from 2001 to 2004. N = 10 in Wuasa, N = 8 each in Rompo and Siliwanga.

		pH (H_2O)	pH ($CaCl_2$)	P-Olsen (ppm)
Wuasa	2001	6.1a (5.3–6.5)	5.7a (4.9–6.3)	71a (34–96)
	2004	5.7a (5.3–6.8)	5.2b (4.8–6.2)	56a (24–118)
Rompo	2001	5.4a (4.7–5.8)	5.0a (4.2–5.7)	35a (8–77)
	2004	5.6a (4.9–5.8)	5.1a (4.3–5.4)	32a (5–106)
Siliwanga	2001	5.0a (4.5–6.5)	4.8a (4.1–5.2)	15a (11–21)
	2004	5.6a (4.8–5.8)	4.8a (4.3–5.2)	10a (5–25)

Medians are given because variables were not normally distributed.

Medians within a column and between years per village followed by different letters are significantly different at $P \leq 0.05$.

4 Discussion

4.1 Are the homegardens socio-economically sustainable?

Concerning socio-economic conditions, a sustainable agricultural system should be able to maintain its productive capacity by continuously yielding adequate amounts of diverse and valuable crops suitable for meeting both subsistence and cash needs of the farmer's household (GLIESSMAN, 1990a; HUXLEY, 1999; TORQUEBIAU, 1992). To maintain this productivity, endogenous, locally available and renewable inputs instead of exogenous, purchased inputs should be used. Besides, a sustainable system should enhance social and gender equity, traditional knowledge, and cultural integrity. Negative impacts on the environment as well as on the community should be small or even negligible. In the following, labour investments in the homegardens studied as well as inputs such as planting material, fertiliser, and pesticides, and outputs were valued according to the sustainability criteria mentioned above.

4.1.1 Labour investments

In a sustainable agricultural system, labour inputs should be rather small, well spread over the year and flexibly allocated (TORQUEBIAU, 1992). Besides, family labour instead of external, cash-demanding hired labour should be used. In the homegardens studied, median daily labour input was as small as 2–4 min. per 100 m^2 garden area (range 0.4–20 min./100 m^2), being rather low in the large migrant homegardens of Siliwanga (see 3.4.1, Table 3.1), many of which had a weedy appearance (see Figure 3.21b and Figure 3.31a, b). As a tendency, labour input seemed to increase with decreasing garden size (due to more intensive production) and with increasing proportion of the ornamental zone. Concerning the three case study homegardens, daily labour input was 13 min./100 m^2 in the small spice garden, but only about 5 min. in the large fruit tree and the very large migrant garden (see 3.8.1).

Labour input in the homegardens studied is comparable only to some of the very variable levels given in the literature. Mean daily labour inputs per 100 m^2 vary from about 1 min. (DASH & MISRA, 2001), 2–4 min. (ALI, 2005), 9 min. (MÉNDEZ et al., 2001), and 5–10 min. (TRINH et al., 2003) to as much as 11–28 min. (HODEL et al., 1999), 25 min. in very small urban gardens of Peru (NIÑEZ, 1985), or even 9–77 min. in intensively managed Javanese homegardens (STOLER, 1978). Higher labour input was said to occur in small as compared to large gardens (HODEL et al., 1999; STOLER, 1978) as well as in commercial as compared to subsistence gardens (ALI, 2005; TRINH et al., 2003). Based on their very low median labour input as compared to the literature, homegardens in the Napu valley could be rated as rather extensively managed.

Daily working time allocation of homegardeners in the Napu valley concerning agricultural tasks was recorded only for the three case study households. The two local families allocated 7% of their total daily working time to homegardening, the migrant family 15% (see 3.8.1, Figure 3.25). For two families, working in their paddy rice fields accounted for about 65% of their time, whereas for the third family, cooperative work as well as cultivation of the plantation were most time consuming (about 33% each of the total time). A rather small proportion of total working time used for homegardening is mentioned also for other regions in Indonesia. In Java, ACHMAT et al. (1978) in SURYANA & SIMATUPANG (1992) recorded 5.5% of the whole family labour used for gardening, STOLER (1978) reported a portion of 8% of men's working time.

Gender division in homegardening

In the Napu valley, main managers of homegardens with regard to labour input were mostly not the household heads, but their wives, apart from the migrant villages (see 3.4.1, Table 3.1 and Table 3.3). A more detailed analysis of the different responsibilities of male and female household members revealed different tasks according to sex. Females mostly managed vegetables, spices, medicinal plants, and ornamentals, whereas males were responsible for fruit trees and cash crops such as coffee and cacao (see 3.4.1, Table 3.4). Thus, in homegardens dominated by subsistence crops, females did most of the work, but in fruit tree and cash crop dominated homegardens, women contributed only little work. Such a clear gender division in homegarden responsibilities is frequently recorded in the literature, e.g. for Indonesia (ACHMAT et al., 1978, cited in CHRISTANTY, 1990), Vietnam (TRINH et al., 2003), Mexico (ALVAREZ-BUYLLA ROCHES et al., 1989; DEL ANGEL-PÉREZ & MENDOZA B., 2004; different sources in HOWARD, 2006), Peru (NIÑEZ, 1985), and Guatemala (AZURDIA & LEIVA, 2004).

In addition to specific crop use categories, gender division was also recorded concerning specific working tasks. In the Napu valley, females did most of the hoeing, planting, weeding, fertilising, and harvesting, whereas males did the spraying and pruning (see 3.4.1, Table 3.3). However, in the cash crop dominated migrant homegardens of Tamadue, males also did much of the fertilising, planting, hoeing, and weeding. Dominance of females in hoeing, weeding, and harvesting, but of males in pruning and hard work such as preparing the land is stated also in the literature (e.g. TCHATAT et al. (1996) for Cameroon, RUGALEMA et al. (1994) for Tanzania, BENNETT-LARTEY et al. (2004) for Ghana). A rather equal division of labour between male and female household members without giving more detailed information is reported from Java, Indonesia (ANDAYANI, 1988, cited in SURYANA & SIMATUPANG, 1992), Vietnam (HODEL et al., 1999), Nicaragua (MÉNDEZ et al., 2001), and Martinique (KIMBER, 1966). However, in some regions, homegardens are said to be managed mainly or even exclusively by females, e.g. in Bangladesh (ALI, 2005; OAKLEY, 2004; OAKLEY & MOMSEN, 2007), Thailand (MORENO-BLACK et al., 1996), Nepal (SHRESTHA et al., 2004), Yemen (CECCOLINI, 2002), or Tanzania (RUGALEMA et al., 1994). In contrast, dominance of males in homegardening is reported only from India (DASH & MISRA, 2001).

Overall, homegardens of the Napu valley can be rated as socio-economically sustainable with regard to labour input. The homegardens studied were managed exclusively by family members, who were mostly following traditional roles in labour division between males and females. The work input in homegardens as compared to other agricultural tasks was regarded as rather small, not very heavy, and having no labour peaks. Instead, gardening was done continuously year-round and was allocated in a quite flexible manner, a feature also described frequently in the literature (ALVAREZ-BUYLLA ROCHES et al., 1989; CHRISTANTY et al., 1986; HVOSLEF, 1994; KIMBER, 1966).

4.1.2 Utilisation of internal and external inputs

Planting material

Concerning the input 'planting material', the homegardens surveyed can be rated as sustainable. Homegardeners obtained about 85% of their planting material for free from locally available sources, mainly from gardens and fields of their own, from their friends and relatives, or from other people as well as from the natural vegetation or inherited from the previous garden owner (see 3.4.1, Figure 3.4). Using locally produced instead of purchased planting material ensures that these species and varieties are suitable for the local agro-ecological conditions and do not require much control of the environment by, for example, applying pesticides. Only about 8% of the planting material was of external, purchased origin. However, the main reason for buying the material mostly was consumption, and only seeds or remnants, otherwise thrown away, were used for planting. Planting material received from projects (7% of the total material) mainly contributed to the diversity of few exportable and marketable crops, e.g. tea, cacao, improved varieties of mandarin or arabica coffee. However, the sustainability of such impacts could be discussed controversially. For example, the promoted cash crops tea and coffee declined tremendously in prices and were, thus, often abandoned or cut down, not only in homegardens but also in plantations. Vegetable crops distributed as seeds by CARE International Indonesia (see 3.10.3) for homegarden cultivation failed to produce seeds for the next growing season. Gardeners that received improved mandarin varieties were not informed that the grafted seedlings needed special pruning. As a consequence, water sprouts and branches of the root stock (*Citrus medica*, bearing only low valued, acid fruits) were not cut back and, thus, suppressed branching and fruiting of the scion.

Many scientists have stated that the main source of planting material in homegardening is obtained from previous crops or exchanged with relatives and friends. In Peru, about 40% of the planting material was received for free from other villagers, 15–23% was obtained from swidden fields, and about 22% was bought (large portions principally for consumption, e.g. fruits) (BAN & COOMES, 2004). For Nepalese homegardens, SUNWAR et al. (2006) found that nearly 78% of the planting material was self-saved material, nearly 16% was purchased (particularly improved vegetable varieties), less than 5% was requested from neighbours, and only 1.4% was gathered in the forest. Proportions of purchased planting material were 6–8% in Cameroon (TCHATAT et al., 1996), 7–9% in Brazil (YAMADA & OSAQUI, 2006), 6–17% in Cuba (CASTIÑEIRAS et al., 2002), or 4–21% and 13% in Bangladesh (MILLAT-E-MUSTAFA et al., 2000 and OAKLEY & MOMSEN, 2007, respectively). Other authors stressed that own or planting material exchanged for free were the main sources without giving exact proportions, e.g. WINKLERPRINS (2002) for urban homegardens in Brazil, SHRESTHA et al. (2002) for Nepal, and FERNANDES et al. (1984) for Tanzania. However, in an urban setting, purchased planting material might be the most important source, as documented by GEBAUER (2005), who recorded 67% of the fruit tree species grown in urban homegardens of El Obeid (Sudan) as bought from local nurseries.

The importance of self-established and wild plant species in homegardens is frequently mentioned in the literature. In South Africa, for example, a mean of 3.4 'cultivated' crop species, but 4.5 wild (i.e. occurring spontaneously) vegetable species were grown in homegardens, the latter accounting for 31% of the total value of all homegarden products

(HIGH & SHACKLETON, 2000). For Kenya, BACKES (2001) reported a mean of more than nine indigenous, but only about two ‘exotic’ tree species in old homegardens. As much as 28%, 32%, or 45% of all plants found in homegardens in Martinique, semi-arid Mexico, and Puerto Rico, respectively, were of spontaneous origin, but tolerated or even cared for (BLANCKAERT et al., 2004; KIMBER, 1973, 1966). These portions were much higher than the mean of 19% species occuring spontaneously in homegardens of the Napu valley (see 3.4.1). Also other scientists reported rather low portions of plant species occuring spontaneously in homegardens, such as about 18% in humid Mexico (ALVAREZ-BUYLLA ROCHES et al., 1989), 6–14% in Peru (BAN & COOMES, 2004; PADOCH & DE JONG, 1991), or 7% in Brazil (YAMADA & OSAQUI, 2006). However, not all species occurring spontaneously are wild species, but also cultivated crops that germinated from seeds thrown away or spread by the mother plant. Protecting spontaneous species or even transplanting them from the wild is said to be a first step towards domestication of a wild species and can be observed as an ongoing process in many tropical homegardens (BAN & COOMES, 2004; ESQUIVEL & HAMMER, 1992; FU et al., 2003; KIMBER, 1978; MILLER & NAIR, 2006; MONTAGNINI, 2006; MORENO-BLACK et al., 1996; SMITH, 1996). This behaviour was also observed in the homegardens surveyed in the Napu valley, were some wild medicinal plants had been transplanted from the natural vegetation or protected after self-establishment in the garden (see 3.4.1 and 3.5.1). In addition to transplanting, several self-established wild tree species were tolerated as sources for fruits, vegetables, medicine, or fuel wood and timber. For Totonac homegardens in Mexico, DEL ANGEL-PÉREZ & MENDOZA B. (2004) found that mostly women played an important role in the conservation of wild forest species for medicinal, food, or ritual uses, whereas men more often tried out the suitability of exotic, commercial field crops in homegardens. One reason for protecting and cultivating useful wild species in homegardens is to evaluate their potential as a future crop, as described, for example, by LEIVA et al. (2002) for the weedy vine *Fernaldia pandurata* that is now increasingly grown as a food and cash crop in homegardens of Guatemala. Another reason for protecting or transplanting of wild species, also given by Napu gardeners, is to have a rare wild species just available when needed, particularly for medicinal plants or in areas largely deforested (FU et al., 2003; MORENO-BLACK et al., 1996).

A sustainable system is characterised not only by low dependence on external inputs and high adaptation to local conditions, but also by long-term maintenance of productive capacity (GLIESSMAN, 1990a; TORQUEBIAU, 1992). In homegardens, domestication of wild plant species as well as conservation and evolution of crop species might help to maintain the long-term productivity of the whole agricultural system. Domestication, as mentioned above, contributes by exploiting new food and income sources simultaneously with reducing the pressure on natural populations, including the conservation of rare wild species (MORENO-BLACK et al., 1996). Conservation and evolution of crop species, on the other hand, is caught in part by extensive exchange of planting material by gardeners (see above). As stated by COOMES & BAN (2004), such exchange also enhances the overall plant diversity in homegardens.

Germplasm exchange in homegarden systems takes place at different levels (BENNETT-LARTEY et al., 2004; FUNDORA MAYOR et al., 2004). Exchange between homegarden and fields of the same owner is the lowest level because mostly the same species and varieties are exchanged. However, homegardens can play a major role in safeguarding and propagation of planting material used for transplanting to fields or plantations, particularly in regions with distinct seasons such as dry or flooding periods (COOMES & BAN, 2004). The protected and easily controlled environment of homegardens offered also a place for detecting, selecting, and multiplying new varieties that might increase crop-genetic diversity (WILLIAMS, 2004). Exchange among gardeners of the same village, e.g. among friends and relatives might be of relative low importance, too, due to the similarity of exchanged varieties. However, FUNDORA MAYOR et al. (2004) stressed its role in restoring genetically eroded varieties.

A much higher level of germplasm exchange is the exchange between different villages that contributes substantially to crop genetic diversity, e.g. by introducing new species and varieties (FUNDORA MAYOR et al., 2004; KIMBER, 1978). Exchange of planting material with neighbouring villages is also said to be important for the maintenance of social networks (WINKLERPRINS, 2002). Although in general more material is exchanged within as compared to between communities (COOMES & BAN, 2004), many gardeners, including those of the Napu valley (see 3.4.1), readily take the opportunity of gathering planting material while travelling or visiting relatives (FU et al., 2003; MORENO-BLACK et al., 1996; SHRESTHA et al., 2004; WILLIAMS, 2004). Many authors have stressed the importance of homegardens as a kind of ‘experimental station’, where gardeners evaluate the suitability and special needs of gathered new species and varieties or where they even breed new varieties (e.g. DEL ANGEL-PÉREZ & MENDOZA B., 2004; MILLER & NAIR, 2005; MONTAGNINI, 2006; NIÑEZ, 1987; SHRESTHA et al., 2004; SMITH, 1996; WILLIAMS, 2004).

Other very high levels of germplasm exchange that increase genetic diversity are the flows from surrounding ecosystems (see above) and from the formal sector such as research institutions, development projects, or markets to the homegardens (BENNETT-LARTEY et al., 2004; FUNDORA MAYOR et al., 2004). The introduction of improved, mostly marketable species and varieties involves, however, also the danger of genetic erosion of local species and varieties (FUNDORA MAYOR et al., 2004; SUNWAR et al., 2006) as well as the overall shift in homegarden function towards commercialisation with its frequently negative consequences for plant species diversity (for more detailed discussion see 4.5). Additionally, many of these introduced species and varieties might reduce the overall sustainability of the homegarden system because they are less adapted to local environments, and their cultivation often requires the use of external, purchased inputs.

In summary, using mostly planting material of local origin and maintaining it in the homegardens surveyed contributed to the sustainability of the system. However, in the future this feature might be threatened by modernisation and commercialisation, as many gardeners rated their local varieties as inferior and wished to replace them with improved varieties (see 3.4.5). In the interviews, more than 20% of the gardeners rated the supply of improved planting material by development projects as most important for improving production in homegardens and other agricultural systems. The general suitability of homegardens for *in situ* conservation of plant genetic resources (of both wild and cultivated plants) is discussed in more detail in 4.6.

Fertiliser

In a sustainable agricultural system, inputs such as fertiliser should mostly be of endogenous origin and should help to ensure long-term maintenance of the soil quality. In the Napu valley, 0–20% of respondents in the local and 40–60% in the migrant villages stated to use industrial fertiliser (see 3.4.3, Figure 3.5), however, mostly in small amounts and only for fertilising cash crops. Nevertheless, some gardeners even reported to apply excessive amounts of industrial fertiliser (e.g. in garden no. 3: about 1600 kg NPK per ha and year, see Appendix 10) that in the future may cause environmental problems, such as water pollution. Much more often than for homegardens, industrial fertiliser was used for paddy rice fields (Figure 3.6). Migrants, as compared to locals, more often (and mostly in larger amounts, see 3.4.3) used industrial fertiliser on all field types, a finding also reported by BURKARD (2002a) for cacao plantations and by FAUST et al. (2003) for cacao (locals 8–10%, migrants about 50%) as well as paddy rice in the Napu valley.

No or nearly no use (less than 5% of the gardeners) of industrial fertiliser in homegardens is stated frequently in the literature (ALI, 2005; ALVAREZ-BUYLLA ROCHES et al., 1989; DASH & MISRA, 2001; FERNANDES et al., 1984; GAJASENI & GAJASENI, 1999; GEBAUER, 2005; KIMBER, 1966; MILLAT-E-MUSTAFA et al., 2000; RUGALEMA et al., 1994; SHRESTHA et al., 2004; TCHATAT et al., 1996). On the other hand, some authors reported that 5–40% of homegardeners used industrial fertiliser (DRESCHER et al., 1999; HVOSLEF, 1994; MÉNDEZ et al., 2001; OAKLEY, 2004). However, within homegardens, most of the industrial fertiliser is said to be mainly applied to cash crops (AZURDIA & LEIVA, 2004; DHARMASENA & WIJERATNE, 1996; HOCHEGGER, 1999; MÉNDEZ et al., 2001; PEYRE et al., 2006), as also recorded in the Napu valley.

Instead of purchased industrial fertiliser, many homegardeners in the tropics use endogenous fertiliser sources such as farm yard manure, ash and refuse from the kitchen, mulch, litter, and compost in different proportions (ALI, 2005; ALVAREZ-BUYLLA ROCHES et al., 1989; BENNETT-LARTEY et al., 2004; DRESCHER et al., 1999; FERNANDES et al., 1984; HVOSLEF, 1994; MILLAT-E-MUSTAFA et al., 2000; OAKLEY, 2004; RUGALEMA et al., 1994; SHRESTHA et al., 2004; TCHATAT et al., 1996; WINKLERPRINS, 2002). In the Napu valley, using such endogenous fertiliser sources was also common (see 3.4.3, Figure 3.5). However, its application could be further increased in some villages, particularly that of the largely available farm yard manure, used by only 20–50% of the gardeners (Figure 3.5). Mulching and using compost were almost unknown in the research region. Thus, a rather high potential for improving soil fertility management by the use of fertiliser sources locally available was detected for the homegardens surveyed. A similar situation of neither sufficient nor effective use of available resources due to lack of information and technical support has also been reported from Sri Lanka (DHARMASENA & WIJERATNE, 1996), Zambia (DRESCHER, 1996), Yemen (CECCOLINI, 2002), and many regions of Mesoamerica (MONTAGNINI, 2006) as well as from migrant settlements in Sumatra (HVOSLEF, 1994). BENJAMIN et al. (2001) further mentioned deterioration of soil fertility in Mexican homegardens due to the unfavourable habit of the owners to sweep and burn all litter, an activity also carried out daily in many of the homegardens surveyed in the Napu valley (3.4.1). This habit (together with insufficient fertilising) might be responsible also for the overall decrease of soil quality detected in the homegardens surveyed over time (see 3.10.4) that is discussed in more detail below (see 4.2). Over time, the use of industrial fertiliser increased only in the migrant village Siliwanga (see 3.10.2). Utilisation of ash increased over time in all villages, whereas that of farm yard manure increased only in Siliwanga, but decreased in the two local villages.

In the future, increasing (and partly excessive) use of industrial fertiliser seems to be probable, thus, reducing the sustainability of the homegardens. Increasing wealth status (natural fertilisers were rated mostly as resource of the ‘poor’ people), higher portions of cash crops (the typical ‘receivers’ of industrial fertiliser), and improved market access (paved road to the remote village Rompo completed in 2004 makes supply of agro-chemicals easier) might contribute to enhance the importance of industrial fertiliser at the expense of readily available endogenous fertiliser sources.

Pesticides

Concerning control of crop pests and diseases as well as weeds, a sustainable agricultural system should rely on endogenous, alternative methods basing on traditional knowledge, instead of using purchased inputs, such as synthetic herbicides, insecticides, or fungicides. In homegardens of the Napu valley, however, herbicides were already used by 75% of the local and 100% of the migrant gardeners (see 3.4.4, Figure 3.7). Nevertheless, still 96% of all gardeners also applied traditional methods for weed control. Insecticides were regularly used by 90% of the migrant gardeners in Tamadue, but only occasionally by 20–40% of the gardeners in the other four villages. In the local villages, many more gardeners carried out alternative methods for pest and disease control than in the migrant villages. A higher utilisation of pesticides by migrants (49%) as compared to locals (16–26%) was also recorded by FAUST et al. (2003) for cacao plantations in the Napu valley.

In the literature, most authors stated that no or nearly no pesticides (including, e.g. herbicides, insecticides, and fungicides) are applied in homegardens (ALI, 2005; ARIFIN et al., 2005; DHARMASENA & WIJERATNE, 1996; GAJASENI & GAJASENI, 1999; GEBAUER, 2005; OAKLEY, 2004; RUGALEMA et al., 1994; SHRESTHA et al., 2004). Low pest and pathogen infestation is said to be attributed to high species and genetic diversity as well as to the complex vegetation structure of homegardens and other multi-species agro-ecosystems that offer a habitat or conservation areas for beneficial organisms (see 1.3 and, e.g., DRESCHER, 1996; HOCHEGGER, 1998). If homegardeners used pesticides, they were applied mostly to cash crops (ARIFIN et al., 2005; AZURDIA & LEIVA, 2004; FERNANDES et al., 1984), a common habit also in the Napu valley (see 3.4.4). However, for homegardens of Zimbabwe, DRESCHER et al. (1999) documented already 100% pesticide use, for those of Zambia (DRESCHER, 1996) about 50–80% insecticide use, particularly in the commercialised periurban gardens. According to ABDOELLAH et al. (2006), utilisation of external inputs such as industrial fertiliser and pesticides was significantly higher in commercialised than in subsistence homegardens in West Java (application by 94% vs. 27% of gardeners).

In the Napu valley, the more frequent application of herbicides in homegardens as compared to insecticides could be explained by the rather high share of labour invested in hoeing and weeding (see 3.4.1, Table 3.2). Particularly in the migrant village Siliwanga, gardeners complained about time and labour force scarcity (households with rather few and/or small children) as well as about high infestation of homegardens with the very problematic weed *Imperata cylindrica* that is hardly to control by occasional hoeing only. Besides, many gardeners rated weeds as a severe problem, whereas pests and diseases were recognised rarely or only on cacao. Herbicides were easily available in the villages and, in contrast to insecticides, their application did not require much special knowledge. On other fields and plantations, spraying herbicides mostly also was more common than applying insecticides (see 3.4.4, Figure 3.7 and Figure 3.8). Leftover herbicides from field spraying were sometimes used for spraying homegardens even by gardeners that did not spray their gardens regularly.

In the future, application of pesticides might further raise, as the importance of cash crop cultivation is still increasing in the research area, even in homegardens (see 3.10.3 and 4.5). From 2001 to 2004, the number of homegardeners using pesticides already increased markedly (see 3.10.2 and Figure 3.37). Besides, 44% of the gardeners mentioned in the interviews that the supply of pesticides and sprayers by development projects would be one of the best approaches to improve production in both homegardens and other agricultural systems. However, about 20% of the respondents rated the supply of industrial fertilisers as most important, instead of pesticides. Due to the increasing use of pesticides, not only dependence on cash sources, but also the risk of endangering human as well as environmental health will further rise. No gardener used protective clothing while spraying, toxicity of pesticides was largely ignored, storing and disposal of pesticide remnants were mostly done in an irresponsible manner (pers. obs.).

In summary, sustainability of the homegardens studied regarding the use of purchased inputs industrial fertilisers and synthetic pesticides is already questionable and put at much more risk in the future, particularly in homegardens with emphasis on commercialisation. However, a detailed analysis of cash used to purchase such inputs (that is not yet carried out) would be necessary to further support this statement.

4.1.3 Outputs

In a sustainable agricultural system, outputs should be diversified and obtained in an efficient manner rather continuously throughout the year (GLIESSMAN, 1990a; HUXLEY, 1999; TORQUEBIAU, 1992). In addition, produce should be of high nutritional value and useful to meet both subsistence and cash needs of the farmer's family. Concerning socio-cultural functions, produce should give farmers the opportunity for exchange and interactions within their communities and for preserving their traditional habits and beliefs. A certain flexibility concerning kind and amount of homegarden produce might be postulated to react to changing needs of the gardener's household.

Homegardens in the Napu valley proved to fulfil many of these conditions. Gardeners obtained very diverse produce from their homegardens, ranging from fruits, vegetables, spices and some staples to medicines, stimulants, beverages, fodder, tools, toys, fuel wood, and timber (see 3.5.1). Some plants had cultural rather than productive functions, e.g. to prevent evil spirits from entering the garden and the house or for sacrifices in the Balinese households. In general, the nutritional value of the harvested products, particularly of fruits, vegetables, and spices, could be regarded as high concerning minerals, vitamins, and partly protein, but energy contents seemed to be quite low. Most of the produce was available year round and often harvested daily, apart from some seasonal fruit species (see 3.8.1). Exchange of produce and planting material played an important role for many gardeners (see 3.4.1 and 3.4.6). However, the amount of homegarden produce for both family consumption and sale seemed to be rather small, but this statement was mainly based on qualitative data. Concerning the three case studies, where quantitative data were assessed during a short time period of only 15 days each, the importance of the gardens was rather high. For example, the family managing the small spice garden obtained 100% of their cash income during the observation from their homegarden (see 3.8.1). The migrant family covered 76% of the value of their daily food needs (apart from the staple crop rice and beverages) by homegarden products. Unfortunately, the efficiency of the homegarden production could not be assessed because detailed quantitative data on both input and output were not available.

A rather low contribution of homegarden produce to the family's total income, comparable to the 3–10% obtained in the Napu valley (see 3.2), is also reported from some other regions in Indonesia. For example, ARIFIN et al. (2005) stated that only 1–7% of the household income was obtained from West Javanese homegardens. Migrants in Sumatra achieved 4–20% of their total income from homegarden products (HOLDEN & HVOSLEF, 1995). However, in other Indonesian regions, higher portions of income gained from homegardens were observed, e.g. 9–24% (ACHMAT et al., 1980, cited in CHRISTANTY et al., 1986), 22–27% (STOLER, 1978), or even 49% (PENNY & GINTING, 1984, cited in SOEMARWOTO & CONWAY, 1992).

For other tropical regions, a high variability of cash income received from homegarden produce has also been recorded, e.g. 0% in Sudan (GEBAUER, 2005), 18% in Guatemala (LEIVA et al., 2002), 35% (range 0–100%) in Nicaragua (MÉNDEZ et al., 2001), 52% in Bangladesh (ALI, 2005), 4–54% in Vietnam (HODEL et al., 1999; TRINH et al., 2003), and as much as 60% in Nigeria (LAGEMANN, 1977, cited by OKIGBO, 1990). The portion of income obtained from homegardens is said to be smaller in regions with rather poor market access, in rich households, or in commercialised homegardens (ACHMAT et al., 1980, cited in CHRISTANTY et al., 1986; ALI, 2005; ARIFIN et al., 2005). However, TRINH et al. (2003) reported a higher portion of cash income in market- than in subsistence-oriented homegardens. The latter statement agrees with findings from the Napu valley, where cash-oriented homegardens contributed markedly more to the total income than subsistence-oriented ones (see 3.2).

Concerning the contribution of homegarden produce to the subsistence needs of the families managing it, quantitative data were said to be difficult to determine because gardeners normally do not register homegarden harvests in precise standard measures (NIÑEZ, 1987). In the Napu valley, most homegardeners also failed to estimate the amounts of homegarden produce used for family consumption (see 3.4.6). However, many quantitative output data are given in the literature. For example, SOEMARWOTO & CONWAY (1992) mentioned that in rural Indonesia about 15% of total food requirement was obtained from homegardens. Portions of the families' daily energy requirements covered by homegarden products were said to range from only 3–18% (ABDOELLAH et al., 1981, and OCHSE & TERRA, 1937, both cited in CHRISTANTY et al., 1986) to 9–38% (HOLDEN & HVOSLEF, 1995). Regarding protein requirements, homegarden products might contribute only 6–8% (DHARMASENA & WIJERATNE, 1996), 3–14% (ABDOELLAH et al., 1981, and OCHSE & TERRA, 1937, both cited in CHRISTANTY et al., 1986), or as much as 20–47% of the households' needs (HOLDEN & HVOSLEF, 1995). Contrary to the mostly rather low contribution to energy and protein supply, homegarden produce covers much of the recommended daily allowance for minerals and vitamins, e.g. 126% of vitamin A and 23% of vitamin C (HARYADI, 1977, cited in CHRISTANTY, 1990) or 6–77% of iron (different sources, cited in SURYANA & SIMATUPANG, 1992). In Bangladesh, families participating in a homegarden project increased both production of vegetables in their gardens and consumption of vegetables (TALUKDER et al., 2000), resulting in lower prevalence of children suffering from night blindness (due to vitamin A deficiency) or underweight as compared to a control group (MARSH, 1996). In Bangladeshi households without a garden, the risk of having a young child suffering from xerophthalmia was 2.1–3.4 times higher than in households with garden (COHAN et al., 1985). BLOEM et al. (1996) found that the vitamin A intake of Bangladeshi women was positively influenced by the number of cultivated crops in their gardens (resulting in dietary diversity), but only little by the amount of harvested products. An increased production and consumption of vegetables by participants of a garden project as compared to non-gardeners has also been reported from Senegal (REYNAUD et al., 1989). In Puerto Rico, sufficiency levels of energy, protein, and certain vitamin and mineral intakes of preschoolers improved with the number of crops cultivated in the homegardens of their mothers (IMMINK et al., 1981). Concerning monetary values of total homegarden produce, only few authors presented precise figures, e.g. nearly 7 $ per 100 m^2 and growing season in South Africa (HIGH & SHACKLETON, 2000) or 14 $/100 m^2 in Peru (NIÑEZ, 1985).

The advantage of homegarden produce to be continuously available was frequently mentioned in the literature (e.g. ALVAREZ-BUYLLA ROCHES et al., 1989; CHRISTANTY et al., 1986; KARYONO, 1990; KIMBER, 1966; MICHON & MARY, 1994; SOEMARWOTO & CONWAY, 1992). Besides, homegardens were said to contribute to food security by providing usually neglected food sources such as tuber crops in times of scarcity (CHRISTANTY, 1990; SOEMARWOTO & CONWAY, 1992). This feature was also found in the Napu valley, where gardeners presently used much of the staple tuber crops only as fodder, but mentioned their value for human nutrition if rice harvest would not be sufficient (see 3.5.1). Homegarden produce, including livestock and valuable timber, might also serve as a kind of insurance or saving for purchasing food or holding important ceremonies in times of need (MONTAGNINI, 2006; SOEMARWOTO, 1987). In the Napu valley, for example, pigs or even cattle raised in the homegardens were sold to pay for school fees, religious ceremonies, or medical doctor bills.

In summary, the homegardens surveyed could be rated as sustainable with regard to their outputs used for family consumption, cash income generation, or exchange within the community, although only few quantitative data were available to support this statement. However, there appeares to be much productive potential of homegardens not sufficiently exploited by the gardeners in the Napu valley.

4.2 Is soil quality in homegardens managed in a sustainable manner?

Maintaining soil fertility as basis for conservation of long-term productivity is widely accepted as one of the most important features of sustainable agricultural systems, thus, being frequently mentioned in the literature (HUXLEY, 1999; KUMAR & NAIR, 2004; TORQUEBIAU, 1992). These authors described different aspects of soil fertility maintenance, e.g. low rates of soil erosion, high soil organic matter content, low soil bulk density, high soil moisture content, and low soil temperature. In homegardens of the Napu valley, not all physico-chemical soil parameter could be rated as favourable. Particularly C content (that is directly related to soil organic matter content) as well as N and K contents were frequently too low (see 3.6.3 and 3.6.4), thus, most likely restricting the level of production, especially for N-demanding vegetables. Cacao production that was very important for gardeners as a source of cash income might also have suffered from low N and K contents of soil in cacao production zones, as already indicated by severe deficiencies of N and K detected in cacao leaves (see 3.6.6 and 3.7). The analysis of cacao leaf nutrient contents could not replace soil nutrient analysis, as only K contents of leaves were correlated to K contents of soil (see 3.7), a result consistent with findings of SCHAFFERS (2002). Some gardeners in the Napu valley initiated to improve unfavourable soil conditions by specifically fertilising certain crops (that, however, made soil quality assessment more difficult due to patchiness). For example, the migrant gardener of the case study homegarden improved the soil of his cacao zone markedly in terms of pH value and $CEC_{eff.}$ (see 3.8.3, Table 3.31); other gardeners regularly fertilised vegetable zones with ash, improving or at least maintaining soil pH values as well as available P and exchangeable cation contents (see 3.6.5, Table 3.25). For extremely P-deficient soils, like those of Tamadue (see 3.6.5, Table 3.21), industrial P-fertiliser may cautiously be applied in addition to measures for rising the availability of P in the soil (e.g. liming, adding organic matter). Nevertheless, unsuitable types of P-fertiliser should be avoided (e.g. Triple Super Phosphate on acid soils in Siliwanga).

C and N contents were markedly lower in vegetable than in adjacent cacao zones (Table 3.24). Considering the significant decrease in C and N contents over time (see 3.10.4, Table 3.40), crop production may become more constrained in the near future, particularly in Wuasa and Rompo, where C and N contents were already very low in many garden soils. Gardeners caused this alarming situation by insufficient soil quality management. For example, only about 20–50% of the gardeners in a village used farm yard manure as a fertiliser, although it was available to most of them (see 4.1.2). Many gardeners removed weeds including their roots for burning or depositing in garbage pits instead of using them for compost preparation. Soil quality deterioration was further accelerated by the habit of many gardeners to remove the litter layer by daily sweeping and burning, as mentioned in 4.1.2. Typical reasons given by the gardeners for this practice were keeping away snakes and insects from the house as well as their aesthetical perception. Sweeping and total weeding was carried out in all front gardens, in most vegetable and ornamental zones and also in some cacao or fruit tree zones. Together with frequent hoeing, particularly of vegetable and ornamental zones, this habit has contributed to severe soil erosion in some homegardens (see 3.8.3). Additionally, removing the litter layer and all weeds in non-shaded zones exposed the soil surface to direct sunlight that caused fairly high soil temperatures, particularly mean maximum temperatures (see Table 3.33 and Figure 3.30). High soil temperatures accelerate the breakdown and turn over rate of organic matter and mineralisation by soil microorganisms (SANCHEZ, 1976; SCHEFFER, 1998), thus, contributing to the lower C and N contents in vegetable as compared to cacao zones (see 3.8.3, Table 3.29 and Table 3.30 as well as 3.6.5, Table 3.24). However, if soil temperature exceeds the optimum for organic matter decomposition, its turn over rate may decrease, as observed by STEFFAN-DEWENTER et al. (2007) in cacao agroforestry systems of different shading levels in the same area of Sulawesi. They reported an increasing soil temperature with decreasing canopy cover, accompanied by decreasing rates of litter decomposition and abundance of certain soil arthropods. Cultivation of annual crops such as vegetables and spices on separate plots of homegardens seemed to reduce certain soil quality parameters over time much more than cultivation of perennials. A similar result was reported by DECHERT et al. (2004), who compared soil quality of maize fields and agroforestry plantations of different cultivation times in the same study region of Sulawesi. They revealed that C and K contents in maize fields decreased significantly over time, but did not change in agroforestry plots.

Contrary to maize cultivation, agroforestry was, therefore, regarded as sustainable by the authors, although soils of the agroforestry plots had significantly lower N and C contents as compared to adjacent primary forest plots. BRODBECK (2004) reported a similar situation when comparing soil quality in forest gardens and primary forest in the same region. In two of three study sites, soil C and N contents in forest gardens were 20–40% lower than those of adjacent primary forest. By comparing soil quality of sun- and shade-grown cacao in plantations adjacent to the Lore Lindu National Park, SIEBERT (2002) described lower soil organic matter and nitrate contents in the non-shaded than in the shaded plantations, due to lower litter production and significantly higher soil temperature in the non-shaded plantation.

Insufficient soil fertility management in homegardens of the Napu valley, however, also needs to be seen in the context of changing traditional land use in this region (see 2.1.3). The previously dominant shifting cultivation has been replaced by permanent agriculture such as paddy rice or upland maize fields as well as cash crop plantations only about 10–30 years ago (BURKARD, 2002b). Therefore, indigenous as well as newly arrived migrant farmers may not be familiar with appropriate sustainable land management practices. Concerning soil fertility management, for example, nearly 98% of the gardeners mentioned fertilising (related mostly to industrial fertiliser) as best measure to improve soil fertility (see 3.4.3). Only 8% of the gardeners referred to mulching, one gardener to growing cover crops in addition (see Appendix 10). No gardener mentioned deliberate crop rotation or mixed cultivation including leguminous crops as advantageous. Negative environmental consequences have similarly been documented for other cases of resettlement, e.g. in Ethiopia (WOOD, 1993), Tanzania (CHARNLEY, 1997), or Sumatra, Indonesia (HOLDEN & HVOSLEF, 1995).

In general, soil fertility in homegardens has been said to be maintained in the long-term due to, for example, dense soil cover by herbs and litter, low soil temperature, low nutrient export by harvested products, or close nutrient cycling as well as application of locally available fertilisers (GAJASENI & GAJASENI, 1999; DRESCHER et al., 1999; KUMAR & NAIR, 2004; MONTAGNINI, 2006; TCHATAT et al., 2004; WICKRAMASINGHE, 1992). Several authors emphasised particularly that dense herbal, litter, and root layers in multi-storied homegardens reduce soil erosion rates markedly (DEL ANGEL-PÉREZ & MENDOZA B., 2004; HOCHEGGER, 1998; JENSEN, 1993a; JOSE & SHANMUGARATNAM, 1993; KARYONO, 1990; SOEMARWOTO & CONWAY, 1991). However, some reports stated problems of soil deterioration and erosion due to insufficient management practices similar to those identified in the Napu valley. Soil erosion, partly caused by lacking vegetation or litter cover was reported from homegardens in Mexico (ANDRIST, 2003) as well as from Indonesia (HOLDEN et al., 1995; HVOSLEF, 1994). SOEMARWOTO (1987) pointed out that lack of litter caused high rates of soil erosion in homegardens dominated either by fruit and clove trees or by vegetables. Regular sweeping and removing of litter leading probably to a decline in soil fertility was observed in Indonesian urban homegardens (CHRISTANTY, 1990) as well as in those of Maya groups in Mexico (BENJAMIN et al., 2001). Declining soil fertility in terms of bulk density and C content was also reported from a South African homegarden (WICHERN et al., 2003). JENSEN (1993b) recognised negative nutrient budgets for N, P, K, Ca, and Mg in an Indonesian homegarden, partly related to insufficient fertilising and high nutrient export rates (e.g. by harvested products or leaching). In Sri Lanka, soil C and N contents were considerably lower in species-poor, commercialised homegardens as compared to extensively managed, forest-like ones (HOCHEGGER, 1998). DRESCHER et al. (1999) stated low soil C and N contents in homegardens of Zimbabwe, although soil fertility was found to be markedly lower in adjacent annual crop fields. Many authors suggested to improve soil fertility management in homegardens, e.g. by promoting the utilisation of farm yard manure (HVOSLEF, 1994; RUGALEMA et al., 1994); by mulching and composting organic residues (BENJAMIN et al., 2001; JENSEN, 1993b; MONTAGNINI, 2006); by growing leguminous cover crops (also against soil erosion) (HVOSLEF, 1994); or by a general claim for better extension services (DRESCHER, 1996).

Spreading of partly non-biodegradable household waste materials in homegardens might cause a new problem affecting long-term soil quality and, consequently, productivity of the system. This has never been mentioned in the homegarden literature. Due to lack of opportunities for waste disposal, many gardeners in the Napu valley spread all garbage on the soil of the backyard, others used their homegardens for burying it in garbage pits, or they simply threw it into the pond (pers. obs., see Figure 4.1). Due to increasing wealth status and market access, this garbage consisted of more and more non-biodegradable items such as glass and plastic bottles, tins, plastic bags, broken plastic toys, household appliances and electronics, as well as old batteries. Mixed with organic wastes from the kitchen, this garbage formed the 'litter' layer in many backyard gardens. This practice will probably cause soil contamination in the near future. On the other hand, the traditional spreading of biodegradable waste on homegarden soil certainly contributes to better nutrient cycling and reduces soil erosion. Thus, proper waste recycling in homegardens has often been mentioned as a positive feature in the literature (MONTAGNINI, 2006), particularly in urban or peri-urban settings (DRESCHER et al., 2006).

Figure 4.1. An example for waste disposal in homegardens. Here, garbage was thrown into a pond in a garden in Tamadue, Napu valley, Central Sulawesi, 2004.

In summary, the homegardens surveyed did not seem to be managed in a sustainable manner in terms of soil quality maintenance, particularly concerning C and N contents. Efficient use of locally available fertilisers should largely be improved, utilisation of compost, mulch, and leguminous cover crops should be promoted. Application of industrial fertiliser in an excessive (see 4.1.2) or inadequate manner ought to be avoided. Simultaneously, unfavourable habits such as removing the litter layer by sweeping or frequent hoeing should be given up as a result of explaining the gardeners their disadvantages. Extension services might play a major role in this effort. Similar suggestions were made by several scientists that claimed for improving soil fertility management in homegardens (see above).

4.3 Is the resource 'light' used efficiently in homegardens?

In a sustainable agricultural system, light should be used efficiently by several vegetation layers to increase the overall yield (TORQUEBIAU, 1992). A multi-storied vegetation structure further contributes to sustainability, e.g. by adding litter and reducing soil erosion as well as soil temperature (see 4.2), thus, it plays a role in maintaining soil fertility. In addition, a complex vegetation structure offers a habitat for wild flora and fauna, including rare and endangered plant species (see 4.6) as well as beneficial organism such as birds and insects for crop pest control (see 4.1.2). Consequently, homegardens with only few vegetation strata were rated as less sustainable than those with a complex, multi-layered structure (CECCOLINI, 2002; HOCHEGGER, 1998).

In the Napu valley, vegetation was stratified into at least four strata in most of the homegardens surveyed (see 3.5.2). However, complexity of the vertical structure differed among gardens. The strata of more than 5 m height were often reached by low or very low portions of species (see Figure 3.17) or individuals, respectively. Particularly in the migrant village Siliwanga, the higher vegetation strata were only sparsely or even not occupied, possibly due to the relative young age of the gardens or the poor soil conditions (see 3.6). Rather small homegardens, e.g. those of cluster 4 (see 3.5.4, Figure 3.20) mostly lacked the upper stratum (i.e. more than 10 m height), not only in 2001 (KEHLENBECK & MAASS, 2004), but still in 2004. On the other hand, the lowest stratum of plants (< 1 m height) was rather poorly developed in the large, cash crop dominated homegardens of cluster 1 that harboured only few vegetables and spices (see 3.5.4, Figure 3.19).

