Chapter 8
Low Carbon Society Through *Pekarangan*, Traditional Agroforestry Practices in Java, Indonesia

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Abstract *Pekarangan*, as a traditional homestead garden, an optimal and sustainable land-use type of agroforestry system in the tropical region of Indonesia, has been researched since 1996. As greenery open space, which is located in the surroundings of a house or residential building, it has spread from rural to urban areas, from the upper to the downstream reaches of watersheds. The area of *pekarangan* varies with the owners and depends on the socioeconomic level, profession, and their distance from the city. However, sustainable and abundant bioresources are expected to be available. Through local wisdom and local knowledge of the community, *pekarangan* have been practiced as agro-forestry, agro-silvo-pastura, and agro-silvo-fishery systems. Agricultural biodiversity and sustainable material circulation are maintained in *pekarangan. Pekarangan* is potential land for ecosystem services, such as carbon sequestration, water resource management, agrobiodiversity conservation, and landscape beautification. Multistory levels of vegetation structures and species richness of *pekarangan* not only can be proposed to mitigate global warming and global climate change impacts, but also can be promoted as supporting agricultural land for food security at the household level. The number of species in a *pekarangan* varies according to local physical circumstances, ecological characteristics of the plants, kinds of animal species, and socioeconomic and cultural factors. Results showed that the size of the open space area of *pekarangan* has decreased, and the number of species has also become less, during the 10-year period of research. If *pekarangan* systems and other smallholder tree-based systems were to expand in currently degraded and

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underutilized lands, such as Imperata grasslands, the C sequestration potential would be about 80 Mg C ha^{-1}. On the other hand, *pekarangan* as an agroforestry system contributes significantly to a region's carbon budget while simultaneously enhancing the livelihoods of the rural community.

Keywords Agrobiodiversity • Agro-silvo-fishery • Agro-silvo-pastura • Species richness • Watershed

8.1 Introduction

The global crisis has been affecting Indonesia in all aspects, such as a social crisis, political crisis, and economic crisis, as well as the environmental and ecological crisis. Those impacts have already touched most of Indonesian communities from the rural to the urban areas. To increase the ecological-social-cultural-economic welfare of the rural community in Indonesia, urgent action is needed to develop environmental conservation through traditional or complex agroforestry practices; thus, community welfare can be gained by eco-village implementation, which is balanced among the ecological, socioeconomic, and spiritual values of the community (Arifin and Arifin 2010). In the micro-level of landscape, *pekarangan*, a piece of land surrounding the house, is potential land for ex situ agrobiodiversity conservation through agroforestry, agro-silvo-fishery, and agro-silvo-pastura system practices.

As greenery open space, *pekarangan* has permanent vegetation. Therefore, ecologically the *pekarangan* is supposed to sequestrate carbon dioxide (CO_2) from the air to be stocked in tree leaves, branches, trunks, roots, and soils. *Pekarangan* has a role not only in carbon (C) sequestration, but also in water resources management, agrobiodiversity conservation, and landscape beautification as part of the scheme of the payment for environmental services (PES) (Kaswanto and Nakagoshi 2012). The PES scheme is being proposed and tested in different contexts as a way to involve the local people in conservation practice (Nurhariyanto et al. 2010). Furthermore, the low carbon society (LCS) can be achieved through *pekarangan*, the traditional agroforestry practices in Java, Indonesia

The *Pekarangan* area was studied mostly in Java island because of the 5,132,000 ha of *pekarangan* in Indonesia, 1,736,000 ha are on Java (Prosterman and Mitchell 2002) (citing 2000 Statistical Yearbook of Indonesia, Table 5.1.1.). As in the distribution of croplands, the distribution of *pekarangan* is very unequal. Thus, for Indonesia as a whole, 40.28 % of households have less than 100 m^2 of *pekarangan*, 25.24 % have 100–200 m^2, 11.72 % have 200–300 m^2, and 22.76 % have 300 m^2 or more (Arifin 1998). Table 8.1 shows the distribution for the four provinces of Java. *Pekarangans* areas spread from rural, to suburban, to urban areas. The LCS could be achieved through *pekarangan*; so long as housing development is constructed by the horizontal building system, it is assumed the more built-up housing, the larger the numbers and area of *pekarangan*.

Table 8.1 Size distribution of *pekarangan* land in agricultural provinces of Java (percentages of households that have *pekarangan* in the size groups shown)

Provinces in Java	<100 m^2 (%)	100–200 m^2 (%)	200–300 m^2 (%)	>300 m^2 (%)
West Java-Banten	52.29	25.00	8.77	8.95
Central Java	27.50	27.57	13.20	31.73
East Java	34.52	25.83	13.33	26.31
D.I. Yogyakarta	33.51	17.48	14.61	34.40

Source: Arifin (1998) [Appendix Table 2 (citing 1995 Housing and Settlement Statistics, Indonesian Statistics Center Bureau 1996)]

8.2 Objectives of Research

The multiyear research on *pekarangan* has the objective to reconstruct and to revitalize traditional Indonesian agroforestry to achieve sustainable bioresources management systems on Java. Furthermore, this research calculates and assesses C sequestration, water resources management, agrobiodiversity conservation, and landscape beautification from *pekarangan*.

8.3 Methods

This study has been ongoing since 1996 in some watersheds of West Java Province for a period of 10 years. This study was divided into four stages with the activity targets in each stage as follows:

1. *Stage I* (*1996–2000*): Survey on traditional *pekarangan* bioresources in rural areas.
2. *Stage II* (*2000–2003*): Analysis interrelationships among components in *pekarangan* bioresource management system and evaluation.
3. *Stage III* (*2003–2005*): Reconstruction of a *pekarangan* bioresources management system.
4. *Stage IV* (*2005–2007*): Adaptation of the new biomanagement system and proposal of the reconstruction of the *pekarangan* bioresources management system.

Simultaneously, these *pekarangan* studies have been extended on Java Island under joint research with the Rural Development Institute (2006–2007), *Hibah Penelitian Tim Pascasarjana* Directorate General of Higher Education (DGHE) of Indonesia (2006–2008), *Hibah Kompetensi* DGHE of Indonesia (2008–2010), and joint research with the Global Environmental Leaders (GEL)s Education Program for Designing a Low Carbon Society (LCS) of Hiroshima University, Japan (2009–2013).

In this chapter, those results were demonstrated to show the conditions and the significant roles of *pekarangan* in Java, Indonesia. Several settlements of hamlets or villages within administrative boundaries were chosen as the study sites of a

microscale research unit. Selection of the study sites in each small-scale catchment area was based on several considerations, as follows:

1. Elevation gradient: 200–500 m, 500–1,000 m, and >1,000 m above sea level (a.s.l.)
2. These study sites are located in the linear slope.

8.4 Results and Discussion

8.4.1 Traditional Agroforestry of Pekarangan

Pekarangan is the traditional and privately owned home garden, and an integrated system with an intimate relationship among human, plants, and animals. It is well known that this garden has multiple functions, such as conservation of genetic resources, soil, and water, crop production, and sociocultural relationships in the rural area. It is thought that *pekarangan* is an optimal and sustainable land use with high productivity in tropical regions (Arifin 1998). Arifin and Arifin (2010) stated that *pekarangan* is a kind of traditional agroforestry practice that is found in rural and agricultural landscapes beside *kebun campuran* (mixed gardens) and *kebun talun* (forest gardens). The design and structure depends on local and ecological knowledge of the surrounding communities. The survey showed that the western part of Indonesia practices agro-silvo-fishery, as there are many water resources, and in contrast, the eastern part of Indonesia practices agro-silvo-pastura because of lack of water (Arifin et al. 2008a).

Pekarangan fulfills an ecological function in that its multilayered vegetation structure resembles that of natural forests and offers habitats and niches for a diverse community of wild plants and animals (Albuquerque et al. 2005; Karyono 1990). This study has confirmed the performance of *pekarangan* at the smallest scale. Those provisions are the contribution of *pekarangan* for nutrition intake, income, wealth assets, family status, access to credit, control of production, and product marketing.

Some research, particularly *pekarangan* biodiversity based on urbanized vegetation structures, was conducted in the landscape ecological unit of Ciliwung and Cisokan Watershed, which covers the Bogor-Puncak-Cianjur (BOPUNJUR) region (Arifin 2004; Arifin et al. 2001). Species richness was elucidated for *pekarangan* starting from the upper stream reaches to the downstream portion of the watersheds. Landscape structure in the traditional agroforestry of the *pekarangan* system has horizontal and vertical diversity (Arifin et al. 1998). Based on plant function, horizontal diversity has been classified into eight groups: ornamental plants, fruit plants, vegetable crops, starchy crops, medicinal plants, spices crops, industrial plants, and others (Arifin 1998). It is found that the size of *pekarangan* and percentage of plant canopy coverage are larger from the upper stream reaches to downstream. However, the highest averages of individual numbers per *pekarangan*

Table 8.2 Number of species and individual numbers per *pekarangan* in Cianjur Watershed

Research area	Average *Pekarangan* size (m^2)	Average plant canopy area[a] (m^2)	Average number of species	Total number of species	Average number of individuals	Total number of individuals	Shannon–Wiener diversity index
Upper stream	188.2	167.0	26.7	90	280.0	1,680	1.17
Middle stream	218.7	629.0	40.4	166	491.5	4,915	1.31
Downstream	562.0	1,733.2	44.0	116	346.2	1,731	1.24

[a]Only trees and shrubs with dbh $>$ 2.5 cm were measured *Pekarangan* size, size of the open space area

Source: Arifin et al. (2001); Arifin (2004)

and species diversity index were found in the middle streams of Cianjur watershed (Table 8.2). This area is a transition zone between the lowland and mountainous areas (Arifin et al. 2001).