Measurement of Photosynthetic Active Radiation (PAR) in the three case study gardens revealed differences in light use efficiency by the vegetation (see 3.8.4). In the small spice garden, light was efficiently used in the fruit tree zone, where only 17% of the total light reached the herbal layer of 0.3 m height (see Table 3.35). However, the cacao zone received much light (96%) at the top of the cacao trees and, at the same time, let much light through (30%) that was not used at the ground due to the mostly bare, regularly swept soil. Shading of cacao was highly recommended as photosynthesis of cacao leaves occurs at rather low rates, even under full sun light (HARDY, 1958). Shading of cacao is said to reduce nutritional imbalances and buffer adverse climatic conditions (BEER et al., 1998; MIYAJI et al., 1997). The authors mentioned suggested that the optimal shading for cacao trees should be 40–70% of full light. Therefore, shading of cacao only seemed to be optimal in the fruit and the migrant gardens with 40% and 62% of full light in 3 m height, respectively, but not in the spice garden. In the cacao zone of the migrant garden, however, only 2% of the full light reached 0.3 m height, resulting in a very sparse herbal layer of only scattered weedy plants. The high density of cacao trees in this garden did not allow an efficient use of light by growing shade-tolerant crops in the lowest layer. Besides, in too heavily shaded cacao, outbreaks of severe diseases such as *Phytophthora* pod rot are enhanced (BEER et al., 1998; MIYAJI et al., 1997). In contrast, the lowest layer in the fruit tree garden was reached by 15% of total light (see Table 3.35), thus, enabling cultivation of shade-tolerant taro, cocoyam, and *Helioconia* under some of the cacao trees. When comparing sun- and shade-grown cacao, SIEBERT (2002) suggested that about 5–15% of full PAR reaching 1 m height was optimal for meeting both soil fertility maintenance (by low soil temperature) and overall productivity (by cultivation of some useful plants under the cacao trees).

In the fruit garden, light was also efficiently used in the vegetable zone because still 25% of the full light reached the lowest layer, where ginger and other spices were grown between some maize and climbing french bean plants. In the cassava zone of the migrant garden, however, light was not used efficiently. More than 50% of full light reached 1.3 m and 0.3 m (see Table 3.35), but only very dense weedy plants were found in the herbal layer (see Figure 3.31). However, the poor soil conditions in the backyard of the migrant garden (see Table 3.31) might have limited the cultivation of other crop species. Finally, PAR data presented in this study might not be representative for the three homegardens studied because, due to time scarcity, measurements were carried out only at a single spot per production zone (see 2.8.3), instead of moving around the equipment in the whole zone to allow calculation of means.

Vegetation structure in homegardens has been mostly described as consisting of 3–5 strata and resembling a forest (ALBUQUERQUE et al., 2005; DAS & DAS, 2005; HEMP, 2006; JOSE & SHANMUGARATNAM, 1993; MICHON & MARY, 1994; NIÑEZ, 1987; SOEMARWOTO & SOEMARWOTO, 1982; WICKRAMASINGHE, 1995). However, neither tree height nor species diversity or structural complexity of a homegarden might reach the respective levels of primary forests (GAJASENI & GAJASENI, 1999; HOCHEGGER, 1998). In the homegardens surveyed in the Napu valley, tree height with a maximum of about 15 m (personal observation) was far below the 35 m and even 50 m reported for emergent trees in primary forests of the Lore Lindu National Park by KESSLER et al. (2005) and BRODBECK (2004), respectively. Also, species richness and diversity were much lower in homegardens as compared to primary forests (see 4.4). Consequently, JENSEN'S (1993a) statement that homegarden structure rather resembles a young secondary forest, kept in a permanent early successional stage, might be more applicable.

Many authors argued that light is used efficiently by the multi-layered structure in homegardens, e.g. by cultivating rather few very tall species in the highest layers (to avoid excessive shading) and shade-tolerant crops such as ginger, taro, cocoyam, and pineapple in the lowest stratum (DE CLERCK & NEGREROS-CASTILLO, 2000; ESQUIVEL & HAMMER, 1992; JOHN & NAIR, 1999; KARYONO, 1990; MILLAT-E-MUSTAFA et al., 1996; OKAFOR & FERNANDES, 1987; SHRESTHA et al., 2002). However, only few scientists have carried out light intensity measurements in homegardens to prove efficient light utilisation. ALLISON (1983, cited in GLIESSMAN, 1990b) documented a rather low light transmission of only 21% in a tree-rich, but 31% in a tree-poor homegarden in Mexico. In a homegarden of West Java, CHRISTANTY (1981, cited in CHRISTANTY et al., 1986) measured only 6% of light reaching the bottom layer (i.e. less than 1 m height), where, however, photosynthetic rates were partly still as high as in the upper strata. GAJASENI & GAJASENI (1999) reported continuously decreasing light intensities from crown to ground levels in three homegardens of Thailand, where the ground level was reached on average over one day by 84% of the full light in a species-poor, but by only 33–41% in a species-rich garden. In three multi-storied homegardens in Guatemala, GILLESPIE et al. (1993) measured on single spots at the ground 45–50% of the PAR in full sun; however, on average over the whole transect area, only 7–14% of the PAR reached the ground. Thus, results of PAR measurement at ground level in three homegardens of the Napu valley corresponded well with data from the literature, although measurements were carried out only for few days at a single spot per production zone (see above). In cacao zones of the fruit and the migrant homegardens, PAR at ground level was similar or even less as compared to 11.5–14% of full light reported by BRODBECK (2004) at the same height in two forest gardens in the same region of Sulawesi. However, PAR at 3 m height was much higher in all cacao zones surveyed (40–96%) as compared to that in the forest gardens (less than 23%). For primary forests, BRODBECK (2004) documented quite low PAR at ground level (only about 1% of full light) as well as at 4.5 m height (about 3%). Thus, contrary to many statements in the literature, the homegardens surveyed were not comparable to adjacent forests concerning not only tree height and species diversity (see above), but also concerning light use efficiency.

A decrease in complexity of vegetation structure similar to that observed in certain homegardens of the Napu valley (i.e. less complex in small or cash crop dominated homegardens, see above) was similarly observed by other scientists. ARIFIN et al. (1998) as well as ABDOELLAH et al. (2002) found that the upper strata (i.e. more than 5 m height) were mostly lacking in small homegardens. In Kerala, India, most of the trees in small homegardens were less than 5 years old, whereas in large homegardens 10–15 year old trees dominated (JOSE & SHANMUGARATNAM, 1993). ABDOELLAH et al. (2006) reported that only about 6% of the cultivated species reached the stratum higher than 10 m in small Javanese homegardens with a mean size of 270 m^2. HOCHEGGER (1998), on the other hand, noted as much as 32% of the cultivated species in the strata above 10 m for very large (mean size about 5,000 m^2) homegardens in Vietnam. Besides size, also commercialisation of homegardens was said to influence the complexity of vegetation structure negatively (CHRISTANTY et al., 1986; HOCHEGGER, 1998). The type of cash crop (annual or perennial) determines which vegetation strata will impoverish. JOHN & NAIR (1999) claimed that perennial cash crops in homegardens dominate on the expense of vegetable crops in the lowest stratum. A similar observation was made in the cacao- and coffee-dominated homegardens of cluster 1 in the Napu valley (see above). However, when annual, light-demanding cash crops predominate, homegardens lack the upper strata as a consequence of removing for example tall forest trees or minor fruit tree species to avoid shading (ABDOELLAH et al., 2006; CECCOLINI, 2002; MICHON & MARY, 1994). In homegardens of the Napu valley, also high altitude might have contributed to the rather poorly developed upper vegetation strata, as similarly reported from other regions. SHRESTHA et al. (2002) noted no or very few trees in highland homegardens of Nepal, referring, however, to very high altitudes of more than 3,000 m asl. In West Java, homegardens at altitudes of more than 1,300 m asl. were dominated only by vegetables (grown mostly as cash crops), whereas those in the lowlands by fruit trees (ARIFIN et al., 2005; KEHLENBECK et al., 2007).

Finally, results of vertical structure analysis suggested that not all homegardens surveyed in the Napu valley fulfilled the sustainability requirement/characteristic of maintaining a multi-layered structure. In the large cacao- and coffee-dominated migrant gardens, light use efficiency could be improved by cultivating more shade-tolerant herbal crops in the lowest stratum, accompanied by slightly reducing the density of cacao and coffee trees in some gardens. On the other hand, in the small gardens as well as in most of the separate vegetable zones of medium-sized ones, structural complexity could be increased by integrating some suitable tree crops. In the future, the observed trend towards more cash crops (see 4.5) might further threaten the sustainability of the homegardens surveyed in terms of structural complexity. As example from the research area, Figure 4.2 shows extreme impoverishments of the vertical structure in homegardens as an ultimate consequence of commercialisation.

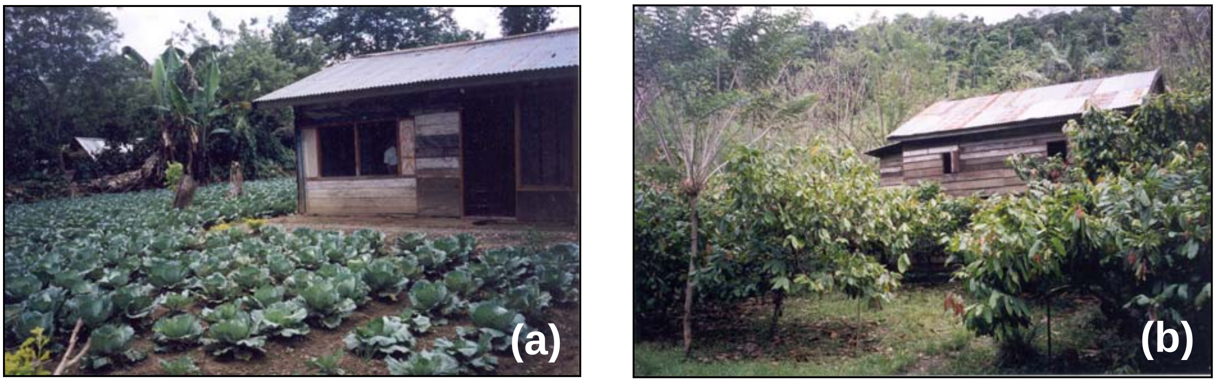

Figure 4.2. Highly commercialised homegardens lacking a multi-layered vegetation structure, managed by migrant families in the Napu valley, Central Sulawesi, 2004. (a) Cabbage garden in Tamadue. (b) Cacao garden with scattered shade trees, south of Wuasa. Note: These homegardens were not included in the sample gardens of this study.

4.4 How valuable and how variable is crop diversity in the homegardens?

Biodiversity, especially of useful plants, but sometimes also including wild plant species or even domestic animals, is frequently considered an important sustainability indicator of agro-ecosystems (GLIESSMAN, 1990a; TORQUEBIAU, 1992; TORQUEBIAU & PENOT, 2006). This is related to the contribution of agro-biodiversity to the overall agro-ecosystem functioning, presented in detail in 1.3. To briefly summarise, plant diversity is seen as a major factor towards sustainability and productivity of a system because it reduces the risk of attacks by pests or diseases and contributes to a favourable microclimate, efficient use of resources, year-round availability of diverse and valuable products, long-term stability of yields, provision of genetic resources for future crop development and improvement, and soil fertility maintenance, among others (SOEMARWOTO & CONWAY, 1992; TORQUEBIAU, 1992). Some of these attributes were not assigned to species diversity *per se*, but rather to a multi-layered structure (discussed in 4.3) or to the presence of certain keystone species or functional groups (NAIR, 2006). However, the strong influence of different factors on the state of crop diversity as well as its temporal changes (see 4.5) should be considered while assessing the sustainability of homegardens by using the indicator ‘biodiversity’.

In the Napu valley, crop species richness was high, as 206 species were cultivated in the 48 homegardens studied in 2004 (see 3.5.1). Many of these crops were grown as vegetable, medicine, fuel wood, fruit, or spice, few ones as staple, stimulant, or for multi-purpose- or other uses (see Table 3.6). Therefore, diverse homegarden crops provide a diverse range of valuable produce for fulfilling the daily needs (both for subsistence and cash) of gardeners and their families, as discussed in more detail in 4.1.3. It should be stresses that, in general, homegarden produce contributes much more to meet the demands of protein and micronutrients than that of energy because the respondents stated to consume rather fruits, vegetables, and spices from their gardens, whereas staple crops were mainly used as animal feed (see 3.5.1). However, the potential for production of neither subsistence nor cash crops was fully exploited in the homegardens of the Napu valley (see 3.4.6 and 4.1.3). Additionally, many gardeners did not recognise the high nutritional value of their homegarden products, stating that the nutrients contained in cooked white rice, served three times a day, already fulfilled completely their nutritional requirements. In many households surveyed, fruits and vegetables were consumed only in very small quantities. Parts of the homegarden produce was left unharvested (e.g. pummelo, water apple) or only fed to pigs (e.g. cassava, sweet potato, taro) in these households. According to the gardeners, this was partly due to relatively low food quality of some local varieties (e.g. fibrous or bitter citrus fruits), but mostly due to disregard and acculturation (e.g. tuber crops, the former main staple, are now replaced by white rice and only recognised as ‘food of the poor and the pigs’). Consequently, not only the homegarden productivity could be increased in the research area, as discussed in detail in 4.8, but also the awareness about the nutritional value of homegarden produce should be raised (see also 4.6).

Concerning medicinal plants, richness in this use category found in homegardens of the Napu valley was highly valuable, including not only the 30 species with a main medicinal use, but also 83 species with a secondary medicinal use (see Appendix 12) as well as 36 weed species regarded potentially useful as medicine (see Appendix 14). This high number of 149 medicinally usable plant species was associated with large indigenous knowledge about the utilisation of each single species. However, the traditional knowledge was not evenly distributed among the sample households. Older respondents were mostly still able to list many medicinal plants together with the respective applications and recipes, whereas younger gardeners often stated to know only little about such plants and to prefer ‘modern’ medicine (see 3.4.6). Thus, genetic as well as cultural erosion might threaten diversity of and knowledge about medicinal plants in the future due to the ongoing process of ‘modernisation’. On the other hand, awareness and appreciation concerning, for example, the conservation of medicinal plants and the related traditional knowledge could be raised by promotion and information campaigns as already observed in Wuasa, where the number of medicinal plants increased over time due to the activities by a development project (see 3.10.3 and Figure 3.40).

Varietal diversity was very high in the homegardens of the Napu valley, where altogether 329 species and/or varieties were cultivated (see 3.5.1). However, a high value, with regard to future development and improvement of crops, might be only assigned to rather few species with high numbers of varieties, e.g. banana, mango, chilli, and common eggplant, whereas 180 crop species (out of 206 spp.) only occurred with a single variety each (see Appendix 12). Future research concerning varietal diversity should, therefore, rather focus on such ‘key-species’. On the other hand, homegardens seemed to be the only production system for cultivation and reproduction of some varieties, particularly of staple crops. At the field level, for example, nearly exclusively improved varieties of rice were grown (i.e. 95% of the 40 different paddy rice plots cultivated by 49 respondent households were planted with improved varieties; pers. obs.). In contrast, the local rice variety 'mpulumaeta' (black-coulored seeds, having a very sticky cooking quality), used to make the local sweet 'onde-onde', was exclusively found in homegarden no. 45 in Wanga, but not in any of the paddy rice fields. Besides, the local maize variety 'pulut', used for making a special soup called 'binte', was grown in three homegardens, but was not mentioned by any of the respondents concerning the 22 maize fields cultivated by their households. Therefore, the homegardens studied showed to have a high value for *in situ* conservation of plant genetic resources, although this function might be threatened in the future, as discussed in more detail in 4.6.

As compared to other agro-ecosystems in the same research area, homegardens harboured a very high crop diversity. The homegardens surveyed covered on average only about 4% of the total agricultural farm land owned by the respondents' households in the Napu valley (see Appendix 4) (portion of homegardens in the whole STORMA research area: 7% of the total agricultural land, according to MAERTENS et al., 2002). Nevertheless, nearly all crop species cultivated in plantations and fields of the Napu valley were also grown in homegardens (pers. obs.). For many crops, on the other hand, homegardens seemed to be the most important production system, as they were only rarely found in fields or plantations of the region (pers. obs.). Homegardens should, thus, be appreciated as a key reservoir for cultivated plant species, important particularly as a source of planting material for plantations and upland fields (COOMES & BAN, 2004; NIÑEZ, 1987). In addition, also some of the wild plant species recorded for the research area were found in the homegardens surveyed (see 4.6). The high crop species richness of homegardens was only comparable to that of forest gardens in and around the same area of Sulawesi, where BRODBECK (2004) documented 183 crop and wild species on three plots of 1 ha size each. A similar total species richness of forest gardens (maximum no. about 140 spp.), however, only concerning tree species on 4 plots of 2,500 m^2 size each in the Napu valley, was estimated by KESSLER et al. (2005). For a simple agroforestry system in the same area (i.e. a cacao plantation, shaded by *Gliricidia sepium*), on the other hand, SCHULZE et al. (2004) reported only about 4 tree and 7 understorey plant species, for a maize field no tree and about 10 understorey plant species, however, determined on only 4 plots of 600 m^2 each. SIEBERT (2002) identified 17 plant species (mostly weeds) in a simple full-sun grown cacao plantation and 21 (mostly useful ones) in a more complex agroforestry system of about 1 ha sizes each, located around the research area. The superiority of homegardens to all other agro-ecosystems concerning their biodiversity has also been emphasised for other regions or even worldwide (COOMES & BAN, 2004; SWIFT & ANDERSON, 1993 in NAIR, 2006; WEZEL & OHL, 2005).

Plant species richness in homegardens of the Napu valley was comparable to those of other regions, when a similar sample size was considered (Table 4.1). If ornamentals were included in the Napu study, the combined species number of 368 (see 3.5.1) even exceeded many of the species numbers recorded for other regions. Particularly in African homegardens, the few studies available documented relatively low species richness as compared to Mesoamerican or Asian ones, possibly due to long dry periods in many parts of Africa, which are said to reduce crop diversity (see 1.4). In African regions of higher humidity, such as the slopes of Mt. Kilimanjaro, relatively high species diversity was recorded (HEMP, 2006), however, including many forest and weedy species (Table 4.1).

Table 4.1. Plant species richness in homegardens (including ornamentals, but excluding weeds, if not differently indicated) as total number per study area and/or mean per garden in different regions of the world. Garden sizes are given in means (ranges in brackets).

Country/ region	N	Elevation (m asl.)	Mean garden size (m^2)	Total spp. no.	Mean spp./ HG	Reference
Indonesia						
C Sulawesi	50	1100	600-2300	206[†]	33-49[†]	This study
W Java	94	1250	340	199	15-16	Abdoellah et al. (2006)
W Java	90	300-1300	190-560	–	27-44	Kehlenbeck et al. (2007)
W Java	351	0-1000	230	602[¶]	19-24[¶]	Karyono (1981) in Soemarwoto (1987)
W Java	41	–	–	272	56	Soemarwoto (1987)
Sumatra	68	–	2500	118[†]	–	Hvoslef (1994)
Asia without Indonesia						
Thailand	4	–	1590	–	34	Gajaseni & Gajaseni (1999)
Vietnam	100	<1010	3050	646[+¶]	68[+¶]	Hodel et al. (1999)
Vietnam	116	<100	1400-7500	202	23-54	Trinh et al. (2003)
Bangladesh	32	–	(100-2200)	86	10-32	Ali (2005)
Bangladesh	80	–	200-2000	92[††]	23[††]	Millat-E-Mustafa et al. (1996)
Nepal	134	100-1500	400	165[†]	31[†]	Sunwar et al. (2006)
S India	30	–	4800	132	27	Peyre et al. (2006)
S India	400	0-1500	3300	107[†]	15[†]	John & Nair (1999)
NE India	50	–	3000	122[‖]	20[‖]	Das & Das (2005)
Sri Lanka	158	<700	5250	640	53[†]	Hochegger (1998)
SW China	9	–	230	126	32	Fu et al. (2003)
Iran	80	0->1500	930	78[†]	7-18	Khoshbakht (2005)
Mesoamerica						
SE Mexiko	8	<400	(225-3400)	338	–	Alvarez-Buylla Roces et al. (1989)
SE Mexiko	40	300	–	223	45	Del Angel-Pérez & Mendoza (2004)
Cuba	31	–	875	101[‡]	18-24[‡]	Wezel & Bender (2003)
Cuba	107	–	–	508	–	Castiñeiras et al. (2002)
SE Guatemala	46	–	(90-2500)	276	33	Azurdia & Leiva (2004)
C Guatemala	–	20-1200	1000-1900	414	50-56	Azurdia & Leiva (2004)
Venezuela	150	0-2400	–	591	52-70	Quiroz et al. (2004)
Costa Rica	1	–	1240	83	–	Gliessman (1990a)
Nicaragua	20	450	3240	324	70	Mendez et al. (2001)
SE Peru	19	<500	–	71[‡]	14-20[‡]	Wezel & Ohl (2005)
NE Peru	51	–	390	161[†]	30[†]	Lamont et al. (1999)
NE Peru	21	–	1280	168	35	Padoch & Jong (1991)
Africa						
Sudan	81	570	(40-150)	32	3	Gebauer (2005)
Ethiopia	36	1200-2100	560	133	8	Belachew Wassihun et al. (2003)
Ethiopia	141	<2300	9000	198	37	Tesfaye Abebe et al. (2006)
Ghana	250	<750	1600-5900	40-104	–	Bennett-Lartey et al. (2004)
Tanzania	62	1000-1800	1000 (sampled)	523[¶]	54[¶]	Hemp (2006)
Zimbabwe	14	<1000	–	27[‡]	–	Drescher et al. (1999)

Note: – = Not available.

[†]: Without ornamental species.

[‡]: Without tree/timber and ornamental species.

[¶]: Including also useful weed species.

[+]: Including also varieties.

[‖]: Only woody species.

[††]: Only perennial species.

To compare crop species diversity among homegardens or between homegardens and other agricultural systems, not only species richness, but also some diversity and evenness indices should be considered (see 1.2.2). However, such indices have only rarely been recorded in the literature, possibly because a time-consuming assessment of species abundances is necessary for their calculation. In the Napu valley, the mean Shannon index per village varied from 2.3 to 3.1 (see 3.5.3, Table 3.11), thus, reflecting the range of this index given by KARYONO (1990) as 2.8–3.0 for Indonesian homegardens, 1.9–2.7 by GAJASENI & GAJASENI (1999) for Thai homegardens, or 3.2 (pooled and for tree species only) by SHASTRI et al. (2002) and 1.1–3.0 (tree species only) by KUMAR et al. (1994) for homegardens of Southwest India. GLIESSMAN (1990a), however, reported a higher Shannon index (i.e. 3.6) for only one homegarden in Costa Rica, whereas lower indices were documented by ABDOELLAH et al. (2006) for homegardens of West Java (i.e. on average 1.1 and 2.0 for commercialised and non-commercialised gardens, respectively) and by WEZEL & BENDER (2003) for those of Cuba (on average 1.6–1.8 for three villages).

Not only plant species richness, but also diversity is generally said to be higher in homegardens as compared to other agro-ecosystems; sometimes it might even be similar or higher than that of natural ecosystems. For fallow plots covered with secondary forest (5 plots of 400 m^2 size each) in the Napu valley, PITOPANG et al. (2004) calculated Shannon indices of 2.0–2.9 for tree species. According to KAYA et al. (2002), tree species diversity of four forest gardens of Central Maluku, Indonesia, was found to be nearly as high as that of adjacent primary forest (2.7–3.1 vs. 3.2, respectively). In homegardens of Southwest India, SHASTRI et al. (2002) reported an even higher tree diversity than in adjacent reserve forest (3.2 vs. 2.5, respectively). Nevertheless, the Shannon indices of these forest areas might have been considerably higher if herbaceous plants were included as the references only referred to the tree components.

Crop species composition, associated with the complexity of vertical structure as well as crop diversity parameters differed markedly among the homegardens. Cluster analysis based on crop species abundances revealed certain spatial patterns and some of the possible underlying reasons (see 3.5.4). The grouping occurred firstly along village differences, determined, on the other hand, by differences in ethnicity of the inhabitants and/or soil quality (see Figure 3.18, Table 3.18). The subsequent separation of the two migrant villages was much more distinct as that of the three local villages. Besides, the results of the cluster analysis reflected the marked differences existing in garden sizes, vertical vegetation structure, and socio-economic characteristics as well as overall crop species richness and diversity parameters (see Table 3.16 and Table 3.17). Some of these factors were also revealed as important for influencing crop diversity by multiple regression analyses (discussed in more detail in 4.5), thus, supporting the cluster analysis. However, PCA of the 48 gardens did not add much information towards classification, as groups were not sufficiently separated (Figure 3.22). KUMAR & NAIR (2004) challenged the search for classification schemes, e.g. by cluster analysis, by stating that it would not get homegarden research any further. However, different from regression analysis of factors determining crop diversity, classification by cluster analysis revealed structural and compositional differences among homegarden types. Therefore, it might help to identify those homegarden types that contain certain key species (important for *in situ* conservation of plant genetic resources) or that are, in general, more sustainable (related to the advantages of a complex vegetation structure or a well-balanced mix of different crop use categories, among others).

Multivariate statistical methods such as cluster analysis or Principal Component Analysis (PCA) based on species abundance or simply presence/absence have only been recently and rarely recorded in the homegarden literature (e.g. ALBUQUERQUE et al, 2005, for PCA), possibly due to the time-consuming data assessment and computing. Such multivariate methods were used mainly in studies focussing on *in situ* conservation of plant genetic resources (e.g. BLANCKAERT et al., 2004; LEIVA et al., 2002; QUIROZ et al., 2002) or on the structural and functional dynamics of crop species diversity (PEYRE et al., 2006; TESFAYE ABEBE et al., 2006). Similar to findings from the Napu valley, a clear division of homegarden clusters along cultural/ethnic lines as well as along an environmental gradient (climate zones) was also reported by LEIVA et al. (2002), a division according to differences in garden sizes and/or commercialisation level by PEYRE et al. (2006) and VOGL et al. (2002; based on Correspondence Analysis).

In the Napu valley, the 30 homegardens surveyed in 2001 had been classified by cluster analysis based on species presence/absence data (KEHLENBECK & MAASS, 2004). The resulting three main garden types also differed markedly with regard to garden age and size, species richness and diversity, and gardener's origin. When re-classifying the same gardens in the 2004-study, 20 more gardens were included, but four of the former study were not available anymore (see Figure 3.18). Many similarities were revealed between these two classifications, although clustering methods were slightly different (i.e. on species abundance in 2004). The former 'small, species-poor spice gardens' (N = 7) were now mostly grouped in cluster 4, but two in cluster 3. Of the 'medium-sized, species-rich fruit tree gardens' (N = 7), most were grouped in cluster 3, whereas two were among the outliers. Finally, the 'large, species-poor migrant gardens' (N = 9) largely corresponded to cluster 2 of the present analysis, but three gardens were moved to cluster 3. Some of the inconsistencies between the two groupings can be explained with the help of the PCA. For example garden no. 5, formerly classified as 'migrant garden', was now put into cluster 3, however, it is located relatively close to gardens from cluster 2 by the PCA (Figure 3.22). In conclusion, different classifications based on species composition consistently grouped the gardens following stable criteria such as garden sizes, species richness, main use categories, or gardener's origin; but they also reflect the development of certain gardens.

In summary, homegardens in the Napu valley harboured high crop species richness and diversity, clearly exceeding those of other agricultural systems in the region. A high varietal diversity, however, was found only for certain key species. Homegardens provided the gardeners' families with a multitude of valuable produce, used not only as highly nutritional food or for cash income generation, but partly also as a medicine. Nevertheless, certain crops were neglected by the gardeners. Both crop species richness or diversity and the associated traditional knowledge about its utilisation was not evenly distributed among the homegardens studied and the gardeners interviewed.

4.5 Can crop diversity be maintained in homegardens? Which factors are responsible?

In a sustainable agricultural system, crop diversity should be high and maintained over time to ensure the ecological, economic, and social functions of the system in the long-term (TORQUEBIAU, 1992). Although stability is requested in such a system, it should, at the same time, also be able to react in a flexible manner to changing household needs and changing environmental or socio-economic conditions (HUXLEY, 1999).

In homegardens of the Napu valley, crop species richness was not only maintained, but even increased over time, particularly that of vegetable and medicinal plants (see 3.10.3, Figure 3.40 and Figure 3.41). Activities of development projects partly might be responsible for this improvement (see below), however, their impact was not perceptible in the migrant village Siliwanga, where crop species richness still increased. Gardeners most likely followed new fashions in growing cash crops only recently in their homegardens, thus, introducing certain species such as cacao, vanilla, clove, teak, or *Gmelina arborea*. Often, homegardens serve as a kind of ‘experimental station’, where the suitability of new crops is tested. The planting material for many of these new crops was mostly not provided by formal, but informal sources (see 3.4.1). Principal Component Analysis of changes in crop diversity (Figure 3.38) confirmed the mentioned trend towards more cash crops in the two villages with rather good market access (i.e. Wuasa and Siliwanga), whereas in the remote village Rompo, such a trend was not detected. These results correspond to other studies, which reported increasing importance of cash crop production, including fruits and ornamentals, in homegardens located close to market opportunities such as large cities or tourist centres (KARYONO, 2000; MÉNDEZ et al., 2001; SOEMARWOTO & CONWAY, 1992; see also 1.4).

Another reason for increasing crop species richness over time in the homegardens studied might have been the author’s own research activities in the year 2001 (KEHLENBECK & MAASS, 2004). Nearly all respondents perceived as an honour to be included in the sample households. Recognition of their homegardens by a foreign scientist might have raised pride and ambition of gardeners and possibly stimulated their interest in crop diversity. As a result, gardeners might have revived networks of seed and plant exchange within their neighbourhoods and were more open for experimental cultivation of new crops. Besides, during the intensive interviews concerning utilisation of plants in the 2001-survey, some gardeners might have learned from the author about the use potential of some of their spontaneously occurring homegarden species, which they might have perceived only as weeds before. Consequently, gardeners might have mentioned these plants as useful crops in their homegardens during the 2003/2004-survey. WEZEL & BENDER (2003) reported a similar positive effect of a previous survey concerning medicinal plants on gardeners’ knowledge, which might have biased the results of a study on species richness in the respective homegardens. In addition, due to the extended sample of homegardens in the Napu valley, a larger pool of gardeners’ knowledge about useful plants was available in the 2003/2004-survey. As a result, plant species mentioned as useful by ‘new’ respondents might already have occurred in the homegardens surveyed in 2001, but neither the former respondents nor the author had recognised these plants before. However, probably only few, mostly ‘weedy’ plant species with, for example, medicinal or mystic values, might have been overseen in this way.

Raised pride of gardeners on a well-tended homegarden, caused probably by the research activity itself, might have affected not only the diversity of crops, but also of ornamentals. As compared to the 2001-survey, species number of ornamentals increased markedly in many homegardens in 2004 (data in Appendix 15)

Particularly in Wuasa, which was classified as the village being rather close to markets and most 'urbanised' (see 2.2), some gardeners raised the number of ornamental species substantially (e.g. from 9 to 52 species in garden no. 6). Also, the abundance of ornamentals was high in Wuasa, thus, numbers of ornamental individuals (and species) in a homegarden sometimes even exceeded those of crops (gardens no. 4 and 6). An increasing importance of ornamentals at the expense of subsistence crops together with urbanisation or the raise in social stratum and living standard has frequently been mentioned in the literature (KARYONO, 1990; KEHLENBECK et al., 2007; RICO-GRAY et al., 1990; SOEMARWOTO & SOEMARWOTO, 1982; see also 1.4). In the study area, however, a decrease of crop species richness over time was not observed, even not in homegardens, where ornamentals largely increased in species number and abundance.

Besides urbanisation, mainly commercialisation, fragmentation, and time scarcity were said to negatively influence crop diversity in homegardens, whereas garden size and age might positively affect it (see 1.4). For homegardens of the Napu valley, multiple regression analysis revealed a negative influence of commercialisation and household's migration background on crop species richness, but a positive influence of garden size, household age, and soil quality expressed as soil available P content (see 3.9.2, Table 3.38). Migration background and mean household age might partly have been related to time scarcity issues (i.e. migrant households mostly were rather small and focussing on staple or plantation crops; in households with a high mean age of adults, some of the older members invested more time into homegardening). Overall, results of regression analysis correlated well with general assertions in the literature (e.g. CHRISTANTY et al., 1986; HOOGERBRUGGE & FRESCO, 1993; see also 1.4). Nevertheless, most of the previous studies were rather descriptive, at best comparing, for example, differences between means separately for every factor. Only few scientists carried out multiple regression analysis to reveal the relative importance of different factors and their interactions in influencing crop diversity (BAN & COOMES, 2004; COOMES & BAN, 2004; TESFAYE ABEBE et al., 2006). Possible problems related to multiple regression analysis were relatively low numbers of cases (e.g. 13–48 cases per regression model in BAN & COOMES, 2004) or low R^2-values (e.g. adjusted R^2 only 0.13 for crop species richness in TESFAYE ABEBE et al., 2006). The results of this study might have partly suffered from such weaknesses, as case number was 48 and adjusted R^2 values ranged from 0.45 to 0.60 for species richness, density, and Margalef index (see Table 3.38). On the other hand, factors found to be of significant influence in the regression analysis were supported by theoretical considerations and findings in the literature. In addition, the large influence of garden size and household's migration background was also demonstrated by Figure 3.15 in chapter 3.5.1, that of commercialisation by the PCA (see 3.10.3, Figure 3.38). Therefore, results of multiple regression analysis can be considered as reliable.

An important finding of the final regression analysis in this study was the lack of influence of market access on crop diversity. Instead, a slightly positive influence of this factor could be derived from the separate regression analysis restricted only to socio-economic factors (see

3.9.1, Table 3.37). This phenomenon partly might have resulted from activities of development agencies that focussed mainly on Wuasa. Due to a planned village competition in autumn 2004 that also considered the appearance of homegardens, the mayor of Wuasa forced gardeners to plant a certain number of medicinal species in their homegardens as recommended by the village development programme. In addition, inhabitants of Wuasa, which is the administrative and commercial centre of the Napu valley (see 2.2), had a higher possibility to gather new planting material by travelling around, by meeting people from outside, or by taking advantage of available training and information opportunities as compared to the other, rather small villages studied. The finding of the present study that a higher crop diversity could be expected in homegardens with intermediately good market access supports the rather few studies postulating the same (HODEL et al., 1999; QUIROZ et al., 2004; SUNWAR et al., 2006). Good market access also not necessarily resulted in commercialisation of homegardens. In Wuasa, only 30% of the gardeners mentioned generation of cash income as a main or second function of their homegardens (see Appendix 8). In contrast, 90% of the gardeners in Tamadue did so, although access to this village was difficult due to the very poor road and bridge conditions (see 2.2).

A strong negative influence of a household's migration background on crop diversity, similarly to the findings in the present study, has not yet been mentioned in quantitative measures in the homegarden literature (see 1.4). In contrast, SOEMARWOTO (1987) reported markedly higher species richness in homegardens of migrants in Sumatra as compared to those in their village of origin in East Java (138 species/village vs. 69, respectively). However, KUSUMANINGTYAS et al. (2006) documented a lower species richness in mixed plantations of migrants than in those of their village of origin (38 species vs. 55, respectively). In Thailand, OKUBO et al. (2003) reported a lower diversity of tall trees in migrant homegardens located on beach ridges with poor soil as compared to those in their village of origin on the nearby foot slopes. Probably, a household's migration background is frequently connected with socio-economic constraints such as labour and land scarcity, poverty, or discrimination (HODEL et al., 1999). In addition, migrants were often settled in areas with poor soil quality (HOLDEN & HVOSLEF, 1995), as also observed in the Napu valley (see 3.6, Tab. 3.20 and 3.22).

Quantitative studies of the influence of soil quality parameters on crop diversity in homegardens are still lacking. For natural systems, the influence of soil characteristics on plant diversity is debated controversially (SOLLINS, 1998; WRIGHT, 1992). On poor soil, some studies noted rather low (GENTRY, 1988; GENTRY & EMMONS, 1987), others high plant species diversity (FABER-LANGENDOEN & GENTRY, 1991; HUSTON, 1980; PAOLI et al., 2006) or even no influence at all (CLINEBELL II et al., 1995). Some authors postulated the highest plant diversity at sites with intermediate soil fertility, e.g. for trees and shrubs in a temperate forest (FU et al., 2004). Of the soil fertility parameters, particularly P, K, and Mg contents were said to have an influence on plant species composition and diversity (ASHTON, 1988; GARTLAN et al., 1986). Concerning cultivated plant species, poor soil conditions such as very low P, but high Al contents, high soil acidity, or waterlogging certainly reduce crop diversity because only few species are able to cope with such adverse situations.

Unfortunately, the overlapping of poor soil quality and a household's migration background in the present study hindered a clear separation of influence of these two factors on homegarden crop diversity. Although the extension of the sample size beyond that of the 2001-study (see 2.2) aimed at clarifying exactly this question, among others, a clear answer might not be possible. In the Napu valley, the local villages occupied the most fertile soils and the few local families living in the migrant villages might have suffered from similar socio-economic and environmental constraints as their migrant neighbours. However, the only slightly negative influence of relatively low available P content of soils as compared to the strong one of the factor 'migrant' detected by multiple regression analysis (see 3.9.2, Tab. 3.35), suggested a primary influence of a household's migration background. This assumption was supported also by the results of the cluster analysis as well as PCA based on species composition in homegardens (see 3.5.4, Figure 3.18 and Figure 3.22). Two homegardens from Siliwanga, but managed at least partly by household members of Central Sulawesian origin (i.e. gardens no. 21 and 25) were not grouped together with the other gardens of Siliwanga, but in cluster 3 (see Figure 3.18), indicating a higher degree of similarity with the other local, rather species-rich homegardens of this cluster. The soil quality parameters examined in this study showed only minor influences on crop diversity. Reasons for this could be that, (i) the actually underlying soil parameters have not been included in the analysis, (ii) the level of soil quality determined still allowed the cultivation of a wide range of crops, and/or (iii) a few gardeners had improved soil quality sufficiently to enable the cultivation of sensitive crop species.

In summary and by combining results of cluster analysis as well as multiple regression and principal component analyses, a homegarden with the following characteristics might harbour and maintain a high crop diversity: intermediate to large garden size, complex vegetation structure, managed by a female of a local household with some rather old family members, production mainly focussing on subsistence, and located in a village with relatively good market access and high soil quality. In the future, however, the maintenance of crop diversity in homegardens might be threatened by attempts of modernisation that include increasing commercialisation of garden products and ornamentalisation.

4.6 Are homegardens suitable for *in situ* conservation of PGR?

Maintenance of species and genetic diversity is considered to be crucial for long-term sustainability of agricultural production systems (see 1.3). Concerning crops, their wild ancestors as well as traditional varieties and landraces are important resources for further development and improvement by breeding activities (BROOKFIELD, 2001). Besides, a high inter- and intra-specific diversity enables a system to adapt to changing environmental and socio-economic conditions (ATTA-KRAH et al., 2004; MAIN, 1999; WIERSUM, 2004).

Homegardens are generally considered as suitable for *in situ* conservation of genetic resources of both wild and cultivated plant species (BENNETT-LARTEY et al., 2004; ESQUIVEL & HAMMER, 1992; FU et al., 2003; MAXTED et al., 1997; MONTAGNINI, 2006; MORENO-BLACK et al., 1996; SMITH et al., 1992; ZEMEDE ASFAW, 2004). Some authors particularly stress the conservation of traditional varieties as well as endangered, neglected, and underutilised crops in homegardens (ESQUIVEL & HAMMER, 1992; LEIVA et al., 2002; OAKLEY, 2004; QUALSET et al., 1997; SHRESTHA et al., 2004; STHAPIT et al., 2004). Particularly women are said to play an important role in conserving both wild and cultivated traditional plant species in homegardens, whereas men often were interested only in the introduction of exotic cash crops

(DEL ANGEL-PÉREZ & MENDOZA B., 2004; WILSON, 2003). Concerning the conservation of wild species, however, homegardens in the study area seemed to play a minor role. Admittedly, about 24% of the 206 useful plant species found in homegardens of the Napu valley in 2004 could be considered as wild species (see 3.5.1), but in their majority these seemed not to be rare or endangered in the region. Instead, many wild species occurring in the homegardens studied might belong to a type of fast-growing pioneer vegetation, covering large areas of surrounding fallows and secondary forests. Of the 46 tree species recorded by PITOPANG et al. (2004) for young secondary forest in the Napu valley (i.e. forest less than 10 years old; overall plot size 2000 m^2), 12 species or 26% were also found in the homegardens surveyed. Compared with 1 ha primary forest near the village Rompo, studied by BRODBECK (2004), only 5 tree species or 5.6% of the 89 forest trees occurred in homegardens. Also SCHROTH et al. (2004) criticised simple counting of wild species in agroforestry systems for evaluating their role for conservation because weedy and pioneer species that do not need any special protection will be included. On the other hand, the same authors stressed the importance of species diverse agroforestry systems for buffering and connecting isolated patches of natural vegetation such as primary forests.

Homegardens as a place for *in situ* conservation of wild species might play a more important role in largely deforested regions, where species of the natural flora lost their habitat. In the semi-arid zone of Guatemala, for example, about 37% of the native flora was also found in homegardens (ALARCÓN, 1992, cited in AZURDIA & LEIVA, 2004). As much as 40% of the perennial native flora of semi-arid north-eastern Brazil was documented in homegardens (ALBUQUERQUE et al., 2005). Native perennial species occurring in homegardens of Mexico, Kenya, and Tanzania made up 15–30% of the natural perennial vegetation of the particular regions (ALVAREZ-BUYLLA ROCHES et al., 1989; BACKES, 2001; HEMP, 2006, respectively). However, in view of the often very small populations of wild species in homegardens, their suitability for *in situ* conservation of these plants might be questionable (ALVAREZ-BUYLLA ROCHES et al., 1989). In homegardens of the Napu valley, 64–88% of the wild species were also represented by less than ten individuals each per village, 24–41% actually by only a single individual per village (see Appendix 12 and Appendix 13).

Even for cultivated species, the problems and risks of rather low intra-specific diversity due to small population sizes and low numbers of varieties in homegardens are sometimes mentioned in the literature (DAMANIA, 1996; ESQUIVEL & HAMMER, 1992; GUARINO & HOOGENDIJK, 2004; HODEL et al., 1999). In the homegardens surveyed in the Napu valley, 41% of the 156 cultivated crop species were represented each by less than 10 individuals (in a sum of all five villages), 74% of the crop species were grown in one variety only (see Appendix 12 and Appendix 13). On the other hand, many varieties were named by the gardeners for certain crop species, such as banana, mango, chilli, or common eggplant (see 3.5.1). Possibly, *in situ* conservation of crop species in the homegardens surveyed should more focus on such diverse key species than on the whole species diversity, an approach suggested in the literature (BENNETT-LARTEY et al., 2004; GESSLER & HODEL, 2004; STHAPIT et al., 2004; WILLIAMS, 2004). On the other hand, problems possibly arising from low intra-specific diversity of small populations, such as danger of genetic drift or inbreeding depression, might be overcome by different strategies. First, many homegardens should be included into one conservation unit and several regions combined for conservation issues (DAMANIA, 1996; GUARINO & HOOGENDIJK, 2004; TRINH et al., 2003). Secondly, exchange of planting material within and between communities could enhance and maintain genetic diversity and should further be promoted (GUARINO & HOOGENDIJK, 2004; MILLAT-E-MUSTAFA et al., 2000; OAKLEY, 2004). However, conservation strategies and identification of minimum sizes of populations have to be adjusted for each single species according to its special characteristics such as mating system (e.g. self- or cross-pollinated), distribution type (e.g. common/rare, widely/locally distributed), propagation method, and extend of germplasm exchange (FUNDORA MAYOR et al., 2004; GUARINO & HOOGENDIJK, 2004; STHAPIT et al., 2004).