Based on plant function, the lower parts of watershed have a smaller ornamental plant ratio (Table 8.3). Fruit plants were found in the downstream predominantly (30.4 %), followed by others (17.1 %), such as fuel wood species, wood for handicrafts material, and wood for building materials (Arifin 2004).

In the BOPUNJUR region, changes of *pekarangan* plant diversity were studied along an urban–rural continuum as well as along an elevation gradient. The vegetation structure and composition of 115 *pekarangans* in six villages were investigated to determine the urbanization effects (Arifin et al. 1998). The six villages differed in urbanization level: one is a rural village, three are characterized as intermediately urbanized, and two are urban villages. In each *pekarangan*, both ornamental and crop plants were inventoried. *Pekarangan* sizes ranged from 30 m^2 to 4,000 m^2; the average size was 270 m^2. In total, 440 plant species were grown in the 115 *pekarangans*; about half the species were ornamentals. The number of species in a *pekarangan* varies according to local physical circumstances, ecological characteristics of plants, kinds of animal species, and socioeconomic and cultural factors. Plant species numbers varied largely among the 115 *pekarangans* studied. Average species number per *pekarangan* were not markedly different between the rural, the intermediate, and the urban *pekarangans* (Arifin 1998 and Arifin et al. 1998). However, the average number of nonornamental plant species per *pekarangan* was markedly higher in rural than in urban *pekarangan*. The proportion of ornamental plants from total species increased with a higher level of urbanization (40 % in rural to 70 % in urban). *Pekarangan* size decreased continuously from rural to urban areas. In many densely populated tropical regions, *pekarangans* appear to be the last forest-like islands surrounded by increasingly extended, uniform staple crop fields. In these areas, *pekarangans* with their multilayered vegetation structure serve as an important habitat for wild flora and fauna. *Pekarangans* fulfill not only important ecological but also many social and cultural functions (Kehlenbeck et al. 2007).

Table 8.3 Ratio of species number by *pekarangan* plant function in Cianjur Watershed

	Species number (%)		
Plant function	Upper stream	Middle stream	Downstream
Ornamental plant	47.5	48.9	24.4
Nonornamental plant			
Fruit plant	16.9	20.8	30.4
Vegetable crop	11.9	12.2	8.3
Spice crop	3.1	4.5	4.6
Medicinal plant	3.1	1.7	4.1
Starchy crops	8.8	5.5	3.7
Industrial plant	3.1	1.5	7.4
Others	5.6	5.1	17.1
Total	100.0	100.0	100.0

Source: Arifin (2004)

Furthermore, a homestead plot survey on Java (Arifin et al. 2008b) was conducted in 144 *pekarangan* samples from three provinces: West, Central, and East Java provinces. The *pekarangan* samples covered two watershed units per province. *Pekarangan* size was divided into two groups: smaller than 120 m^2 (small *pekarangan*) and between 120 and 400 m^2 (moderate-size *pekarangan*). The total species number is 196 (Table 8.4), consisting of ornamental plants (103 species), fruit plants (29 species), vegetable crops (21 species), medicinal plants (13 species), spice crops (9 species), industrial plants (9 species), other plants (7 species), and starchy crops (5 species).

8.4.2 The Dynamics of Pekarangan

Vegetation structure dynamics in *pekarangan* was analyzed between years 1996 and 2006 (Mayanti et al. 2007). The sample sites were located in BOPUNJUR, West Java Province. The samples were taken at the selected sites with different levels of urbanization, that is, the least urbanized sites, less urbanized sites, and urbanized sites. In 2006, there are 362 plants species in *pekarangans*. The result showed that between 1996 and 2006, the size of open space areas of *pekarangan* decreased, and the number of spesies also became less. However, the number of individual was increased because some plants, especially shrubs and ground covers can reproduce by themselves vegetatively. Some factors that influenced the changes of vegetation structure at *pekarangan* are (1) small open space area, (2) land fragmentation, (3) different owner, (4) changes in function of some part of the *pekarangan*, (5) plant popularity trend, and (6) economic condition changes.