The general suitability of homegardens for *in situ* conservation of crop genetic resources might be threatened in the future by cultural and socio-ecomomic changes, such as introduction of exotic species or improved varieties, increase of cash or staple crop production, migration followed by scarcity of labour force, adoption of 'western' lifestyle, or loss of tribal culture and knowledge (FUNDORA MAYOR et al., 2004; GUARINO & HOOGENDIJK, 2004; QUIROZ et al., 2004; SMITH et al., 1992; ZEMEDE ASFAW, 2004). Some of these threats have already reached the relatively remote Napu valley and its homegardens, e.g. by increasing importance of cash crops (see 3.10.3); by low appreciation of local varieties (see 3.4.5); or by little use of and knowledge about medicinal plants or weeds by migrant or young gardeners (see 3.4.6 and 3.5.1, Table 3.10), discussed in 4.4 and 4.5. Loss of interest in and knowledge about medicinal plants was reported also from Ethiopia, where many traditional medicinal plants in homegardens recently were only regarded as shade plants, ornamentals, or even weeds due to acculturation and modernisation, thus, causing both genetic and cultural erosion (BELACHEW WASSIHUN et al., 2003). For Totonac homegardens in Mexico, DEL ANGEL-PÉREZ & MENDOZA B. (2004) reported that gardeners younger than 40 years already lacked the knowledge about names and uses of many plant species as a result of cultural changes. However, homegardens (as well as other agricultural systems) are not static over time, but dynamic. They continue to steadily be transformed by changing environmental, cultural, and socio-economic conditions, resulting in loss of some, but also evolution of other single species or varieties (BROOKFIELD, 2001; MORENO-BLACK et al., 1996; WILLIAMS, 2004). Decrease or loss of traditional varieties and locally used species due to different consequences of 'modernisation' were reported also for other agricultural systems all over the world, e.g. for potatoes in Peru and wheat in Turkey (BRUSH, 1995), for French beans in Cuba (ESQUIVEL & HAMMER, 1992), for African vegetables (KELLER et al., 2006), or for rice replacing minor field crops in Bangladesh (OAKLEY & MOMSEN, 2005). However, improved varieties did not necessarily displace traditional varieties because the latter might be better adapted to marginal environments, used for special dishes, or simply have a better taste (BRUSH & MENG, 1998; OAKLEY & MOMSEN, 2005; SMITH et al., 1992).

According to HODEL et al. (1999) and SUNWAR et al. (2006), conservation of crop genetic resources is closely linked to their utilisation. Maintenance of diverse traditional species and varieties can be further enhanced by several approaches such as developing consumer markets for special unique attributes of such varieties, increasing their prestige (e.g. by seed fairs, competitions), increasing and maintaining knowledge, improving seed supply (e.g. by community seedbanks, seed exchange, seed propagation in demonstration gardens, registration of varieties, seed savers programmes), or by improving the quality of traditional varieties, e.g. by participatory breeding (BRUSH, 1995; BRUSH & MENG, 1998; DAMANIA, 1996; HODEL et al., 1999; QUALSET et al., 1997; RHOADES & NAZAREA, 1999; SMALE et al., 2004; SUNWAR et al., 2006; WILLIAMS, 2004). In addition, SMITH et al. (1992) discussed the designation of target zones or museum farms, where subsidies compensate for not adopting modern varieties. Economic benefits for farmers maintaining such genetic diversity that is of high significance for the global community but not being valued up to now, were claimed also by CORREA (1999) and RHOADES & NAZAREA (1999).

However, for the Napu valley, only some of these approaches seem to be practicable for enhancing the maintenance of traditional species and varieties. For example, competitions among villages already exist that focus on village development and appearance, including ornamentals and medicinal plants in homegardens. Seed supply could be improved by extending the aim of the already existing village demonstration gardens for medicinal plants to also propagate these (and other useful) species and to provide interested gardeners with planting material. More important might be to inform gardeners about the nutritional and cultural value of traditional species and varieties as compared to exotic and modern ones (e.g. young cassava leaves contain 7 g protein, 10,000 IU Vitamin A, and 5.6 mg iron per 100g fresh weight, but chinese cabbage, promoted by the CARE project, only 1.5 g, 4,470 IU, and 0.8 mg, respectively (REHM & ESPIG, 1991; USDA, 2006)). Raising and dissemination of the still existing traditional knowledge within the region as well as strengthening cultural identity are further issues. By this research that started already in 2001, awareness of the sample gardeners concerning species diversity in their homegardens was already raised markedly. Many gardeners were very proud to be included in the sample households and, possibly, tried to satisfy the implied wishes of the author by creating a better tended homegarden and increasing its species richness. The overall increase of crop diversity over time (see 3.10.3), discussed in more detail in 4.5, partly might have resulted from these distortions (KEHLENBECK & MAASS, 2006).

In summary, the homegardens surveyed de facto were loci of *in situ* conservation of plant genetic resources. They maintained high species richness over time. However, this attribute might decrease in the future due to more market-oriented production. Besides, not all homegardens seemed to be equally suitable for conservation issues. Small homegardens or those of migrants harboured less crop species (see 3.9.2 and 4.5). To ensure the suitability of homegardens for conservation of plant genetic resources, a detailed participatory strategy must be developed together with the gardeners as an active part in the whole process.

4.7 Can productivity of homegardens be improved?

The production potential of homegardens in the Napu valley was not fully exploited neither for subsistence production nor for cash income generation (see 3.4.6 and 4.1.3). Parts of some gardens were fallowed, others overgrown with weeds (pers. obs., Figure 4.3). Low-valued species were frequently not harvested, but their fruits were left to rot or only used for feeding pigs. Consumption of fruits and vegetables, although available, was alarmingly low due to their low appreciation and, at the same time, overestimation of the nutritional value of white rice (see 4.4). Lack both of knowledge and extension service caused insufficient management of demanding crops (e.g. not pruning cacao, not pollinating vanilla flowers by hand). It also led to the cultivation of some unsuitable crop species such as salak palm or rambutan, whose growth and production are known to suffer at higher elevations in the tropics (VERHEIJ & CORONEL, 1992).

Figure 4.3. Fallowed vegetable zone in a homegarden of Wanga, Napu valley, Central Sulawesi, 2004.

A relatively low productivity of homegardens has frequently been recorded in the literature (FERNANDES et al., 1984; MILLAT-E-MUSTAFA et al., 2000). Their production potentials were not fully exploited due to, for example, poor management concerning soil fertility maintenance and weed as well as pest control (BENJAMIN et al., 2001; DHARMASENA & WIJERATNE, 1996; GEBAUER, 2005; RUGALEMA et al., 1994) or labour scarcity resulting in partly fallowed gardens (DHARMASENA & WIJERATNE, 1996; JOHN & NAIR, 1999). Also in the Napu valley, gardeners mainly mentioned labour scarcity as a reason for fallowed garden parts, besides soil quality constraints (migrant gardeners) or simply laziness (local gardeners).

In many studies, a large potential for improving productivity of homegardens has been detected (KARYONO, 1990; SOEMARWOTO & CONWAY, 1992), e.g. by integrated pest management or an increased use of compost or other organic fertilisers readily available (BENJAMIN et al., 2001; DASH & MISRA, 2001; DRESCHER, 1996; RUGALEMA et al., 1994). Besides, introducing suitable species or improved varieties of established species as well as promoting cultivation of leguminous and/or perennial crops have been suggested (DASH & MISRA, 2001; GEBAUER, 2005; KARYONO, 2000; MILLAT-E-MUSTAFA et al., 2000; SOEMARWOTO, 1987). The involvement of an effective extension service focussing on homegardens has frequently been claimed to be important for improving their productivity (DHARMASENA & WIJERATNE, 1996; DRESCHER, 1996; HOLDEN & HVOSLEF, 1995; HOLDEN et al., 1995; MILLAT-E-MUSTAFA et al., 2000). Indirectly, homegarden productivity could also be raised by processing homegarden products to create added value, e.g. by the processing of fruits to jams (KARYONO, 2000; SOEMARWOTO & CONWAY, 1992).

Many well-meaning development projects with a focus on improving of homegardens, unintentionally have threatened the ecological, economic, and socio-cultural sustainability of this agro-ecosystem, for example, by introducing light-demanding exotic vegetable species for sale that need a continuous supply of exogenous inputs and may not automatically improve the nutrition situation of the gardeners' families (DRESCHER et al., 1999; SHRESTHA et al., 2002; SOEMARWOTO, 1987). To minimise such negative effects of modernisation and intensification that may accompany efforts towards improving homegarden productivity, the overall species richness ought to be maintained, including useful tree species in order to retain the multi-layered vegetation structure (CHRISTANTY, 1990; DRESCHER, 1999; MARTEN & ABDOELLAH, 1988; SOEMARWOTO, 1987). Besides, only such species or varieties should be introduced or promoted that fulfil most of the following requirements:

- Being rich in micronutrients and well adapted to the local environment as well as to the extensive level of traditional management (MARTEN & ABDOELLAH, 1988; MIDMORE et al., 1991; MILLAT-E-MUSTAFA et al., 2000; NIÑEZ, 1985).
- Meeting the traditional food preferences instead of urban demands for exotic crops that need many exogenous inputs and may largely not be consumed by the family, but sold (NIÑEZ, 1987).
- Being easily to reproduce by gardeners instead of being dependent on an external seed supply system (NIÑEZ, 1985).

Such development projects, however, should not solely focus on individual crops, but apply an integrated, holistic approach for improving not only homegarden productivity but also family nutrition and well-being (FERNANDES et al., 1984; TALUKDER et al., 2000). Promotion of the cultivation of micronutrient-rich crops in homegardens should, for example, be accompanied by nutrition education of gardeners and their families via training courses, visits in schools, or public media campaigns (NIÑEZ, 1985). Establishing model gardens and extension centres that provide gardeners with information and planting material most likely would support such efforts (NIÑEZ, 1985). The gardeners' knowledge about costs and risks associated with the participation in a market economy should be strengthened (HODEL et al., 1999). However, as the concept of sustainable agro-ecosystems also includes their ability to adjust to changing socio-economic conditions (PEYRE et al., 2006; WIERSUM, 2004), modernisation and commercialisation of homegardens should not generally be rejected. Therefore, the aim of fulfilling both the subsistence and cash income needs of the gardeners' families without destroying structure or functioning of their homegardens and further development of this system should be integrated in comprehensive homegarden projects.

In the Napu valley, the subsistence function of homegardens may be supported by promoting vegetable production and consumption. Traditional, perennial leafy vegetables such as cassava, *Abelmoschus manihot,* or *Clerodendron minahassae* should be preferred because they are mostly shade-tolerant, rich in micronutrients, and less susceptible than annual vegetables to damages caused by free-roaming chicken. Even in small gardens, such perennials can easily be planted along the borders as living fences. Concerning cash income generation, promotion of vanilla may be more suitable than that of cacao because vanilla can easily be integrated in the existing multi-layered vegetation structure of many homegardens. Besides, vanilla obtains higher and more stable prices than cacao. Extension would be essential for a successful vanilla production, and providing such a service will most likely simultaneously benefit the overall productivity in homegardens as well as in plantations.

4.8 Did the methods applied in this study serve the research questions?

Assessment of socio-economic sustainability

The first research question concerned socio-economic sustainability of homegardens that was exclusively investigated by interviewing the gardeners. Overall, the interview results could be rated as reliable. For example, respondents remembered surprisingly well the seed sources of every single plant species occurring in their garden; often they provided much more information than requested (e.g. by naming the village or market of seed origin, or by giving the name of the 'donor' of the material). However, some differences were found when homegarden functions as given by the respondents were compared to the own classification into market or subsistence-oriented gardens (based on the dominance of cash crop individuals), where only about 50% agreement was found (see Appendix 8). Some respondents also had problems in estimating working time per single management activity, related partly to the fact that he or she was not responsible for the plant type requiring that specific work (see Appendix 8). In such situations, probably respondents rather underestimated their time investments. For the three case study gardens, where intensive interviews concerning daily working time allocation were conducted every evening, the calculated monthly working time for homegardening (see Figure 3.24) was markedly higher than the medians of the respective villages given in Table 3.1. On the other hand, during the time of the investigation, some working activities were performed in the case study gardens that were rather extraordinary (e.g. fencing in the spice garden) and/or not included in the 'normal' perception of homegarden work (e.g. cutting fodder in the migrant garden).

Concerning soil quality management, many respondents could easily list the fertiliser types used in their homegardens, including recipient crops, fertiliser sources, and application procedure, but they had problems to quantify frequencies and applied amounts. Ash from the kitchen, for example, was applied, when the bucket used for its gathering simply was full or was needed for something else. Concerning purchased industrial fertiliser, on the other hand, respondents were frequently able to remember applied amounts (see Appendix 10). For a more detailed assessment of fertiliser utilisation and its efficiency, an exact measurement of the amounts of applied fertiliser would be necessary that, however, would be difficult and time-consuming to perform. The same applies concerning the assessment of homegarden outputs. Most respondents were only able to give rough quantitative estimates about the yields in their homegardens (see 3.4.6), a problem also mentioned in the literature (e.g. NIÑEZ, 1987, see also 4.1.3). Data obtained for the case study homegardens by daily interviews were considered to be more reliable because the household members still remembered the produce that they had harvested from their garden the same day (see 3.8.1, Figure 3.26). However, such detailed daily interviews would not be feasible for investigating 50 households.

To quantitatively assess productivity and efficiency of homegarden management, exact measurements of the amounts of in- and outputs would be essential. However, for a qualitative evaluation of the two features, the methods applied in this study were rated as suitable. The combination of investigating a considerable number of gardens relatively long-term and a few representative cases intensively, but over short time only, hence, produced complementary results.

Assessment of the soil-based sustainability

To answer the second research question on soil quality maintenance, both interviews as well as physical and chemical soil analyses were performed. Concerning both present conditions and changes of soil quality, assessments by the gardeners mainly did not match the results of soil quality analyses. When gardeners, for example, mentioned soil fertility deterioration in their homegardens, in 58% and 67% of these cases, N and C contents, respectively, decreased according to soil analyses, but only in 42% and 25% concerning pH (H_2O) value and P-Olsen content, respectively. For amelioration, on the other hand, gardeners' assessments only matched the analyses in 0–22% of the cases for C, N, and P-Olsen contents, and in 56% for pH (H_2O) value (Appendix 24). Thus, soil quality estimation of gardeners could not substitute physico-chemical analyses of soil quality parameters. Probably, the gardeners' estimations referred back to longer time periods than that of this study. Nutrient content analysis of cacao leaves could also not substitute soil analyses because a correlation was only detected for K contents (see 4.2).

Overall, the soil quality parameters analysed in this study were considered to be sufficient for assessing soil-based sustainability of homegardens. Only the assessment of soil erosion by analysing Caesium-137 was not adequate, and further studies should should use other methods. Concerning bulk density assessment, the sampling method applied in this study could be improved referring to the soil corer utilised. As a standard soil corer designed for bulk density sampling was not available during the field research (i.e. the corer was stolen), the one used instead had a rather small diameter (see 2.6.1). This might have caused slight distortions of the respective results. In addition, it rained unusually much in the Napu valley during the period of soil sampling in the village Tamadue, which resulted in wet and muddy soils. These sampling problems may have distorted some results towards very low bulk density of homegarden soils in Tamadue (see Table 3.20).

Another point of improvement concerns analysis of plant available P. According to LANDON (1991), the P-Olsen method should be applied for analysis of soil with a pH value > 7. Although most soils were slightly acid in the Napu valley (see 3.6.2, Table 3.21), in the P-Olsen method was used the 2001-study as a concession to the standard measures of the STORMA-laboratory that were set in advance. To compare soil quality parameters of 2001 and 2004, the P-Olsen method, consequently, was also applied in the 2004-study, in addition to the P-Bray method that is recommended for slightly acid soils (LANDON, 1991). Results of the two methods showed similar trends concerning differences among villages, apart from the village Wanga (see 3.6.2, Table 3.21), whereas the rating of available P contents differed strongly. Garden soils of the villages Wanga, Siliwanga, and Tamadue were mostly rated as 'very low' to 'medium' concerning P-Olsen content, but P-Bray assessments resulted in rating all garden soils as 'high'. However, 50% of the cacao leaf samples contained less than 'normal' amounts of P. In addition, maize grown in some homegardens in Wanga and Siliwanga often showed typical symptoms of P deficiency (i.e. purple-coloured stripes on older leaves near the vines and on the stems (pers. obs.). Thus, results of P-Bray analysis corresponded less than those of P-Olsen to the P deficiencies observed in cacao and maize. Probably, neither the Bray, nor the Olsen method sufficiently reflected the real situation of available P content in the soils analysed. Instead, the anion exchange resin method, as described by TIESSEN & MOIR (1993), might be more suitable for further studies of plant available P in garden soils. Nevertheless, for assessing temporal changes of available P contents in soils (see 3.10.4, Table 3.41), the results of the applied P-Olsen analysis were considered to reflect best the possible supply to plants.

Giving soil nutrient concentrations (e.g. percentages, ppm) instead of soil nutrient stocks in kg/ha was chosen because also in the few homegarden studies that included soil analyses, nutrient concentrations were given (e.g. DRESCHER et al., 1999; GAJASENI & GAJASENI, 1999; JENSEN, 1993a), thus, allowing for comparisons. In addition, rating of nutrient levels was done according to literature that also referred to nutrient concentrations (e.g. LANDON, 1991; OLSEN & SOMMERS, 1982). In this study, statistical analyses of C and N as well as P-Olsen and P-Bray soil nutrient stocks (calculated from the available nutrient concentrations and bulk density data) revealed similar trends of soil quality differences among villages as the respective analyses of nutrient concentrations. Therefore, the results of the former analyses and calculations were not given. Concerning the severe soil fertility problem combined with poor crop performances in the migrant village Siliwanga, the analyses of the soil quality parameters chosen in this study did not reveal the underlying causes. Including additional analyses of the subsoil and/or investigations of the level and possible fluctuations of the water table may contribute to uncover the causes and, consequently, lead to recommendations of suitable measures for improving these gardeners' situations.

Assessment of light-use efficiency

The third research question dealt with light use efficiency. The analysis of vertical stratification of the vegetation only allowed for a rough estimate of light use efficiency in the homegardens surveyed, but it could not substitute exact measurements of light transmission because the former does not consider density or cover of the canopy, even if plant individual numbers per stratum would habe been assessed.

Measurement of Photosynthetic Active Radiation (PAR) could be improved in further studies, if more time and larger numbers of measurement units would be available. More homegardens and production zones should then be investigated and the equipment should be moved around in every garden to cover also small-scale differences of PAR within zones. BRODBECK (2004), for example, suggested to measure daily courses of PAR in a 1 ha plot for a period of 25 days by moving the equipment every day, followed by calculation of mean daily courses of PAR. For estimating light use efficiency, alternative methods for indirect mesurement of the light regime are available, including assessments of canopy closure by using, for example, a spherical densiometer, as documented by STEFFAN-DEWENTER et al. (2007). Performance of these alternative methods might be faster, easier, and cheaper than PAR measurements, but they are not suitable for recording daily courses of light transmission or light flecks of direct solar radiation in the different vegetation strata.

Assessment of crop species diversity and its maintenance

The fourth and fifth research questions considered the assessment of spatial differences and temporal changes of crop diversity. When asked for 'lost' crops in the interviews, most gardeners remembered no or only few species, particularly valuable tree crops. The results of these interviews did not correspond so well to the results of species inventories, where mostly many more 'lost' species were detected per garden (data not shown). Thus, results of studies concerning changes of species composition in homegardens over time, but exclusively relying on information gathered by interviews (e.g. PEYRE et al., 2006) might underestimate species loss, particularly concerning non-marketable species such as vegetables or medicinal plants.

In contrast, the detailed species inventories carried out in homegardens of the Napu valley over a time period of three years yielded highly reliable results and revealed marked differences, both in space and time (see 3.5.1; Table 3.8 and 3.10.3, Figure 3.41). The claim of HUSTON (1994), LUDWIG & REYNOLDS (1988), and PIEPHO (1996), among others, for using not only species richness, but also different diversity and evenness indices for assessing biodiversity (see also 1.2.2) can be supported by this study. Calculating such indices revealed opposing trends as compared to species richness in some homegardens, e.g. in garden no. 9, where species richness increased markedly from 2001 to 2004, but values of diversity and evenness indices decreased in the same time (see Appendix 15 and Appendix 16), caused by a shift towards large scale cultivation of groundnuts for sale.

However, using many of the recommended diversity and evenness indices did not completely satisfy the expectations of the author on a measure that would integrate all aspects of crop diversity (including also structure and function) among the homegardens studied. For example, the applied indices valued a single spring onion plant exactly the same as a large single mango tree. Apart from differences in sizes, the mango tree most likely contributes much more than the onion to the ecological functioning of the agro-ecosystem (e.g. by supplying litter, shade, and habitat for other organisms) and to its socio-economic functions (e.g. by providing the gardener not only with lots of fruits, but also with fuel wood and timber). These differences among species are not reflected by the diversity and evenness indices applied in this study. A theoretically possible solution considering size differences may be to calculate these indices not on the basis of individuals per species, but of total biomass per species, as suggested by BAUMGÄRTNER (2005). However, this method requires time-consuming assessments of biomass, either destructive (which would not be feasible in homegardens), or by measurements of tree heights and diameters for a calculation of tree biomass, combined with weighing sub samples of cut herbs and shrubs (as performed by JENSEN, 1993a). Such measure would be practicable only on the scale of case studies. A relatively easy solution could be to calculate separate indices for different size classes (COUSINS, 1991), e.g. for trees, shrubs, and herbaceous plant species each, or to weigh the different strata differently (ANAND & ORLÓCI, 2000). The suitability of such indices calculated differently should be tested in further homegarden studies.

Structural and functional components of biodiversity could be included, if taxonomic dissimilarities of species would be considered in the calculation of indices, based on the idea that, for example, three different *Citrus* species in a garden may be less valuable than one species of *Citrus*, *Manihot*, and *Allium* each. The calculation of a ‘taxonomic information index’ like the Weitzman index includes an aggregate measure of the dissimilarity among all species in a system (BAUMGÄRTNER, 2005). This calculation is mostly performed based on taxonomic and phylogenetic dissimilarities, but such information is still limited (WEIKARD, 2002). Instead taxonomical, also functional or even morphological dissimilarities could be used for calculating the Weitzman index (BAUMGÄRTNER, 2005), a method that might be useful (but very time-consuming) also for the investigation of plant species diversity in homegardens.

The choice of the 'right' index or indicator for assessing biodiversity depends much on the objective of a study (BAUMGÄRTNER, 2005; COUSINS, 1991; DUELLI & OBRIST, 2003), resulting in different perceptions of the value of biodiversity. According to WEIKARD (2002), the overall value of biodiversity consists of the direct value of single species (e.g. as food, medicine, raw material), the instrumental value of biodiversity (e.g. its contribution to ecosystem functioning, but also its 'option' value for future demands), and its intrinsic value (e.g. forming a beautiful landscape). If conservation of plant genetic resources or of certain rare/endangered or endemic species is the main task, target species ought to be valued higher than abundant species. The importance of a system for conservation issues could then simply be assessed by counting target species richness, but not by calculating diversity and evenness indices. However, high richness of target species in a system is not necessarily correlated to its overall species richness (DUELLI & OBRIST, 2003). If not conservation, but rather ecological resilience and functioning of a system is the motivation of a study, the diversity of functional groups should be assessed. Abundant species may be more important for the system functioning than rare species that could even be ecologically redundant (DUELLI & OBRIST, 2003). Therefore, not only species richness *per se*, but also species composition and dominance patterns may be relevant to assess, e.g. by calculating diversity indices. If an assessment of biodiversity is oriented economically, quite different characteristics should be assessed than for ecologically oriented studies, resulting in a different set of suitable indicators or indices (BAUMGÄRTNER, 2005). Until now, no single index has been developed, which combines not only species numbers and abundances, but also species functions or other characteristics.

However, for answering the research question concerning spatial differences and temporal changes of crop diversity in the homegardens studied, the chosen combination of assessing species richness, density, diversity, and evenness was considered to be useful.

Revealing factors causing spatial differences and/or temporal changes of crop diversity

To answer the last research question concerning the factors triggering spatial differences and/or temporal changes of crop diversity in homegardens, multiple regression analyses as well as Principal Component Analysis (PCA) were carried out. The results of multiple regression analyses were considered as reliable because influences of several factors revealed by this method were also mentioned in the literature, although the analyses in this study might have slightly suffered from small case numbers (see 4.5). The PCA, used for detecting temporal changes of crop diversity, was considered as a useful tool for this purpose, as it clearly revealed those crop species out of the rather confusing total number of 196 species, which were responsible for most of the variation (see 3.10.3, Figure 3.38). Probably, this method was applied in homegarden research for the first time, as it has not yet been mentioned in the literature available.

Data recorded in this study could have been further analysed to confirm or even extend the findings of the regression analyses concerning influencing factors. For example, a constrained ordination such as Canonical Correspondence Analysis (CCA) might detect environmental variables that could be responsible for certain patterns/differences of species composition (MCCUNE et al., 2002), whereas the applied regression analysis refers only to those of total species richness or diversity indices. Another promising method for revealing more about spatial patterns of crop diversity might be the Mantel test that analyses the relationship between two distance matrices (McCune et al., 2002). For example, the Mantel test allows to analyse the relationships between floristic similarities among homegardens and their geographical or ecological (e.g. concerning soil quality parameters) distances. However, such measures were not applied in the present study due to time scarcity, but they may be helpful for further investigations of crop diversity in homegardens.

Could the suitability of homegardens for in situ *conservation of PGR be assessed by more easy and rapid methods than those applied in this study?*

For a detailed assessment of crop diversity and a sound understanding of the factors causing its spatial and temporal dynamics, the combination of methods applied in this study was considered indispensable. In fact, even more analytical methods could have been applied for a more thorough understanding. However, for a large scale investigation of, for example, all homegardens of a region concerning their value as a conservation unit, a more rapid assessment measure would be required. The multi-layered vegetation structure was found to be a key factor towards sustainability of homegardens (see 1.3, 4.3, and 4.4). Consequently, the number of vertical strata and their coverage must primarily be considered as a critical measure. Remote sensing could help to analyse vegetation patterns of homegardens in a large scale, if high resolution satellite images are available and, at the same time, detailed, GPS-based species mapping of certain homegardens of the target region is performed to enable classification of the respective images. However, analysis of satellite images may result only in a pre-selection of ‘valuable’ homegardens. A rapid assessment of such ‘pre-selected’ gardens should follow, for example, by evaluating certain key indicators for crop diversity and its maintenance. Based on the homegardens studied in detail in the Napu valley, such key indicators (and their rough assessment) should include:

- Garden size (intermediate size of about 1000 m^2 would be optimal).
- Number of vegetation strata (the more, the better).
- Dominance of single crop species, particularly cash crop species (negative).
- Main gardener is female and of indigenous origin (positive).
- Presence of relatively old members in the household (positive).
- Regular application of purchased industrial fertilisers and pesticides (negative because related to market-oriented production).

The suggested key indicators could be assessed during a short visit of a garden, including an interview of the gardener. Depending on project objectives, the presence of certain plant species groups, previously identified as target species, can be recorded in addition, e.g. medicinal plant species or traditional leafy vegetables. However, detailed studies are necessary for adjusting these key indicators to the particular conditions of a research/project region.

4.9 Do homegardens have a future? What kind of research is necessary for better understanding this agro-ecosystem?

Despite the threats of modernisation and commercialisation, homegardens have a future, not only in the research area, but also worldwide (Nair, 2006). Managing homegardens is deeply rooted in the traditions of so many people, who appreciate the ecological, economic, and socio-cultural benefits of this agro-ecosystem. In addition, homegardens serve as an important back-up resource for gardeners in cases of 'emergency' (MARSH, 1996). Homegardens can easily and quickly be changed from 'leisure' or 'supplement' gardens into subsistence gardens whenever necessary. Such situations may occur due to harvest failure, prolonged unemployment or events of illness suffered by household members, or a more general economic crisis (MARSH, 1996; WEZEL & BENDER, 2003). However, homegardens have ever been and will continuously be subjects of changes related to ecology, economics, and culture (NAIR, 2006).

In the Napu valley, particularly socio-economic factors have been causing such changes. Modernisation and commercialisation have been threatening the sustainability and functioning of homegardens by an increased and indiscriminate use of industrial fertiliser and pesticides (see 4.1.2), by an impoverishment of structural complexity (see 4.3), and by cultural and genetic erosion (see 4.4, 4.5, and 4.6). In addition, gardeners failed to manage soil quality in a sustainable manner (see 4.2). In the future, the mentioned threats to sustainability and functioning of the homegardens studied may further increase because most gardeners only recognise the short-term benefits of commercialisation, but not its potential long-term disadvantages. A well thought-out concept for improving productivity of homegardens without destroying their manifold ecological, economic, and socio-cultural functions most likely contributes to minimise the negative effects of intensification and modernisation (see 4.7).

Despite a recently increasing body of homegarden literature (e.g. KUMAR & NAIR, 2006; EYZAGUIRRE & LINARES, 2004) that reflects the growing importance of this agro-ecosystem in science, its functioning and potentials have not been satisfactorily investigated and understood. Research is needed, particularly, concerning nutrient and water balances, interactions between garden components, seed supply systems, the value of non-conventional products and services (e.g. carbon sequestration), system productivity, and its sustainability, including temporal changes and factors driving them (KUMAR & NAIR, 2004; MENDEZ, 2001; MIDMORE et al., 1991; MILLAT-E-MUSTAFA et al., 2000; NAIR, 2006).

In the Napu valley, future research should particularly cover the problems related to soil quality/erosion and identify possible solutions. For assessing economic efficiency in homegarden production, inputs and outputs should be investigated in more detail. The suitability of certain cash and subsistence crops for improving the productivity of homegardens should be tested. Concerning plant diversity, key species responsible for maintaining the system's functioning and target species for *in situ* conservation of plant genetic resources should be identified and promoted. The role of plant diversity located in the homegardens, as a model agroforestry system, also needs to be investigated in the overall landscape context as it may provide important reservoirs for recolonisation of the agricultural landscape by many organisms (TSCHARNTKE et al., 2005) and, therefore, assist in important agro-ecosystem functions. Finally, the initiated time-series study of crop diversity dynamics and their underlying factors should be continued in the same homegardens because they provide an unique opportunity for a long-term study.

5 Conclusions and Recommendations

In the previous chapters, crop diversity, soil quality, and management of rural homegardens in Central Sulawesi have been presented and assessed with regard to the sustainability of this agro-ecosystem and its suitability for *in situ* conservation of plant genetic resources. Integrating all results, it can be concluded that:

- The homegardens surveyed were managed by family members that mostly used endogenous inputs for producing year-round available food and non-food items as well as cash crops with relatively low labour investment.
- Productivity of homegardens was not fully exploited neither in cash nor in subsistence-oriented gardens.
- Soil quality maintenance was not adequate over time, and soil erosion was considered problematic in some homegardens.
- The homegardens surveyed harboured a high crop diversity that is not only maintained, but slightly increased over time, partly due to activities of development projects.
- Crop diversity and species composition in homegardens showed spatial differences and was mainly influenced by garden size, commercialisation, mean age of adults in the household, and origin of the gardener.
- Homegardens are suitable for *in situ* conservation of plant genetic resources, but crop diversity was found to be highly dynamic over time and may, in future, be threatened by modernisation and commercialisation.
- The homegardens surveyed were sustainable concerning socio-economic dimensions and the resource ‘crop diversity’, but not regarding the resource ‘soil’.

The following main recommendations are given to improve the sustainability of homegardens in the Napu valley as well as their suitability for *in situ* conservation of plant genetic resources:

- To achieve sustainable soil quality management, gardeners should be trained to use compost, mulch, and farm yard manure as well as to grow N_2-fixing cover crops, not only in homegardens, but also in their other cropping systems.
- The existing extension service should not exclusively focus on paddy rice production, but also on proper management and improvement of agroforestry systems (including homegardens) with their great significance for cash income generation and the ecological sustainability of the overall landscape.
- Suitable subsistence and cash crops for improving homegarden productivity without destroying its structure and functioning should be identified and promoted. Gardeners should be integrated as an active part in the whole process of developing a holistic approach for raising and maintaining the sustainability of homegardens together with conserving its agro-biodiversity.

6 Summary

Homegardens are generally regarded as a very complex, species-rich agro-ecosystem managed in a sustainable manner over decades or even centuries. The major purposes of homegardens are subsistence production and income generation, particularly in rural areas. In addition, they fulfil important ecological, social, and cultural functions. Furthermore, homegardens should be considered as a model for sustainable agricultural production systems that integrate both economic and ecological advantages. Sustainability of agro-ecosystems refers to maintaining production levels that meet the needs of present and future generations without destroying the natural resource base on which the production depends. The concept of sustainability includes not only ecological, but also economic and social dimensions. As sustainability can not be assessed *per se*, certain descriptors and indicators have been used instead, e.g. soil fertility parameters or biodiversity. Plant diversity is considered as a basis for homegarden productivity and sustainability, however, it is not static over time. Both plant diversity and species composition are largely influenced by a combination of agro-ecological and socio-economic factors, whose complex interactions are not yet fully understood. In addition, the sustainability of homegardens has rarely been examined in a quantitative way or in a time series.

The main objective of this study was to assess the sustainability of selected rural homegardens in Central Sulawesi, Indonesia, with the help of certain sustainability indicators. The study aimed at determining spatial and temporal differences of resource quality in homegardens and the underlaying driving forces, focussing on plant species diversity, soil quality, microclimate, and homegarden management. Finally, potentials for improving homegarden productivity and their suitability for *in situ* conservation of plant genetic resources were assessed.

The research was carried out in the Napu valley, Central Sulawesi, located at the eastern margins of the Lore Lindu National Park at an elevation of about 1,100 m asl. Five villages were chosen that differ in their market access, origin of inhabitants, and soil quality, among others. Ten households with homegardens were randomly selected per village and sizes of homegardens were measured. Complete plant species inventories were carried out to assess the number and abundance of crop species (i.e. all useful plant species) and ornamentals. Tree height was also estimated. For assessing temporal dynamics of crop diversity, 30 homegardens in the villages Wuasa, Rompo, and Siliwanga, which had been previously investigated in 2001, were re-inventoried in 2003 and 2004. Top soil samples (0–15 cm depth) were randomly taken in all homegardens for analysis of soil texture, bulk density, pH value, total C and N contents, plant available P content, effective CEC, and base saturation. Parts of these soil analyses were performed also in the 2001-study. All gardeners were individually interviewed about homegarden management and plant utilisation, among others. Secondary data concerning household and farm characteristics were gathered through additional interviews. Microclimate (i.e. air and soil temperature as well as photosynthetic active radiation) and soil erosion were investigated only in a subsample of three homegardens, where also more detailed management data were recorded. In addition to crop species richness and density, several diversity and similarity indices were calculated. Cluster analysis was performed to detect spatial patterns of crop diversity and, hence, classify different homegarden types based on their plant species composition. To identify factors that influence crop diversity, multiple linear regression analysis was applied. Principal component analysis (PCA) based on species abundance data was carried out to detect and visualise changes of plant species composition over time.

In the Napu valley, homegardens were cultivated for periods between 2 and 40 years, their cropped area varied from 300 to 2,400 m^2 (on average 600–2,300 m^2). The primary function of homegardens was subsistence-oriented production of non-staple food (e.g. fruits, vegetables, spices) as well as non-food items (e.g. medicine, fodder, fuel wood). Homegarden produce was available year-round. Some gardens were largely used for income generation by cultivating cash crops (particularly cacao, arabica coffee, and vanilla). In both subsistence and market-oriented homegardens, the production potential was not fully exploited. Homegardens were mainly worked by women, but fruit trees and cash crops were mostly managed by men. According to the gardeners, monthly working hours per 100 m^2 garden area ranged from 0.2 to 10.1 hours (on average 1–2 hours). Planting material was largely of endogenous origin, e.g. saved from own seeds, requested from relatives and friends, or self-established. Concerning soil quality management, local gardeners reported to apply mostly ash, manure, or no fertiliser, whereas many migrant gardeners also used industrial fertiliser. Gardeners mainly controlled weeds by spraying herbicides, although hoeing or cutting weeds was still performed, particularly in the local villages. Application of insecticides was reported mainly by gardeners managing cash crop-dominated gardens.

In 2004, a combined total of 206 crop species belonging to 71 plant families were cultivated in the 50 homegardens surveyed. Besides, 162 ornamental and 58 weedy species were found in the gardens. On average, 33–49 crop species were cultivated per garden; crop species density varied from 30 to 51 species per 1000 m^2 cultivated garden area. Composition as well as richness and diversity of crops differed markedly among villages, reflected partly also in differences of structural complexity. In the three local villages Wuasa, Rompo, and Wanga, species richness and diversity were rather high and vegetation structure more complex as compared to the migrant villages Siliwanga and Tamadue. In Wuasa, the administrative and commercial centre of the Napu valley, homegardens harboured many spices, partly cultivated also for sale. On the other hand, homegardens in Rompo and Wanga were characterised by a mixture of crops not dominated by any use category. In the migrant village Siliwanga, homegardens were largely used for staple crop production, as suitable fields for staples were limited around this village. Due to the poor soil quality in Siliwanga, only few trees reached the higher vegetation layers. In the migrant village Tamadue, many gardens were dominated by the cash crops cacao and arabica coffee as well as some shade trees. Shading and regular herbicide application resulted in a poorly developed herbaceous vegetation layer. Cluster analysis based on species abundances partly reflected these differences between migrant and local gardens as well as villages. However, local gardens were not separated according to villages, indicated also by high similarity coefficients among the local villages.

Soil quality parameters were highly variable both within and among homegardens. Total C and N contents were mostly rated as low to intermediate. In garden zones used for vegetable production, C and N contents were significantly lower than in adjacent parts of the same garden used for cacao/coffee production. Among other reasons, this could be caused by the higher soil temperature in the vegetable zones as recorded in the case study gardens. Average soil pH values ranged from 5.6 to 5.8, being slightly lower in Siliwanga. Plant available P-Bray contents varied largely from 26 to 440 ppm, being on average very low in Tamadue and high in Wuasa. When vegetable zones were regularly fertilised with ash, P-Bray contents of their soils were significantly higher than in adjacent cacao/coffee zones of the same garden, but lower, when vegetable zones were not fertilised. Effective cation exchange capacity was rated as high in Tamadue, very low in Siliwanga, and low to intermediate in the other three villages. Soil erosion was considered as problematic in some of the homegardens surveyed, particularly in the vegetable and ornamental zones.

Multiple regression analysis applied to all gardens revealed the most important factors influencing crop species richness and diversity. A negative influence was detected for the characteristics ‘low soil P content’, ‘cash-oriented production’, and ‘migrant gardener’. Garden size and mean age of adults in the gardener’s household influenced crop species richness and diversity positively. PCA applied to the 30 re-inventoried gardens showed that crop species composition shifted in the two villages with relatively good market access, Wuasa and Siliwanga, towards more cash crops, whereas in the remote village Rompo, no such changes were detected over time. In these three villages, overall crop species richness and diversity slightly increased from 2001 to 2004. This increase partly might have been caused by activities of development projects in the area and by the previous homegarden research in the year 2001, which stimulated the interest of gardeners in crop diversity. Soil pH values as well as C and N contents decreased significantly over time; although not significant, P content showed a similar trend. This was, most likely, due to insufficient soil quality management.

In conclusion, the homegardens surveyed were considered to be sustainable in socio-economic dimensions and also concerning the resource ‘crop diversity’, but not in terms of appropriate management for the maintenance of soil quality. In the future, sustainability of these homegardens may additionally be threatened by different aspects of ‘modernisation’, such as an increased use of external inputs and a shift towards cash-oriented production. Particularly, when commercialisation was possible, crop diversity was shown to be fairly dynamic over time. To maintain the sustainability of these homegardens and their suitability for *in situ* conservation of plant genetic resources, any promotion to intensify production should consider to keep the structure and overall functioning of this agro-ecosystem in a landscape context.

7 Zusammenfassung

Hausgärten gelten allgemein als sehr komplexes, artenreiches Agrar-Ökosystem, das auf nachhaltige Weise über Jahrzehnte oder gar Jahrhunderte hinweg bewirtschaftet wird. Die wichtigsten Funktionen von Hausgärten sind neben der Subsistenz-Produktion auch die Einkommensschaffung, besonders im ländlichen Raum. Zusätzlich erfüllen Hausgärten aber auch wichtige ökologische, soziale und kulturelle Funktionen. Darüberhinaus können Hausgärten als ein Modell für ein nachhaltiges landwirtschaftliches Produktionssystem angesehen werden, das sowohl ökonomische, als auch ökologische Vorteile vereinigt. Die Nachhaltigkeit von Agrar-Ökosystemen besteht darin, dass ein Produktionsniveau erhalten wird, welches die Bedürfnisse jetziger und zukünftiger Generationen erfüllt, ohne dabei die natürlichen Ressourcen zu zerstören, auf denen diese Produktion basiert. Das Konzept der Nachhaltigkeit beinhaltet nicht nur ökologische, sondern auch ökonomische und soziale Dimensionen. Da Nachhaltigkeit *per se* nicht erfasst und bewertet werden kann, kommen stattdessen bestimmte Deskriptoren und Indikatoren zum Einsatz, z.B. Bodenfruchtbarkeits-Parameter oder Biodiversität. Als Grundlage für die Produktivität und Nachhaltigkeit von Hausgärten wird pflanzliche Diversität angesehen, die jedoch über die Jahre nicht stabil bleibt. Sowohl Diversität als auch Zusammensetzung von Pflanzengemeinschaften werden weitgehend von einer Kombination verschiedenster agro-ökologischer wie auch sozio-ökonomischer Faktoren beeinflusst, deren komplexe Interaktionen bisher aber nicht vollständig verstanden werden. Darüberhinaus wurde die behauptete Nachhaltigkeit von Hausgärten nur selten in quantitativer Art oder in Zeitreihen überprüft.

Das Hauptziel der vorliegenden Arbeit war die Bewertung der Nachhaltigkeit ausgewählter ländlicher Hausgärten in Zentral-Sulawesi, Indonesien. Dabei wurden räumliche Unterschiede und zeitliche Veränderungen der Ressourcenqualität in Hausgärten sowie die dafür verantwortlichen Faktoren erfasst. Besonderer berücksichtigt wurden Nutzpflanzendiversität, Bodenqualität, Mikroklima und Management dieser Gärten. Schließlich wurden mögliche Potentiale für die Produktivitätssteigerung in Hausgärten und ihre Eignung für die *in situ*-Konservierung pflanzengenetischer Ressourcen abgeschätzt.

Die Untersuchung wurde im Napu-Tal, Zentral-Sulawesi, durchgeführt. Dieses Tal liegt am östlichen Rand des Lore Lindu Nationalparks auf einer Höhe von ca. 1.100 m über NN. In fünf Dörfern, die sich unter anderem hinsichtlich Marktzugang, Herkunft ihrer Bewohner und Bodenqualität unterschieden, wurden jeweils 10 Haushalte mit Hausgärten randomisiert ausgewählt. Die Gärten wurden vermessen und in jedem eine Inventur sämtlicher Pflanzenarten durchgeführt, bei der Anzahl und Abundanz aller Nutz- und Zierpflanzen ermittelt wurden. Für Bäume wurde zusätzlich deren Höhe abgeschätzt. Um die zeitliche Dynamik der Nutzpflanzendiversität zu erfassen, wurden 30 Hausgärten in den Dörfern Wuasa, Rompo und Siliwanga, die schon im Jahr 2001 untersucht worden waren, in den Jahren 2003 und 2004 erneut inventarisiert. In allen Hausgärten wurde der Oberboden (0–15 cm tief) randomisiert beprobt und dessen Textur, Bodendichte, pH-Wert, Gehalt an C, N, und pflanzenverfügbarem P, sowie dessen effektive Kationenaustauschkapazität und Basensättigung analysiert. Einige dieser Analysen wurden mit denen des Jahres 2001 verglichen. Außerdem wurden Interviews mit den Gartenbetreibern u.a. zu den Themen Gartenmanagement sowie Nutzung der angebauten Pflanzen durchgeführt. Mit Hilfe weiterer Interviews wurden Sekundärdaten zu Haushalt und Hof dokumentiert. In einer Fallstudie wurden in drei der Gärten Bodenerosion und Mikroklima (d.h. Luft- und Bodentemperaturen sowie photosynthetisch-aktive Strahlung (PAR)) untersucht sowie detaillierte Managementdaten ermittelt. Neben der Erfassung von Nutzpflanzenanzahl und –dichte wurden zusätzlich mehrere Diversitäts- und Ähnlichkeitsindices berechnet. Mit Hilfe einer Clusteranalyse wurden räumliche Diversitätsmuster aufgedeckt und unterschiedliche Gartentypen auf der Grundlage ihrer Artenzusammensetzung klassifiziert. Zur Identifizierung der Faktoren, die die Nutzpflanzendiversität beeinflussen, wurden multiple, lineare Regressionsanalysen eingesetzt. Hauptkomponentenanalyse (PCA) auf der Basis von Artenabundanzen wurde zur Aufdeckung und Visualisierung zeitlicher Veränderungen der Artenzusammensetzung durchgeführt.

Die Hausgärten im Napu-Tal wurden 2 bis 40 Jahre lang kontinuierlich bewirtschaftet und verfügten über eine Anbaufläche zwischen 300 und 2.400 m^2 (im Mittel 600–2.300 m^2). Die Gärten dienten in erster Linie der subsistenzorientierten Produktion von Nahrungsmitteln (aber nicht von Grundnahrungsmitteln, sondern eher von Obst, Gemüse und Gewürzen) und von Nicht-Nahrungsmitteln wie Medizinalpflanzen, Futter oder Brennholz. Die Hausgartenerzeugnisse waren ganzjährig verfügbar. Einige Gärten trugen durch den Anbau von *cash crops* (besonders von Kakao, Arabika-Kaffee und Vanille) weitgehend zur Einkommensschaffung ihrer Besitzer bei. Das Produktionspotential wurde jedoch sowohl in den subsistenz- wie auch den markt-orientierten Hausgärten nicht vollständig ausgenutzt. Die Gärten wurden überwiegen von Frauen bewirtschaftet, doch lag die Pflege von Obstbäumen und *cash crops* meistens im Verantwortungsbereich der Männer. Die Gartenbetreiber gaben an, pro 100 m^2 Gartenfläche monatlich zwischen 0,2 und 10,1 Stunden ihrer Arbeitszeit für Gartenarbeiten zu investieren (im Mittel 1–2 Stunden). Das verwendete Pflanzmaterial war größtenteils endogener Herkunft, z.B. aus eigener Nachzucht, von Verwandten und Freunden erbeten oder von selbst gekeimt. Befragt zu Management und Erhaltung der Bodenqualität nannten einheimische Gartenbetreiber u.a. die Anwendung von Asche oder Mist bzw. keinerlei Düngeranwendung, zugewanderte dagegen auch die von synthetischem Dünger. Als Maßnahme zur Unkrautbekämpfung wurde vorwiegend die Herbizidanwendung genannt, jedoch erwähnten besonders die einheimischen Gartenbetreiber auch Hacken und Schneiden zur Unkrautkontrolle. Insektizide wurden hauptsächlich von solchen Gartenbetreibern eingesetzt, die einen markt-orientierten Garten bewirtschafteten.

Im Jahr 2004 wurden insgesamt 206 Nutzpflanzenarten aus 71 Pflanzenfamilien in den 50 untersuchten Gärten angebaut. Zusätzlich kamen 162 Zier- und 58 Unkrautarten in den Gärten vor. Pro Garten fanden sich im Mittel 33 bis 49 Nutzpflanzenarten, ihre Dichte schwankte zwischen 30 und 51 Arten pro 1000 m^2 Gartenfläche. Sowohl Artenzusammensetzung als auch Artenzahl und –dichte in Hausgärten wiesen deutliche Unterschiede zwischen den Dörfern auf, die sich auch in einer unterschiedlichen strukturellen Komplexität der Vegetation widerspiegelten. In den drei überwiegend von Einheimischen bewohnten Dörfern Wuasa, Rompo und Wanga fand sich eine höhere Artenzahl und –diversität sowie eine komplexere Vegetationsstruktur als in den Migrantendörfern Siliwanga und Tamadue. In Wuasa, dem administrativen und kommerziellen Zentrum des Napu-Tales, kamen viele Gewürzarten in den Hausgärten vor, die teilweise zu Verkaufszwecken angebaut wurden. Dagegen zeichneten sich die Gärten in Rompo und Wanga durch eine ausgewogene Mischung von Nutzpflanzen aus, ohne dass einzelne Nutzungsklassen dominierten. Im Migrantendorf Siliwanga dienten die Gärten weitgehend der Produktion von Grundnahrungsmitteln, da in der Nähe dieses Dorfes nur wenige dafür geeignete Felder zur Verfügung standen. Aufgrund der nur geringen Bodenqualität in Siliwanga erreichten nur wenige Bäume die obersten Vegetationsschichten. In den Hausgärten des Migrantendorfes Tamadue dominierten die *cash crops* Kakao und Kaffee sowie deren Schattenbäume. Aufgrund der Beschattung und regelmäßiger Herbizidanwendung war in diesen Gärten die Krautschicht nur sehr spärlich entwickelt. Diese Unterschiede zwischen von Einheimischen und Migranten bewirtschafteten Gärten sowie zwischen deren Dörfern bestätigte teilweise auch die auf der Artenabundanz basierende Clusteranalyse. Die Gärten der von Einheimischen bewohnten Dörfer wurden allerdings durch die Clusteranalyse nicht deutlich getrennt, was aufgrund der relativ hohen Ähnlichkeitskoeffizienten dieser drei Dörfer auch nicht zu erwarten war.

Die erfassten Bodenqualitätsparameter schwankten sowohl innerhalb einzelner Gärten als auch zwischen verschiedenen Gärten stark. Die Gehalte an C und N wurden zumeist als niedrig bis mittel bewertet. Boden von vorwiegend der Gemüseproduktion dienender Bereiche innerhalb eines Gartens enthielt signifikant weniger C und N als derjenige angrenzender, aber für Kakao- und/oder Kaffeeproduktion genutzter Zonen desselben Gartens. Diese Unterschiede könnten u.a. mit der höheren Bodentemperatur von Gemüse- gegenüber Kakao/Kaffeezonen begründet werden, die in den Fallstudien dreier Gärten festgestellt wurde. Die mittleren pH-Werte schwankten zwischen 5,6 und 5,8, wobei sie in Siliwanga eher niedrig waren. Gehalte an pflanzenverfügbarem P (Bray) variierten sehr stark von 26 bis 440 ppm; im Mittel waren sie in Tamadue sehr niedrig, aber in Wuasa relativ hoch. Gemüsezonen, die regelmäßig mit Asche gedüngt wurden, verfügten über einen höheren Bodengehalt an P (Bray) als angrenzende Kakao/Kaffeezonen desselben Gartens, aber über einen niedrigeren, wenn sie nicht gedüngt wurden. Die effektive Kationenaustauschkapazität wurde in Tamadue als hoch, in Siliwanga als sehr niedrig und in den drei anderen Dörfern als niedrig bis mittel bewertet. In einigen Gärten wurde die Bodenerosion als problematisch eingeschätzt, besonders in Gemüse- und Zierpflanzenzonen.

Die multiple Regressionsanalyse der Daten aller 50 untersuchten Gärten ermittelte die wesentlichen, die Nutzpflanzenartenzahl und –diversität beeinflussenden Faktoren. Ein negativer Einfluß wurde für die Merkmale „geringer P-Gehalt des Bodens“, „markt-orientierte Produktion“ und „Zugewanderter Gartenbetreiber“ nachgewiesen. Dagegen beinflussten Gartengröße und mittleres Alter der Erwachsenen im Haushalt des Gartenbetreibers die Nutzpflanzenartenzahl und –diversität positiv. Die Hauptkomponentenanalyse der Daten der 30 in einer Zeitreihe untersuchten Gärten zeigte, dass sich die Artenzusammensetzung in den Gärten der zwei Dörfer mit relativ gutem Marktzugang (d.h. Wuasa und Siliwanga) zugunsten der *cash crops* verschoben hatte. Im abgelegenen Dorf Rompo wurde dagegen keine derartige Veränderung über die Jahre nachgewiesen. Insgesamt nahmen sowohl Artenzahl als auch –diversität der Nutzpflanzen in allen drei Dörfern im Untersuchungszeitraum von drei Jahren zu. Zum Teil mag dieser Anstieg mit regionalen Aktivitäten von Dorfentwicklungsprojekten zusammenhängen, zum Teil aber auch mit der im Jahr 2001 durchgeführten Studie in denselben Hausgärten, die das Interesse der Gartenbetreiber an einer hohen Nutzpflanzendiversität gesteigert haben könnte. Sowohl pH-Werte als auch C- und N-Gehalte der Gartenböden nahmen von 2001 bis 2004 signifikant ab. Auch für den P-Gehalt der Böden konnte eine solche Tendenz, die jedoch nicht signifikant war, festgestellt werden. Dieser Rückgang wurde höchstwahrscheinlich durch unzureichendes Bodenfruchtbarkeits-Management verursacht.

Abschließend lassen sich die untersuchten Hausgärten als nachhaltig in Bezug auf sozio-ökonomische Kriterien und auf die Ressource „Nutzpflanzendiversität“ bewerten, nicht jedoch bezüglich einer angemessenen, auf Erhaltung der Bodenqualität ausgerichteten Bodenbewirtschaftung. Zusätzlich könnte die Nachhaltigkeit dieser Hausgärten durch verschiedene Auswirkungen der „Modernisierung“ beeinträchtigt werden, z.B. durch steigende Nutzung exogener Inputs oder stärkere Marktorientierung der Produktion. Die Nutzpflanzendiversität erwies sich besonders dort als sehr veränderlich über die Zeit, wo eine Kommerzialisierung von Gärten leicht möglich war. Damit die Nachhaltigkeit dieser Hausgärten sowie ihre Eignung für *in situ*-Konservierung pflanzengenetischer Ressourcen erhalten bleibt, sollten jegliche Maßnahmen zur Produktionsintensivierung die Struktur und Gesamtfunktion dieses Agrar-Ökosystems auch im jeweiligen landschaftlichen Kontext berücksichtigen.

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9 Appendices

Appendix 1. Questionnaire for socio-economic data survey of 50 households with homegardens in five villages of the Napu valley, Central Sulawesi, designed by subproject A4 of STORMA.

STORMA (Stability of Rainforest Margins)
Household survey questionnaire

1. Household identification

Kecamatan/village/dusun RT : Lore Utara/………../……
Date of interview :
Name of household head :
Name of respondent :

2. Residence of parents/grandparents

2.1. Residency table head of household

	Do you use to live in this village all your life?	If 2 (no) then answer the following questions			If already moved twice	
	1 = yes 2 = no	Year of migration to this vill.	From where did you move to the vill.? (code 1)	Why did you come to this vill.? (code 2)	From where moved to vill. mentioned before?	Year of migr.
Head of household						
Parents of the head						
Ancestors of head						

Code 1
1 = Same Kecamatan as village
2 = Other Kecamatan in Central Sulawesi
3 = North Sulawesi
4 = South Sulawesi
5 = Southeast Sulawesi
6 = Other Provincy of Indonesia ………….
7 = From outside Indonesia

Code 2
1 = Transmigrasi project
2 = Marriage
3 = Land was available
4 = Insecure situation in former village
5 = Job opportunities
6 = Other reason

2.2. If the code 1 is 1 or 2 (same Kecamatan as village or other Kecamatan in Central Sulawesi) name of village/kec/kab :

2.3. Residency table spouse

	Do you use to live in this village all your life?	If 2 (no) then answer the following questions			If already moved twice	
	1 = yes 2 = no	Year of migration to this vill.	From where did you move to the vill.? (code 1)	Why did you come to this vill.? (code 2)	From where moved to vill. mentioned before?	Year of migr.
Spouse						
Parents of spouse						
Ancestors						

2.4 If code 1 is 1 or 2 (same Kecamatan as village or other Kecamatan in Central Sulawesi) name of village /kec./kab. :

3. Religion of the head of the household:

1. Muslim, 2. Catholic, 3. Protestant, 4. Others (Hindu)

4. Household composition

Note: Members of household are all people, who usually eat from the same pot and sleep under the same roof. Include also members, who are absent for less than two months

Member I.D. 1=head 2=spouse	Name	Sex 1=male 2=female	Age in years	Relation with head Code 1	Marital status Code 2	Able to write? 1=yes 2=no	Level of schooling Code 3	Professional training 1=yes 2=no	Main occupation in the current year Code 4	Clothes/footwear expenses in last 12 months (Rp)
1										
2										
3										
4										
5										
6										
7										
8										

Code 1
1= Son or daughter
2= Father or mother
3= Grandchild
4= Grandparents
5= Father/mother/son/daughter in law
6= Other relative
7= Other non relative

Code 2
1= Unmarried
2= Married
3= Widow/widower
4= Divorced

Code 3
1= Never attended
2= Some SD
3= Completed SD
4= Attended SMP
5= Completed SMP
6= Attended SMA
7= Completed SMA
8= Attended academy or Univ.

Code 4
1= Self-employed in agriculture
2= Self-employed in non farm enterprise
3= Government employee
4= Casual worker
5= Salaried worker in agriculture
6= Salaried worker in non-agriculture
7= Domestic worker
8= Student
9= Unemployed, looking for a job
10= Unwilling to work or retired
11= Unable to work (handicapped)

5. Land and livestock possession

5.1 Current possession of livestock

Please do not include animals that are younger than two months (poultry) or 6 months (all other animals)

Code of animal and breed Code 1	How many heads household owns now	Resale value at current market prices Rp	Only for buff., cattle, horses: how many heads did HH own 12 months ago	Only for buff., cattle, horses: how many heads did you loose in last 12 months?	Main components of fodder Code 2		Function of animal (self-consumption, sale, gift, …)

Code 1

1= Buffaloes
2= Dairy cows
3= Bulls
4= Oxen
5= Heifer
6= Pig
7= Goats
8= Sheep
9= Duck
10= Chicken
11= Horse
12= Other animal

Code 2

1= Grazing on pasture
2= Grazing in the forest
3= Cut fresh grass
4= Forest products
5= Grains
6= Roaming around the house
7= Residuals of maize
8= Cassava
9= Rice bran
10= Left-over
11= Other components

5.2 Do you own any land at present? (1= yes, 2= no)

If 2 (no) skip to question 5.4

5.3 Current possession of land (land owned at present)

Please fill out for each parcel of land owned. Begin with homestead/home garden (lahan pekarangan)

Code of plot	Description	Area (ares)	Type of plot Code 1	Current land use (1., 2., 3. crop) Code 2			If 1 or 2 (rice/maize) variety Code 3		If 3 or 4 (coffee/cocoa) age in years		Quality of soil Code 4	Slope graph	Distance plot-house in walking minutes
1	Home garden												
2													
3													
4													
5													
6													

Code 1
1= Home garden
2= Sawah with simple irrigation
3= Sawah with semi technical irrigation
4= Sawah with technical irrigation
5= Tegalan
6= Ladang
7= Garden in the forest
8= Non agriculture land
9= Primary forest

Code 2
1= Wetland rice
2= Maize
3= Cocoa
4= Coffee
5= Peanuts
6= Bananas
7= Coconuts
8= Cassava
9= Upland rice
10= French beans
11= Other vegetables
12= Avocados
13= Pasture
14= Bushes/fallow
15= Secondary forest
16= Don't know
17= Others

Code 3
1= Local variety
2= Improved variety
3= Recyled

Code 4
1= Fertile soils
2= Medium fertile soils
3= Less-fertile soils

5.4 Does your household rent in or borrow any land at present? (1=yes, 2=no)

If 2 (no) skip to question 6

5.5 Land rented in/borrowed

Please fill out for each parcel for each rented in or borrow

Code of plot	Description	Area (ares)	Type of plot Code 1	Current land use (1., 2., 3. crop) Code 2			If 1 or 2 (rice/maize) variety Code 3		If 3 or 4 (coffee/cocoa) age in years		Quality of soil Code 4	Slope graph	Distance plot-house in walking minutes	How much do you pay (Rp/year)
1	Home garden													
2														
3														
4														
5														
6														

Code 1
1= Home garden
2= Sawah with simple irrigation
3= Sawah with semi technical irrigation
4= Sawah with technical irrigation
5= Tegalan
6= Ladang
7= Garden in the forest
8= Non agriculture land
9= Primary forest

Code 2
1= Wetland rice
2= Maize
3= Cocoa
4= Coffee
5= Peanuts
6= Bananas
7= Coconuts
8= Cassava
9= Upland rice
10= French beans
11= Other vegetables
12= Avocados
13= Pasture
14= Bushes/fallow
15= Secondary forest
16= Don't know
17= Others

Code 3
1= Local variety
2= Improved variety
3= Recyled

Code 4
1= Fertile soils
2= Medium fertile soils
3= Less-fertile soils

6. Plot-specific output and input data

Note for enumerator: the next questions concern the plots from table 5.1, but refers only to the last crop harvested (annual crops) and to the last twelve months for all perennial crops respectively. The input use refers to the time before the last harvest (annuals) and to the last twelve months for all perennials respectively

Code of plot	Refers to the first crop on the plot						Refers to the second crop on the plot						Costs for land prepar.	Costs for seeds and planting
	Crop Code 1	Month of planting	Month of harvest	Quantity harvested	Unit Code 2	How was the yield? Code 3	Crop Code 1	Month of planting	Month of harvest	Quantity harvested	Unit Code 2	How was the yield	Rp	Rp
1														
2														
3														
4														
5														
6														

Code 1
1= Wetland rice
2= Maize
3= Cocoa
4= Coffee
5= Peanuts
6= Bananas
7= Coconuts
8= Cassava
9= Upland rice
10= French beans
11= Other vegetables
12= Avocados
13= Pasture
14= Bushes/fallow
15= Secondary forest
16= Don 't know
17= Others

Code 2
1= Kg
2= Litres
3= Bundles
4= Pieces
5= Hands (bananas)
6= Container
7= Roots (cassava)

Code 3
1= Good
2= Average
3= Below average

6. Plot-specific output and input data (continued)

Code of plot	Chemical fertiliser use						Do you apply organic fertiliser?	Do you apply mulch?	Costs for irrigation	Pesticide used	Costs for pesticides	Transport procession costs	Labour costs		Soil conser-vation meas.
	Type Code 1	Quantity bags	Price per bag Rp/bag	Type Code 1	Quantity bags	Price per bag Rp/bag	1=yes 2= no	1=yes 2=no	Rp		Rp	Rp	Paid in costs	Paid in kind	1=yes 2=no
1															
2															
3															
4															
5															
6															

Code 1
1= Urea
2= Triple super phosphate
3= ZA
4= KCL
5= NPK

7. Food-related indicators

Note : Both the head of the household and his or her spouse should be present when answering for this section.

7.1. How many meals were served to the household members during the last 2 days? ….

7.2. During the last seven days, for how many days were the following foods served in a main meal eaten by the household?

Luxury food	Number of days served
Poultry	
Beef	
Pork	
Fish	

7.3. During the last 12 months, for how many days did your household not have enough to eat everyday? ……….

7.4. How often do you purchase the following?

Staple	Frequency served (Code 1)
Rice	
Cooking oil	
Sugar	

Code 1:

1=Daily	*2=Twice a week*	*3=Weekly*
4=Fortnightly	*5=Monthly*	*6=Less frequent than a month*

7.5. For how many weeks do you have a stock of rice in your house? ……….

8. Dwelling-related indicators

Note: Information should be collected about the dwelling in which the family currently resides.

8.1. What is the ownership status of dwelling? ……….

1=Built on squatter land	*2=Owned*	*3=Given by relative or other to use*
4=Provided by government	*5=Rented*	

8.2. How many rooms does the dwelling have? ……….

Note: Include detached rooms in same compound if same household.

8.3. What type of roofing material is used in main house? ……….

1=Straw	*2=Clay bricks*	*3=Pressed bricks*
4=Asbestos	*5=Corrugated iron*	*6=Concrete*

8.4. What type of exterior walls does the dwelling have? ……….

1=Bamboo	*2=Wooden plates*	*3=Brick or stone with mud*
4=Brick or stone with cement plaster		

8.5. What type of flooring does the dwelling have? ……….

1=Earth	*2=Wood*	*3=Stones*
4=Stone plates	*5=Cement*	*6=Cement with additional covering*

Note: You must not ask the next question to the respondent. Please give your own estimation.

8.6. What is the observed structural condition of main dwelling? ……….

1=Seriously dilapidated *2= Need for major repairs* *3= Sound structure*

8.7. What is the electricity supply? ……….

1=No connection *2=Shared connection* *3=Own connection*

8.8. What type of cooking fuel source primarily is used? ……….

1=Dung *2=Collected wood* *3=Purchased wood or sawdust* *4=Charcoal*
5=Kerosene *6=Gas* *7=Electricity*

8.9. What is the source of drinking water? ……….

1=Rainwater *2=Dam* *3=Pond or lake* *4=River or stream*
5=Spring *6=Public well-open* *7=Public well-sealed by pump* *8=Well in residence yard*
9=Piped public water *10=Bore hole in residence*

8.10. What type of toilet facility is available? ……….

1=Bush, field, or no facility *2=Shared pit toilette* *3=Own pit toilette*
4=Shared improved latrine *5=Own improved latrine* *6=Flush toilet*

9. Other asset-based indicators

Number and value of selected assets owned by household.

Asset type and code	Number owned	Resale value at current market price
Transportation		
1. Cars		
2. Motorcycles		
3. Bicycles		
4. Tractor		
5. Carts		
Appliances and electronics		
6. Radios, Tape		
7. Television		
8. Kerosene cooker		
9. Electric or gas cookers		
10. Knapsack sprayer		
11. Water pump		
12. Chainsaw		
13. Sewing machine		
14. Fans		

Appendix 2. Questionnaire for homegarden-specific data, used for a survey of 50 households with homegardens in five villages of the Napu valley, Central Sulawesi, in 2001 and 2004.

Homegarden Questionnaire

1. Name of gardener: Date of interview:
2. When did you establish the garden?
3. How was the land used before?
4. If it was used as a homegarden before, who was the owner and what kind of plants were already grown?

Biodiversity

5. What kind of weeds do you have in your garden? Please give the local names!
6. Do you use some of the weeds? If yes, which species and how?
7. In the past, do you remember growing some plants that are presently not grown? If yes, which species and why did you stop growing them?
8. In the future, would you like to grow some more plant species? If yes, which species or varieties, what is the purpose and why did you not grow them up to now?
9. If seeds of modern varieties would be available, would you like to replace your local varieties with the modern ones? Why and which species first?
10. Do you keep any livestock in your garden?
    Which species and breeds?

Soil

11. What do you think about the quality of the soil in your garden?
12. Has the soil quality changed in the past? How?
13. Are there local names given to the different soil types? Please list and describe!
14. Do you have an idea how to improve the soil?
15. How do you work the land?
16. How many times a week/a month do you hoe your garden?
17. How deep (in cm) do you hoe usually?
18. Do you work the whole garden in the same manner or differently according to different plants?
    Ornamentals :
    Vegetables :
    Coffee and cacao trees :
    Fruit trees :
19. Do you use fertiliser in your garden?

Fertiliser	Frequency	Last application	Amount	For which plants	Application procedure	Fertiliser source
NPK						
Manure						
Ashes						
Compost						
Mulch						
Other						

If not, why not? Would you like to use fertiliser? What kind of fertiliser?

Management

20. What kind of work do you do in your garden throughout the year?

Work	Frequency	Last performing	Person working	Plant species/ production zone	Time needed
Hoeing					
Sowing/planting					
Fertilising					
Spraying					
Weeding					
Cutting trees					
Harvesting					
Other					

21. In general, who carries out most of the work in your homegarden (e.g. farmer, his wife, children, relatives, neighbours, ...)?

22. Who is responsible for the following kinds of plants?
Ornamentals Vegetables Spices Medicals Coffee/cacao Trees

23. If you compare the work in your homegarden, your paddy rice fields and your coffee/cacao plantation:
- where do you work the most time 1. 2. 3.
- where is the work hardest 1. 2. 3.

24. If you compare the costs for fertiliser, pesticides or farm worker in your homegarden,
- your paddy rice fields and your coffee/cacao plantation:
- where do you have to pay most 1. 2. 3.

Function

25. What is the main function of your garden? What is the second function?

26. For the life of you and your family, is your homegarden very important or not important at all?

27. If you compare the yield of food stuffs for home consumption coming from your homegarden, your paddy rice fields and your coffee/cacao plantation:
from where comes the highest portion 1. 2. 3.

28. If you compare the yield of cash crops for sale coming from your homegarden, your paddy rice fields and your coffee/cacao plantation:
from where comes the highest portion 1. 2. 3.
If possible, can you please give the portion in percent of cash income coming from your: garden % , paddy rice field % , plantation % , other %

Problems

29. Are there any problems with weeds or pests and diseases?

Problem	Plants/production zones attacked	Description	Controlling procedure	Name of pesticide	Last application	Success
Weeds						
Pests:						
Diseases:						

30. Please rate the importance of following problems in managing your homegarden (very serious, serious, medium, no problem):
    - Weeds
    - Pests and diseases
    - Poor soil
    - Time shortage
    - Poor varieties/lack of seeds
    - Free roaming livestock
    - Other
31. If you sell products of your homegarden, do you have any problems with sale? If yes, please name and describe these problems!
32. Was there ever any extension service for home gardens? If yes:
    - What organisation gave the extension?
    - How often/when the last time?
    - Was it helpful for you?
33. Would you like to improve your homegarden? How?
34. Did you and your family ever get some agricultural support from NGO's or the government? If yes, please describe what kind, how often, from whom?
35. If there was some agricultural support from NGO's or the government, what kind of assistance would you need? Please rate the importance of the item (very important, important, medium, useless)!
    - Fertiliser
    - Seeds/seedlings
    - Livestock
    - Extension service/training
    - Pesticides and sprayer
    - Other

Note: Questions no. 4, 9, 22–24, 26–28, 34, and 35 were not asked in 2001, no.18–20, 29, 30, and 32 not in such detail.

Appendix 3. Basic socio-economic data of 50 households (HH) with homegardens surveyed in five villages of the Napu valley, Central Sulawesi, in 2004. (HH-H = Household head).

Vil-lage	HH no.	No.of small children (< 5)	No.of school children (5-14)	No. of adults (15-67)		No. of old HH members (> 67)	Total no. of HH members	Dependance ratio (%) (no. children/total HH member)	Age of		Mean age of adults in HH	Religion	Origin of		Formal education of		Portion (%) of adults not finished prim. school	Portion (%) of adults finished sec. school	Occupation of HH-H		Occupation of HH-H's wife		Attendance at an agricultural training course	
				Females	Males				HH-H	HH-H's wife			HH-H	HH-H's wife	HH-H	HH-H's wife			Main	Side	Main	Side	HH-H	Wife
Wu	1	0	0	2	1	0	3	0	65	59	47	1	1	1	5	3	0	33	1	0	7	1	1	0
Wu	2	1	2	2	2	1	8	38	51	39	43	1	1	1	7	6	0	60	3	1	7	1	1	1
Wu	3	1	1	2	4	0	8	25	63	58	38	2	1	1	5	5	0	67	10	1	7	0	1	1
Wu	4	1	1	2	1	0	5	40	43	43	34	2	2	1	7	8	0	67	1	2	2	7	1	0
Wu	5	1	2	1	5	0	9	33	58	53	33	2	1	1	4	2	67	0	1	4	1	7	0	0
Wu	6	1	4	3	2	0	10	50	34	32	30	1	1	1	3	3	0	0	1	4	1	7	1	0
Wu	7	1	3	3	6	1	14	29	69	58	35	1	1	1	7	5	0	60	10	1	7	0	0	0
Wu	8	0	1	1	2	0	4	25	40	43	34	1	1	1	6	3	0	0	1	4	1	7	0	0
Wu	9	1	0	2	4	1	8	13	52	52	41	1	1	1	8	5	0	71	3	1	7	1	0	0
Wu	10	1	1	1	2	1	6	33	67	71	54	1	1	1	3	2	75	0	1	4	7	0	0	0
R	11	2	0	1	2	0	5	40	54	54	45	1	1	1	3	3	0	0	1	0	7	1	0	0
R	12	0	0	1	0	0	1	0	n.a.	22	22	1	n.a.	2	n.a.	8	0	100	n.a.	n.a.	3	0	n.a.	n.a.
R	13	0	1	1	2	0	4	25	44	35	31	1	3	3	7	5	0	33	1	3	1	7	1	0
R	14	0	5	2	3	1	11	45	89	60	44	1	2	2	8	5	0	33	1	0	1	7	1	1
R	15	2	0	1	1	0	4	50	25	23	24	1	1	1	3	5	0	0	1	0	1	7	0	0
R	16	1	0	1	3	0	5	20	50	44	35	1	1	1	5	3	0	0	1	0	1	7	1	0
R	17	1	0	1	1	0	3	33	30	20	25	1	3	1	5	3	0		1	4	1	7	0	1
R	18	1	2	1	1	0	5	60	56	32	44	3	1	1	3	3	0	0	1	0	1	7	0	0
R	19	1	3	3	3	0	10	40	56	52	30	1	1	1	7	5	0	17	1	0	7	0	1	0
R	20	0	0	2	4	0	6	0	44	49	29	1	1	1	6	3	0	17	1	0	1	7	1	0
S	21	1	1	1	1	1	5	40	34	28	45	4	2	5	7	3	33	33	1	5	1	7	1	0
S	22	1	2	1	1	0	5	60	60	37	49	1	3	3	5	1	50	0	1	0	1	7	0	0
S	23	1	1	1	1	0	4	50	37	32	35	5	6	6	7,5	2	50	50	1	3	7	1	1	0
S	24	0	1	1	1	0	3	33	42	38	40	5	6	6	8	7	0	100	3	1	7	1	1	1
S	25	2	0	1	1	0	4	50	30	33	32	2	2	4	8	8	0	100	12	1	7	12	1	1
S	26	0	2	1	1	0	4	50	35	33	34	5	6	6	5	2	50	0	1	0	1	7	1	0
S	27	0	1	1	1	0	3	33	33	31	32	5	6	6	3	3	0	0	1	2	1	7	1	0
S	28	1	2	1	2	0	6	50	45	45	37	5	6	6	2	2	67	0	1	5	1	7	1	0
S	29	0	1	1	1	0	3	33	31	32	32	5	6	6	3	3	0	0	1	4	1	7	1	0
S	30	0	1	2	1	0	4	25	40	30	29	5	6	6	2	1	67	0	1	0	1	7	0	0
T	31	0	0	2	1	0	3	0	35	35	29	5	6	6	2	1	67	0	1	2	1	7	0	0
T	32	0	0	2	2	0	4	0	39	37	29	5	6	6	3	1	25	0	1	0	1	7	0	0
T	33	0	2	1	1	0	4	50	35	35	35	5	6	6	8	7	0	100	2	1	3	7	1	0
T	34	0	0	1	1	0	2	0	60	55	58	5	6	6	2	2	100	0	1	0	1	7	1	0
T	35	0	1	1	2	0	4	25	32	31	26	5	6	6	2	3	33	0	2	1	1	7	0	0
T	36	0	1	1	1	0	3	33	65	36	51	1	6	6	7	5	0	50	1	0	7	1	0	0
T	37	1	1	1	1	0	4	50	45	34	40	5	6	6	2	2	100	0	1	4	2	7	0	0
T	38	0	1	1	1	0	3	33	39	36	38	5	6	6	2	2	100	0	1	2	7	2	0	0
T	39	2	0	2	2	0	6	33	62	55	45	5	6	6	5	1	25	25	1	2	7	0	1	0
T	40	0	1	1	1	0	3	33	44	41	43	5	6	6	3	3	0	0	1	4	7	1	0	0
Wg	41	0	0	1	2	0	3	0	44	47	37	7	2	2	3	3	0	0	1	4	1	7	1	0
Wg	42	0	0	1	3	0	4	0	n.a.	47	26	1	n.a.	1	n.a.	2	50	0	n.a.	n.a.	1	7	n.a.	0
Wg	43	0	1	1	3	1	6	17	71	45	35	1	7	1	3	3	0	0	1	0	7	1	0	0
Wg	44	1	2	2	3	0	8	38	44	33	45	1	1	1	7	7	0	60	3	1	7	1	1	0
Wg	45	0	1	2	4	1	8	13	69	52	33	1	1	1	5	3	0	14	1	0	7	1	1	0
Wg	46	0	0	2	3	0	5	0	47	48	30	1	1	1	3	3	0	0	1	13	1	7	0	0
Wg	47	0	2	1	1	0	4	50	44	39	42	1	1	1	5	3	0	0	3	1	7	1	0	0
Wg	48	0	2	1	3	0	6	33	55	48	37	1	2	1	3	2	25	0	1	0	7	1	0	0
Wg	49	1	2	2	1	0	6	50	65	55	54	1	1	1	5	5	33	0	10	1	7	1	1	0
Wg	50	0	1	1	2	0	4	25	43	37	35	1	8	1	7	7	0	67	1	0	1	7	1	0

Wu=Wuasa
R=Rompo
S=Siliwanga
T=Tamadue
Wg=Wanga

1=Protestant
2=Pentecost
3=Catholic
4=Muslim
5=Hindu
7=Salvation Army

1=Napu
2=Central Sulawesi
3=Toraja
4=North Sulawesi
5=Java
6=Bali
7=South Sulawesi
8=Sumatra

1=Never attended
2=Attended prim. school
3=Finished prim. school
4=Attended junior high school
5=Finished junior high school
6=Attended senior high school
7=Finished senior high school
8=Finished university/academy

1=Farmer
2=Self-employed (trade/transport)
3=Civil servant
4=Craftsmen
5=Farm worker
6=Wage labouror
7=Housewife
10=Pensioner
12=Pastor
13=Fisherman

0=No
1=Yes

Appendix 4. Farm-specific data of 50 households (HH) with homegardens (HG) surveyed in five villages of the Napu valley, Central Sulawesi, in 2004. (IR = Indonesian Rupiah; exchange rate in 2004: 10,000 IR ≈ 1 Euro).

		Livestock possession										Land holdings								
Village	HH no.	Buffaloes No.	Cattle No.	Horses No.	Pigs No.	Dogs No.	Ducks No.	Chicken No.	Rabbits No.	Tropical Livestock Units	Value of livestock (1,000 IR)	Sizes^{+} of HG [m^2]	Paddy rice [m^2]	Annual crops [m^2]	Plantation [m^2]	Fallow [m^2]	Total farm size [ha]	Cropped area [ha]	Cropped area/ HH member [m^2]	Proportion total HG/ total farm (%)
Wuasa	1	0	0	0	2	0	13	2	2	0.94	835	1,800	5,000	0	0	4,000	1.1	0.6	1,880	16.7
Wuasa	2	0	0	0	2	3	6	21	0	1.44	905	1,200	5,800	0	12,000	2,000	3.3	1.9	2,359	3.6
Wuasa	3	0	0	0	3	4	7	0	0	1.44	2,010	450	10,000	5,000	15,000	30,000	7.5	3.0	3,789	0.6
Wuasa	4	0	0	0	1	2	20	8	0	1.06	1,620	1,000	7,000	5,000	15,000	20,000	6.3	2.7	5,494	1.6
Wuasa	5	0	0	0	6	0	0	23	0	2.26	1,750	700	0	10,000	15,000	5,000	4.6	2.6	2,849	1.5
Wuasa	6	0	0	0	2	1	3	0	0	0.76	680	400	0	5,000	15,000	0	3.5	2.0	2,028	1.1
Wuasa	7	0	5	0	5	1	1	12	3	5.42	15,515	1,000	10,000	12,000	10,000	55,000	9.8	3.3	2,347	1.0
Wuasa	8	0	0	0	1	0	0	5	0	0.40	225	600	3,000	0	3,000	2,000	1.2	0.7	1,633	5.2
Wuasa	9	5	0	3	2	3	9	12	0	8.72	26,570	1,000	12,000	5,000	15,000	7,000	5.5	3.3	4,108	1.8
Wuasa	10	0	0	0	1	0	5	0	0	0.40	290	1,100	5,000	2,000	2,000	0	1.2	1.0	1,650	9.1
Rompo	11	0	0	0	1	6	0	19	0	1.28	1,170	1,500	3,000	0	400	30,000	3.5	0.5	968	4.2
Rompo	12	0	0	0	0	0	0	3	0	0.06	90	700*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rompo	13	0	0	0	0	8	0	27	0	1.34	710	500*	0	5,000	13,000	40,000	7.1	1.8	4,613	0.9
Rompo	14	0	0	0	3	4	0	21	0	1.72	1,500	1,500	7,500	3,000	9,000	25,000	5.5	2.1	1,893	2.7
Rompo	15	0	0	0	3	0	7	10	0	1.24	1,125	700	3,000	0	13,000	0	3.0	1.7	4,128	2.4
Rompo	16	1	0	0	4	0	4	21	0	2.70	2,455	500	0	3,000	3,000	65,000	7.5	0.6	1,274	0.7
Rompo	17	0	0	0	0	0	0	11	0	0.22	45	350	0	10,000	10,000	40,000	7.0	2.0	6,760	0.5
Rompo	18	2	0	0	2	0	0	0	0	2.60	11,200	1,000	5,000	0	8,500	10,000	3.3	1.4	2,828	3.0
Rompo	19	0	0	0	2	1	0	22	0	1.14	2,225	2,000	10,000	15,000	16,000	72,000	13.1	4.2	4,193	1.5
Rompo	20	0	0	0	3	5	0	9	0	1.58	1,520	800	10,000	5,000	10,000	45,000	8.1	2.6	4,278	1.0
Siliwanga	21	0	0	0	0	0	0	19	0	0.38	70	2,500	13,000	7,000	5,000	17,500	5.0	2.6	5,142	5.0
Siliwanga	22	0	1	0	1	4	0	9	0	1.58	2,725	2,500	3,000	0	0	15,000	2.1	0.3	694	12.2
Siliwanga	23	0	3	0	0	0	0	15	0	2.40	6,800	2,500	0	2,500	17,500	65,000	10.5	2.2	5,553	2.4
Siliwanga	24	0	4	0	1	1	0	19	0	3.58	9,475	2,500	5,000	0	0	11,500	1.9	0.6	1,977	13.2
Siliwanga	25	0	0	0	0	2	0	12	0	0.44	150	2,500	0	2,500	2,500	20,000	3.0	0.6	1,398	8.3
Siliwanga	26	0	7	0	0	1	0	17	0	5.34	20,340	2,500	0	10,000	25,000	17,500	8.0	3.6	8,908	3.1
Siliwanga	27	0	6	0	1	1	0	11	0	4.82	10,210	2,500	0	0	17,500	0	3.8	2.0	6,627	6.7
Siliwanga	28	0	0	0	0	0	2	1	0	0.06	75	2,500	0	5,000	15,000	20,000	5.8	2.1	3,500	4.3
Siliwanga	29	0	5	0	1	2	0	6	0	4.12	11,660	2,500	9,000	5,000	2,500	15,000	3.7	1.9	6,307	6.8
Siliwanga	30	0	3	0	0	1	0	2	0	2.24	7,600	2,500	5,000	0	5,000	7,500	2.5	1.1	2,718	10.0
Tamadue	31	0	2	0	9	10	13	50	0	6.36	12,745	2,000	40,000	0	5,000	13,000	6.5	4.7	15,633	3.1
Tamadue	32	0	0	0	1	0	0	5	0	0.40	550	2,500	9,500	0	10,000	0	3.2	2.2	5,445	7.8
Tamadue	33	0	0	1	13	0	0	0	0	4.70	5,450	2,500	0	10,000	50,000	230,000	34.3	6.2	15,555	0.7
Tamadue	34	0	0	0	2	3	0	0	0	0.90	570	2,500	7,500	0	7,500	0	2.5	1.7	8,650	10.0
Tamadue	35	0	0	0	2	0	3	3	0	0.72	710	2,500	10,000	0	17,500	10,000	5.8	3.0	7,453	4.3
Tamadue	36	0	0	0	4	0	7	0	0	1.34	2,175	2,500	6,000	0	25,000	40,000	9.9	3.2	10,655	2.5
Tamadue	37	0	0	0	2	1	0	5	0	0.80	100	2,500	0	0	10,000	7,500	3.0	1.1	2,680	8.3
Tamadue	38	0	0	0	2	0	4	13	0	0.94	760	2,500	7,500	0	20,000	0	5.0	3.0	9,907	5.0
Tamadue	39	0	0	0	0	1	0	4	0	0.18	95	2,500	0	0	50,000	10,000	11.3	5.2	8,725	2.2
Tamadue	40	0	0	0	3	0	3	5	0	1.06	1,195	2,500	0	10,000	27,500	0	6.8	4.0	13,317	3.7
Wanga	41	0	2	0	2	2	0	6	0	2.32	7,440	1,400	0	4,000	6,000	10,000	2.7	1.1	3,760	5.1
Wanga	42	0	0	0	1	1	0	1	0	0.42	340	600	2,000	9,500	1,500	12,000	2.7	1.4	3,385	2.2
Wanga	43	0	4	0	2	3	0	0	0	3.70	10,630	350	5,000	60,000	40,000	90,000	23.5	10.5	17,542	0.1
Wanga	44	0	0	0	2	5	2	10	0	1.34	2,060	900	7,500	7,000	25,000	33,000	9.8	4.0	5,019	0.9
Wanga	45	0	3	0	2	3	0	11	0	3.22	7,645	450	3,000	9,000	6,000	20,000	4.4	1.8	2,289	1.0
Wanga	46	0	0	0	2	0	0	0	0	0.60	450	550	5,000	1,500	1,500	27,000	3.7	0.8	1,688	1.5
Wanga	47	0	0	0	2	3	0	1	0	0.92	870	500	3,000	0	0	35,000	3.9	0.3	858	1.3
Wanga	48	0	0	0	1	4	0	6	0	0.82	960	750	3,900	3,500	5,000	26,500	4.5	1.3	2,180	1.7
Wanga	49	0	2	0	8	8	0	5	0	4.70	9,360	1,600	10,000	10,000	7,500	20,000	5.7	2.9	4,817	2.8
Wanga	50	0	0	0	2	0	0	7	0	0.74	700	2,000	0	0	21,000	10,000	5.4	2.3	5,680	3.7

$^{+}$=As given by respondents

*=Rented

Appendix 5. Asset-specific data of 50 households with homegardens surveyed in five villages of the Napu valley, Central Sulawesi, in 2004. (IR = Indonesian Rupiah; exchange rate in 2004: 10,000 IR ≈ 1 Euro).