Regarding vegetation stratification, it was observed that the first stratum of vegetation such as grasses and herbs was predominant in each level of urbanization, both in 1996 and 2006. In the intervening 10 years, the availability of tree strata was

Table 8.4 Number of species by plant function in 144 *pekarangan* samples on Java Island

Category	No.	Latin name	Family name	English name
I Starchy crops				
	1	*Ipomoea batatas*	Convolvulaceae	Sweet potato
	2	*Manihot esculenta*	Euphorbiaceae	Cassava
	3	*Oryza sativa*	Poaceae	Asian rice
	4	*Solanum tuberosum*	Solanales	Potato
	5	*Zea mays*	Poaceae	Maize
II Fruit plants				
	1	*Ananas comosus*	Bromeliaceae	Pineapple
	2	*Annona muricata*	Annonaceae	Soursop
	3	*Annona squamosa*	Annonaceae	Sugar-apple
	4	*Artocarpus altilis*	Moraceae	Breadfruit
	5	*Artocarpus heterophyllus*	Moraceae	Jack fruit
	6	*Averrhoa carambola*	Oxalidaceae	Starfruit
	7	*Carica papaya*	Caricaceae	Papaya
	8	*Citrullus lanatus*	Cucurbitaceae	Watermelon
	9	*Citrus sinensis*	Rutaceae	Orange
	10	*Cucumis melo*	Cucurbitaceae	Melon
	11	*Dimocarpus longan*	Sapindaceae	Longan
	12	*Durio zibethinus*	Malvaceae	Durian
	13	*Fragaria xananassa*	Rosaceae	Strawberry
	14	*Garcinia mangostana*	Clusiaceae	Mangosteen
	15	*Lansium domesticum*	Meliaceae	Dookoo
	16	*Malus domestica*	Rosaceae	Apple
	17	*Mangifera indica*	Anacardiacea	Mango
	18	*Manilkara zapota*	Sapotaceae	Sapodilla
	19	*Musa paradisiaca*	Musaceae	Banana
	20	*Nephellium lappaceum*	Sapindaceae	Rambutan
	21	*Passiflora edulis*	Passifloracea	Passionfruit
	22	*Persea americana*	Lauraceae	Avocado
	23	*Phoenix dactylifera*	Arecaceae	Date palm
	24	*Punica granatum*	Lythraceae	Pomegranate
	25	*Salacca zalacca*	Arecaceae	Snake fruit
	26	*Sandoricum koetjape*	Meliaceae	Santol or Sandorica
	27	*Spondias dulcis*	Anacardiaceae	Golden apple
	28	*Syzygium samarangense*	Myrtaceae	Wax apples
	29	*Vitis vinifera*	Vitaceae	Grape
III Vegetable				
	1	*Allium fistulosum*	Alliaceae	Spring onion
	2	*Amaranthus* spp.	Amaranthaceae	Amaranth
	3	*Apium graveolens*	Apiaceae	Celery
	4	*Archidendron pauciflorum*	Fabaceae	Jengkol
	5	*Brassica oleracea*	Brassicaceae	Cabbage
	6	*Brassica rapa*	Brassicaceae	Chinese cabbage
	7	*Citrus aurantifolia*	Rutaceae	Key lime
	8	*Cucumis sativus*	Cucurbitaceae	Cucumber
	9	*Daucus carota*	Apiaceae	Carrot

(continued)

Table 8.4 (continued)