		Stock	Weekly			Exp.	Housing							Transportation					Other assets (no.)									Value of assets			
		of rice	consumption of			on	House	Type	Type	Type	Elec-	Type of	Im-	assets (no.)											Sew-			(Mio. IR)		Poverty	Poverty
Vil-	HH	(no. of	fish	sugar	cook.	C+F	size	of	of	of	trici-	water	proved		Motor-	Bi-	Trac-		Pest.	Chain	Radio		Video	Ker.	ing	Rice	Water	Trans-		index	index
lage	no.	weeks)	(freq.)	(kg)	oil (l)	*	$[m^2]$	roof	walls	floor	ty$^+$	supply	latrine	Car	cycle	cycle	tor	Cart	spr.^{a}	saw	tape	TV	player	co.^{b}	mach.	mill	pump	port	Other	ranking	class
Wu	1	1	4	1.0	1.0	67	150	5	2.4	5	1	9	1	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0.0	2.4	27	2
Wu	2	2	3	3.0	2.0	138	130	5	2.4	5	1	9	1	0	1	1	0	1	1	0	1	1	0	1	0	0	0	35.0	2.8	43	3
Wu	3	4	7	3.0	1.5	206	150	5	4	5	1	9	1	0	0	0.5	0	0	1	0	1	1	0	1	1	0	0	0.2	3.0	45	3
Wu	4	1	7	3.0	2.0	140	180	5	4	5	1	9	1	0	1	0	0	0	1	1	1	1	1	2	0	0	0	12.0	4.8	47	3
Wu	5	1	2	3.0	1.0	n.a.	60	5	2	5	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	16	1
Wu	6		1	3.0	1.5	95	90	5	2.4	5	1	10	1	0	0	2	0	0	1	0	1	0	0	1	0	0	0	0.8	0.7	31	2
Wu	7	1	7	5.0	1.5	143	170	5	4	5	1	9	1	0	1	0	0	0	1	0	2	1	1	1	0	0	0	12.0	3.4	49	3
Wu	8	4	2	0.5	0.8	13	60	5	2	5	1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	4	1
Wu	9	8	4	5.0	2.3	144	140	2.5	2.4	5	1	8	1	0	0	0	0.5	0	1	0	1	0	0	1	1	0	0	0.0	6.3	42	3
Wu	10	1	0	1.0	0.5	5	80	1	2	5	1	9	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0.0	0.5	1	1
R	11	0.2	0.3	2.0	0.8	22	60	1	1.2	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0.0	0.2	3	1
R	12	n.a.	n.a.	n.a.	n.a.	n.a.	90	5	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	23	2
R	13	0.7	4	7.5	1.2	250	100	5	2.4	5	0	1	1	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0.0	2.4	41	3
R	14	1	2	1.5	0.8	86	160	5	2.4	5	0	9	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0.0	1.5	35	3
R	15	8	7	1.0	0.8	94	70	1	2	5	1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	17	2
R	16	0	0.5	1.0	1.0	110	100	1	2.4	5	0	8	1	0	0.5	0	0	0	1	0	0	0	0	0	0	0	0	6.0	0.5	26	2
R	17	1	2	4.0	0.8	167	60	1.5	2	5	0	8	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0.0	0.5	24	2
R	18	4	0	0.5	0.3	80	190	5	2.4	5	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	21	2
R	19	4	7	3.0	2.5	170	120	5	2	5	1	9	1	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0.0	1.6	39	3
R	20	1	4	3.0	0.8	217	80	5	2	5	0	1	1	0	0	0	0	0	0	0	1	0	0	0.5	1	0	0	0.0	0.8	33	2
S	21	3	1	3.0	1.5	72	60	5	2	1	1	9	0.5	0	0	1	0	0	0.5	0	1	0	0	1	0	0	0	0.4	0.5	11	1
S	22	8	2	1.0	1.0	100	50	5	2	1	1	9	0.5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0.4	0.0	7	1
S	23	4	1	1.0	1.0	131	140	5	2	5	1	9	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0.8	0.5	19	2
S	24	4	1	1.0	1.0	133	100	5	2	5	1	9	0	0	1	1	0	0	1	0	2	0	0	1	0	0	0	12.4	0.9	18	2
S	25	3	3	2.0	1.5	100	70	5	2	5	1	9	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0.4	0.2	14	1
S	26	4	1			125	40	5	2	5	1	9	1	0	0	1	0	0	1	0	1	1	1	1	0	0	0	0.4	3.2	13	1
S	27	4	1	1.0	1.0	133	40	5	2	5	1	9	0	0	0	1.5	0	0	1	0	0	1	0	0	0	0	0	0.6	2.2	10	1
S	28	0.6	0.5	1.0	0.8	54	70	5	2	5	1	10	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0.4	0.2	5	1
S	29	4	0.3	0.8	1.0	100	80	5	2	5	1	1	1	0	0	2	0	0	1	0	1	0	0	0	0	0	0	0.8	0.5	9	1
S	30	4	0	1.0	1.0	95	40	5	2	1	1	10	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0.4	0.5	2	1
T	31	24	7	3.5	1.6	250	40	5	2	1	0	8	0	1	0	2	1	0	2	1	1	0	0	1	1	1	0	23.8	16.3	44	3
T	32	24	7	1.2	1.0	100	70	5	2	5	1	3	1	0	0	1	0	0	1	0	1	1	1	1	0	0	0	0.4	3.2	20	2
T	33	4	7	5.0	1.3	113	130	5	4	5	1	3	1	0	2	1	0	0	3	1	1	1	1	1	0	0	2	24.4	7.7	50	3
T	34	16	2	2.0	0.8	100	120	5	2	5	1	3	0	0	0	2	0	0	1	0	1	0	0	0	0	0	0	0.8	0.7	8	1
T	35	8	2	1.5	2.3	150	140	5	2	5	1	3	0	0	1	1	0	0	1	0	1	1	0	2	0	0	0	12.4	2.5	29	2
T	36	4	7	1.0	1.0	83	100	5	2	6	1	8	1	0	0	2	0	0	1	0	1	1	0	0	0	0	0	0.8	2.4	30	2
T	37	4	3	2.0	0.8	50	80	5	2	5	1	3	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0.4	0.5	6	1
T	38	8	1	0.5	0.8	83	130	5	4	6	1	3	1	0	1	2	0	0	1	0	0	1	1	2	0	0	0	12.8	3.1	25	2
T	39	2	7	2.0	1.3	100	100	5	2	5	1	9	1	0	1	2	0	0	2	0	1	1	1	1	0	0	1	12.8	4.7	37	3
T	40	16	7	1.2	1.3	217	80	5	2	5	1	8	0	0	0	3	0	0	1	0	1	0	0	0	0	0	0	1.2	0.7	28	2
Wg	41	0.2	1	2.0	0.8	n.a.	80	5	2	5	1	9	1	0	0	0.5	0	0	1	0	1	0	0	1	0	0	0	0.2	0.7	12	1
Wg	42	0.6	4	3.0	1.5	163	40	5	2	5	0	10	1	0	0	0.5	0	1	0	0	0.5	0	0	1	1	0	0	0.2	0.7	15	1
Wg	43	12	7	3.0	1.5	350	90	5	2.4	5	0	9	1	0	0	1	0	0	0	0	1	0	0	2	0	0	0	0.4	0.3	46	3
Wg	44	3	7	3.5	2.3	250	200	5	2.4	5	1	9	1	0	1	0.5	0	0	1	1	1	1	0	1	0	0	0	12.2	3.9	48	3
Wg	45	4	7	7.0	0.8	231	110	5	2	5	1	9	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0.0	0.6	40	3
Wg	46	1	7	2.0	1.5	260	80	5	2	5	1	10	1	0	0	0.5	0	0	0	0	0	0	0	0	1	0	0	0.2	0.6	32	2
Wg	47	0.2	7	1.0	0.8	325	90	5	2	5	1	10	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0.0	1.5	34	3
Wg	48	1	1	3.0	0.8	250	80	5	2	5	1	9	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0.0	0.0	22	2
Wg	49	1	3	3.0	0.8	n.a.	170	5	2	5	1	9	1	0	0.5	1	0	0	2	0	1	1	0	2	1	0	0	6.2	3.6	36	3
Wg	50	0.4	3	2.0	0.8	300	220	5	2.4	5	1	9	1	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0.0	0.6	38	3

$^+$=Connection
0.5=Broken down

Wu=Wuasa
R=Rompo
S=Siliwanga
T=Tamadue
Wg=Wanga

*=Expenditures on clothes+ footwear per head and year (1,000 IR)

1=Bamboo
2=Wood
4=Brick

1=Bamboo
2=Wood
5=Corrug. iron

1=Earth
5=Cement
6=Tiles

1=Yes
2=No

1=Public taps
3=Self-dug holes
8=Well
9=Pipe
10=Shared pipe

^{a}=Sprayer for pesticides

^{b}=Kerosine cooker

1=Poor
2=Intermediate
3=Well-off

Appendix 6. Poverty indicators and their weights, resulting from Principal Component Analysis based on data of 50 households in five villages of the Napu valley, Central Sulawesi, 2004.

Dimension	Indicator	Weight
Human resources	Per capita expenditures on clothes/footwear	0.532
	No. of household members	0.444
	Percentage of adults who did not complete elementary school	-0.413
Food security	Days of fish consumption per week	0.691
	Amount of weekly sugar purchase	0.649
Dwelling	Size of the house	0.564
	Type of walls	0.691
Assets	Farm size	0.645
	Total value of transportation assets	0.541
	Total value of other assets	0.575

Appendix 7. Sizes and micro-zonation of 50 homegardens surveyed in five villages of the Napu valley, Central Sulawesi, in 2004.

Village	HH no.	Garden size measured (m^2)	Proportion of cultivated zones (%) Orna-mentals	Vege-tables	Coffee/ Cacao	Fruit trees	Mixed vegetation	Tree nursery	Proportion of non-cultivated zones (%) Fallow	House	Yard, toilet	Stable	Pond	Other	HG open space* (m^2)	Additionally excluded area/zone
Wuasa	1	1,800	4.7	5.4	6.2	8.4	14.9	0.06	25.4	8.3	4.8	0.2	21.7	0.0	803	Fallow+pond
Wuasa	2	1,260	2.7	3.5	51.5	9.0	0.0	0.16	0.0	10.3	19.9	0.3	0.0	2.5	1,130	
Wuasa	3	460	3.7	2.6	0.0	2.2	5.4	0.11	34.6	32.6	18.7	0.0	0.0	0.0	310	
Wuasa	4	930	20.9	4.7	12.8	3.9	0.0	0.22	0.0	19.4	7.6	0.0	0.0	30.5	466	Kiosk
Wuasa	5	730	2.1	0.0	73.7	0.0	0.0	0.00	0.0	8.2	16.0	0.0	0.0	0.0	670	
Wuasa	6	370	7.3	39.2	2.7	8.1	0.0	0.00	0.0	24.3	17.6	0.8	0.0	0.0	280	
Wuasa	7	1,030	4.7	3.6	16.5	4.7	0.0	0.58	21.2	16.5	29.9	1.0	1.0	0.5	860	
Wuasa	8	640	6.3	13.0	26.1	3.1	6.3	0.00	0.0	9.4	33.6	0.5	1.9	0.0	580	
Wuasa	9	1,000	8.1	22.7	36.6	5.0	0.0	0.00	0.0	14.0	11.8	0.2	0.0	1.6	860	
Wuasa	10	1,130	2.0	2.8	65.8	0.0	0.0	0.04	0.0	7.1	19.8	0.0	2.2	0.2	1,050	
Rompo	11	1,500	1.1	1.2	22.7	0.0	0.0	0.07	61.6	4.0	9.3	0.0	0.0	0.0	1,440	
Rompo	12	675	3.7	4.1	0.1	0.7	0.0	0.00	72.9	13.3	5.0	0.0	0.0	0.0	585	
Rompo	13	540	2.6	2.0	38.0	15.0	0.0	0.19	0.0	18.5	23.7	0.0	0.0	0.0	440	
Rompo	14	1,490	0.4	21.3	0.0	28.7	28.7	0.27	0.0	10.7	8.4	1.2	0.0	0.3	1,330	
Rompo	15	580	2.2	56.2	9.5	0.0	0.0	0.09	6.9	12.1	10.9	0.2	0.0	1.9	510	
Rompo	16	470	2.1	10.4	41.7	0.0	0.0	0.11	0.0	21.3	24.3	0.0	0.0	0.0	370	
Rompo	17	330	1.2	10.3	0.0	0.0	0.0	0.61	1.8	18.2	67.9	0.0	0.0	0.0	270	
Rompo	18	830	1.2	13.0	45.4	0.0	0.0	0.00	0.0	22.9	17.5	0.0	0.0	0.0	640	
Rompo	19	1,570	0.0	0.0	32.7	0.0	0.0	0.00	31.5	7.6	19.6	1.2	0.0	7.4	956	Fallow
Rompo	20	750	1.9	9.6	8.0	0.0	52.9	0.13	0.0	10.7	16.8	0.0	0.0	0.0	670	
Siliwanga	21	770	2.5	19.5	4.0	0.0	14.3	0.06	13.5	7.8	31.3	0.8	0.0	6.2	710	
Siliwanga	22	520	0.0	2.7	1.0	8.5	0.0	0.38	61.5	9.6	8.5	1.3	0.0	6.5	470	
Siliwanga	23	2,350	0.5	0.0	1.3	1.1	41.0	0.00	41.0	6.0	8.0	0.5	0.0	0.7	2,210	
Siliwanga	24	1,030	2.3	2.4	8.4	4.6	0.0	0.00	53.0	9.7	17.0	0.5	0.0	2.0	930	
Siliwanga	25	750	5.6	3.6	0.0	0.0	3.3	1.33	26.9	9.3	22.4	0.0	7.2	20.3	528	Church building
Siliwanga	26	670	0.1	0.1	24.9	9.0	12.5	0.00	12.5	6.0	26.1	0.0	3.4	5.2	630	
Siliwanga	27	2,420	1.1	0.1	3.6	2.7	42.0	0.00	42.0	1.7	5.5	0.3	0.0	1.0	2,380	
Siliwanga	28	1,060	1.0	0.5	35.9	2.5	18.0	0.05	18.0	6.6	15.3	0.0	0.0	2.0	990	
Siliwanga	29	2,500	1.4	0.2	4.9	2.6	38.9	0.00	38.9	3.2	7.3	1.2	0.0	1.4	2,420	
Siliwanga	30	910	1.6	0.5	38.9	0.0	19.5	0.00	19.5	4.4	8.6	0.0	4.7	2.3	870	
Tamadue	31	2,000	3.9	0.0	5.0	23.0	0.0	0.00	41.3	2.0	8.8	3.9	0.0	12.3	1,960	
Tamadue	32	2,350	1.5	0.0	64.0	0.0	0.0	0.00	17.4	3.0	11.3	1.0	0.0	1.8	2,280	
Tamadue	33	2,350	1.0	0.3	56.7	2.3	0.0	0.00	0.0	5.5	15.6	1.8	14.9	1.7	1,869	Pond
Tamadue	34	2,420	1.0	0.6	73.3	1.5	0.0	0.00	11.0	5.0	6.3	0.5	0.0	0.9	2,300	
Tamadue	35	2,450	0.4	0.2	80.4	0.0	0.0	0.04	0.0	5.7	8.4	1.0	2.5	1.3	2,310	
Tamadue	36	1,070	4.6	0.6	1.4	0.8	26.1	0.28	26.1	9.3	12.2	1.1	14.5	3.0	815	Pond
Tamadue	37	800	1.5	0.1	0.0	2.3	13.8	0.00	41.4	10.0	28.3	0.6	0.0	2.1	720	
Tamadue	38	2,350	0.8	0.6	79.9	0.5	0.0	0.00	0.0	5.5	10.3	0.8	0.6	1.0	2,220	
Tamadue	39	2,450	1.8	0.0	80.9	0.0	0.0	0.00	0.0	4.1	12.4	0.0	0.0	0.9	2,350	
Tamadue	40	2,500	1.6	0.0	88.5	0.0	0.0	0.16	0.0	3.2	5.6	0.3	0.0	0.6	2,420	
Wanga	41	1,360	2.2	1.0	28.2	0.0	25.0	0.44	25.0	5.9	11.5	0.0	0.0	0.7	1,280	
Wanga	42	590	3.4	2.0	3.4	0.0	67.8	0.51	0.0	6.8	14.9	0.0	0.0	1.2	550	
Wanga	43	340	5.0	2.6	10.6	0.0	0.0	0.88	0.0	26.5	54.4	0.0	0.0	0.0	250	
Wanga	44	880	4.1	6.6	43.6	0.0	0.0	0.00	0.0	22.7	19.3	0.0	0.0	3.6	648	Barn
Wanga	45	420	2.9	2.1	0.0	0.0	6.2	0.12	31.2	26.2	31.2	0.0	0.0	0.0	310	
Wanga	46	520	2.1	2.3	30.2	0.0	15.0	0.00	0.0	15.4	34.0	1.0	0.0	0.0	440	
Wanga	47	520	7.3	4.6	21.7	0.0	21.7	0.00	0.0	17.3	24.6	2.7	0.0	0.0	430	
Wanga	48	750	0.1	14.4	40.1	0.0	17.9	0.67	0.0	10.7	14.3	0.5	0.0	1.3	670	
Wanga	49	1,610	2.7	6.0	28.7	0.0	28.7	0.43	0.0	10.6	21.1	0.6	0.0	1.4	1,440	
Wanga	50	1,940	0.0	0.0	59.9	0.0	0.0	0.00	17.7	11.3	11.0	0.0	0.0	0.0	1,377	Fallow

*=Without house

Appendix 8. Data on age and function as well as management characteristics of 50 homegardens (HG) surveyed in five villages of the Napu valley, Central Sulawesi, in 2004.

Village	HH no.	Age of HG	Former land use	Function of HG		Importance of HG for daily life	Main source for		Cash income from HG (% of total income)	Portion of cash crops (%)	Main gardener	Characteristics of main gardener						Responsible person for:					
				Main	Side		Subsistance	Cash income				Sex	Age	Origin	Occupation	Education	School-years	Ornamentals	Medicinal plants	Spices	Vegetables	Fruit trees	Cacao/coffee trees
Wuasa	1	24	1	1	2	2	1	1	5	4	2	0	59	0	7	3	6	2;3	2	2;3	2	1	1
Wuasa	2	24	2	2	1	2	2	2	1	15	9	1	68	0	1	3	6	2	2	2	2	9	9
Wuasa	3	37	1	2		0	2	2	0	1	1	1	63	0	10	5	9	3		2	4	1	
Wuasa	4	37	3	2	3	1	1	2	n.a.	22	2	0	43	0	2	8	15	2	2	2	2	2	2
Wuasa	5	17	1	1	3	0	2	2	10	40	1	1	58	0	1	4	7	3				1	1
Wuasa	6	31	1	1		0	1	2	n.a.	2	2	0	32	0	1	3	6	5	2	2	2	1	1
Wuasa	7	28	1	2	1	2	1	2	10	18	3	0	37	0	7	5	9	3	3	3	3	1	1
Wuasa	8	10	6	1	2	0	1	1	1	12	2	0	43	0	1	3	6	2	2	2	2	1	1;2
Wuasa	9	20	6	1	2	1	1	2	20	1	2	0	52	0	7	5		2;3		2;3	2;3	1;4	1
Wuasa	10	31	6	3		0	2	1	n.a.	27	1	1	67	0	7	3	6	2		2	2	1	1
Rompo	11	14	1	1	2	1	2	2	n.a.	19	2	0	54	0	7	3	6	2	1	2	2	1	1
Rompo	12	13	6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	n.a.	n.a.	n.a.	0	n.a.	n.a.	n.a.						
Rompo	13	4	3	1	2	0	2	2	n.a.	11	n.a.	n.a.	n.a.	0	n.a.	n.a.	n.a.	2	2	2	2	1;2	1;2
Rompo	14	40	5	1	3	1	1	2	n.a.	10	2	0	60	0	1	5	9	2	2	2	2	7	2
Rompo	15	4	3	1	2	1	1	2	n.a.	13	2	0	23	0	1	5	9	2		2	2	1	1
Rompo	16	17	3	1	2	1	2	2	1	13	2	0	44	0	1	3	6	2	1;2	2	2	1	1;4
Rompo	17	4	6	1	2	1	2	2	0	3	2	0	20	0	1	3	6	2		2	2	1	1
Rompo	18	33	1	1		1	1	2	n.a.	13	1	1	56	0	1	3	6	2	2	2	2	1	1
Rompo	19	9	2	1	3	1	2	2	10	26	1	1	56	0	1	7	12	2	1;2	2	2	1	1
Rompo	20	22	2	1	2	1	1	1	10	18	2	0	49	0	1	3	6	2;3	2	2	2	1	1;4
Siliwanga	21	8	6	3	1	0	1	2	n.a.	15	2	0	28	1	1	3	6	2;8		2;8	2;8	1	1
Siliwanga	22	11	6	3	1	1	1	n.a.	0	10	2	0	37	0	1	1	0	2;4		2		2	1
Siliwanga	23	9	6	1	2	0	2	2	1	30	1	1	37	1	1	7	14	1;2				1	1
Siliwanga	24	4	3	1	2	1	1	1	0	23	2	0	38	1	7	7	12	1;2		2	2	1	1
Siliwanga	25	6	6	1	2	1	2	2	0	5	1	1	30	0	12	8	15	2		2	1	1	1
Siliwanga	26	11	6	2	1	1	2	2	1	23	2	0	33	1	1	2	2	2;3;4	1	2	1;2	1	1
Siliwanga	27	10	6	1	2	0	2	2	n.a.	33	1	1	33	1	1	3	6	2		1	1	1	1
Siliwanga	28	10	6	1	3	0	n.a.	2	n.a.	22	4	1	21	1	1	3	6	2;3		2;3	2;3;4		4;1
Siliwanga	29	11	6	1	3	1	1	1	n.a.	18	2	0	32	1	1	3	6	2		2	2	1	1
Siliwanga	30	9	6	1		0	1	1	n.a.	18	2	0	30	1	1	1	0	2		2	2	1	1
Tamadue	31	9	5	1	3	1	1	1	10	53	1	1	35	1	1	2	1	2	2	2		1	1
Tamadue	32	10	5	3	1	1	1	1	0	21	1	1	39	1	1	3	6	2	2	2		1	1
Tamadue	33	10	5	1	3	2	3	2	n.a.	49	1	1	35	1	2	8	17	2	2	2		1	1
Tamadue	34	10	6	3	1	0	1	1	10	64	1	1	60	1	1	2	3	2	2	2		1	1
Tamadue	35	10	6	1	3	1	1	1	5	55	2	0	31	1	1	3	6	2				1	1
Tamadue	36	6	3	4	2	0	1	1	n.a.	10	n.a.	n.a.	n.a.	1	n.a.	n.a.	n.a.	1;2	1;2	1;2		1;2	1;2
Tamadue	37	2	3	1	3	1	n.a.	n.a.	0	4	1	1	45	1	1	2	2	1		1	1	1	1
Tamadue	38	9	5	1	3	2	2	2	33	36	1	1	39	1	1	2	2	2	1	1		1	1
Tamadue	39	10	3	1	3	1	2	2	10	58	1	1	62	1	1	5	9	2	2	2		1	1
Tamadue	40	10	6	3	1	2	2	2	25	69	1	1	44	1	1	3	6	1;2	1;2	1;2		1;2	1;2
Wanga	41	11	6	1	3	1	2	2	10	41	2	0	47	0	1	3	6	2	2	2	2	1	1;4
Wanga	42	5	1	1	2	1	1	2	0	24	2	0	47	0	1	2	5	2		2	2	4;2	4;2
Wanga	43	23	6	1	2	0	2	2	0	36	2	0	45	0	7	3	6	2		2	2	4	4
Wanga	44	13	1	1	2	2	1	2	n.a.	7	2	0	33	0	7	7	12	2	2	2	2	1	1
Wanga	45	24	6	2		0	2	2	0	1	2	0	52	0	7	3	6	2;3		2;3	2;3	1;4	1;4
Wanga	46	27	4	1	2	1	1	2	0	63	2	0	48	0	1	3	6	2		2	2	1	1
Wanga	47	7	2	1	2	1	1	2	0	11	2	0	39	0	7	3	6	2	2	2	2	1;2	1;2
Wanga	48	17	6	1	3	1	1	2	n.a.	15	1	1	55	0	1	3	6	2		1	1	1	1
Wanga	49	15	4	1	2	1	1	2	n.a.	11	2	0	55	0	7	5	9	2	2	2	2	1	1
Wanga	50	4	2	3		0	2	2	n.a.	42	1	1	43	1	1	7	12			2		2	1
			1=Mixed annual crops 2=Coffee plantation 3=HG 5=Forest 6=Fallow/ grassland	1=Subsistence 2=Decoration 3=Cash income generation 4=Pharmacy		0=none 1=important 2=very important	1=Paddy rice 2=Plantation/ annual crop 3=HG				1=HH-Head 2=Wife 3=Daughter 4=Son 9=Father	0=Female 1=Male		0=Local 1=Migrant from outside Sulawesi	1=Farmer 2=Self-employed 7=Housewife 10=Pensioner 12=Pastor	1=Never attended 2=Attended prim. school 3=Finished prim. school 4=Attended jun. high school 5=Finished jun. high school 7=Finished sen. high school 8=Finished university/academy		1=HH-H 2=Wife 3=Daughter/Daughter-in-law 4=Son/son-in-law 5=Sister-in-law 6=Grandchild (female) 7=Nephew 8=Mother/mother-in-law/ grandmother 9=Father/father-in-law					

Appendix 9. Labour management in 50 homegardens (HG) surveyed in five villages of the Napu valley, Central Sulawesi, in 2004. (HH-H = Household head).

		Monthly working time (h)						Daily working time per 100 m^2 (minutes)	Portion of HG work done by females (%)	Working hours spent per month for:						
Village	HH no.	HH-Head	HH-H's wife	Children	Other relatives	Total	per 100 m^2 HG area			Hoeing	Weeding	Harvesting	Spraying	Fertilising	Planting	Pruning
Wuasa	1	2.8	19.3	20.3	0.0	42.3	5.3	10.5	93.3	6.0	30.0	3.0	0.13	2.00	0.75	0.44
Wuasa	2	0.5	0.7	0.7	1.5	3.4	0.3	0.6	41.6	1.0	0.2	0.7	0.25	0.96	0.02	0.28
Wuasa	3	4.4	2.4	0.0	0.0	6.8	2.2	4.4	35.4	4.0	0.0	2.4	0.09	0.24	0.05	0.00
Wuasa	4	0.7	32.0	14.8	0.0	47.4	10.2	20.4	98.6	36.0	6.0	2.4	0.15	0.08	2.25	0.55
Wuasa	5	2.9	0.6	1.6	0.0	5.1	0.8	1.5	11.7	0.0	0.0	1.8	1.80	0.00	0.96	0.51
Wuasa	6	0.1	2.6	0.0	2.1	4.9	1.7	3.5	54.3	2.0	2.0	0.5	0.13	0.10	0.03	0.10
Wuasa	7	0.1	0.0	15.2	0.0	15.3	1.8	3.6	99.4	12.0	0.0	2.4	0.00	0.50	0.30	0.09
Wuasa	8	0.0	9.2	0.1	0.0	9.3	1.6	3.2	99.6	6.0	0.5	2.4	0.00	0.00	0.30	0.13
Wuasa	9	11.6	13.7	3.1	0.0	28.3	3.3	6.6	59.2	6.0	15.0	0.3	0.60	0.04	6.12	0.25
Wuasa	10	23.1	2.4	0.0	0.0	25.5	2.4	4.9	9.4	7.5	15.0	2.4	0.00	0.04	0.17	0.38
Rompo	11	4.1	4.4	1.0	0.0	9.5	0.7	1.3	46.3	4.0	2.0	2.4	0.00	0.00	1.02	0.09
Rompo	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rompo	13	1.1	10.4	0.0	6.0	17.5	4.0	8.0	59.3	12.0	1.9	2.4	0.04	0.50	0.51	0.12
Rompo	14	0.0	4.5	0.0	0.1	4.6	0.3	0.7	98.3	1.0	0.3	2.4	0.00	0.32	0.13	0.40
Rompo	15	0.0	10.1	0.0	0.0	10.1	2.0	3.9	100.0	6.0	1.2	2.4	0.00	0.16	0.30	0.00
Rompo	16	0.5	4.6	0.0	0.0	5.1	1.4	2.8	89.9	2.0	0.5	2.4	0.01	0.00	0.17	0.01
Rompo	17	0.2	5.7	0.0	0.0	5.9	2.2	4.3	97.1	2.0	1.0	2.4	0.17	0.17	0.13	0.00
Rompo	18	22.0	14.6	0.0	0.0	36.6	5.7	11.4	40.0	24.0	6.0	2.4	0.00	0.00	0.24	3.96
Rompo	19	10.4	0.2	5.7	0.1	16.4	1.7	3.4	1.4	10.8	0.6	4.0	0.09	0.19	0.04	0.66
Rompo	20	1.0	19.3	12.0	0.0	32.2	4.8	9.6	97.0	4.0	24.0	2.4	0.17	0.68	0.17	0.79
Siliwanga	21	3.8	4.0	0.0	0.0	7.7	1.1	2.2	51.5	0.5	3.0	2.4	0.08	0.68	0.90	0.17
Siliwanga	22	4.6	7.1	0.0	0.0	11.7	2.5	5.0	60.9	0.5	7.2	0.0	0.48	3.00	0.48	0.00
Siliwanga	23	12.2	0.5	0.0	0.0	12.7	0.6	1.1	4.0	6.1	2.0	0.5	0.51	3.00	0.48	0.00
Siliwanga	24	0.5	4.3	0.0	0.0	4.8	0.5	1.0	89.3	0.2	1.0	2.4	0.50	0.68	0.04	0.01
Siliwanga	25	4.0	2.7	0.0	0.0	6.7	1.3	2.5	39.7	0.8	0.8	2.4	0.04	2.40	0.25	0.08
Siliwanga	26	1.2	4.8	0.0	0.0	6.0	0.9	1.9	80.3	0.0	0.1	2.4	1.00	2.40	0.00	0.09
Siliwanga	27	7.5	2.0	0.0	0.0	9.5	0.4	0.8	21.1	0.2	5.4	2.0	0.51	0.32	0.04	1.02
Siliwanga	28	0.0	0.2	28.0	0.0	28.2	2.8	5.7	50.4	9.0	18.0	0.3	0.51	0.17	0.04	0.13
Siliwanga	29	20.0	22.9	9.0	0.0	51.9	2.1	4.3	44.2	2.0	45.0	3.0	0.90	0.68	0.01	0.32
Siliwanga	30	2.1	2.7	2.3	0.0	7.1	0.8	1.6	38.2	1.4	2.0	2.4	0.08	0.64	0.48	0.09
Tamadue	31	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	32	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	33	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	34	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	35	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	36	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	37	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	38	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	39	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tamadue	40	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wanga	41	0.0	8.7	1.2	0.0	9.9	0.8	1.6	87.6	6.0	0.3	2.4	0.15	0.00	0.01	1.08
Wanga	42	n.a.	20.9	0.2	0.0	21.1	3.8	7.7	99.0	12.0	4.0	2.4	0.08	2.40	0.05	0.12
Wanga	43	2.0	12.3	0.5	0.0	14.8	5.9	11.9	83.2	12.0	0.3	2.0	0.50	0.00	0.04	0.00
Wanga	44	0.8	18.8	8.0	0.0	27.6	4.3	8.5	97.0	9.0	15.0	2.4	0.25	0.04	0.34	0.58
Wanga	45	0.0	3.1	5.5	0.0	8.6	2.8	5.6	100.0	4.0	2.0	2.4	0.09	0.08	0.05	0.02
Wanga	46	0.3	6.5	0.0	0.0	6.8	1.5	3.1	95.7	4.0	0.1	2.4	0.25	0.00	0.04	0.04
Wanga	47	0.4	6.5	0.0	0.0	6.9	1.6	3.2	94.5	0.5	1.0	2.4	0.30	2.40	0.17	0.08
Wanga	48	19.0	0.0	0.0	0.0	19.0	2.8	5.7	0.2	6.0	8.0	4.0	0.17	0.04	0.34	0.49
Wanga	49	0.7	7.7	0.0	0.1	8.5	0.6	1.2	91.1	3.0	1.0	2.4	0.09	0.30	1.02	0.67
Wanga	50	1.7	1.1	0.0	0.0	2.8	0.2	0.4	39.6	0.0	0.6	0.5	0.30	0.00	0.00	1.38

Appendix 10. Soil fertility management in 50 homegardens surveyed in five villages of the Napu valley, Central Sulawesi, in 2004.

		Gardener's assessment of:			**Industrial fertiliser**				**Farm yard manure**				**Ash**						Reasons for not using:		
Village	HH no.	Soil fertility	Changes in soil fertility	Measures for soil fert. improvement	Kind	Freq. (year)	Amount (kg/ year*ha)	Used for	Usage	Freq. (year)	Amount (lg.buck./ year)	Used for	Usage	Freq. (year)	Amount (sm.buck./ month)	Used for	Main fertiliser	Additional fertiliser	Industr. fertiliser	FY manure	Ash
Wuasa	1	2	1	1	0.5				0				1	52	4	2;4	3			2	
Wuasa	2	2	1	1	1	1	9	1;3	0.5	1		2	0.5			2;4	1				
Wuasa	3	1	1	1;2	3	1	1613	10	0				1	12	1	2;4	1				
Wuasa	4	2	1	1	0				1	1	8	2;4	0.5			2;4	2		1		
Wuasa	5	1	1	1;2	0				0				0				0		1		
Wuasa	6	2	1	1	0				1	1	10	2;4	1	52	4	2;4	3				
Wuasa	7	3	3	1;3	0.5				0				1	12	0.25	2;4	3				
Wuasa	8	2	3	1	0				0				0				0		1	2	
Wuasa	9	1	1	4	0				1	1	2	2;4	1	52	1	2;3	3		1		
Wuasa	10	3	1	1	0				0.5			3	1			2	3		1		
Rompo	11	1;3	1	1;5	0				0				0				0		1	2	2
Rompo	12	n.a.			n.a.				n.a.				n.a.				n.a.				
Rompo	13	1	2	1;4	0				0				1	12	1	2;4	3		1	2;3	
Rompo	14	2	1	1;2	0				0				1	52	4	2;4	3		1	2	
Rompo	15	2	2	1;2	0				0				1	24	2	4	3		1	2	
Rompo	16	2	1	1	0				0				0				0		1	2	2
Rompo	17	2	1	1;2	0				0				1	12	2	2	3		1	2	
Rompo	18	2	2	1	0				0				0				0		1	2	2
Rompo	19	2	2	1;2;6	0				1	1	4	10	1	9	0.75	10	2	4 (past)	1		
Rompo	20	2	1	1	0				1	2	2	2	1	52	1	2;4	3	5	1		
Siliwanga	21	1	3	1	0				1	6	6	1;3	1	52	4	3;4	3		1		
Siliwanga	22	1	3	1	0				0.5				1	12	1	1	3		1		
Siliwanga	23	1	3	1;3	0				1	6	180	10	0				2	1			
Siliwanga	24	1	2	1	2	1	54	1	1	4	4	3	1	52	2	1;4	3				
Siliwanga	25	2	3	1;2	3	4	102	2	1	2	2	3	1	365	4	2;3	3	6			
Siliwanga	26	2	3	1	0				0.5				1	365	4	1;3	3		1		
Siliwanga	27	2	3	1;2	0				0				1	52	4	3	3		1	4	
Siliwanga	28	1	3	1	3	2	140	3	0				1	12	1	3	3				
Siliwanga	29	1	3	1	0				1	1	40	1;3	1	52	4	1;3	3		1		
Siliwanga	30	1	3	1;2	1	1	11	1;3	0				1	52	4	4	3		1	5	
Tamadue	31	3	3	1;2	0				1	12	3	1;3	0				2				
Tamadue	32	2	1	1	1;2	2	439	1;3	0				0				1				
Tamadue	33	3	2	1	3	2	225	1;3	0.5				0				1				
Tamadue	34	1	1	1;2;3	3	4	435	3	0				1	12			1				
Tamadue	35	3	1	1	0.5				0				0				0		1	4	
Tamadue	36	1	3	1	0				1	1	60	10	0				2	5			
Tamadue	37	3	2	1	0				1	0.5	2.5	1;3	0				2				
Tamadue	38	2	2	1	3	2	135	3	0				0				1	4			
Tamadue	39	2	1	1	3	2	213	1;3	1	1		1;3	1	365			1	4			
Tamadue	40	2	1	1	3	2	204	3	n.a.				n.a.				1	7			
Wanga	41	1	3	1;2	0				0				0.5			2;4	3		1	6	
Wanga	42	2	1	1;4	0.5			3	0				1	365	4	2;4	3	8		5;6	
Wanga	43	2	1	1	0				0				0				0			2	2
Wanga	44	2	1	1;7	0.5		77	2	0				1	3		2;4	1		1		
Wanga	45	2	3	3;1	0				0				1	12	0.5	2;4	3		1	2	
Wanga	46	1	1	1	0.5		45	4	0				0.5				1			2	
Wanga	47	2	2	1	0.5		12	4	0				1	365	4	3	3			5	
Wanga	48	3	3	1	0				1		4	2;4	1	6	0.25	2;4	2		1		
Wanga	49	1	2	1	0				1	4	8	2;4	0.5			4	2		1		
Wanga	50	2	2	1;4	0				0.5				0				0		1		7
		1=Poor 2=Intermediate 3=Good	1=Deterioration 2=No changes 3=Improvement	1=Fertilising 2=Hoeing 3=Drainage 4=Mulching 5=Spraying herbicides 6=Terrassing 7=Green manure	0.5=Used in the past 1=Urea 2=TSP 3=NPK			1=Fruits 2=Vegetables 3=Stimulants 4=Spices 10=All zones	0=No 0.5=Used in the past 1=Yes		Lg.buck.= Large bucket (10 l)	1=Fruits 2=Vegetables 3=Stimulants 4=Spices 10=All zones	0=No 0.5=Used in the past 1=Yes		Sm.buck.= Small bucket (5 l)	1=Fruits 2=Vegetables 3=Stimulants 4=Spices 10=All zones	0=None 1=Industr. fertiliser 2=Farm yard manu 3=Ash	4=Rotten wood 5=Hoed weeds 6=Salt (Cocos) 7=Mikronutrients 8=Rice husks	1=Too expensive 2=Lack of knowledge 3=Laziness 4=Amount too small 5=Lack of time 6=Revulsion 7=Used for other plots		

Appendix 11. Use of pesticides and alternatives as well as rating of management problems in 50 homegardens surveyed in five villages of the Napu valley, Central Sulawesi, in 2004.

		Herbicides			**Insecticides**					**Fungicides**					**Rating of problems in homegardening**							
Village	HH no.	Usage	Freq. (year)	Alter-natives	Pests	Infested crops	Usage	Freq. (year)	Alter-natives	Diseases	Infested crops	Usage	Freq. (year)	Alter-natives	Poor soil	Weeds	Pests+ diseases	Lack of time	Inferior varieties	Live-stock	Children	Sale
Wuasa	1	1	3	1;2	1;2	1;2;3	0	0	1	0		0	0	0	2	2	2	3	1	2		4
Wuasa	2	1	3	1;3	1;2;3	3	1	0.5	2	1	3	0	0	3	2	2	2	2	4	2		2
Wuasa	3	1	2	1	0		0	0	0	0		0	0	0	1	2	3	2	2	4		n.a.
Wuasa	4	1	4	1;2	1;2;3	2	1		4;5	2	n.a.	0	0	0	1	1	2	1	4	1	1	4
Wuasa	5	1	4	0	1;2	3	0	0	0	1	3	0	0	6	2	2	1	4	2	2		1
Wuasa	6	1	3	1;3	1;2;3	2;3	1		1;4	1	3	0	0	2	2	2	1	4	2	1		2
Wuasa	7	0	0	1	1	1	0	0	1	3	1;3	0	0	2	4	2	2	4	4	2		4
Wuasa	8	0	0	1;2	1,2,3	1;3	0	0	4	0		0	0	0	3	1	2	2	2	1		1
Wuasa	9	1	4	1;2	1	2	1		0	0		0	0	0	1	2	2	1	4	2	2	2
Wuasa	10	0	0	1;3	1;2;4	3	0	0	2;7	1;3	n.a.	0	0	2;3	4	2	2	2	2	2		2
Rompo	11	0	0	1;2;3	0		0	0	0	1	3	0	0	2	1	2	2	2	2	3		4
Rompo	12	n.a.			n.a.					n.a.					n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Rompo	13	1	2	1;2	1;2	3	0	0	8	0		0	0	0	1	2	2	1	4	1	1	2
Rompo	14	0	0	1;2	1;2;3	2;3	0	0	1;2;4;8	3	2;4	0	0	0	1	2	1	1	4	1	1	n.a.
Rompo	15	0	0	1;2;3	1;5	1;2;3	0	0	4	1	3	0	0	2	1	1	2	4	4	1	1	4
Rompo	16	1	1	1;2	1;2	2;3	0	0	4;6	1;4	3	0	0	2	1	2	2	1	2	1	1	1
Rompo	17	1	2	1;2	1;2	2;4	0	0	1;4	3	4	0	0	2	2	2	2	1	4	1		n.a.
Rompo	18	0	0	1;2;3	1;2	3	0	0	3;4	1;3	3	0	0	0	1	1	1	1	3	1	1	1
Rompo	19	1	2	1;2	1	3	1	0.5	9	1;3	3	0	0	2;8	2	2	1	4	4	2	2	4
Rompo	20	1	2	1;2;3	1;2;3	3	1	n.a.	1	1;3	3	0	0	2;1	1	2	1	1	4	1		4
Siliwanga	21	1	1	1;2	3	3	1	n.a.	0	3	3;8	0	0	2	1	2	2	2	4	4		4
Siliwanga	22	1	1	1;2	1;2	1;3	0	0	0	0		0	0	0	2	2	2	1	4	2		n.a.
Siliwanga	23	1	2	1;3	1;3	n.a.	0	0	0	3	3	1	n.a.	0	2	1	2	4	4	4		4
Siliwanga	24	1	6	1;2;3	2;3	1;3	0	0	0	3	3	0	0	0	1	2	2	4	2	2		n.a.
Siliwanga	25	1	2	1;2	1;3	2;4	0	0	4	3	2;4	0	0	2	1	2	2	2	4	1	1	n.a.
Siliwanga	26	1	12	2;3	1;2;3	3	1	n.a.	0	1	3	0	0	0	2	2	2	2	2	4		2
Siliwanga	27	1	2	3	1	3	1	n.a.	0	1	3	0	0	2	1	1	1	2	1	4		4
Siliwanga	28	1	2	1;2;3	1	3	1	n.a.	0	1	3	0	0	2	1	2	2	1	1	1	1	4
Siliwanga	29	1	4	1;2;3	1;2	1;3	0	0	2	1	3	0	0	2	1	1	2	1	1	1		1
Siliwanga	30	1	1	1;3	1;2	n.a.	0	0	0	0		0	0	0	1	1	2	1	2	1		1
Tamadue	31	1	2	1;3	1	n.a.	1	n.a.	3	1;3	3	1	n.a.	3	4	2	2	2	1	2		4
Tamadue	32	1	2	3	1;2	3	1	6	2	1;3	3	0	0	2	4	1	2	2	1	4		4
Tamadue	33	1	2	3	1	3	1	4	0	1;3	3	1	4	0	4	2	1	4	4	4		2
Tamadue	34	1	3	3	1;2;3	3	1	n.a.	0	1;3	3	1	n.a.	0	2	2	2	1	1	2		2
Tamadue	35	1	6	1;2	1;2;3	3	1	n.a.	0	1;3	3	1	n.a.	0	2	2	2	2	1	2		2
Tamadue	36	1	4	3	1	n.a.	1	12	0	0		0	0	0	2	1	1	4	1	4		2
Tamadue	37	1	4	1	0		0	0	0	0		0	0	0	4	4	4	2	1	2		n.a.
Tamadue	38	1	4	3	1;3	3	1	n.a.	0	2	3	0	0	2	2	4	1	4	2	4		4
Tamadue	39	1	3	1	1	3	1	12	0	1;3	3	1	n.a.	2	4	2	2	2	2	2		4
Tamadue	40	1	4	0	1;3	3	1	12	2	1;3	3	1	12	2	2	1	2	2	3	4		1
Wanga	41	1	4	1;2;3	1;2	2;3	0	0	4	3	3	0	0	2	1	2	1	1	1	1	1	1
Wanga	42	1	1	1;2;3	1;2;3	2;3	0	0	1;4	3	3	0	0	2	1	2	1	1	1	1		n.a.
Wanga	43	1	6	1;2	0		0	0	0	0		0	0	0	1	2	4	2	4	2		n.a.
Wanga	44	1	12	1;2	1	4	1	0.5	0	0		0	0	0	1	2	2	1	3	2		2
Wanga	45	1	4	1;2;3	1;2;3	2;4	0	0	1	0		0	0	0	1	1	2	1	4	1		n.a.
Wanga	46	1	12	1;2;3	2		0	0	0	0		0	0	0	2	2	4	1	4	1	1	n.a.
Wanga	47	1	4	1;2;3	1;2	2;3	0	0	4	0		0	0	0	1	2	2	4	2	1		n.a.
Wanga	48	1	2	1;2;3	1;2;3	2;3	1	0.5	1	1	3	0	0	2	3	2	1	1	4	1		n.a.
Wanga	49	1	2	1;2;3	1;2	3;4	0	0	1;6	0		0	0	0	1	2	2	1	4	1	1	1
Wanga	50	1	3	3	1;2;3	3	0	0	4	0		0	0	0	1	2	1	2	1	4		1
		0=No 1=Yes		1=Hoeing 2=Pulling up 3=Cutting	0=None 1=Caterpillars 2=Ants 3=Aphids 4=Worms (fruits) 5=Mice	1=Fruits 2=Vegetables 3=Stimulants 4=Spices	0=No 1=Yes		0=None 1=Dusting with ash 2=Cutting of infested parts 3=Cutting down totally 4=Collecting+killing of pests 5=Destroying nests of ants 6=Spraying soap-sud 7=Fumigating 8=Applying soap/kerosine at the trunk 9=Plugging caterpillars hole in the twig	0=None 1="Cancer" 2=Withered branches 3=Die-back 4=Black cancer	1=Fruits 2=Vegetables 3=Stimulants 4=Spices 8=MPT	0=No 1=Yes		0=None 1=Dusting with ash 2=Cutting of infested parts 3=Cutting down totally 6=Spraying soap-sud 8=Applying soap/kerosine at the trunk	1=Very serious 2=serious 3=Normal 4=No problem							

Appendix 12. Combined list of crop plant species (ordered by main use categories) cultivated in 30–50 homegardens in 3–5 villages of the Napu valley, Central Sulawesi, in 2001, 2003, and 2004. Besides scientific, common, Indonesian, and local species names, also numbers of cultivated varieties in the year 2003 (Var no.), domestication status (Wild), life form (Ann.), origin, and main and secondary uses are given. (For coding see footnotes).

No.	Species name	Family	Common name	Indonesian name (local name)	Var no.	Wild	Ann.	Ori-gin	Main use	Secondary uses
1	*Anacardium occidentale* L.	Anacardiaceae	Cashew	Jambu monyet	1	0	0	5	1	
2	*Ananas comosus* (L.) Merr.	Bromeliaceae	Pineapple	Nanas	2	0	0	5	1	5;13;14;15;16
3	*Annona muricata* L.	Annonaceae	Soursop	Sirsak	2	0	0	5	1	5
4	*Carica papaya* L.	Caricaceae	Papaya	Pepaya	2	0	0	5	1	2;5;10;13
5	*Citrullus lanatus* ssp. *vulgaris* Dessert Group	Cucurbitaceae	Watermelon	Semangka	1	0	1	3	1	
6	*Citrus aurantiifolia* (Christm. & Panz.) Swingle	Rutaceae	Lime	Jeruk nipis kuning	1	0	0	1	1	4;5;13
7	*Citrus maxima* (Burm.) Merr.	Rutaceae	Pummelo	Jeruk besar	3	0	0	1	1	5;13;15
8	*Citrus medica* L.	Rutaceae	Citron	Jeruk sukade (doku)	1	0	0	2	1	4
9	*Citrus reticulata* Blanco	Rutaceae	Mandarin	Jeruk manis	4	0	0	1	1	4;5;13;15
10	*Citrus sinensis* (L.) Osbeck	Rutaceae	Sweet orange	Jeruk cina	3	0	0	2	1	13;15
11	*Citrus* sp.	Rutaceae		Jeruk nipis oranye	1	0	0		1	4
12	*Clausena* sp.?	Rutaceae		Jeruk baru	1	0	0	1	1	5
13	*Cocos nucifera* L.	Arecaceae	Coconut palm	Kelapa	4	0	0	1	1	2;5;11;13;14;15
14	*Dimocarpus longan* Lour.	Sapindaceae	Longan	Klengkeng	2	0	0	2	1	
15	*Durio zibethinus* Murray	Bombacaceae	Durian	Durian	4	0	0	1	1	5;13
16	*Garcinia mangostana* L.	Clusiaceae	Mangosteen	Manggis	1	0	0	1	1	
17	*Lansium domesticum* Correa	Meliaceae	Langsat	Langsat	1	0	0	1	1	5;13
18	*Mangifera indica* L.	Anacardiaceae	Mango	Mangga	11	0	0	2	1	5;13;15
19	*Manilkara zapota* (L.) van Royen	Sapotaceae	Sapodilla	Sawo	1	0	0	5	1	
20	*Musa x paradisiaca* L.	Musaceae	Banana	Pisang	28	0	0	1	1	2;5;10;11;13;15
21	*Nephelium lappaceum* L.	Sapindaceae	Rambutan	Rambutan	4	0	0	1	1	13
22	*Passiflora edulis* Sims	Passifloraceae	Passionfruit	Markisa hitam	1	0	0	5	1	15
23	*Passiflora ligularis* Juss.	Passifloraceae	Sweet granadilla	Markisa kuning	1	0	0	5	1	15
24	*Persea americana* Miller	Lauraceae	Avocado	Adpukat	3	0	0	5	1	5;13
25	*Pometia pinnata* J.R. Forster & G. Forster	Sapindaceae	Kasai tree	Matoa	1	1	0	1	1	
26	*Psidium guajava* L.	Myrtaceae	Guava	Jambu biji	4	0	0	5	1	4;5;10
27	*Rubus rosifolius* Sm.	Rosaceae	Queensland raspberry	Arbei (lole-lole)	1	1	0	1	1	5
28	*Salacca zalacca* (Gaertner) Voss	Arecaceae	Salak palm	Salak	1	0	0	1	1	14;15
29	*Syzygium aqueum* (Burm.f.) Alston	Myrtaceae	Water apple	Jambu air	3	0	0	1	1	5;10;13;14;15
30	*Syzygium malaccense* (L.) Merr. & Perry	Myrtaceae	Malay apple	Jambu bol (gora)	2	0	0	1	1	13;15
31	*Abelmoschus manihot* (L.) Medik.	Malvaceae	Sunset hibiscus	Sayur gedi	1	0	0	1	2	5
32	*Amaranthus tricolor* L.	Amaranthaceae	Amaranth	Bayam	2	0	1	1	2	5;13
33	*Artocarpus altilis* (Park.) Fosberg	Moraceae	Breadfruit	Sukun	1	0	0	1	2	
34	*Artocarpus heterophyllus* Lam.	Moraceae	Jackfruit	Nangka	5	0	0	2	2	1;5;6;10
35	*Athyrium esculentum* (Retz.) Copel.	Woodsiaceae	Fern	Sayur paku	1	1	0	1	2	13
36	*Brassica juncea* (L.) Czernjaew	Brassicaceae	Indian mustard	Sawi	1	0	1	2	2	13
37	*Brassica oleracea* L. ssp. *oleracea* convar. *capitata* (L.) Alef. var. *capitata* L. *forma alba*	Brassicaceae	White cabbage	Kol	1	0	1	4	2	13
38	*Brassica rapa* ssp. *chinensis* (L.) Hanelt in J.Schultze-Motel	Brassicaceae	Pak choi	Sayur putih	1	0	1	2	2	
39	*Brassica rapa* ssp. *pekinensis* (Lour.) Hanelt in J.Schultze-Motel	Brassicaceae	Chinese cabbage	Sayur sekatar	1	0	1	2	2	
40	*Cajanus cajan* (L.) Millsp.	Fabaceae	Pigeonpea	Kacang kayu (undis)	1	0	0	3	2	
41	*Canavalia ensiformis* (L.) DC.	Fabaceae	Sword bean	Kacang parang	1	0	0	5	2	
42	*Clerodendron minahassae* Teijsm. & Binn.	Verbenaceae		(Dongato/leilem)	1	1	0	1	2	5
43	*Cosmos caudatus* H.B. K.H.B.K.	Asteraceae	Cosmos	Kenikir	1	1	1	5	2	12
44	*Cucumis sativus* L.	Cucurbitaceae	Cucumber	Ketimun	1	0	1	2	2	5
45	*Cucurbita pepo* L.	Cucurbitaceae	Pumpkin	Labu	3	0	1	5	2	5;10
46	*Daucus carota* ssp. *sativus* (Hoffn.) Schübl. & Mart.	Apiaceae	Carrot	Wortel	2	0	1	4	2	5
47	*Enydra fluctuans* Lour.	Asteraceae	Buffalo spinach	(Sayur taugaruk)	1	1	0	2	2	
48	*Etlingera elatior* (Jack) R.M. Sm.	Zingiberaceae	Torch ginger	Combrang (cicang)	1	0	0	1	2	12
49	*Glycine max* (L.) Merr.	Fabaceae	Soya bean	Kedelai	1	0	1	2	2	
50	*Hedychium coronarium* Koenig in Retz.	Zingiberaceae	Butterfly ginger	Gandasuli (pambuku)	1	1	0	1	2	5
51	*Ipomoea aquatica* Forsskal	Convolvulaceae	Water spinach	Kangkung	2	0	0	2	2	4;5;10
52	*Lablab purpureus* (L.) Sweet	Fabaceae	Hyacinth bean	Kacang komak	1	0	1	3	2	
53	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Bottle gourd	Labu air	1	0	1	3	2	
54	*Limnocharis flava* (L.) Buchenau	Butomaceae	Sawah lettuce	Genjer	1	1	0	5	2	12

No.	Species name	Family	Common name	Indonesian name (local name)	Var no.	Wild	Ann.	Ori-gin	Main use	Secondary uses
55	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	Ridged gourd	Gambas	1	0	1	2	2	
56	*Luffa aegyptiaca* Mill.	Cucurbitaceae	Sponge gourd	Blustru	1	0	1	1	2	
57	*Lycopersicon esculentum* Miller	Solanaceae	Tomato	Tomat	4	0	1	5	2	4;5;13
58	*Moringa oleifera* Lam.	Moringaceae	Horseradish tree	Kelor	1	0	0	2	2	5
59	*Phaseolus lunatus* L.	Fabaceae	Lima bean	Kacang manis	2	0	1	5	2	
60	*Phaseolus vulgaris* L. ssp. *vulgaris* var. *Nanus* (L.) Asch.	Fabaceae	French bean	Kacang merah/buncis	1	0	1	5	2	
61	*Psophocarpus tetragonolobus* (Stickm.) DC.	Fabaceae	Winged bean	Kecipir	1	0	0	1	2	
62	*Sauropus androgynus* (L.) Merr.	Euphorbiaceae	Star gooseberry	Katuk	1	0	0	1	2	5
63	*Sechium edule* (Jacq.) Swartz	Cucurbitaceae	Chayote	Labu siam	3	0	0	5	2	5;10
64	*Solanum aethiopicum* L.	Solanaceae	Bitter tomato	(Palolakao)	1	0	0	3	2	5
65	*Solanum macrocarpon* L.	Solanaceae	African eggplant	Terong cina/kelapa	1	0	0	3	2	5;13
66	*Solanum melongena* L.	Solanaceae	Eggplant	Terong biasa/kuning	8	0	0	3	2	13;15
67	*Solanum nigrum* L.	Solanaceae	Black nightshade	Kampai	1	0	1	4	2	5
68	*Solanum torvum* Sw.	Solanaceae	Devil's fig	Terong hutan	1	1	0	5	2	
69	*Solanum tuberosum* L.	Solanaceae	Potato	Kentang	1	0	0	5	2	13
70	*Vigna angularis* (Willd.) Ohwi & Ohashi	Fabaceae	Adzuki bean	Kacang cina	1	0	1	2	2	
71	*Vigna radiata* (L.) R. Wilczek	Fabaceae	Mung bean	Kacang hijau	1	0	1	2	2	
72	*Vigna* sp.	Fabaceae		Kacang duduk	1	0	1	2	2	13
73	*Vigna unguiculata* (L.) Walp. ssp. *sesquipedalis*	Fabaceae	Yard-long bean	Kacang panjang	3	0	1	2	2	5;13
74	*Youngia japonica* (L.) DC. (=*Crepis jap.*)	Asteraceae		Sayur sawi bunga	1	1	1		2	
75	*Areca catechu* L.	Arecaceae	Betelnut palm	Palem pinang	1	0	0	1	3	5
76	*Areca* sp.	Arecaceae		Pinang hutan (harao)	1	1	0	1	3	5
77	*Arenga pinnata* (Wurmb.) Merr.	Arecaceae	Sugar palm	Enau	1	0	0	1	3	1;2;13;14
78	*Camellia sinensis* (L.) Kuntze	Theaceae	Tea	Teh	1	0	0	2	3	5;12;16
79	*Coffea arabica* L.	Rubiaceae	Arabica coffee	Kopi arabika	3	0	0	3	3	5;13
80	*Coffea canephora* Pierre ex Froehner	Rubiaceae	Robusta coffee	Kopi robusta	1	0	0	3	3	5;14
81	*Coffea liberica* Bull.	Rubiaceae	Liberica coffee	Kopi besar (belulang)	1	0	0	3	3	
82	*Nicotiana tabacum* L.	Solanaceae	Tobacco	Tembakau	2	0	0	5	3	5;12
83	*Piper betle* L.	Piperaceae	Betel pepper	Sirih	1	0	0	1	3	5;15
84	*Saccharum officinarum* L.	Poaceae	Sugar cane	Tebu	3	0	0	2	3	5;13;15;16
85	*Theobroma cacao* L.	Sterculiaceae	Cacao	Coklat	7	0	0	5	3	13
86	*Aleurites moluccana* (L.) Willd.	Euphorbiaceae	Candle nut tree	Kemiri	1	0	0	1	4	5;7;8;13
87	*Allium cepa* L. Aggregatum Group *(var. ascalonicum)*	Alliaceae	Shallot	Bawang merah	1	0	0	2	4	
88	*Allium fistulosum* L.	Alliaceae	Spring onion	Bawang daun	2	0	0	2	4	5;13
89	*Allium schoenoprasum* L.	Alliaceae	Chives	Bawang piara/nkundu	1	0	0	4	4	5
90	*Alpinia galanga* (L.) Willd.	Zingiberaceae	Great galanga	Lengkuas	1	0	0	1	4	5
91	*Alpinia* sp.	Zingiberaceae		(Bumbu talas)	1	0	0	2	4	5
92	*Apium graveolens* L. var. *secalinum* Alef.	Apiaceae	Celery	Seledri	1	0	0		4	5
93	*Arachis hypogaea* L.	Fabaceae	Groundnut	Kacang tanah	2	0	1	5	4	13
94	*Capsicum annuum* L.	Solanaceae	Chilli	Cabe	10	0	0	5	4	2;5;13;15
95	*Cinnamomum burmanii* (Nees) Blume	Lauraceae	Indonesian cassia	Kayu manis	1	0	0	1	4	
96	*Citrus hystrix* DC.	Rutaceae	Kaffir lime	Jeruk ikan/purut	1	0	0	1	4	1
97	*Curcuma longa* L.	Zingiberaceae	Turmeric	Kunyit	1	0	0	1	4	5;13
98	*Cymbopogon citratus* (DC.) Stapf	Poaceae	Lemon grass	Daun serai	1	0	0	1	4	5
99	*Cymbopogon flexuosus* (Steud.) Stapf	Poaceae	Malabar lemon grass	Daun serai belanda	1	0	0	2	4	5
100	*Etlingera* sp.	Zingiberaceae		(Bongkot)	1	0	0	2	4	
101	*Foeniculum vulgare* Mill.	Apiaceae	Fennel	Adas	1	0	0	4	4	2;5
102	*Kaempferia galanga* L.	Zingiberaceae	East Indian galangal	Kencur	1	0	0	2	4	5
103	*Mentha x piperita* L.	Lamiaceae	Peppermint	Daun solasi	1	0	0	4	4	5
104	*Momordica charantia* L.	Cucurbitaceae	Bitter gourd	Paria	1	0	1	2	4	2;5
105	*Ocimum basilicum* L.	Lamiaceae	Basil	Kemangi	1	0	1		4	5;13
106	*Pandanus amaryllifolius* Roxb.	Pandanaceae	Fragant screw pine	Pandan	1	0	0		4	5;11;15
107	*Piper nigrum* L.	Piperaceae	Pepper	Merica	1	0	0	2	4	5;13
108	*Sesamum indicum* L.	Pedaliaceae	Sesame	Wijen	1	0	1	2	4	
109	*Suaeda* sp.	Chenopodiaceae		Bumbu tinotuan (pasote)	1	1	0		4	5
110	*Syzygium aromaticum* (L.) Merr. & Perry	Myrtaceae	Clove	Cengkeh	1	0	0	1	4	13
111	*Syzygium polyanthum* (Wight) Walp.	Myrtaceae	Indonesian bay-leaf	Salam	1	0	0	2	4	2;7
112	*Tamarindus indica* L.	Fabaceae/Caes.	Tamarind	Asam jawa	1	0	0	3	4	5
113	*Vanilla planifolia* Andr.	Orchidaceae	Vanilla	Vanili	1	0	0	5	4	13
114	*Zingiber officinale* Roscoe	Zingiberaceae	Ginger	Jahe	2	0	0	2	4	5;13
115	*Acorus calamus* L.	Araceae/Acoraceae	Sweet flag	Dringo (kariango)	1	0	0	2	5	17
116	*Allium ramosum* L. (= *A. tuberosum* Rottler ex Sprengel)	Alliaceae	Chinese chives	Bawang kucai (lehune mpipi)	1	0	0	2	5	4
117	*Aloe barbadensis* Mill.	Asphodelaceae	True aloe	Lidah boaya	1	0	0	3	5	12
118	*Blumea balsamifera* (L.) DC.	Asteraceae	Camphor plant	Sembung (tobuburi)	1	0	0	1	5	
119	*Celosia argentea* L.	Amaranthaceae	Green soko	(Bunga imba)	1	0	1		5	
120	*Centella asiatica* (L.) Urb. in Mart.	Apiaceae	Asiatic pennywort	Tapu kuda	1	1	0	1	5	
121	*Clematis smilacifolia* Wall.	Ranunculaceae		Obat gigi	1	1	0	1	5	

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122	*Clerodendron* sp.	Verbenaceae		Patah tulang (lelimbanua)	1	1	0	1	5	
123	*Cordyline fruticosa* (L.) Goepp.	Asteliaceae	Palm lily	Andong (bunga tabang)	1	0	0	1	5	12;17
124	*Costus speciosus* (Koenig in Retz.) J.E. Sm.	Zingiberaceae	Crepe ginger	Pacing (tuwu-tuwu)	1	0	0	1	5	
125	*Curcuma xanthorrhiza* Roxb.	Zingiberaceae		Temu lawak	1	0	0	1	5	
126	*Cyperus rotundus* L.	Cyperaceae	Purple nut grass	Rumput tekih	1	1	0	3	5	
127	*Dichrocephala integrifolia* (L.f.) Kuntze	Asteraceae		(Panaramanu)	1	1	1	1	5	
128	*Eleutherine palmifolia* (L.) Merr.	Iridaceae		Bawang kapal (lehune topeole)	1	1	0	5	5	
129	*Equisetum debile* Roxb.	Equisetaceae		(Uhouhou/tikel balung)	1	1	0	1	5	
130	*Graptophyllum pictum* (L.) Griff.	Acanthaceae	Carricature plant	Daun teman/ungu	1	0	0	3	5	15
131	*Gynura procumbens* (Lour.) Merr.	Asteraceae		Sambung myawa	1	0	0	3	5	
132	*Hemigraphis bicolor* Boerl.	Acanthaceae		Kembang	1	0	0		5	17
133	*Hibiscus acetosella* Welw. ex Hierr.	Malvaceae	False roselle	Obat bunga merah	1	0	0	3	5	
134	*Hippeastrum puniceum* (Lam.) Voss	Amaryllidaceae	Barbados lily	Bunga oktober	1	0	0	5	5	12
135	*Homalomena cordata* Schott	Araceae		(Kalomba)	1	1	0	1	5	17
136	*Jatropha curcas* L.	Euphorbiaceae	Purging nut	Jarak pagar (belacair)	1	0	0	5	5	7;16
137	*Kalanchoe pinnata* (Lam.) Pers.	Crassulaceae	Floppers	Sosor bebek (lompo-lompo)	2	0	0	3	5	12
138	*Morinda citrifolia* L.	Rubiaceae	Indian mulberry	Mengkudu	1	0	0	1	5	
139	*Orthosiphon aristatus* (Blume) Miq.	Lamiaceae	Cat´s whizkers	Kumis kucing	1	0	0	1	5	16
140	*Picria felterrae* Lour.	Scrophulariaceae		(Lubi-lubi)	1	1	1	1	5	
141	*Piper caninum* Blume	Piperaceae		Sirih hutan	1	1	0	1	5	
142	*Plectranthus amboinicus* (Lour.) Spreng.	Lamiaceae	Indian borage	Daun tebal/jinten	1	0	0	1	5	4
143	*Premna trichostoma* Miq.	Verbenaceae		(Daluman)	1	0	0	1	5	
144	*Ricinus communis* L.	Euphorbiaceae	Castor bean	Jarak	1	0	0	2	5	
145	*Sansevieria trifasciata* Prain	Dracaenaceae	Bowstring hemp	Lidah mertua (bunga pedang)	1	0	0	3	5	
146	*Senna alata* (L.) Roxb.	Fabaceae/Caes.	Ringworm bush	Ketepeng	1	0	0	5	5	
147	*Solenostemon scutellarioides* (L.) Codd	Lamiaceae	Painted nettle	Bunga mayana	2	0	0	1	5	2;12
148	*Strobilanthes crispa* (L.) Blume	Acanthaceae	Cone head	Pijahbeling	1	0	0		5	12
149	*Symphytum officinale* L.	Boraginaceae	Common Comfrey	Obat jamur/komfrey	1	0	0	4	5	
150	*Synadenium grantii* Hook.f.	Euphorbiaceae	African milk bush	Obat panas	1	0	0	3	5	
151	*Talinum paniculatum* (Jacq.) Gaertn.	Portulacaceae	Fame flower	Rumput ginseng	1	0	0	5	5	
152	*Talinum triangulare* (Jacq.) Willd.	Portulacaceae	Surinam purslane	Ginseng poslen	1	0	0	5	5	12
153	*Tinospora crispa* Miers	Menispermaceae		Bratawali (pancar sona)	1	0	0	1	5	
154	*Zingiber aromaticum* Val.	Zingiberaceae		Lempuyang wangi (gambongan)	1	0	0	1	5	4;15;17
155	*Zingiber purpureum* Roscoe	Zingiberaceae	Cassumunar ginger	Banglai	1	0	0	2	5	2
156	*Canna edulis* Ker-Gawl.	Cannaceae	Queensland arrowroot	Ganyong	1	0	0	5	6	
157	*Colocasia esculenta* (L.) Schott ex Schott & Endl.	Araceae	Taro	Keladi (upe)	2	0	0	1	6	2;10
158	*Dioscorea bulbifera* L.	Dioscoreaceae	Aerial yam	Sekapo	1	0	0	3	6	
159	*Ipomoea batatas* (L.) Lam.	Convolvulaceae	Sweet potato	Ubi jalar/ubi merah	3	0	0	5	6	2;5;10;13
160	*Manihot esculenta* Crantz	Euphorbiaceae	Cassava	Ubi kayu	4	0	0	5	6	2;10;13;16
161	*Maranta arundinacea* L.	Marantaceae	Arrowroot	Garut (parus)	1	0	0	5	6	10
162	*Oryza sativa* L.	Poaceae	Rice	Padi	2	0	1	2	6	
163	*Xanthosoma sagittifolium* (L.) Schott ex Schott & Endl.	Araceae	New cocoyam	Keladi putih	1	0	0	5	6	5;10
164	*Xanthosoma violaceum* Schott	Araceae	Blue taro/cocoyam	Keladi hitam	1	0	0	5	6	10
165	*Zea mays* L.	Poaceae	Maize	Jagung	3	0	1	5	6	2;5;10;13
166	*Acalypha caturus* Blume	Euphorbiaceae		(Beranahe)	1	1	0		7	5
167	*Acalypha marginata* Spreng.	Euphorbiaceae		(Ampana)	1	1	0		7	16
168	*Bischofia javanica* Blume	Euphorbiaceae	Bishop wood	Pepolo	1	1	0	1	7	5;16
169	*Breynia microphylla* (Kurz. ex Teijsm. & Binn.) Muell. Arg.	Euphorbiaceae		Kayu rumput (teturu)	1	1	0		7	
170	*Cananga odorata* (Lam.) Hook.f. & Thoms.	Annonaceae	Ilang-ilang	Kenanga (sandat)	1	1	0	1	7	15
171	*Crescentia cujete* L.	Bignoniaceae	Calabash tree	Kayu tabu (bila)	1	0	0	5	7	14;16
172	*Dendrocalamus* sp.	Poaceae	Giant bamboo	Bambu	1	0	0	1	7	2;14;16
173	*Elmerrillia ovalis* (Miq.) Dandy	Magnoliaceae		Uru/cempaka	1	1	0	1	7	
174	*Euonymus javanicus* Blume	Celastraceae		(Patingka)	1	1	0	1	7	16
175	*Ficus septica* Burm.f.	Moraceae		(Leboni/lewunu)	1	1	0	1	7	5;11
176	*Ficus* sp. 1	Moraceae		(Dodonga)	1	1	0		7	
177	*Ficus* sp. 2	Moraceae		(Lamba)	1	1	0		7	14
178	*Flemingia strobilifera* (L.) Aiton & W.T. Aiton	Fabaceae		(Soa-soa)	1	1	0	1	7	5
179	*Globba* sp.?	Zingiberaceae		(Kahimpo)	1	1	0		7	5
180	*Glochidion rubrum* Blume	Euphorbiaceae		(Kahio)	1	1	0		7	1;5
181	*Glochidion* sp.	Euphorbiaceae		(Bure-bure, tambone)	1	1	0		7	5;16
182	*Gmelina arborea* Roxb.	Verbenaceae		Jati putih	1	0	0	2	7	13

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183	*Grewia laevigata* Vahl.	Tiliaceae		(Bonoh)	1	1	0		7	
184	*Hibiscus macrophyllus* Roxb.	Malvaceae		(Tawe meapo)	1	1	0		7	11
185	*Homalanthus populneus* Pax	Euphorbiaceae		(Belante)	1	1	0		7	5;16
186	*Leucosyke condissima* Wedd.	Urticaceae		(Balowira)	1	1	0		7	1
187	*Litsea* sp. 1	Lauraceae		(Bitiahu)	1	1	0		7	3
188	*Litsea* sp. 2	Lauraceae		(Salamate)	1	1	0		7	5
189	*Macaranga tanarius* (L.) Muell. Arg.	Euphorbiaceae		(Potimata)	1	1	0	1	7	11
190	*Macaranga triloba* (Thunb.) Muell. Arg.	Euphorbiaceae		(Lengkobu)	1	1	0		7	11
191	*Melastoma malabathricum* L.	Melastomataceae	Singapore rhododendron	(Wua-wua)	1	1	0	1	7	1;5
192	*Melochia umbellata* (Wight) Stapf	Sterculiaceae		(Bentunu)	1	1	0	2	7	8
193	*Morus alba* L.	Moraceae	White mulberry	Murbei	1	0	0	2	7	1;2;16
194	*Nauclea orientalis (*L.) L.	Rubiaceae		Kayu telur (towote)	1	1	0	2	7	
195	*Pinus merkusii* Jungh. & de Vriese	Pinaceae	Sumatra pine	Pinus	1	0	0	1	7	12
196	*Pisonia umbellifera* (J.R. & G. Forst.) Seem.	Nyctaginaceae		(Berombo)	1	1	0	2	7	
197	*Platea* sp.	Icacinaceae		(Nkanona)	1	1	0		7	
198	*Pothomorphe umbellata* (L.) Miq.	Piperaceae		(Lepo-lepo)	1	1	0	5	7	4;5
199	*Premna serratifolia* L.	Verbenaceae		(Arogo)	1	1	0	2	7	2;5;16
200	*Sambucus canadensis* L.	Caprifoliaceae	Canadian elder	(Doda)	1	1	0	5	7	15
201	*Tectona grandis* L.f.	Verbenaceae	Teak wood	Jati mas	1	0	0	1	7	13
202	*Trema orientalis* (L.) Blume	Ulmaceae	Indian charcoal tree	(Bolah)	1	1	0	1	7	
203	*Trema* sp.	Ulmaceae		(Ntowiroe)	1	1	0		7	
204	*Wendlandia paniculata* (Roxb.) DC.	Rubiaceae		(Parahoa)	1	1	0		7	5
205	*Wendlandia* sp.	Rubiaceae		(Urio)	1	1	0		7	
206	*Erythrina subumbrans* (Hassk.) Merrill (=variegata) (orientalis?)	Fabaceae	December coral tree	Dadap	1	0	0	2	8	2;5;10;16
207	*Flemingia macrophylla* (Willd.) Blume ex Miq.	Fabaceae		(Ingan-ingan)	1	0	0	1	8	16
208	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	Mother of cocoa	Gamal	1	0	0	5	8	2;5;10;16
209	*Leucaena leucocephala* (Lam.) De Wit	Fabaceae/Mim.	Horse tamarind	Lamtoro	1	0	0	5	8	2;4;5;10
210	*Manihot glaziovii* Müll. Arg. in Mart.	Euphorbiaceae	Tree cassava	Ubi karet	1	0	0	5	8	2;5;10
211	*Mucuna pruriens* cv. group *utilis* (L.) DC.	Fabaceae	Velvet bean	Kacang benguk	1	0	1		8	2
212	*Paraserianthes falcataria* (L.) Nielsen	Fabaceae/Mim.	White albizia	Sengon	1	0	0		8	
213	*Tephrosia vogelii* Hook.f. in Hook.	Fabaceae	Fish poison bean	(Gereng-gereng)	1	0	0	3	8	
214	*Calamus* sp.	Arecaceae	Rattan cane	Rotan	1	1	0	1	9	13;14
215	*Ceiba pentandra* (L.) Gaertn.	Bombacaceae	Silk-cotton tree	Pohon kapuk	1	0	0	5	9	14
216	*Coix lacryma-jobi* L.	Poaceae	Job´s tears	Jali (kalide)	1	0	0	2	9	12;15
217	*Gossypium barbadense* L.	Malvaceae	Cotton	Kapok/kapas	1	0	0		9	12;14;15
218	*Heliconia indica* Lam.	Heliconiaceae	False bird-of-paradise	Daun bungkus	1	0	0		9	5;11
219	*Pennisetum purpureum* Schum.	Poaceae	Napier grass	Rumput gadjah	1	0	0		9	10
220	*Phrynium pubinerve* Blume	Marantaceae		(Malanipa)	1	1	0	1	9	11
221	*Stephania corymbosa* (Blume) Spreng.	Menispermaceae		Cincau (daluman)	1	0	0	1	9	5

Note: Coloured cells = Species cultivated only in 2001 and/or 2003.

Coding:

Domestication status:
0 = Domesticated
1 = Wild

Life form :
0 = Perennial
1 = Annual

Origin:
1 = SE-Asia
2 = Asia
3 = Africa
4 = Europe
5 = America

Main and secondary uses:
1=Fruit
2=Vegetable
3=Stimulant
4=Spice
5=Medicine
6=Staple
7=Wood
8=MPU
10=Fodder
11=Wrapping
12=Ornament
13=Cash
14=Handicraft
15=Sacrifices
16=Fence
17=Mystic

Appendix 13. Individual numbers and frequencies of crop plant species (ordered by main use categories) cultivated in 30–50 homegardens in 3–5 villages of the Napu valley, Central Sulawesi, in 2001, 2003, and 2004. N per village = 10, apart from Rompo 2004: N = 8; Siliwanga 2003: N = 9, Siliwanga 2004: N = 8. (Sili. = Siliwanga; Sili. new = Siliwanga including two 'new' homegardens to replace the abandoned ones; Ta. = Tamadue; Wg. = Wanga).

	Number of individuals									Sili.			Frequencies (%)									Sili.		
	Wuasa			Rompo			Sili.			new	Ta.	Wg.	Wuasa			Rompo			Sili.			new	Ta.	Wg.
Species name	01	03	04	01	03	04	01	03	04	04	04	04	01	03	04	01	03	04	01	03	04	04	04	04
Anacardium occidentale	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Ananas comosus	210	169	267	63	69	33	244	171	248	262	0	23	60	60	70	50	60	63	70	89	88	80	0	30
Annona muricata	0	0	0	1	3	2	0	0	0	0	2	1	0	0	0	10	20	25	0	0	0	0	20	10
Carica papaya	9	15	19	31	25	35	15	8	9	10	12	26	50	50	60	80	70	75	50	44	63	60	20	80
Citrullus lanatus ssp. *vulgaris* Dessert Group	0	0	1	0	2	0	0	0	0	0	0	1	0	0	10	0	20	0	0	0	0	0	0	10
Citrus aurantiifolia	0	0	0	1	1	1	0	0	0	0	0	3	0	0	0	10	10	13	0	0	0	0	0	20
Citrus maxima	10	23	15	12	18	16	3	3	2	2	4	6	60	80	70	80	70	75	20	22	25	20	40	50
Citrus medica	0	0	2	0	0	2	0	1	6	7	2	9	0	0	20	0	0	13	0	11	38	40	10	50
Citrus reticulata	23	23	24	5	52	38	47	87	86	121	43	23	50	50	60	40	90	88	80	89	88	90	80	50
Citrus sinensis	1	1	1	5	4	9	13	17	16	18	0	7	10	10	10	20	20	38	50	56	50	60	0	40
Citrus sp.	6	5	2	1	3	4	1	2	4	4	1	10	20	30	20	10	20	38	10	22	38	30	10	50
Clausena sp.?	0	0	2	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Cocos nucifera	10	10	13	12	10	7	13	11	11	11	50	9	60	60	60	40	40	50	60	67	75	60	80	40
Dimocarpus longan	3	3	3	0	0	0	0	0	0	0	2	0	20	20	20	0	0	0	0	0	0	0	20	0
Durio zibethinus	4	4	3	10	8	8	1	1	2	2	9	5	30	40	30	30	20	38	10	11	25	20	40	20
Garcinia mangostana	0	1	1	0	0	2	0	0	0	0	0	2	0	10	10	0	0	13	0	0	0	0	0	10
Lansium domesticum	5	6	9	2	2	2	0	0	0	0	0	1	10	20	30	10	10	13	0	0	0	0	0	10
Mangifera indica	20	19	30	12	30	22	11	7	7	8	39	20	100	100	100	70	90	63	70	56	63	60	100	100
Manilkara zapota	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0
Musa x paradisiaca	195	186	184	161	116	143	295	187	268	300	128	29	100	100	80	90	90	100	90	89	88	90	90	50
Nephelium lappaceum	2	8	10	3	3	4	2	3	2	4	15	9	20	50	50	20	30	38	20	33	25	30	60	30
Passiflora edulis	0	1	2	2	0	0	7	6	2	2	9	1	0	10	10	20	0	0	40	33	13	10	50	10
Passiflora ligularis	0	0	0	0	0	0	4	1	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Persea americana	17	17	25	1	0	0	9	9	8	8	5	7	60	90	90	10	0	0	40	56	50	40	30	40
Pometia pinnata	4	3	3	0	0	0	0	0	0	0	0	0	10	10	10	0	0	0	0	0	0	0	0	0
Psidium guajava	32	32	39	35	43	42	84	76	68	84	51	101	60	80	80	90	90	75	100	100	100	100	100	100
Rubus rosifolius	0	0	8	0	9	16	0	0	0	0	0	32	0	0	10	0	10	13	0	0	0	0	0	30
Salacca zalacca	2	1	2	2	2	3	1	1	1	1	2	0	10	10	20	10	10	13	10	11	13	10	10	0
Syzygium aqueum	15	13	15	8	8	6	4	3	3	4	8	3	80	60	70	60	50	50	20	22	25	30	50	10
Syzygium malaccense	0	0	0	1	1	1	0	0	0	0	4	0	0	0	0	10	10	13	0	0	0	0	20	0
Abelmoschus manihot	8	1	2	1	0	0	0	0	2	2	0	7	30	10	20	10	0	0	0	0	13	10	0	10
Amaranthus tricolor	63	19	84	40	123	29	77	29	10	19	9	21	20	50	50	50	80	50	40	78	50	60	30	60
Artocarpus altilis	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	10	11	13	10	10	10
Artocarpus heterophyllus	21	21	17	23	25	30	14	13	11	12	24	13	70	70	60	70	70	75	60	67	63	60	90	50
Athyrium esculentum	0	16	28	0	0	6	0	0	0	0	11	0	0	30	40	0	0	25	0	0	0	0	30	0
Brassica juncea	25	18	23	100	22	36	0	0	0	0	3	55	10	30	40	50	50	75	0	0	0	0	10	30
Brassica oleracea ssp. *oleracea* convar. *capitata* var. *capitata* forma *alba*	60	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Brassica rapa ssp. *chinensis*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Brassica rapa ssp. *pekinensis*	0	0	0	1	25	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0
Cajanus cajan	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Canavalia ensiformis	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	10
Clerodendron minahassae	7	15	17	138	99	160	0	0	0	0	0	5	20	30	40	40	40	38	0	0	0	0	0	30
Cosmos caudatus	0	0	0	0	0	0	7	13	34	34	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Cucumis sativus	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	10	10
Cucurbita pepo	24	45	76	20	30	20	9	32	27	27	8	36	80	90	70	60	50	50	40	78	100	80	30	80
Daucus carota ssp. *sativus*	0	6	2	7	0	0	0	9	2	2	0	0	0	20	10	10	0	0	0	11	13	10	0	0
Enydra fluctuans	0	0	0	0	0	0	25	65	45	45	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Etlingera elatior	0	0	0	0	0	0	1	3	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Glycine max	0	0	0	0	0	0	0	2	92	92	0	0	0	0	0	0	0	0	0	11	13	10	0	0
Hedychium coronarium	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	13	0	0	0	0	0	10
Ipomoea aquatica	13	34	8	40	16	12	130	28	46	46	49	0	30	50	30	10	20	25	40	56	63	50	40	0
Lablab purpureus	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20	0
Lagenaria siceraria	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Limnocharis flava	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	10	0
Luffa acutangula	0	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	13	0	11	0	0	0	0
Luffa aegyptiaca	0	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	10	13	0	0	0	0	0	10
Lycopersicon esculentum	77	87	163	79	110	30	30	35	26	26	7	35	70	100	100	90	100	75	60	56	75	60	20	70
Moringa oleifera	0	0	0	0	2	2	0	0	0	0	2	0	0	0	0	0	10	25	0	0	0	0	10	0
Phaseolus lunatus	0	0	0	0	0	0	3	12	33	36	1	0	0	0	0	0	0	0	10	33	50	50	10	0
Phaseolus vulgaris ssp. *vulgaris* var. *nanus*	7	15	13	39	52	1	1	10	1	1	2	4	30	30	40	20	40	13	10	11	13	10	10	20