Category	No.	Latin name	Family name	English name
	10	*Gnetum gnemon*	Gnetaceae	Melinjo
	11	*Ipomoea aquatica*	Convolvulaceae	Water spinach
	12	*Luffa acutangula*	Cucurbitaceae	Silk squash
	13	*Momordica charantia*	Cucurbitaceae	Bitter melon
	14	*Parkia speciosa*	Fabaceae	Stink bean
	15	*Phaseolus lunatus*	Fabaceae	Lima bean
	16	*Sauropus androgynus*	Phyllanthaceae	Sweet leaf
	17	*Sechium edule*	Cucurbitaceae	Chayote
	18	*Solanum lycopersicum*	Solanaceae	Tomato
	19	*Solanum melongena*	Solanaceae	Eggplant
	20	*Solanum nigrum*	Solanaceae	Black nightshade
	21	*Vigna unguiculata*	Fabaceae	Yardlong bean
IV Spice crops				
	1	*Alpinia galanga*	Zingiberaceae	Blue ginger
	2	*Capsicum annuum*	Solanaceae	Chili
	3	*Curcuma longa*	Zingiberaceae	Turmeric
	4	*Cymbopogon citratus*	Poaceae	Lemon grass
	5	*Etlingera elatior*	Zingiberaceae	Torch ginger
	6	*Myristica fragrans*	Myristicaceae	Nutmeg
	7	*Pandanus amaryllifolius*	Pandanaceae	Pandan
	8	*Syzygium polyanthum*	Myrtaceae	Bay leaf
	9	*Zingiber zerumbet*	Zingiberaceae	Shampoo ginger
V Medicinal plants				
	1	*Andrographis paniculata*	Acanthaceae	Creat
	2	*Blumea balsamifera*	Asteraceae	Sambong
	3	*Chloranthus erectus*	Chloranthaceae	Cryphaea
	4	*Hydrocotyle sibthorpioides*	Apiaceae	Lawn pennywort
	5	*Melastoma polyanthum*	Melastomataceae	Grass jelly
	6	*Morinda citrifolia*	Rubiaceae	Great morinda
	7	*Orthosiphon aristatus*	Lamiaceae	Cat's whiskers
	8	*Phaleria papuana*	Thymelaeaceae	God's crown
	9	*Piper betle*	Piperaceae	Betel
	10	*Pluchea indica*	Asteraceae	Marsh fleabane
	11	*Sonchus arvensis*	Asteraceae	Swine thistle
	12	*Tinospora crispa*	Menispermaceae	Guduchi
	13	*Zingiber officinale*	Zingiberaceae	Ginger
VI Industrial plants				
	1	*Camellia sinensis*	Theaceae	Tea
	2	*Ceiba pentandra*	Malvaceae	Kapok
	3	*Cocos nucifera*	Arecaceae	Coconut
	4	*Coffea arabica*	Rubiaceae	Coffee
	5	*Hevea brasiliensis*	Euphorbiaceae	Rubber tree
	6	*Paraserianthes falcataria*	Fabaceae	Albizia
	7	*Saccharum officinarum*	Poaceae	Sugar cane
	8	*Syzygium aromaticum*	Myrtaceae	Clove
	9	*Theobroma cacao*	Malvaceae	Cacao

(continued)

Table 8.4 (continued)

Category	No.	Latin name	Family name	English name
VII Ornamental plants				
	1	*Acalypha macrophylla*	Euphorbiaceae	Copperleaves
	2	*Adenium obesum*	Apocynaceae	Desert-rose
	3	*Adiatum* spp.	Pteridaceae	Maidenhair ferns
	4	*Agave* spp.	Agavaceae	Agave
	5	*Aglaonema* spp.	Araceae	Aglaonema
	6	*Aloe vera*	Asphodelaceae	Aloe vera
	7	*Alternanthera amoena*	Amaranthaceae	Alternanthera
	8	*Anthurium scherzeranum*	Araceae	Flamingo plant
	9	*Araucaria heterophylla*	Araucariaceae	Norfolk island pine
	10	*Axonopus compressus*	Poaceae	Lawn grass
	11	*Bauhinia purpurea*	Fabaceae	Hongkong orchid tree
	12	*Begonia* spp.	Begoniaceae	Begonia
	13	*Bougenvillea* spp.	Nyctaginaceae	Paper flower
	14	*Caesalpinia pulcherrima*	Fabaceae	Peacock flower
	15	*Caladium* spp.	Araceae	Caladium
	16	*Calathea makoyana*	Marantaceae	Peacock plant
	17	*Cananga odorata*	Annonaceae	Cananga tree
	18	*Canna edulis*	Cannaceae	Canna
	19	*Carex morrowii*	Cyperacea	Japanese sedge
	20	*Catharanthus roseus*	Apocynaceae	Vinca
	21	*Chlorophytum comosum*	Agavaceae	Spider plant
	22	*Chrysalidocarpus lutescens*	Arecaceae	Golden cane palm
	23	*Chrysanthemum* spp.	Asteraceae	Chrysanths
	24	*Clerodendron paniculatum*	Clerodendron	Pagoda flower
	25	*Codiaeum variegatum*	Euphorbiaceae	Garden croton
	26	*Coleus blumei*	Lamiaceae	Coleus
	27	*Cordyline fruticosa*	Asparagaceae	Red palm lily
	28	*Cordyline terminalis*	Asparagaceae	Green palm lily
	29	*Crinum* spp.	Amaryllidaceae	Crinum
	30	*Cuphea hyssopifolia*	Lythraceae	Mexican heather
	31	*Cupressus papuana*	Cupressaceae	Italian cypress
	32	*Cycas rumphii*	Cycadaceae	Queen sago
	33	*Datura mollis*	Solanaceae	Trumpet flower
	34	*Delonix regia*	Fabaceae	Flamboyant
	35	*Dieffenbachia seguine*	Araceae	Dumb cane
	37	*Dracaena angustifolia*	Dracaenaceae	Dracaena
	38	*Dracaena sanderiana*	Ruscaceae	Ribbon dracaena
	39	*Duranta* spp.	Verbenaceae	Golden dewdrop
	40	*Epiphyllum oxypetalum*	Cactaceae	Night queen
	41	*Epipremnum aureum*	Araceae	Silver vine
	42	*Episcea cupreata*	Gesneriaceae	Flame violet
	43	*Eugenia uniflora*	Myrtaceae	Surinam cherry
	44	*Euphorbia milii*	Euphorbiaceae	Christ plant