	Number of individuals									Sili.			Frequencies (%)									Sili.		
	Wuasa			Rompo			Sili.			new	Ta.	Wg.	Wuasa			Rompo			Sili.			new	Ta.	Wg.
Species name	01	03	04	01	03	04	01	03	04	04	04	04	01	03	04	01	03	04	01	03	04	04	04	04
Psophocarpus tetragonolobus	0	2	0	3	1	10	0	0	0	0	0	0	0	10	0	10	10	25	0	0	0	0	0	0
Sauropus androgynus	0	0	0	0	0	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0	13	20	0	0
Sechium edule	23	32	31	12	14	19	8	6	9	11	27	10	50	60	70	30	50	50	20	33	75	70	70	50
Solanum aethiopicum	12	7	10	4	7	12	0	0	0	0	0	41	30	30	30	30	40	50	0	0	0	0	0	80
Solanum macrocarpon	5	1	5	27	32	17	0	0	0	0	0	8	10	10	20	60	60	50	0	0	0	0	0	40
Solanum melongena	24	25	39	59	104	68	6	17	23	24	2	30	30	60	80	80	70	75	20	33	50	50	10	20
Solanum nigrum	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0
Solanum torvum	0	0	0	0	11	1	0	0	0	0	7	0	0	0	0	0	20	13	0	0	0	0	40	0
Solanum tuberosum	6	1	17	0	0	1	0	0	0	0	0	0	20	10	10	0	0	13	0	0	0	0	0	0
Vigna angularis	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Vigna radiata	0	0	0	0	0	0	0	0	21	21	0	0	0	0	0	0	0	0	0	0	13	10	0	0
Vigna sp.	0	14	0	0	0	24	607	115	0	0	0	0	0	10	0	0	0	25	20	33	0	0	0	0
Vigna unguiculata ssp. *sesquipedalis*	93	17	67	47	88	228	48	6	3	3	54	33	40	30	70	30	60	88	30	22	25	20	10	20
Youngia japonica	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0
Areca catechu	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	10	10	13	0	0	0	0	0	0
Areca sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Arenga pinnata	1	0	9	4	1	11	0	0	0	0	0	0	10	0	10	30	10	25	0	0	0	0	0	0
Camellia sinensis	0	0	0	0	0	0	36	36	30	30	1	0	0	0	0	0	0	0	40	67	63	50	10	0
Coffea arabica	376	156	110	136	75	72	398	225	222	277	890	310	90	90	90	80	80	75	100	100	100	100	100	100
Coffea canephora	44	42	55	146	115	173	120	139	150	150	168	54	70	80	70	80	80	88	60	78	75	60	80	70
Coffea liberica	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	10	10	13	0	0	0	0	0	0
Nicotiana tabacum	4	22	24	14	17	39	0	9	4	4	4	7	20	60	50	20	40	38	0	11	13	10	10	30
Piper betle	0	1	3	0	0	1	0	0	0	0	3	0	0	10	30	0	0	13	0	0	0	0	20	0
Saccharum officinarum	20	18	16	13	12	12	18	2	7	7	16	4	40	60	60	40	50	63	80	11	38	30	60	20
Theobroma cacao	246	306	377	244	225	263	200	259	408	460	1028	204	90	100	100	90	100	100	80	89	100	100	100	100
Aleurites moluccana	3	6	7	13	15	15	1	1	1	1	18	10	30	30	40	30	30	50	10	11	13	10	50	50
Allium cepa L. Aggregatum Group	25	0	0	0	0	0	0	0	0	0	2	0	10	0	0	0	0	0	0	0	0	0	10	0
Allium fistulosum	784	3490	661	566	343	296	35	94	221	221	7	279	80	90	80	80	80	88	20	11	25	20	10	70
Allium schoenoprasum	29	12	12	142	23	8	0	0	0	0	0	18	50	30	40	70	50	25	0	0	0	0	0	10
Alpinia galanga	19	27	52	7	9	10	43	11	21	21	6	33	50	60	50	20	50	50	50	56	63	50	50	60
Alpinia sp.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	10	0
Apium graveolens var. *secalinum*	30	23	48	12	9	19	12	4	6	6	20	14	20	30	80	40	20	50	40	22	38	30	40	40
Arachis hypogaea	520	28	2455	2	1	30	3	0	0	0	0	0	40	30	30	10	10	25	20	0	0	0	0	0
Capsicum annuum	57	72	116	109	105	97	57	53	116	123	17	100	90	90	100	100	90	88	70	100	100	100	70	90
Cinnamomum burmanii	1	1	1	0	0	0	0	0	0	0	0	0	10	10	10	0	0	0	0	0	0	0	0	0
Citrus hystrix	1	4	4	0	0	0	1	0	1	1	0	0	10	30	30	0	0	0	10	0	13	10	0	0
Curcuma longa	63	65	98	42	17	18	11	9	23	23	12	71	70	80	80	90	70	75	40	67	75	60	60	90
Cymbopogon citratus	37	60	67	24	16	6	13	17	17	18	33	45	90	90	90	60	50	50	50	67	88	80	50	60
Cymbopogon flexuosus	0	1	1	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0
Etlingera sp.	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	20	0
Foeniculum vulgare	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	10	0
Kaempferia galanga	0	3	11	2	11	2	1	0	0	0	2	4	0	30	30	20	20	13	10	0	0	0	10	20
Mentha x piperita	5	12	31	5	3	2	6	3	0	0	0	28	20	20	50	10	10	13	10	11	0	0	0	60
Momordica charantia	0	1	0	0	0	16	1	0	0	0	2	5	0	10	0	0	0	63	10	0	0	0	10	30
Ocimum basilicum	77	30	97	74	19	21	6	5	23	23	2	32	80	60	90	90	40	38	20	22	38	30	20	70
Pandanus amaryllifolius	37	39	32	54	45	43	30	41	44	45	73	11	90	70	60	60	50	63	80	78	75	70	60	40
Piper nigrum	4	1	1	0	0	0	2	2	6	6	3	3	10	10	10	0	0	0	10	11	25	20	20	20
Sesamum indicum	0	0	0	0	0	0	490	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Suaeda sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10
Syzygium aromaticum	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	13	10	0	0
Syzygium polyanthum	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Tamarindus indica	0	0	1	0	0	0	0	0	0	0	1	2	0	0	10	0	0	0	0	0	0	0	10	10
Vanilla planifolia	17	50	212	22	20	41	0	0	22	22	47	66	20	30	80	10	20	50	0	0	63	50	20	30
Zingiber officinale	126	61	63	50	19	11	4	9	30	30	16	77	90	60	80	70	50	50	30	44	38	30	50	70
Acorus calamus	8	40	58	1	27	25	0	3	8	8	34	7	20	50	50	10	50	50	0	22	38	30	10	20
Allium ramosum	27	50	44	213	39	42	0	0	0	0	0	10	50	60	60	80	50	38	0	0	0	0	0	50
Aloe barbadensis	0	0	1	0	0	0	0	0	0	0	0	2	0	0	10	0	0	0	0	0	0	0	0	10
Blumea balsamifera	1	3	3	0	3	3	1	0	0	0	0	0	10	10	10	0	10	13	10	0	0	0	0	0
Celosia argentea	0	0	0	1	29	2	0	0	0	0	0	0	0	0	0	10	10	13	0	0	0	0	0	0
Centella asiatica	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10
Clematis smilacifolia	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	10	13	0	0	0	0	0	0
Clerodendron sp.	4	2	5	35	32	49	0	0	0	0	0	0	20	10	10	20	20	25	0	0	0	0	0	0
Cordyline fruticosa	0	0	0	6	9	12	0	0	0	0	0	0	0	0	0	20	20	25	0	0	0	0	0	0
Costus speciosus	4	11	17	0	2	1	0	0	0	0	0	6	10	20	20	0	10	13	0	0	0	0	0	10
Curcuma xanthorrhiza	1	1	6	4	0	3	0	0	2	2	7	23	10	10	30	20	0	13	0	0	13	10	30	40
Cyperus rotundus	0	0	0	0	0	0	15	10	10	10	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Dichrocephala integrifolia	5	12	15	0	0	0	0	0	0	0	0	0	10	10	10	0	0	0	0	0	0	0	0	0
Eleutherine palmifolia	21	30	32	90	139	150	0	0	0	0	0	0	20	20	20	40	40	38	0	0	0	0	0	0
Equisetum debile	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	10

	Number of individuals									Sili.			Frequencies (%)									Sili.		
	Wuasa			Rompo			Sili.			new	Ta.	Wg.	Wuasa			Rompo			Sili.			new	Ta.	Wg.
Species name	01	03	04	01	03	04	01	03	04	04	04	04	01	03	04	01	03	04	01	03	04	04	04	04
Graptophyllum pictum	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20	0
Gynura procumbens	0	1	4	0	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0
Hemigraphis bicolor	0	7	3	0	1	1	0	0	0	0	0	0	0	10	10	0	10	13	0	0	0	0	0	0
Hibiscus acetosella	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20	0
Hippeastrum puniceum	2	1	5	0	0	0	0	0	0	0	0	0	10	10	10	0	0	0	0	0	0	0	0	0
Homalomena cordata	0	0	0	1	2	2	0	0	0	0	0	0	0	0	0	10	20	25	0	0	0	0	0	0
Jatropha curcas	16	28	38	4	9	1	2	5	5	5	1	14	50	60	60	10	40	13	10	33	38	30	10	40
Kalanchoe pinnata	12	38	45	0	1	1	11	10	4	4	11	1	40	50	60	0	10	13	30	33	25	20	40	10
Morinda citrifolia	0	1	1	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0	0
Orthosiphon aristatus	53	41	64	8	32	1	3	6	4	4	0	24	40	60	80	10	20	13	10	44	38	30	0	50
Picria felterrae	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Piper caninum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Plectranthus amboinicus	0	2	4	0	0	0	0	0	0	0	0	7	0	10	20	0	0	0	0	0	0	0	0	30
Premna trichostoma	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0
Ricinus communis	0	0	1	0	0	0	1	0	0	0	0	13	0	0	10	0	0	0	10	0	0	0	0	10
Sansevieria trifasciata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Senna alata	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0
Solenostemon scutellarioides	3	32	32	1	37	2	14	29	20	20	3	15	10	60	60	10	30	13	40	33	38	30	10	20
Strobilanthes crispa	1	1	1	0	0	0	0	0	0	0	0	2	10	10	10	0	0	0	0	0	0	0	0	10
Symphytum officinale	5	2	5	0	0	0	0	0	0	0	2	0	10	10	20	0	0	0	0	0	0	0	20	0
Synadenium grantii	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	20
Talinum paniculatum	0	0	0	0	0	0	0	0	9	9	0	9	0	0	0	0	0	0	0	0	13	10	0	20
Talinum triangulare	6	21	47	1	8	6	0	5	23	23	0	0	10	20	40	10	10	25	0	11	13	10	0	0
Tinospora crispa	0	0	3	0	1	2	4	5	3	3	0	0	0	0	10	0	10	13	10	11	13	10	0	0
Zingiber aromaticum	0	0	0	0	0	0	0	1	4	6	3	0	0	0	0	0	0	0	0	11	25	30	10	0
Zingiber purpureum	4	17	21	7	1	2	5	3	4	8	0	2	10	30	40	50	10	13	30	33	38	50	0	10
Canna edulis	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	10	0
Colocasia esculenta	57	149	322	35	67	57	287	321	352	360	31	75	70	70	70	50	50	50	60	100	100	90	20	60
Dioscorea bulbifera	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	11	0	0	10	0
Ipomoea batatas	123	199	111	209	103	109	430	346	245	259	260	13	90	60	70	90	80	88	90	89	88	90	70	20
Manihot esculenta	427	449	376	157	360	634	2766	993	828	1039	156	144	70	80	80	70	100	88	100	100	100	100	80	80
Maranta arundinacea	0	0	0	0	0	0	0	5	4	4	0	0	0	0	0	0	0	0	0	11	13	10	0	0
Oryza sativa	0	0	0	0	0	0	145	200	105	105	0	250	0	0	0	0	0	0	10	11	13	10	0	10
Xanthosoma sagittifolium	106	157	196	119	219	376	206	182	147	156	413	101	60	90	80	90	100	88	80	100	88	90	90	90
Xanthosoma violaceum	0	14	25	0	1	2	0	1	0	0	15	8	0	30	50	0	10	25	0	11	0	0	20	20
Zea mays	125	41	233	206	35	66	23	8	30	30	0	2	20	20	60	50	30	38	10	11	13	10	0	10
Acalypha caturus	1	3	2	2	2	1	0	0	0	0	2	2	10	20	20	20	20	13	0	0	0	0	10	20
Acalypha marginata	0	0	6	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
Bischofia javanica	2	1	0	3	2	3	0	0	0	0	2	0	20	10	0	10	20	25	0	0	0	0	20	0
Breynia microphylla	0	0	0	0	0	0	1	3	5	5	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Cananga odorata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0
Crescentia cujete	1	3	3	3	4	3	0	0	0	0	0	0	10	10	10	20	20	25	0	0	0	0	0	0
Dendrocalamus sp.	2	3	3	3	3	3	0	0	0	0	0	5	10	20	20	20	20	25	0	0	0	0	0	30
Elmerrillia ovalis	2	1	2	0	0	0	0	0	0	0	0	0	10	10	10	0	0	0	0	0	0	0	0	0
Euonymus javanicus	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Ficus septica	1	1	1	2	4	2	0	0	0	0	1	12	10	10	10	20	20	25	0	0	0	0	10	60
Ficus sp. 1	0	2	1	0	1	5	0	0	0	0	2	1	0	10	10	0	10	38	0	0	0	0	20	10
Ficus sp. 2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Flemingia strobilifera	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	10	13	0	0	0	0	0	0
Globba sp.?	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Glochidion rubrum	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	10	11	13	10	0	0
Glochidion sp.	0	1	1	1	7	2	3	3	3	3	0	1	0	10	10	10	20	25	30	33	25	20	0	10
Gmelina arborea	0	2	4	0	5	5	0	0	0	0	0	0	0	10	10	0	20	25	0	0	0	0	0	0
Grewia laevigata	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	10	0	0	0	0	0	10	0
Hibiscus macrophyllus	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	10	13	0	0	0	0	0	0
Homalanthus populneus	3	1	3	1	3	4	0	0	0	1	23	9	10	10	20	10	20	25	0	0	0	10	60	40
Leucosyke condissima	0	0	0	1	6	3	0	0	0	0	0	0	0	0	0	10	20	38	0	0	0	0	0	0
Litsea sp. 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Litsea sp. 2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Macaranga tanarius	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10
Macaranga triloba	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Melastoma malabathricum	0	0	0	1	4	3	0	0	0	0	0	0	0	0	0	10	20	25	0	0	0	0	0	0
Melochia umbellata	1	0	0	9	7	7	0	0	0	0	0	4	10	0	0	30	40	50	0	0	0	0	0	30
Morus alba	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	30
Nauclea orientalis	2	3	5	0	0	1	0	0	0	0	0	0	20	30	50	0	0	13	0	0	0	0	0	0
Pinus merkusii	1	1	0	4	4	1	0	0	0	0	0	3	10	10	0	30	30	13	0	0	0	0	0	20
Pisonia umbellifera	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0
Platea sp.	1	4	4	0	1	0	0	0	0	0	0	0	10	20	20	0	10	0	0	0	0	0	0	0
Pothomorphe umbellata	0	0	0	0	1	1	0	0	0	0	0	4	0	0	0	0	10	13	0	0	0	0	0	30
Premna serratifolia	0	0	0	1	3	2	0	0	0	0	0	3	0	0	0	10	20	25	0	0	0	0	0	20
Sambucus canadensis	0	3	16	7	0	0	0	0	0	0	43	6	0	10	30	10	0	0	0	0	0	0	80	20

	Number of individuals									Sili.			Frequencies (%)									Sili.		
	Wuasa			Rompo			Sili.			new	Ta.	Wg.	Wuasa			Rompo			Sili.			new	Ta.	Wg.
Species name	01	03	04	01	03	04	01	03	04	04	04	04	01	03	04	01	03	04	01	03	04	04	04	04
Tectona grandis	0	8	7	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	0	0	0	0
Trema orientalis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0
Trema sp.	0	0	0	3	3	1	1	1	1	1	0	0	0	0	0	10	20	13	10	11	13	10	0	0
Wendlandia paniculata	0	0	0	2	3	2	0	0	0	0	0	0	0	0	0	10	10	25	0	0	0	0	0	0
Wendlandia sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10
Erythrina subumbrans	9	10	23	12	8	11	61	39	40	69	94	14	40	50	80	40	30	50	80	78	88	90	90	40
Flemingia macrophylla	0	0	0	0	0	0	0	5	8	8	13	0	0	0	0	0	0	0	0	11	13	10	40	0
Gliricidia sepium	175	154	441	113	126	163	228	130	171	199	392	197	80	90	100	80	100	100	70	78	88	90	100	100
Leucaena leucocephala	0	0	0	0	0	0	2	4	9	21	16	0	0	0	0	0	0	0	20	22	38	40	20	0
Manihot glaziovii	0	0	0	0	0	2	36	23	19	24	0	0	0	0	0	0	0	13	70	67	50	50	0	0
Mucuna pruriens cv. group *utilis*	0	0	0	0	0	0	0	6	1	1	0	0	0	0	0	0	0	0	0	22	13	10	0	0
Paraserianthes falcataria	0	0	0	6	5	3	4	1	1	1	0	0	0	0	0	10	10	13	10	11	13	10	0	0
Tephrosia vogelii	0	0	0	0	0	0	14	40	19	33	0	0	0	0	0	0	0	0	30	33	25	40	0	0
Calamus sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Ceiba pentandra	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	10	10	0
Coix lacryma-jobi	2	1	0	2	39	29	8	13	11	11	63	0	10	10	0	10	20	13	10	33	13	10	30	0
Gossypium barbadense	1	2	2	1	0	1	4	2	1	1	1	1	10	20	20	10	0	13	20	22	13	10	10	10
Heliconia indica	72	82	107	51	43	30	0	4	3	3	0	55	60	60	50	50	50	38	0	11	13	10	0	60
Pennisetum purpureum	0	0	0	0	0	0	18	56	139	159	6	0	0	0	0	0	0	0	20	56	63	70	10	0
Phrynium pubinerve	0	1	1	1	1	0	0	0	0	0	0	0	0	10	10	10	10	0	0	0	0	0	0	0
Stephania corymbosa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10	0

Appendix 14. List and potential use of weed species identified in 50 homegardens in five villages of the Napu valley, Central Sulawesi, in 2004.

No.	Species name	Family	Common name	Indonesian name	Local names Napu/Behoa language	Usage	Medically used plant part
1	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	Alligator weed	Daun rusa/tolod	Palantanga		
2	*Amaranthus lividus* L.	Amaranthaceae	African spinach	Bayam itik/monyet	Tantaimanu	M (livestock), F, V	
3	*Cyathula prostrata* (L.) Blume	Amaranthaceae	Sand spinach	Rumput jarang-jarang	Tomapolo	M, fishing	
4	*Centella asiatica* (L.) Urb.	Apiaceae	Asiatic pennywort	Daun kaki kuda	Kaki kuda	M	
5	*Ageratum conyzoides* L.	Asteraceae	Billy goatweed	Babadotan	Behoa, putih sese	M	Leaves, sap
6	*Bidens pilosa* L.	Asteraceae	Black jack/Spanish needles	Ketul	Karukahi	M, V	Leaves, seeds, sap, young shoot
7	*Crepis japonica* Bth.	Asteraceae		Rumput sawi		V	
8	*Dichrocephala bicolor* (Roth.) Schlecht.	Asteraceae		Wedahan	Panaramanu	M	Leaves, roots
9	*Eclipta prostrata* (L.) L.	Asteraceae	Ink plant	Urang-aring	Nali bula		
10	*Elephantopus scaber* L. var *sinuata* Miq.	Asteraceae	Prickly-leaved elephant's foot	Tapak liman, rumput kelapa	Kaluku	M, F	Roots
11	*Erechtites valerianifolia* (Wolf.) DC.	Asteraceae			Nipo	M, F, V	Leaves
12	*Erigeron sumatrensis* Retz.	Asteraceae			Sulepe	M, F, C, soil improvement	Leaves, roots
13	*Galinsoga parviflora* Cav.	Asteraceae			Hehito basmillan	M (livestock)	Sap
14	*Sigesbeckia orientalis* L.	Asteraceae	Yellow crown-beard		Ranta-ranta	M	
15	*Spilanthes iabadicensis* A.H. Moore	Asteraceae		Karukahi kuning	Nali	M, F	Leaves
16	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	Pig's grass	Bruwan	Kaluku kecil, nali	M, F	Leaves
17	*Drymaria cordata* (L.) Willd. Ex R. & S.	Caryophyllaceae			Sende-sende	M, F	Leaves
18	*Commelina nudiflora* L. (=*C. diffusa*)	Commelinaceae	Creeping dayflower	Rumput kupu-kupu	Lehoka	F, fishing	
19	*Cyperus kyllingia* Endl.	Cyperaceae	Nut sedge	Melaran	Hila	F, talisman	
20	*Cyperus pilosus* Vahl.	Cyperaceae		Rumput pisau		M, F	Roots
21	*Cyperus rotundus* L.	Cyperaceae	Purple nut grass	Rumput teki	Kukuboe	M, F, C, soil improvement	Tubers
22	*Fimbristylis miliacea* (L.) Vahl.	Cyperaceae			Tiu walehu	Weaving baskets/mats	
23	*Scleria purpurascens* Steud.	Cyperaceae			Tatari, hihila	M, F	Seeds
24	*Euphorbia hirta* L.	Euphorbiaceae	Hairy spurge	Daun biji kacang	Pakuli-katuli	M	Leaves, fruits
25	*Phyllanthus urinaria* L.	Euphorbiaceae	Leaf flower	Meniran	Hinuntu	M, magic	Leaves
26	*Dysophylla auricularia* (L.) Blume	Lamiaceae			Ikomeo		
27	*Hyptis brevipes* Poit.	Lamiaceae			Sambuku	M	Leaves, roots
28	*Hyptis rhomboidea* Mart. & Gal.	Lamiaceae			Boa-boa malei/bula, bimbing kalo	M	Leaves, smoke of flowers
29	*Scurula fusca* (Blume) G.Don	Loranthaceae			Benalu	M	
30	*Cuphea balsamona* Cham. & Schlecht.	Lythraceae		Gunung colo			
31	*Sida rhombifolia* L.	Malvaceae	Queensland hemp	Sidaguri		M, broome/toothbrush	Roots
32	*Urena lobata* L.	Malvaceae	Indian mallow	Pulutan sapi	Delupa	M, ropes	
33	*Nephrolepis falcate* (Cav.) C.Hr.	Nephrolepidaceae			Luku/tongko	Grave decoration	
34	*Ludwigia hyssopifolia* (G.Don) Exell. (*Jussiaea linifolia* Vahl.)	Onagraceae	Willow herb	Jukut anggereman, rica tikus		M	Leaves, roots, young fruits
35	*Oxalis corniculata* L.	Oxalidaceae	Indian sorrel	Daun asam kecil	Sende-sende owai	M, fruit, spice	Leaves
36	*Plantago major* L.	Plantaginaceae	Great plantain	Daun sendok		M	
37	*Cyrtococcum acrescens* Stapf	Poaceae			Hirero		
38	*Digitaria sanguinalis* Scop.	Poaceae			Kere-kere	M (livestock), F	
39	*Eleusine indica* (L.) Gaertn.	Poaceae	Dog's tail grass	Rumput belulang	Bisoa, barigi popenga	M, F, decoration	Roots
40	*Eragrostis* sp. 1	Poaceae			Tirangka	F	
41	*Eragrostis* sp. 2	Poaceae			Gawu-gawu	M, F	Roots
42	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Poaceae			Nkundu		
43	*Imperata cylindrica* (L.) Raeuschel	Poaceae	Imperata	Alang-alang		M, F, thatching roofs	Rhizomes, buds
44	*Ischaemum indicum* (Houtt.) Merrill	Poaceae			Luane bose	F	
45	*Oplismenus compositus* (L.) Beauv.	Poaceae			Holedena, palemba	M, F, making traps/snares	Leaves
46	*Paspalum conjugatum* Berg.	Poaceae	Buffalo grass	Rumput kerbau/pahit	Lepa	M, F	Leaves
47	*Paspalum scrobiculatum* L.	Poaceae					
48	*Pennisetum purpureum* Schumach.	Poaceae	Napier grass	Rumput gadjah	Meo	F	
49	*Setaria palmifolia* (Willd.) Stapf	Poaceae			Dinding kelapa		
50	*Sporobolus indicus* (Linn.) R.Br. var. *major* (Buse) Baaijens	Poaceae			Bariri	Decoration	
51	*Polygonum chinense* L.	Polygonaceae			Andeo kokou		
52	*Polygonum perfoliatum* L.	Polygonaceae			Sankada, tankada	M, fruit	Leaves
53	*Polygonum barbatum* L.	Polygoniaceae		Rica kerbau	Mantilala	M	Sap
54	*Portulaca oleracea* L.	Portulacaceae	Purslane	Krokok	Tontoru	M, F, V	Leaves
55	*Borreria laevis* (Lamk.) Griseb.	Rubiaceae	Button weed	Jugul	Katuli	M	Leaves
56	*Borreria ocymoides* (Burm.f.) DC.	Rubiaceae	Button weed	Balungan	Taunkada	F, V	
57	*Hedyotis (=Oldenlandia) corymbosa* (L.) Lamk.	Rubiaceae		Pokok telur belangkas	Panangi	Fishing	
58	*Lindernia cordifolia* Merr. (*L. anagallis*)	Scrophulariaceae			Topendele	M, F, ornamental	Leaves
59	*Sphaerostephanos* sp.	Thelypteridaceae			Poto	C	
60	*Pouzolzia zeylanica* Benn.	Urticaceae	Red eclipta	Daun deresan	Walugai towao	C	

Coloured cells = Species already counted as crop

M=Medicine
F=Fodder
V=Vegetable
C=Cosmetic, hygiene

Appendix 15. Homegarden (HG) sizes, cluster numbers, species richness and individual numbers of crops and ornamentals as well as numbers of named and used weed species occurring in 50 homegardens in five villages of the Napu valley, Central Sulawesi, in 2001, 2003, and 2004.

		HG size*		Clus-	Species				Individual				Crop species per use category (no.)									Ornamentals			Weed species	
	HH	2001	2004	ter	richness (no.)				no.				2004									species no.		Ind. no.	(no.) in 2004	
Village	no.	(m^2)	(m^2)	No.	2001	2003	2004	2004 all	2001	2003	2004	2004 all	Fruit	Veget.	Stimul.	Spice	Medic.	Staple	Wood	MPT	Other	2001	2004	2004	Named	Used
Wuasa	1	519	803		55	60	65	65	997	1,874	1,307	1,307	12	11	4	13	12	6	2	2	3	22	27	808	27	15
Wuasa	2	1,134	1,130		45	53	68	68	492	1,164	690	690	16	8	4	13	11	5	8	2	1	17	44	355	12	6
Wuasa	3	283	310	4	15	16	23	23	33	47	91	91	4	6	1	7	2	0	1	2	0	6	15	51	15	7
Wuasa	4	778	466	3	38	46	47	47	685	557	570	570	9	6	4	12	5	5	5	1	0	41	60	931	15	10
Wuasa	5	670	670	3	33	30	35	35	353	361	467	467	12	9	3	5	0	4	0	2	0	3	13	138	16	9
Wuasa	6	236	280	4	20	33	40	40	190	206	191	191	6	8	4	10	6	2	2	2	0	9	52	461	10	4
Wuasa	7	858	860	3	41	53	52	52	343	288	478	478	9	5	6	10	13	4	2	2	1	15	24	283	6	2
Wuasa	8	547	580	3	26	44	50	50	230	359	545	545	5	9	4	15	9	5	1	2	0	18	23	346	12	2
Wuasa	9	865	860		36	50	51	51	1,136	1,858	3,392	3,392	18	8	5	9	4	5	0	1	1	23	40	476	23	10
Wuasa	10	1,043	1,050	3	43	44	54	54	390	371	465	465	10	8	6	11	6	5	4	2	2	4	11	192	15	10
Rompo	11	1,450	1,440	2	56	68	65	65	498	483	672	672	13	10	5	9	5	4	15	3	1	14	18	104	12	7
Rompo	12	583	585		32	30			421	451												12				
Rompo	13	445	440		36	30			272	139												10			3	3
Rompo	14	1,323	1,330		44	50	60	60	647	599	1,272	1,272	12	15	8	11	4	5	2	2	1	8	9	33	20	18
Rompo	15	534	510	3	32	36	34	34	361	358	341	341	4	6	3	12	3	3	2	1	0	8	19	188	12	4
Rompo	16	358	370	3	34	38	42	42	200	204	302	302	11	10	5	7	3	3	1	1	1	7	11	154	11	4
Rompo	17	287	270	4	21	22	28	28	145	124	260	260	4	9	1	9	0	2	0	2	1	0	5	59	7	5
Rompo	18	381	640	3	33	33	34	34	614	374	522	522	10	8	4	3	4	3	1	1	0	13	12	149	15	6
Rompo	19	1,376	956	1	38	48	47	47	293	405	374	374	8	5	4	3	4	5	14	3	1	1	1	2	29	20
Rompo	20	668	670	3	48	48	49	49	584	590	428	428	10	9	4	9	9	5	2	1	0	12	16	235	29	27
Siliwanga	21	717	710	3	24	30	39	39	2,154	600	654	654	9	8	5	10	2	3	0	2	0	4	7	54	2	2
Siliwanga	22	471	470	2	30	37	40	40	331	450	516	516	8	8	5	6	5	4	0	4	0	12	4	11	2	2
Siliwanga	23	464	2,210	2	19			22	749			296	4	3	2	2	1	4	0	4	2		14	66		
Siliwanga	24	927	930	2	24	30	33	33	454	298	292	292	8	5	3	6	1	4	1	4	1	12	10	94	3	3
Siliwanga	25	585	528	3	25	30	39	39	242	265	519	519	7	8	2	11	3	5	0	2	1	9	22	101	4	4
Siliwanga	26	633	630	2	43	34	35	35	467	174	217	217	10	5	4	5	1	4	1	4	1	7	6	18	3	2
Siliwanga	27	2,383	2,380	2	29	42	44	44	603	617	859	859	9	7	4	7	4	4	2	5	2	14	16	115	3	2
Siliwanga	28	999	990	2	30	36	36	36	957	483	488	488	9	7	4	4	3	5	0	2	2	13	15	93	4	3
Siliwanga	29	2,225	2,420	2	37	40	41	41	1,120	1,011	1,183	1,183	11	6	4	5	5	4	2	3	1	13	13	118	2	2
Siliwanga	30	957	870	2	31	35		30	429	481		306	10	5	2	2	2	3	1	4	1	17	11	50		
Tamadue	31		1,960	4				28				145	9	5	5	3	2	1	2	1	0		27	119	2	2
Tamadue	32		2,280	1				30				429	8	6	2	6	0	2	2	3	1		15	152	3	1
Tamadue	33		1,869	1				25				348	8	3	3	5	1	3	0	2	0		20	158	0	0
Tamadue	34		2,300	1				33				606	9	4	3	6	3	3	2	2	1		17	118	3	0
Tamadue	35		2,310	1				28				484	5	5	4	5	0	4	2	2	1		9	114	2	2
Tamadue	36		815	1				34				179	4	6	5	6	4	4	2	2	1		27	135	3	3
Tamadue	37		720	4				22				170	7	3	3	4	0	1	0	3	1		20	73	0	0
Tamadue	38		2,220	1				50				1,029	12	6	5	9	3	4	6	3	2		17	111	0	0
Tamadue	39		2,350	1				38				532	10	6	5	5	2	3	4	3	0		14	71	0	0
Tamadue	40		2,420	1				42				690	12	3	3	9	3	5	3	4	0		21	114	3	0
Wanga	41		1,280	3				48				498	13	8	3	10	4	4	3	2	1		17	237	18	12
Wanga	42		550	3				48				269	10	10	4	9	6	3	4	1	1		32	299	10	8
Wanga	43		250	4				13				72	4	5	2	1	0	0	0	1	0		11	169	9	13
Wanga	44		648	3				50				435	7	8	3	13	8	5	4	1	1		20	201	10	7
Wanga	45		310	4				25				364	3	3	2	8	2	3	1	2	1		12	83	7	4
Wanga	46		440	4				21				136	4	1	2	4	2	2	4	1	1		11	140	4	3
Wanga	47		430	4				38				150	7	4	5	10	5	4	1	1	1		25	125	4	3
Wanga	48		670	3				54				433	16	10	4	10	3	4	5	2	0		5	14	9	2
Wanga	49		1,440	3				56				457	12	10	4	13	6	2	7	1	1		33	165	19	14
Wanga	50		1,377	4				28				272	8	2	3	5	1	2	5	2	0		2	2	6	3

=Different gardens

*=Without house,
large pond, fallow

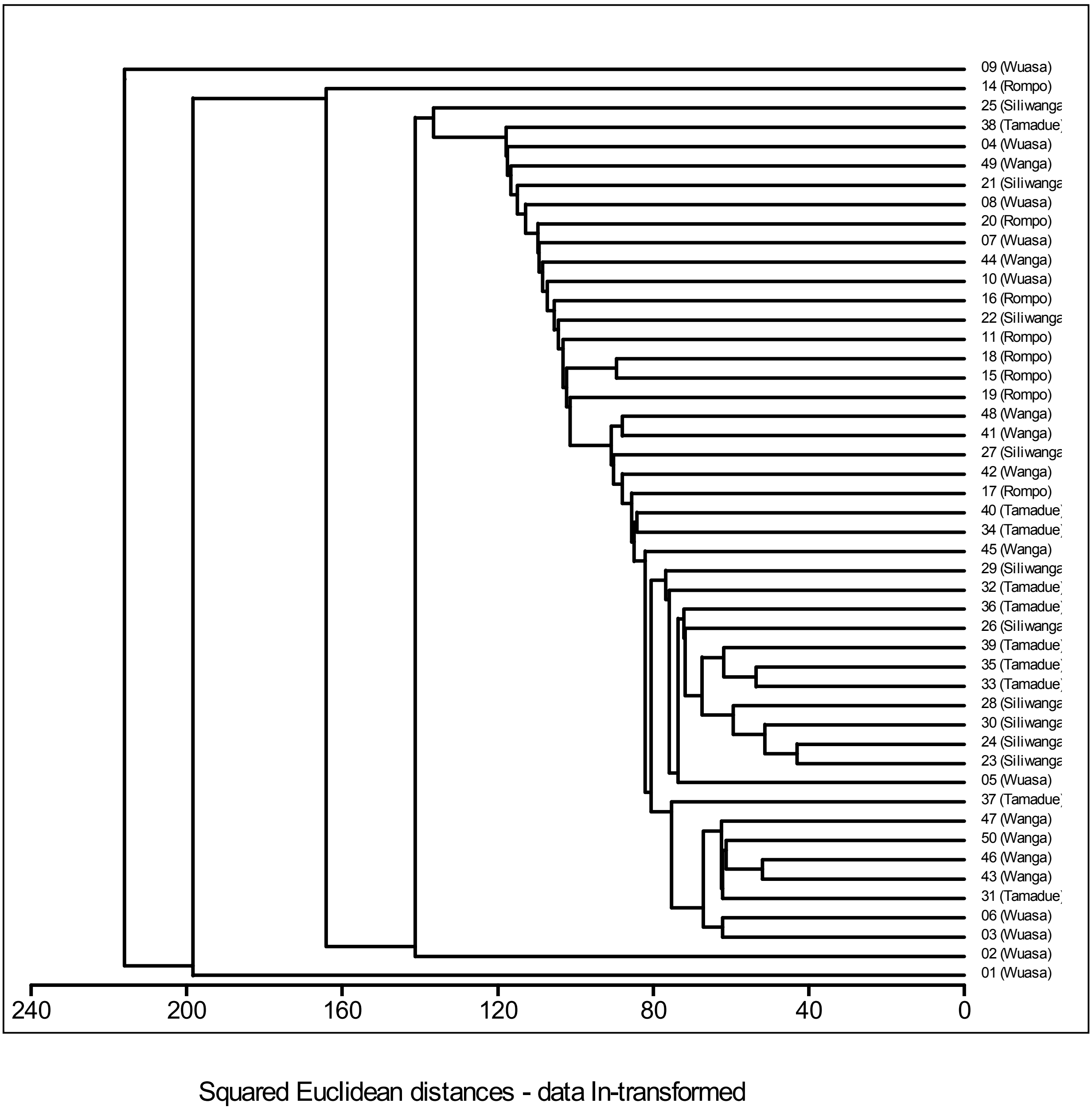
Appendix 16. Homegarden (HG) sizes, cluster numbers, as well as crop diversity and evenness indices of 50 homegardens in five villages of the Napu valley, Central Sulawesi, in 2001, 2003, and 2004.

		HG size*		Clus-	Margalef				Species density				Shannon				Shannon Evenness				Simpson				Hill's N2			
	HH	2001	2004	ter	index				(Arrhenius)(no./1000 m^2)				index				index				index				index			
Village	no.	(m^2)	(m^2)	No.	2001	2003	2004	2004 all	2001	2003	2004	2004 all	2001	2003	2004	2004 all	2001	2003	2004	2004 all	2001	2003	2004	2004 all	2001	2003	2004	2004 all
Wuasa	1	519	803		7.8	7.8	8.9	8.9	60.8	62.0	67.1	67.1	3.14	2.25	3.18	3.18	0.78	0.55	0.76	0.76	0.08	0.29	0.07	0.07	13.3	3.5	14.1	14.1
Wuasa	2	1,134	1,130		7.1	7.4	10.2	10.2	44.2	52.1	66.8	66.8	2.80	2.12	3.45	3.45	0.74	0.53	0.82	0.82	0.10	0.30	0.05	0.05	9.7	3.4	20.4	20.4
Wuasa	3	283	310	4	4.0	3.9	4.9	4.9	18.3	19.3	27.7	27.7	2.48	2.38	2.48	2.48	0.91	0.86	0.79	0.79	0.10	0.13	0.16	0.16	9.8	7.5	6.1	6.1
Wuasa	4	778	466	3	5.7	7.1	7.2	7.2	39.4	51.7	52.8	52.8	2.45	2.22	2.89	2.89	0.67	0.58	0.75	0.75	0.17	0.29	0.10	0.10	6.0	3.5	10.5	10.5
Wuasa	5	670	670	3	5.5	4.9	5.5	5.5	35.0	31.8	37.2	37.2	2.49	2.46	2.53	2.53	0.71	0.72	0.71	0.71	0.14	0.12	0.13	0.13	7.1	8.3	8.0	8.0
Wuasa	6	236	280	4	3.6	6.0	7.4	7.4	25.3	40.4	49.0	49.0	1.57	2.70	2.92	2.92	0.53	0.77	0.79	0.79	0.41	0.13	0.09	0.09	2.4	7.9	11.0	11.0
Wuasa	7	858	860	3	6.9	9.2	8.3	8.3	41.9	54.2	53.2	53.2	3.10	3.59	3.49	3.49	0.84	0.90	0.88	0.88	0.07	0.04	0.04	0.04	14.9	26.3	23.8	23.8
Wuasa	8	547	580	3	4.6	7.3	7.8	7.8	28.5	47.8	54.3	54.3	2.73	3.09	3.07	3.07	0.84	0.82	0.79	0.79	0.09	0.08	0.08	0.08	10.8	13.2	12.8	12.8
Wuasa	9	865	860		5.0	6.5	6.2	6.2	36.8	51.1	52.1	52.1	2.08	1.19	1.46	1.46	0.58	0.30	0.37	0.37	0.24	0.61	0.50	0.50	4.2	1.7	2.0	2.0
Wuasa	10	1,043	1,050	3	7.0	7.3	8.6	8.6	42.7	43.7	53.6	53.6	3.02	3.03	3.01	3.01	0.80	0.80	0.76	0.76	0.08	0.08	0.09	0.09	12.8	13.0	10.9	10.9
Rompo	11	1,450	1,440	2	8.9	10.8	9.8	9.8	53.1	64.6	61.7	61.7	3.02	3.37	2.94	2.94	0.75	0.80	0.71	0.71	0.09	0.06	0.11	0.11	10.9	16.4	9.4	9.4
Rompo	12	583	585		5.1	4.7			34.7	32.5			2.17	2.87		2.87	0.63	0.85		0.85	0.21	0.07		0.07	4.9	14.3		14.3
Rompo	13	445	440		6.2	5.9			40.8	34.0			2.95	2.87		2.87	0.82	0.84		0.84	0.08	0.09		0.09	13.0	11.5		11.5
Rompo	14	1,323	1,330		6.6	7.7	8.3	8.3	42.3	48.0	57.6	57.6	2.88	3.07	2.97	2.97	0.76	0.78	0.73	0.73	0.10	0.08	0.09	0.09	10.4	12.0	11.1	11.1
Rompo	15	534	510	3	5.3	6.0	5.7	5.7	35.2	39.9	37.7	37.7	2.66	2.66	2.90	2.90	0.77	0.74	0.82	0.82	0.12	0.12	0.08	0.08	8.3	8.1	12.8	12.8
Rompo	16	358	370	3	6.2	7.0	7.2	7.2	39.9	44.4	49.0	49.0	2.95	3.18	3.25	3.25	0.84	0.87	0.87	0.87	0.08	0.06	0.05	0.05	12.7	16.7	18.9	18.9
Rompo	17	287	270	4	4.0	4.4	4.9	4.9	25.6	27.1	34.5	34.5	2.49	2.13	2.70	2.70	0.82	0.69	0.81	0.81	0.12	0.20	0.10	0.10	8.4	5.0	10.5	10.5
Rompo	18	381	640	3	5.0	5.4	5.3	5.3	38.3	35.3	36.3	36.3	2.74	2.90	2.37	2.37	0.78	0.83	0.67	0.67	0.10	0.07	0.17	0.17	10.3	13.9	6.0	6.0
Rompo	19	1,376	956	1	6.5	7.8	7.8	7.8	36.3	48.3	47.3	47.3	2.72	3.14	3.02	3.02	0.75	0.81	0.79	0.79	0.12	0.06	0.07	0.07	8.2	16.1	14.1	14.1
Rompo	20	668	670	3	7.4	7.4	7.9	7.9	51.0	50.9	52.0	52.0	3.25	3.11	3.09	3.09	0.84	0.80	0.80	0.80	0.05	0.07	0.07	0.07	18.9	14.9	14.3	14.3
Siliwanga	21	717	710	3	3.0	4.5	5.9	5.9	25.2	31.6	41.0	41.0	1.43	2.14	2.41	2.41	0.45	0.63	0.66	0.66	0.35	0.20	0.15	0.15	2.8	5.1	6.6	6.6
Siliwanga	22	471	470	2	5.0	5.9	6.2	6.2	33.7	41.5	44.9	44.9	2.75	2.62	2.67	2.67	0.81	0.73	0.72	0.72	0.10	0.12	0.11	0.11	10.0	8.3	8.8	8.8
Siliwanga	23	464	2,210	2	2.7			3.7	21.4			19.7	1.32			2.27	0.45			0.74	0.46			0.17	2.2			5.7
Siliwanga	24	927	930	2	3.8	5.1	5.6	5.6	24.3	30.3	33.3	33.3	1.89	2.58	2.89	2.89	0.59	0.76	0.83	0.83	0.22	0.10	0.07	0.07	4.5	9.7	13.7	13.7
Siliwanga	25	585	528	3	4.4	5.2	6.1	6.1	27.1	33.1	43.0	43.0	2.57	2.56	2.94	2.94	0.80	0.75	0.80	0.80	0.11	0.16	0.08	0.08	9.0	6.4	11.9	11.9
Siliwanga	26	633	630	2	6.8	6.4	6.3	6.3	46.0	36.4	37.5	37.5	2.72	3.00	3.04	3.04	0.72	0.85	0.86	0.86	0.11	0.07	0.06	0.06	9.0	14.3	15.4	15.4
Siliwanga	27	2,383	2,380	2	4.4	6.4	6.4	6.4	25.8	37.3	39.1	39.1	2.32	2.97	2.81	2.81	0.69	0.79	0.74	0.74	0.14	0.08	0.09	0.09	7.2	13.2	10.9	10.9
Siliwanga	28	999	990	2	4.2	5.7	5.7	5.7	30.0	36.1	36.1	36.1	2.11	2.50	2.54	2.54	0.62	0.70	0.71	0.71	0.22	0.16	0.15	0.15	4.6	6.1	6.8	6.8
Siliwanga	29	2,225	2,420	2	5.1	5.6	5.7	5.7	33.2	35.5	36.4	36.4	2.00	2.41	2.51	2.51	0.55	0.65	0.68	0.68	0.30	0.15	0.13	0.13	3.4	6.5	7.5	7.5
Siliwanga	30	957	870	2	4.9	5.5		5.1	31.2	35.7		30.6	2.43	2.44		2.51	0.71	0.69		0.74	0.15	0.18		0.15	6.7	5.6		6.8
Tamadue	31		1,960	4				5.4				25.5				2.64				0.79				0.11				8.8
Tamadue	32		2,280	1				4.8				26.8				2.31				0.68				0.18				5.7
Tamadue	33		1,869	1				4.1				22.9				2.10				0.65				0.23				4.3
Tamadue	34		2,300	1				5.0				29.5				2.28				0.65				0.18				5.5
Tamadue	35		2,310	1				4.4				25.0				2.23				0.67				0.20				5.1
Tamadue	36		815	1				6.4				35.0				2.92				0.83				0.08				12.0
Tamadue	37		720	4				4.1				23.1				2.27				0.74				0.16				6.4
Tamadue	38		2,220	1				7.1				44.8				2.52				0.65				0.15				6.7
Tamadue	39		2,350	1				5.9				33.8				2.16				0.60				0.20				4.9
Tamadue	40		2,420	1				6.3				37.2				2.18				0.58				0.23				4.3
Wanga	41		1,280	3				7.6				46.3				3.07				0.79				0.07				13.5
Wanga	42		550	3				8.4				52.5				3.32				0.86				0.05				18.9
Wanga	43		250	4				2.8				16.3				2.11				0.82				0.16				6.2
Wanga	44		648	3				8.1				53.3				3.23				0.83				0.08				13.2
Wanga	45		310	4				4.1				30.1				1.48				0.46				0.48				2.1
Wanga	46		440	4				4.1				23.8				2.04				0.67				0.22				4.5
Wanga	47		430	4				7.4				43.3				3.19				0.88				0.06				17.2
Wanga	48		670	3				8.7				57.3				3.08				0.77				0.08				12.5
Wanga	49		1,440	3				9.0				53.2				3.33				0.83				0.06				17.5
Wanga	50		1,377	4				4.8				26.8				2.42				0.73				0.14				7.1

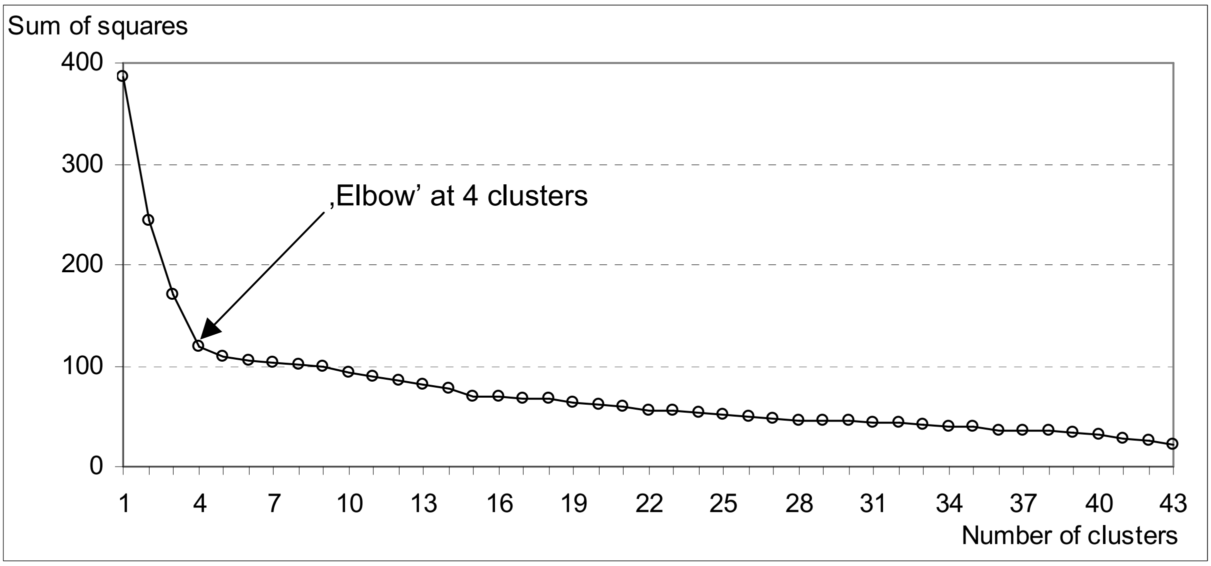
=Different gardens

*=Without house, large pond, fallow

Appendix 17. Dendrogram as result of hierarchical cluster analysis for outlier detection, carried out on the basis of ln-transformed crop species abundance data of 48 homegardens in five villages of the Napu valley, Central Sulawesi, 2004, using 'Nearest neighbour' method and squared Euclidian distances. Homegardens no. 1, 2 (bottom) as well as no. 9 and 14 (top) were identified visually as outliers.