(continued)

Table 8.4 (continued)

Category	No.	Latin name	Family name	English name
	45	*Euphorbia pulcherrima*	Euphorbiaceae	Poinsettia
	46	*Ficus benjamina*	Moraceae	Ficus tree
	47	*Ficus elastica*	Moraceae	Rubber plant
	48	*Ficus lyrata*	Moraceae	Fiddle-leaf fig
	49	*Gardenia augusta*	Rubiaceae	Gardenia
	50	*Gerbera* spp.	Asteraceae	Daisy
	51	*Gomphrena* spp.	Amaranthaceae	Globe amaranth
	52	*Helianthus annuus*	Asteraceae	Sun flower
	53	*Heliconia* spp.	Heliconiaceae	Heliconia
	54	*Hemigraphis alternata*	Acanthaceae	Metal leaf
	55	*Hibiscus rosa-sinensis*	Malvaceae	Shoe flower
	56	*Hydrangea* spp.	Hydrangeaceae	Hortensia
	57	*Hyophorbe lagenicaulis*	Arecaceae	Bottle palm
	58	*Impatiens balsamina*	Balsaminaceae	Garden balsam
	59	*Impatiens walleriana*	Balsaminaceae	Balsam/busy lizzy
	60	*Ixora javanica*	Rubiaceae	Javanese ixora
	61	*Jasminum multiflorum*	Oleaceae	Indian jasmine
	62	*Jasminum sambac*	Oleaceae	Jasmine
	63	*Kalanchoe pinnata*	Crassulaceae	Miracle leaf
	64	*Lilium* spp.	Liliaceae	Lily
	65	*Livistona* spp.	Arecaceae	Fan palms
	66	*Maihuenia* spp.	Cactaceae	Cactus
	67	*Manihot esculenta* "variegata"	Euphorbiaceae	Variegated tapioca
	68	*Maranta leuconeura*	Marantaceae	Maranta
	69	*Michelia alba*	Magnoliaceae	White champaca
	70	*Michelia champaca*	Magnoliaceae	Champaca
	71	*Mirabilis jalapa*	Nyctaginaceae	Four o'clock flower
	72	*Neoregelia* spp.	Bromeliaceae	Bromelia
	73	*Nerium oleander*	Apocynaceae	Oleander
	74	*Nothopanax scutellarium*	Araliaceae	Saucer-leaf
	75	*Nymphaea* spp.	Nymphaeaceae	Water lily
	76	*Pachystachys lutea*	Acanthaceae	Golden shrimp plant
	77	*Pedilanthus tithymaloides*	Euphorbiaceae	Christmas candle
	78	*Phalaenopsis amabilis*	Orchidaceae	Moon orchid
	79	*Philodendron* spp.	Araceae	Philodendron
	80	*Pilea cadierei*	Urticaceae	Aluminium plant
	81	*Pinus merkusii*	Pinaceae	Pine tree
	82	*Platycerium bifurcatum*	Polypodiaceae	Elkhorn fern
	83	*Plumeria alba*	Apocynaceae	Caterpillar tree
	84	*Polianthes tuberosa*	Agavaceae	Tuberose
	85	*Portulaca* spp.	Portulacaceae	Moss roses
	86	*Rhapis excels*	Arecaceae	Bamboo palm
	87	*Rhoeo discolor*	Asteraceae	Oyster plant
	88	*Ricinus communis*	Euphorbiaceae	Castor oil plant
	89	*Rosa* spp.	Rosaceae	Rose

(continued)

Table 8.4 (continued)