Appendix 18. Graphical detection of the correct number of clusters for the final solution using the 'elbow' criterion. Sum of squares was plotted against the respective number of clusters. A final solution of 4 clusters was suggested because at the right of the 'elbow' the small decrease of the plotted line indicates no further significant increase in dissimilarity among additional clusters.



Appendix 19. Number and percentage of cases correctly classified as result of stepwise discriminant analysis, carried out on the basis of ln-transformed crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004.

Klassifizierungsergebnisse[b,c]

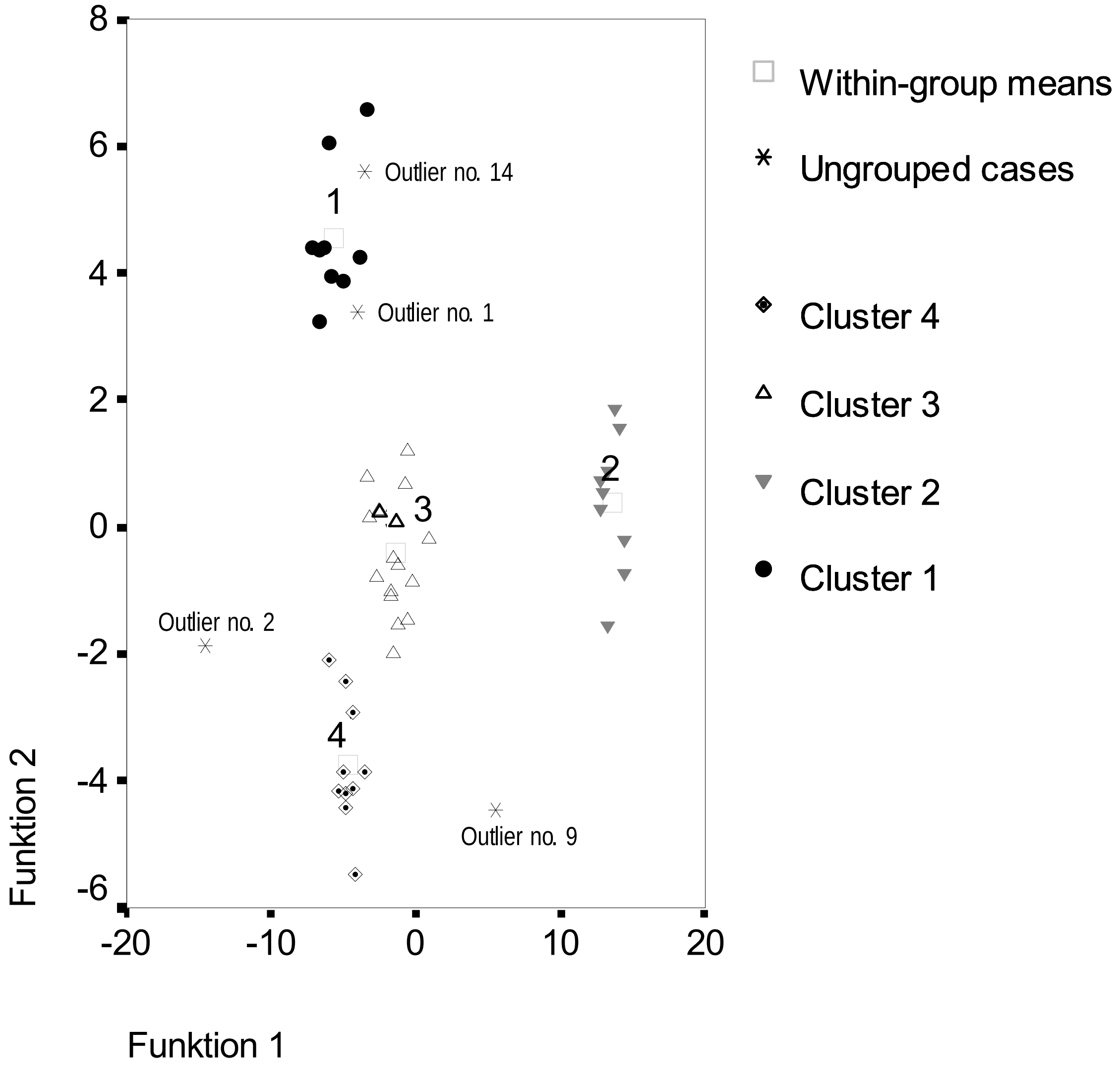
			Vorhergesagte Gruppenzugehörigkeit				
		Cluster-Nr.	1	2	3	4	Gesamt
Original	Anzahl	1	9	0	0	0	9
		2	0	9	0	0	9
		3	0	0	16	0	16
		4	0	0	0	10	10
		Ungruppierte Fälle	2	0	1	1	4
	%	1	100,0	,0	,0	,0	100,0
		2	,0	100,0	,0	,0	100,0
		3	,0	,0	100,0	,0	100,0
		4	,0	,0	,0	100,0	100,0
		Ungruppierte Fälle	50,0	,0	25,0	25,0	100,0
Kreuzvalidiert[a]	Anzahl	1	9	0	0	0	9
		2	0	9	0	0	9
		3	0	0	16	0	16
		4	0	0	0	10	10
	%	1	100,0	,0	,0	,0	100,0
		2	,0	100,0	,0	,0	100,0
		3	,0	,0	100,0	,0	100,0
		4	,0	,0	,0	100,0	100,0

[a] Die Kreuzvalidierung wird nur für Fälle in dieser Analyse vorgenommen. In der Kreuzvalidierung ist jeder Fall durch die Funktionen klassifiziert, die von allen anderen Fällen außer diesem Fall abgeleitet werden.

[b] 100,0% der ursprünglich gruppierten Fälle wurden korrekt klassifiziert.

[c] 100,0% der kreuzvalidierten gruppierten Fälle wurden korrekt klassifiziert.

Appendix 20. Plotted functions of stepwise canonical discriminant analysis, carried out on the basis of ln-transformed crop species abundance data of 44 homegardens in five villages of the Napu valley, Central Sulawesi, 2004.



Appendix 21. Mean quality parameters of top soil (0–15 cm) in 50 homegardens of five villages in the Napu valley, Central Sulawesi, in 2004.

Village	HH no.	Contents (%) of			Bulk density (g/cm3)	pH ($CaCl_2$)	pH (H_2O)	P contents (ppm)		Contents (%) of		C/N ratio	Cation contents (cmol/kg)							CEC $_{eff.}$ (cmol/kg)	BS (%)
		Sand	Silt	Clay				(Olsen)	(Bray I)	N	C		Al	Ca	Fe	K	Mg	Mn	Na		
Wuasa	1	48	28	24	0.80	4.8	5.5	26	78	0.16	1.9	12.1	0.14	7.8	0.01	0.58	1.8	0.34	0.20	10.9	94.0
Wuasa	2	55	29	16	0.95	5.6	5.3	90	305	0.19	2.3	12.2	0.00	9.8	0.00	0.65	2.8	0.14	0.12	13.6	98.8
Wuasa	3	51	35	14	1.01	6.2	6.8	118	333	0.11	1.7	15.0	0.01	12.6	0.00	0.80	2.2	0.03	0.21	15.8	99.7
Wuasa	4	74	11	15	1.00	5.5	6.0	80	300	0.13	1.7	14.1	0.00	6.9	0.00	0.43	2.1	0.10	0.10	9.6	99.0
Wuasa	5	86	8	5	1.15	5.1	5.8	24	91	0.13	1.4	10.7	0.02	3.6	0.00	0.95	0.8	0.11	0.07	5.7	96.0
Wuasa	6	75	10	14	1.11	5.9	6.5	99	440	0.13	1.6	12.3	0.00	7.6	0.00	0.48	1.7	0.02	0.10	9.9	99.8
Wuasa	7	75	10	15	1.09	5.4	6.0	81	223	0.16	1.8	11.6	0.02	7.1	0.00	0.60	1.9	0.10	0.16	9.9	98.3
Wuasa	8	53	27	19	1.05	4.9	5.5	27	73	0.11	1.3	12.1	0.13	6.2	0.00	0.47	1.5	0.10	0.11	8.7	94.7
Wuasa	9	66	13	22	0.98	4.9	5.4	32	138	0.19	2.6	13.8	0.26	6.9	0.00	0.44	1.4	0.06	0.09	9.3	92.4
Wuasa	10	68	14	18	1.08	4.9	5.4	24	338	0.12	1.5	13.1	0.06	5.4	0.00	0.50	1.6	0.20	0.04	8.0	94.7
Rompo	11	45	29	26	0.94	4.5	5.0	11	30	0.12	1.6	12.7	0.82	4.8	0.00	0.36	2.8	0.15	0.11	9.5	85.9
Rompo	12	68	22	10	1.30	5.3	6.0	34	120	0.07	0.9	13.6	0.00	4.5	0.00	0.16	0.9	0.02	0.06	5.8	98.8
Rompo	13	49	27	25	0.97	5.1	5.8	26	73	0.15	1.8	12.5	0.01	8.9	0.00	0.30	2.1	0.11	0.10	11.6	97.9
Rompo	14	42	28	30	0.81	4.9	5.4	44	114	0.26	2.9	11.7	0.15	8.3	0.01	0.59	2.7	0.29	0.09	12.4	94.0
Rompo	15	71	14	15	1.20	4.8	5.7	13	46	0.08	1.1	13.5	0.12	3.6	0.00	0.19	1.3	0.05	0.03	5.5	92.9
Rompo	16	70	16	15	1.13	5.2	5.6	106	247	0.09	1.3	13.6	0.01	6.8	0.00	0.57	1.6	0.11	0.06	9.1	98.0
Rompo	17	31	40	29	0.92	6.1	6.3	74	141	0.22	2.5	11.1	0.00	13.8	0.00	0.84	4.7	0.04	0.14	19.5	99.8
Rompo	18	66	16	18	0.94	5.0	5.4	77	235	0.19	2.5	13.1	0.02	8.2	0.00	0.40	2.0	0.13	0.04	10.8	97.7
Rompo	19	32	37	32	0.83	5.1	5.5	32	75	0.25	3.2	12.7	0.01	11.8	0.00	0.25	5.0	0.60	0.20	18.0	95.7
Rompo	20	32	47	21	0.71	5.4	5.8	51	132	0.22	2.9	12.9	0.01	12.8	0.00	0.63	3.6	0.12	0.13	17.3	98.9
Siliwanga	21	52	29	19	1.02	4.3	4.8	25	75	0.21	3.0	14.3	1.27	2.1	0.10	0.29	0.8	0.00	0.03	4.8	58.4
Siliwanga	22	47	33	20	0.57	4.6	5.6	18	55	0.34	4.7	14.0	0.34	4.5	0.06	0.45	1.3	0.00	0.05	6.9	91.8
Siliwanga	23	67	10	24	0.76	4.0	4.6	12	36	0.21	2.8	13.2	1.88	0.9	0.15	0.11	0.5	0.01	0.02	4.0	39.8
Siliwanga	24	47	38	15	0.96	5.0	5.4	9	80	0.24	3.1	12.7	0.44	4.5	0.05	0.28	2.7	0.00	0.04	8.2	85.8
Siliwanga	25	57	31	12	0.99	4.8	5.6	9	97	0.20	3.0	15.0	0.42	3.2	0.01	0.26	0.7	0.00	0.04	4.7	85.2
Siliwanga	26	58	24	18	1.12	4.8	5.8	5	52	0.16	2.5	15.6	0.32	2.5	0.00	0.21	1.2	0.00	0.00	4.4	88.8
Siliwanga	27	50	36	15	1.05	4.7	5.6	14	45	0.23	2.7	11.6	0.30	2.6	0.01	0.22	1.6	0.00	0.01	4.9	91.2
Siliwanga	28	51	24	25	1.10	5.2	5.7	10	111	0.21	3.0	14.3	0.15	4.5	0.00	0.19	2.0	0.00	0.01	7.0	96.4
Siliwanga	29	43	41	16	1.00	4.5	5.6	7	29	0.22	2.9	13.2	0.53	2.6	0.00	0.12	1.5	0.00	0.00	5.0	84.7
Siliwanga	30	22	32	47	0.95	4.6	5.2	34	188	0.13	2.0	15.4	0.35	2.6	0.00	0.25	1.2	0.18	0.02	4.7	85.3
Tamadue	31	9	53	38	0.57	5.2	5.4	1	52	0.41	4.5	11.0	0.01	17.6	0.00	0.23	6.8	0.59	0.07	25.4	97.5
Tamadue	32	12	58	30	0.63	4.9	5.2	2	32	0.28	3.4	12.1	0.06	14.7	0.00	0.13	7.2	0.83	0.11	23.1	95.6
Tamadue	33	15	58	28	0.55	5.4	5.8	2	34	0.33	4.1	12.4	0.00	17.0	0.00	0.16	9.2	0.30	0.12	26.7	98.9
Tamadue	34	9	46	45	0.59	5.2	5.6	1	26	0.32	3.8	11.9	0.00	20.7	0.00	0.11	8.5	0.50	0.11	29.9	98.3
Tamadue	35	9	46	45	0.54	5.4	5.8	2	32	0.36	4.3	11.9	0.00	21.8	0.00	0.17	9.7	0.61	0.11	32.4	98.1
Tamadue	36	9	53	37	0.52	5.5	6.1	3	65	0.41	4.9	11.9	0.00	20.3	0.00	0.34	11.3	0.63	0.33	32.9	98.1
Tamadue	37	51	28	22	0.96	5.3	5.9	3	58	0.20	2.8	13.6	0.00	13.0	0.00	0.16	4.1	0.37	0.09	17.8	97.9
Tamadue	38	27	43	30	0.67	5.0	5.6	2	44	0.25	3.2	12.5	0.00	12.8	0.00	0.09	5.0	0.19	0.07	18.2	98.7
Tamadue	39	10	45	44	0.47	5.8	6.1	3	55	0.46	5.1	11.2	0.00	29.5	0.00	0.33	7.6	0.38	0.07	37.9	99.0
Tamadue	40	49	24	27	0.63	5.6	5.9	3	50	0.35	3.9	11.3	0.00	23.6	0.00	0.20	5.9	0.21	0.04	30.0	99.3
Wanga	41	42	32	26	0.76	4.9	5.4	1	45	0.38	4.8	12.4	0.04	10.5	0.00	0.20	6.2	0.54	0.06	17.7	96.1
Wanga	42	55	26	19	1.08	5.0	5.6	7	180	0.14	1.8	13.0	0.03	9.7	0.00	0.26	2.9	0.05	0.12	13.1	98.4
Wanga	43	44	34	22	1.03	5.8	6.1	11	345	0.20	2.8	14.0	0.00	11.9	0.00	0.59	2.4	0.01	0.17	15.0	100.0
Wanga	44	51	28	21	0.91	5.0	5.5	7	208	0.19	2.3	12.1	0.04	9.1	0.00	0.39	2.7	0.05	0.14	12.6	98.3
Wanga	45	43	38	19	0.90	5.6	5.8	10	256	0.20	2.4	12.0	0.00	11.5	0.00	0.57	3.2	0.02	0.21	15.5	99.9
Wanga	46	45	33	23	0.97	5.7	6.2	19	300	0.21	2.8	13.0	0.00	13.2	0.00	0.51	2.9	0.01	0.09	16.7	99.9
Wanga	47	37	33	30	0.80	5.3	5.7	17	393	0.25	3.0	12.2	0.00	11.7	0.00	0.78	3.8	0.01	0.02	16.3	99.9
Wanga	48	33	41	26	0.79	5.0	5.6	11	217	0.22	2.7	11.7	0.03	12.7	0.00	0.45	4.1	0.03	0.05	17.4	98.9
Wanga	49	44	32	24	0.78	5.2	5.7	17	309	0.26	3.1	11.9	0.00	12.0	0.00	0.60	3.6	0.05	0.04	16.3	99.5
Wanga	50	40	37	23	0.70	5.0	5.4	9	203	0.27	3.2	12.0	0.06	9.8	0.00	0.51	3.7	0.13	0.02	14.3	97.8

Appendix 22. Quality parameters of top soil (0–15 cm) of vegetable (= Veg.) and cacao/coffee zones (= CC) in 50 homegardens of five villages in the Napu valley, Central Sulawesi, in 2004.

		Contents (%) of						pH				P contents (ppm)				Contents (%) of						Cation content (cmol/kg)				CEC eff.		BS		Fertiliser	
	HH	Sand		Silt		Clay		(CaCl$_2$)		(H$_2$O)		Olsen		Bray I		N		C		C/N ratio		Ca		K		(cmol/kg)		(%)			
Village	no.	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC	Veg.	CC
Wuasa	1	67.0	39.6	19.8	36.8	13.2	23.6	5.3	5.0	6.1	5.7	17	22	66	57	0.09	0.17	1.15	2.01	12.8	12.0	7.3	10.7	0.32	0.38	8.8	13.8	99.7	96.5	5	0
Wuasa	2	58.9	52.7	25.9	30.9	15.2	16.4	5.0	5.7	5.6	5.2	38	93	171	309	0.12	0.20	1.52	2.37	12.4	12.1	7.5	10.1	0.33	0.59	9.6	13.9	98.0	98.9	6	2
Wuasa	3	50.9		35.1		13.9		6.2		6.8		118		333		0.11		1.70		15.0		12.6		0.80		15.8		99.7		1;5	n.a.
Wuasa	4	65.1	67.8	16.0	14.7	18.9	17.5	5.7	5.3	6.1	5.8	13	148	343	512	0.19	0.21	2.59	2.66	13.7	12.8	11.0	8.6	0.55	0.82	13.8	13.9	99.6	98.5	6	0
Wuasa	5		86.3		8.4		5.2		5.1		5.8		24		91		0.13		1.43		10.7		3.6		0.95		5.7		96.0	n.a.	0
Wuasa	6	75.5		10.2		14.4		5.9		6.5		99		440		0.13		1.58		12.3		7.6		0.48		9.9		99.8		6;5	n.a.
Wuasa	7	78.9	74.6	9.4	9.4	11.8	16.1	6.0	5.1	6.7	5.8	80	65	275	164	0.06	0.17	0.93	1.70	15.6	9.9	5.8	7.1	0.39	0.40	7.5	9.4	99.6	97.7	5	0
Wuasa	8	61.8	47.2	20.3	32.7	18.0	20.2	4.6	5.1	5.4	5.6	10	40	24	109	0.09	0.13	1.03	1.53	11.9	12.2	5.3	6.8	0.15	0.70	6.8	10.1	91.8	96.8	0	0
Wuasa	9	68.5	63.7	7.3	16.4	24.3	19.9	4.3	5.3	4.8	5.8	13	44	66	184	0.18	0.20	2.18	2.95	12.5	14.6	3.2	9.5	0.29	0.53	5.6	11.8	80.3	99.5	6	5
Wuasa	10	76.4	67.4	14.6	13.8	9.1	18.9	6.4	4.9	6.9	5.4	92	21	463	333	0.10	0.12	1.50	1.52	14.4	13.0	7.0	5.4	0.79	0.49	9.1	7.9	100.0	94.4	5	6
Rompo	11		66.8		19.3		13.9		4.9		5.4		29		75		0.13		1.64		12.3		5.2		0.23		7.1		95.4	n.a.	0
Rompo	12	67.8		22.1		10.1		5.3		6.0		34		120		0.07		0.92		13.6		4.5		0.16		5.8		98.8		n.a.	n.a.
Rompo	13		48.6		26.9		24.5		5.1		5.8		26		73		0.15		1.84		12.5		8.9		0.30		11.6		97.9	n.a.	0
Rompo	14[#]	31.5	44.2	42.3	24.7	26.2	31.1	6.2	4.7	6.5	5.2	110	31	223	93	0.18	0.27	2.29	3.06	12.8	11.5	14.5	7.1	0.78	0.56	18.5	11.2	99.6	92.9	5	0
Rompo	15	71.2		14.2		14.6		4.8		5.7		13		46		0.08		1.10		13.5		3.6		0.19		5.5		92.9		5	n.a.
Rompo	16	70.4	69.4	16.1	15.5	13.5	15.2	6.0	5.0	6.3	5.5	90	110	258	244	0.07	0.10	0.93	1.40	12.6	13.9	7.5	6.6	0.53	0.58	9.2	9.1	100.0	97.6	0	0
Rompo	17	31.3		39.6		29.1		6.1		6.3		74		141		0.22		2.47		11.1		13.8		0.84		19.5		99.8		5	n.a.
Rompo	18	71.8	64.7	12.4	17.0	15.8	18.3	4.8	5.1	5.4	5.4	20	86	57	262	0.14	0.20	1.55	2.64	11.2	13.4	5.0	8.6	0.13	0.44	6.3	11.5	96.0	97.9	0	0
Rompo	19		31.6		36.6		31.8		5.1		5.5		32		75		0.25		3.21		12.7		11.8		0.25		18.0		95.7	n.a.	1;6
Rompo	20	49.9	28.5	35.3	48.9	14.8	22.7	5.6	5.5	5.9	5.8	44	40	85	100	0.08	0.21	1.09	2.41	13.3	11.6	6.8	10.0	0.25	0.62	9.5	14.6	97.2	98.4	6;5	7
Siliwanga	21	51.6	55.4	28.9	29.2	19.5	15.4	4.1	5.2	4.7	5.7	27	15	56	169	0.21	0.23	2.96	3.42	14.1	15.2	1.3	5.8	0.15	0.97	3.9	9.0	49.9	99.5	0?	5;6
Siliwanga	22															*															
Siliwanga	23															*															
Siliwanga	24	37.1	49.3	38.9	38.3	24.1	12.4	5.9	4.7	6.2	5.2	12	8	160	57	0.25	0.24	3.44	2.95	13.9	12.4	11.8	2.4	0.69	0.16	21.1	4.5	100.0	81.7	5	3;5;6
Siliwanga	25	55.6		24.4		20.0		6.2		6.4		15		31		0.16		2.43		15.3		10.3		0.42		12.0		100.0		1;5	n.a.
Siliwanga	26		57.8		24.5		17.8		4.8		5.8		5		52		0.16		2.49		15.6		2.5		0.21		4.4		88.8	n.a.	5;6?
Siliwanga	27		51.1		31.8		17.1		4.6		5.9		22		92		0.15		2.32		15.3		2.7		0.26		4.6		87.4	n.a.	5
Siliwanga	28		51.3		23.9		24.9		5.2		5.7		10		111		0.21		3.00		14.3		4.5		0.19		7.0		96.4	n.a.	1?;5
Siliwanga	29		41.3		45.1		13.7		4.8		5.6		17		63		0.18		2.83		15.4		4.1		0.48		7.2		95.9	n.a.	5;6
Siliwanga	30		21.7		31.8		46.5		4.6		5.2		34		188		0.13		2.04		15.4		2.6		0.25		4.7		85.3	n.a.	2;5
Tamadue	31		9.2		52.8		38.0		5.2		5.4		1		52		0.41		4.50		11.0		17.6		0.23		25.4		97.5	n.a.	6
Tamadue	32		12.1		57.9		30.0		4.8		5.0		2		32		0.29		3.40		11.8		14.5		0.13		22.7		94.9	n.a.	2;3
Tamadue	33		14.6		57.7		27.7		5.4		5.8		2		34		0.33		4.10		12.4		17.0		0.16		26.7		98.9	n.a.	1;6?
Tamadue	34		9.2		45.9		45.0		5.2		5.6		1		26		0.32		3.80		11.9		20.7		0.11		29.9		98.3	n.a.	1;5?
Tamadue	35		9.2		45.9		45.0		5.4		5.8		2		32		0.36		4.30		11.9		21.8		0.17		32.4		98.1	n.a.	0
Tamadue	36		9.4		53.2		37.5		5.5		6.1		3		65		0.41		4.90		11.9		20.3		0.34		32.9		98.1	n.a.	6;7
Tamadue	37	50.5		27.8		21.7		5.3		5.9		3		58		0.20		2.80		13.6		13.0		0.16		17.8		97.9		6?	n.a.
Tamadue	38		26.9		42.9		30.2		5.0		5.6		2		44		0.25		3.20		12.5		12.8		0.09		18.2		98.7	n.a.	1;5?
Tamadue	39		10.4		45.2		44.5		5.8		6.1		3		55		0.46		5.10		11.2		29.5		0.33		37.9		99.0	n.a.	1;5;6
Tamadue	40		14.0		48.6		37.5		5.5		6.0		3		64		0.33		3.40		10.5		22.6		0.20		28.3		98.9	n.a.	1;5;7?
Wanga	41		28.7		33.1		38.2		4.9		5.5		1		27		0.37		4.70		13.0		11.2		0.23		19.3		96.7	5	0
Wanga	42	55.2		26.0		18.9		5.0		5.6		7		180		0.14		1.80		13.0		9.7		0.26		13.1		98.4		8;5	n.a.
Wanga	43		43.8		34.5		21.8		5.8		6.1		11		345		0.20		2.80		14.0		11.9		0.59		15.0		100.0	n.a.	0
Wanga	44	48.9	51.6	30.6	27.5	20.5	20.9	5.0	5.0	5.9	5.5	8	7	240	203	0.18	0.19	2.30	2.30	13.0	12.0	10.9	8.9	0.40	0.39	14.2	12.4	99.7	98.1	1;5	0
Wanga	45	42.9		38.0		19.1		5.6		5.8		10		256		0.20		2.40		12.0		11.5		0.57		15.5		99.9		5	n.a.
Wanga	46	44.7		32.6		22.7		5.7		6.2		19		300		0.21		2.80		13.0		13.2		0.51		16.7		99.9		5	n.a.
Wanga	47	55.7	35.1	26.5	33.2	17.8	31.6	5.7	5.2	6.4	5.7	26	16	373	395	0.30	0.24	4.30	2.90	14.0	12.0	19.9	10.9	0.94	0.76	25.1	15.4	100.0	99.9	5	5?
Wanga	48	27.2	35.4	44.6	39.7	28.1	24.9	4.7	5.2	5.3	5.7	11	11	287	191	0.18	0.24	2.00	2.90	11.0	12.0	8.8	14.1	0.28	0.51	12.1	19.4	96.8	99.6	6;5	0
Wanga	49	54.8	43.0	20.3	33.1	24.9	23.8	5.2	5.2	5.6	5.7	7	18	127	328	0.24	0.26	2.60	3.10	11.0	12.0	9.3	12.2	0.55	0.61	14.2	16.5	98.6	99.6	6	0
Wanga	50		40.3		36.5		23.2		5.0		5.4		9		203		0.27		3.20		12.0		9.8		0.51		14.3		97.8	n.a.	0

* = Only fruit tree and/or fallow zones

[#] = Fruit tree zone, mixed with young cacao trees instead of cacao/coffee zone

0=no fertiliser
1=Industrial fertiliser
2=N fertiliser
3=P fertiliser
4=K fertiliser
5=Ash
6=Farm yard manure
7=Mulch
8=Rice husks
?=Respond. not sure

Appendix 23. Medians (ranges in brackets) of different quality parameters of top soil in cacao/coffee production zones of 38 homegardens in five villages of the Napu valley, Central Sulawesi, 2004. N = 8 in Wuasa; N = 7 each in Rompo, Wanga, and Siliwanga; N = 9 in Tamadue.

	N content (%)		C content (%)		C/N ratio	
Wuasa	0.17b	(0.12–0.21)	1.86b	(1.43–2.95)	12.2ab	(9.9–14.6)
Rompo	0.20b	(0.10–0.27)	2.41b	(1.40–3.21)	12.5ab	(11.5–13.9)
Wanga	0.24ab	(0.19–0.37)	2.90ab	(2.30–4.70)	12.0ab	(12.0–14.0)
Siliwanga	0.18b	(0.13–0.24)	2.83ab	(2.04–3.42)	15.3a	(12.4–15.6)
Tamadue	0.33a	(0.25–0.46)	4.10a	(3.20–5.10)	11.9b	(10.5–12.5)

Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

	pH (H_2O)		pH ($CaCl_2$)		P-Olsen (ppm)		P-Bray (ppm)	
Wuasa	5.8a	(5.2–5.8)	5.1ab	(4.9–5.7)	42a	(21–148)	174a	(57–512)
Rompo	5.5a	(5.2–5.8)	5.1ab	(4.7–5.5)	32a	(26–110)	93ab	(73–262)
Wanga	5.7a	(5.4–6.1)	5.2ab	(4.9–5.8)	11ab	(1–18)	203a	(27–395)
Siliwanga	5.7a	(5.2–5.9)	4.8b	(4.6–5.2)	15ab	(5–34)	92ab	(52–188)
Tamadue	5.8a	(5.0–6.1)	5.4a	(4.8–5.8)	2b	(1–3)	44b	(26–65)

Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

	CEC $_{\text{eff.}}$ (cmol/kg)		Exchangeable K (cmol/kg)		Exchangeable Ca (cmol/kg)		Base saturation (%)	
Wuasa	11.0b	(5.7–13.9)	0.56a	(0.38–0.95)	7.8b	(3.6–10.7)	97.3ab	(94.4–99.5)
Rompo	11.5b	(7.1–18.0)	0.44ab	(0.23–0.62)	8.7b	(5.2–11.8)	97.6ab	(92.9–98.4)
Wanga	15.4ab	(12.4–19.4)	0.51a	(0.23–0.76)	11.3ab	(8.9–14.1)	99.6a	(96.7–100)
Siliwanga	4.7b	(4.4–9.0)	0.25ab	(0.16–0.97)	2.7b	(2.4–5.8)	88.8b	(81.7–99.5)
Tamadue	28.3a	(18.2–37.9)	0.17b	(0.09–0.34)	20.3a	(12.8–29.5)	98.3ab	(94.9–99.0)

Medians in a column followed by different letters are significantly different at $P \leq 0.05$.

Appendix 24. Rating of changes in soil fertility by gardeners and analysed quality parameters of top soil (0–15 cm) in 26 homegardens of three villages in the Napu valley, Central Sulawesi, in 2001 and 2004.

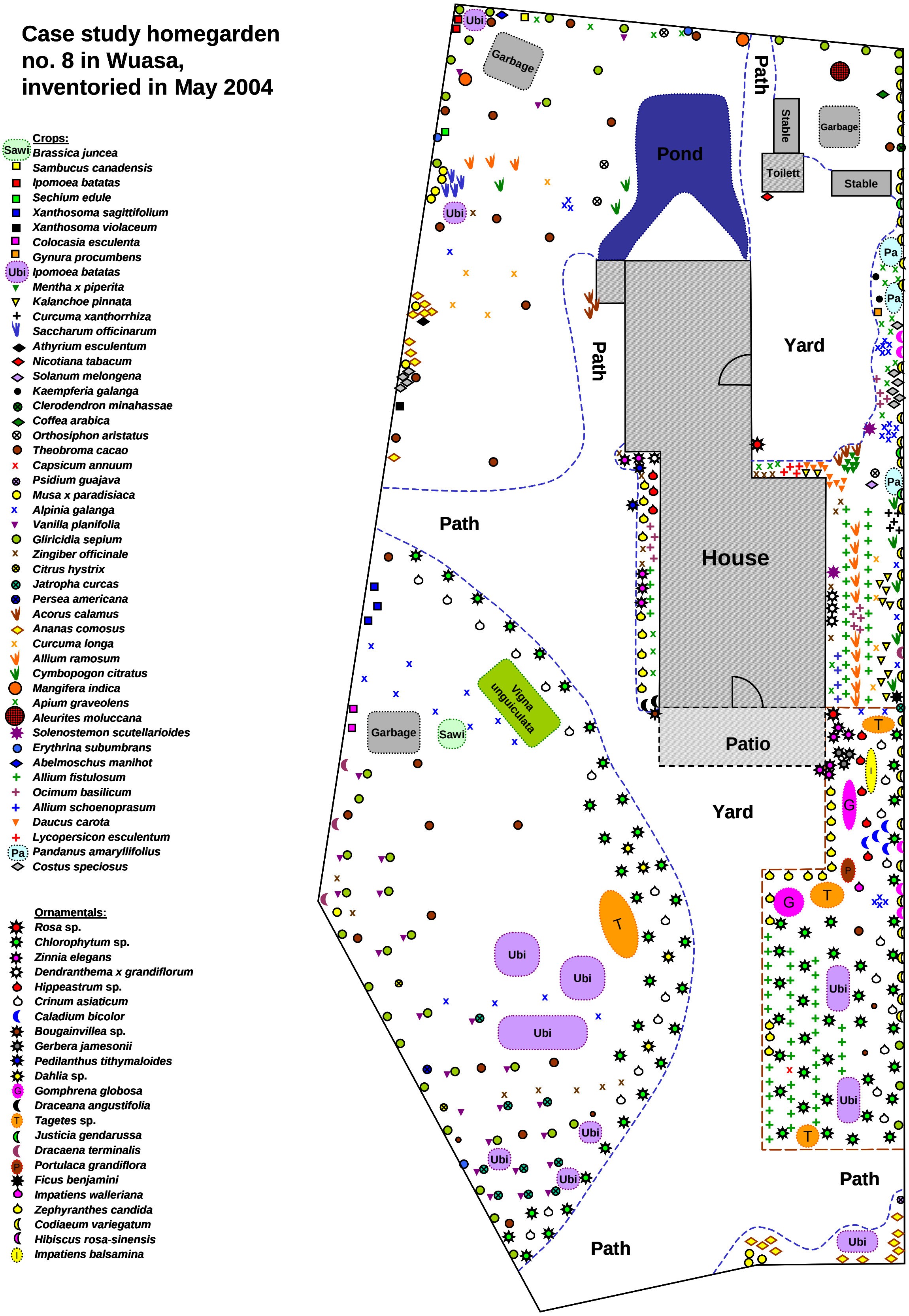
	HH	Rating of soil fertility	N content (%)		C content (%)		pH (H_2O)		P-Olsen contents (ppm)		Sand content (%)		Silt content (%)		Clay content (%)	
Village	no.	changes by gardeners	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004	2001	2004
Wuasa	1	1	0.18	0.16	1.96	1.88	5.4	5.5	40	26	47	48	37	28	16	24
Wuasa	2	1	0.19	0.19	2.23	2.33	5.5	5.3	68	90	57	55	31	29	12	16
Wuasa	3	1	0.13	0.11	1.93	1.70	6.5	6.8	96	118	52	51	36	35	13	14
Wuasa	4	1	0.18	0.13	2.19	1.73	6.3	6.0	83	80	69	74	20	11	11	15
Wuasa	5	1	0.11	0.13	1.27	1.43	6.3	5.8	36	24	87	86	8	8	5	5
Wuasa	6	1	0.13	0.13	1.69	1.58	6.4	6.5	81	99	70	75	25	10	6	14
Wuasa	7	3	0.16	0.16	2.15	1.79	6.4	6.0	84	81	68	75	20	10	12	15
Wuasa	8	3	0.17	0.11	2.03	1.32	5.8	5.5	54	27	53	53	30	27	18	19
Wuasa	9	1	0.15	0.19	2.05	2.65	5.3	5.4	34	32	69	66	17	13	14	22
Wuasa	10	1	0.14	0.12	1.64	1.52	5.5	5.4	73	24	72	68	17	14	12	18
Rompo	11	1	0.19	0.12	2.19	1.50	4.7	4.9	8	5	38	37	34	33	28	31
Rompo	13	2	0.16	0.15	1.84	1.84	5.4	5.8	29	26	48	49	34	27	19	25
Rompo	14	1	0.25	0.27	3.02	3.06	5.5	5.2	51	31	52	44	31	25	18	31
Rompo	15	2	0.15	0.08	1.70	1.10	5.2	5.7	21	13	64	71	22	14	15	15
Rompo	16	1	0.13	0.09	1.63	1.31	5.6	5.6	77	106	66	70	20	16	14	15
Rompo	18	2	0.22	0.20	2.80	2.64	5.8	5.4	65	86	67	65	21	17	12	18
Rompo	19	2	0.29	0.25	3.35	3.21	5.3	5.5	25	32	33	32	38	37	30	32
Rompo	20	1	0.21	0.22	2.47	2.87	5.3	5.8	40	51	43	32	41	47	16	21
Siliwanga	21	3	0.29	0.21	3.70	3.04	4.5	4.8	13	25	49	52	35	29	16	19
Siliwanga	22	3	0.35	0.34	4.48	4.67	4.9	5.6	16	18	48	47	32	33	20	20
Siliwanga	24	2	0.25	0.24	3.05	3.06	5.0	5.4	20	9	45	47	38	38	18	15
Siliwanga	25	3	0.20	0.20	2.62	3.00	5.0	5.6	13	9	53	57	30	31	17	12
Siliwanga	26	3	0.18	0.16	2.62	2.49	6.5	5.8	19	5	56	58	30	24	13	18
Siliwanga	27	3	0.23	0.23	3.04	2.66	4.9	5.6	13	14	50	50	36	36	14	15
Siliwanga	28	3	0.27	0.21	3.58	3.00	6.3	5.7	21	10	55	51	29	24	17	25
Siliwanga	29	3	0.28	0.22	3.09	2.90	5.3	5.6	11	6	42	43	40	41	19	17

1=Deterioration
2=No changes
3=Improvement

Appendix 25. Dry weights as well as dry matter and nutrient contents of cacao leaves sampled in 40 homegardens of five villages in the Napu valley, Central Sulawesi, 2004.

	HH	Dry weight	Dry matter	Contents (%) of			Contents (ppm) of				
Village	no.	(g)	content (%)	N	C	C/N ratio	P	K	Mg	Fe	Ca
Wuasa	1	16.7	39.8	1.87	50.06	26.73	2505	14,200	4690	54	10,650
Wuasa	2	19.3	36.1	1.94	48.26	24.88	2390	13,150	4635	40	11,050
Wuasa	4	11.9	39.7	1.62	43.64	27.01	2340	11,600	5350	40	19,100
Wuasa	5	13.3	41.2	1.71	45.03	26.32	1970	10,350	5800	98	15,850
Wuasa	6	15.4	43.0	1.41	44.71	31.74	1640	6,850	7550	133	20,100
Wuasa	7	17.4	43.0	1.43	45.52	31.81	1625	9,550	6200	76	16,550
Wuasa	8	12.8	42.2	1.45	45.75	31.49	1460	10,200	5500	74	15,900
Wuasa	9	16.4	39.9	1.79	47.82	26.77	2515	11,850	6100	31	18,150
Wuasa	10	15.6	42.4	1.56	41.92	26.87	1945	9,600	6000	125	20,550
Rompo	11	13.5	37.8	1.55	45.24	29.13	1700	9,600	5650	36	18,850
Rompo	13	13.9	39.2	1.47	42.45	28.80	1905	6,700	7400	108	15,700
Rompo	14	17.7	34.4	1.73	48.62	28.10	2430	11,700	5000	30	9,150
Rompo	15	14.7	38.9	1.66	43.47	26.26	1660	8,850	5750	237	12,900
Rompo	16	12.9	35.3	1.87	47.70	25.54	2250	13,250	4490	47	14,900
Rompo	18	13.8	36.8	1.65	45.65	27.64	1655	10,950	5950	49	18,450
Rompo	19	18.1	34.2	1.60	48.93	30.63	1995	10,700	5150	139	10,750
Rompo	20	14.6	35.4	1.92	44.59	23.25	2295	13,350	5150	72	14,750
Siliwanga	21	10.3	41.0	1.54	51.02	33.06	2795	18,250	4815	60	8,800
Siliwanga	22	14.1	42.0	1.43	48.68	33.98	2640	12,900	5900	98	13,800
Siliwanga	23	13.4	42.7	1.45	43.74	30.14	1510	7,700	6050	67	9,450
Siliwanga	26	9.2	39.8	1.49	46.98	31.50	2135	15,550	5950	63	9,000
Siliwanga	27	11.2	35.6	1.92	49.17	25.55	2710	17,700	4440	140	7,800
Siliwanga	28	13.1	41.5	1.55	46.11	29.79	1705	10,800	7450	41	14,500
Siliwanga	29	13.4	47.7	1.37	42.16	30.68	1330	8,700	8550	78	17,050
Siliwanga	30	9.8	37.5	1.97	47.25	23.96	2255	12,950	5550	65	12,050
Tamadue	31	11.8	41.1	1.82	43.00	23.69	1710	9,200	5750	156	17,950
Tamadue	32	12.3	44.4	2.43	45.57	18.74	2360	4,235	7900	42	12,500
Tamadue	33	15.0	42.7	1.32	42.60	32.26	1745	7,500	6700	52	15,800
Tamadue	34	12.2	39.9	1.56	45.46	29.18	2680	6,450	8050	100	14,550
Tamadue	35	15.0	39.1	1.42	47.20	33.32	2210	6,450	6250	393	13,100
Tamadue	36	10.8	40.4	1.32	42.44	32.23	2635	10,000	6100	60	14,150
Tamadue	38	13.4	41.1	1.64	46.02	28.06	2200	5,150	7700	79	15,650
Tamadue	39	13.1	39.0	1.64	48.87	29.80	1825	11,000	4105	26	10,350
Tamadue	40	16.7	40.0	1.72	47.69	27.71	2320	11,800	5400	38	11,100
Wanga	41	12.0	42.3	1.57	44.00	28.09	1475	6,050	7900	44	18,000
Wanga	44	13.3	41.2	1.54	43.64	28.29	1960	9,850	5650	43	16,350
Wanga	47	11.9	37.4	1.75	48.32	27.56	2080	11,650	6150	63	14,900
Wanga	48	15.7	37.4	1.32	46.60	35.44	3360	16,750	4265	66	12,000
Wanga	49	12.5	38.7	1.45	49.93	34.55	1600	14,550	4390	31	23,350
Wanga	50	15.4	39.3	1.56	47.46	30.45	1600	13,850	6400	41	19,400

Appendix 26. Sketch of the homegarden no. 8 in Wuasa, Napu valley, Central Sulawesi, 2004.



10 Curriculum Vitae

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