Category	No.	Latin name	Family name	English name
	90	*Sansevieria trifasciata*	Agavaceae	Snake plant
	91	*Saraca asoca*	Fabaceae	West Indian jasmine
	92	*Schefflera arboricola*	Araliaceae	Dwarf umbrella tree
	93	*Scindapsus* spp.	Araceae	Scindapsus
	94	*Spondias pinnata*	Anacardiaceae	Common hog plum
	95	*Stachytarpheta mutabilis*	Acanthaceae	Keji beling
	96	*Stenochlaena palustris*	Blechnaceae	Epiphytic fern
	97	*Syngonium podophyllum*	Araceae	Syngonium
	98	*Tagetes erecta*	Asteraceae	African marigold
	99	*Thuja occidentalis*	Cupressaceae	Graveyard cypress
	100	*Wedelia biflora*	Asteraceae	Beach sunflower
	101	*Yucca guatemalensis*	Agavaceae	Spineless yucca
	102	*Zepiranthes* spp.	Amaryllidaceae	Fairy lily or Rain lily
	103	*Zinnia* spp.	Asteraceae	Zinnia
VIII Others				
	1	*Albizia saman*	Fabaceae	Saman tree
	2	*Bambusa* spp.	Poaceae	Bamboo
	3	*Canarium ovatum*	Burseraceae	Cesnut
	4	*Maesopsis eminii*	Rhamnaceae	Umbrella tree
	5	*Pterocarpus indicus*	Fabaceae	Narra
	6	*Swietenia mahogany*	Meliaceae	Mahogany
	7	*Tectona grandis*	Lamiaceae	Teak wood

reduced in *pekarangan* (Fig. 8.1). Most of these factors were thought to be correllated with the impact of urbanization. This study also proposed some actions to utilize *pekarangan* effectively through a Participatory Rural Appraisal (PRA) approach, such as in plant selection, recycling systems, and revitalizing mixed agroforestry practices.

8.4.3 Low Carbon in Pekarangan

Pekarangan, a traditional biodiversity–low carbon system in Indonesia to establish green procurement, promote greening, and set green guidelines, species diversity, or biodiversity plays an important role in sustaining the ecosystem at present and in the future (Arifin and Nakagoshi 2011). *Pekarangan* is a common smallholder agroforestry system in Indonesia and throughout the tropics, from the rural to the urban areas (Arifin 1998). These species-rich, tree-based systems produce non-wood and wood products for both home use and market sale. High biodiversity is an intrinsic property of the home gardens (Kumar 2006), which presumably favors greater net primary productivity (NPP) and higher C sequestration potential than monospecific production systems. Projections by Roshetko et al. (2002) revealed that, depending

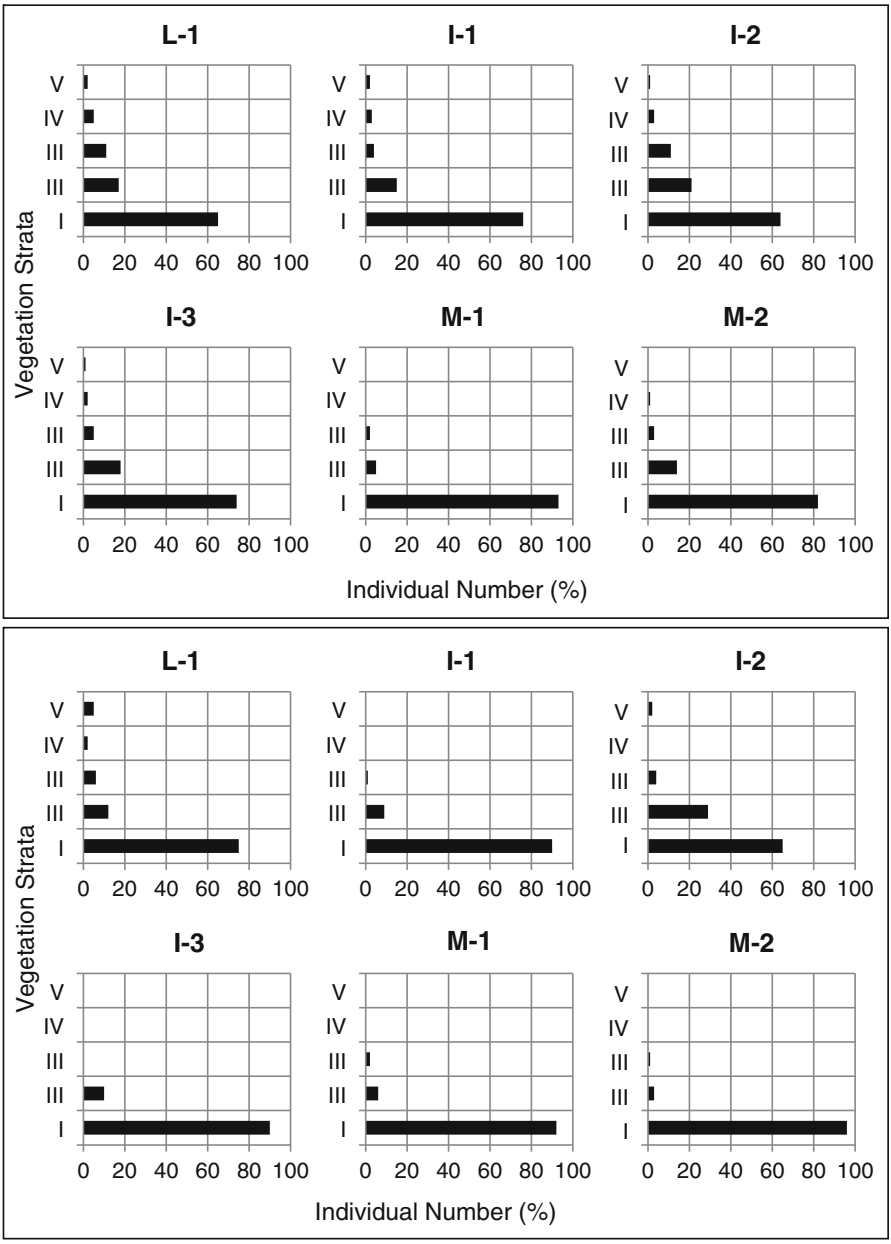

Fig. 8.1 Percentage of individual plant number in each stratum by urbanization level in 1996 (*above*) and in 2006 (*bottom*). L-I, the least urbanized area; I-1, I-2, I-3, intermediate urbanized areas; M-1, M-2, the most urbanized area); 1st strata, 0–1 m; 2nd strata, 1–2 m; 3rd strata, 2–5 m; 4th strata, 5–10 m; 5th strata, >10 m

on management options, the time-averaged above-ground C stocks of *pekarangan* systems could vary from 30 to 123 Mg C ha^{-1}. These projected time-averaged above-ground C stocks of *pekarangans* are substantially higher than those of Imperata–cassava systems (2.2 Mg C ha^{-1}), which is an extensive vegetation type in the Lampung study area. *Pekarangan* research showed these systems simultaneously offer potential for C storage because of their high biomass. Although small size limits the amount of C stored by individual smallholder agroforestry systems, on a per area basis these systems can store as much C as some secondary forests. In aggregate, smallholder *pekarangan* agroforestry systems can contribute significantly to a regional C budget while simultaneously enhancing smallholder livelihoods. A field study in other areas outside Java Island, that is, Lampung, Indonesia indicates that *pekarangans* with an average age of 13 years store 35.3 Mg C ha^{-1} in their above-ground biomass, which is on par with the C stocks reported for similar-aged secondary forests in the same area (Roshetko et al. 2002).

Some experimental evidence also suggests that plant diversity and composition influence the enhancement of biomass and C acquisition in ecosystems subjected to elevated atmospheric CO_2 concentrations (Kumar 2006). Reich et al. (2001) reported that biomass accumulation was greater in species-rich than in species-poor experimental populations under conditions of CO_2 and N fertilization. By extension, home gardens, which are inherently species rich, may trap progressively greater quantities of atmospheric CO_2 under rising levels of this gas.

If *pekarangan* systems and other smallholder tree-based systems were to expand in currently degraded and underutilized lands, such as Imperata grasslands, the C sequestration potential would be about 80 Mg C ha^{-1}, with considerable variation depending on species composition and management practices. Clearly, opportunity exists to induce management that leads to higher C stocks at the systems level. However, incentive mechanisms are needed that assure smallholders will benefit from selecting management practices that favor higher C stocks (Arifin and Nakagoshi 2011).

8.5 Summary

Published articles and a dissertation (Arifin 1998) such as those on *pekarangan* defined that Indonesian home gardens are generally regarded as a complex, species-rich agroforestry system, a diverse mixture of perennial and annual plant species arranged in a multilayered vertical structure, often in combination with raising livestock managed in a sustainable manner over decades or even centuries. A wide spectrum of multiple-use products can be generated with relatively low labor, cash, or other external inputs. In many densely populated tropical regions, *pekarangan* appear to be the last forest-like islands surrounded by increasingly extended, uniform staple crop fields. Some research sponsored by the Core University Research Program JSPS Japan/DGHE Indonesia, and STORMA Germany (1998–2007), concluded that with their multilayered vegetation structure, *pekarangan* serves as an important habitat for included wild flora and fauna.

Pekarangan fulfils not only important ecological but also many social and cultural functions (Arifin et al. 1998; Arifin et al. 2001). However, the major purposes of *pekarangan* are subsistence production and income generation, particularly in rural areas (Kehlenbeck et al. 2007). At forest margins, high production levels in *pekarangan* might help to reduce deforestation. Furthermore, *pekarangan* should be considered as a model for sustainable agroforestry systems, integrating both economic and ecological benefits.

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