Revitalizing *Pekarangan* Home Gardens, a Small Agroforestry Landscape for a Low Carbon Society

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The development of small agroforestry landscapes for low carbon societies can resolve environmental problems in rural areas, particularly in developing countries. Inadequate landscape management practices may suppress economic, social and ecological development in rural marginal communities. Therefore by revitalizing small agroforestry systems such as *pekarangan*, marginal communities have the possibility to advance economically, socially and ecologically. The aim of this research is to develop an original environmental service concept around the small agroforestry landscape of *pekarangan*, a home garden landscape. Those environmental services of *pekarangan* are (1) biodiversity conservation, (2) carbon stock accumulation, (3) economic resource possession and (4) additional nutrition for humans. It was found *pekarangan* has high biodiversity and carbon stock may account for up to 20% of forest landscape, while total income could be increased by up to 12.9%. Finally it was recorded that *pekarangan* may provide 2.0% of daily calorie intake.

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Introduction

Agroforestry landscape is defined as the landscapes between agriculture and forestry needed in order to balance agriculture intensification and forested land sustainability. Agroforestry is often developed in complex land management system that optimizes the environmental, social and economic benefits arising from the biological interactions created when ecosystems are grown effectively. Furthermore, perennial plants and annual cash crops are cultivated in the same agroforestry land with a spatial and temporal arrangement.

Pekarangan is a small scale agroforestry landscape in Indonesia. *Pekarangan* also known as homegardens, homestead plot and open space surrounding a house. *Pekarangan* is defined as a complex, species rich agroforestry system (Arifin *et al*. 2001; Hochegger 1998) with a diverse mixture of perennial and annual plants arranged in a multi-layered vertical structure, often in combination with livestock (Soemarwoto 1987; Christanty 1990). *Pekarangan* comprises of an assemblage of plants which includes trees, shrubs, herbaceous plants and vines grown in/adjacent to a homestead (Landauer & Brazil 1990). A wide variety of multiple-use products of *Pekarangan* can be generated with relatively low labor, cash or other external inputs (Christanty 1990; Soemarwoto & Conway 1992; Hochegger 1998). In addition, *Pekarangan* also can contribute significantly to a region's carbon stock while simultaneously enhancing the livelihoods of rural community (Arifin & Nakagoshi 2011).

The design of agroforestry landscapes for low carbon societies (LCS) is a concept which seeks to solve landscape management problems through a multidiscipline approach. The management of

agroforestry networks, socio-economic and cultural landscape processes has to be considered as ecological function of biotic fluxes linked to landscape structures in a landscape ecological perspectives (Naveh & Lieberman 1994; Forman 1995). Therefore, in this study, the design of agroforestry landscape is analyzed by a landscape ecological perspective. In addition, the benefits of *Pekarangan* as a landscape management practice for LCS is also examined.

The following definition of LCS is not intended as a scientific statement but rather as a flexible framework which would permit fruitful discussions, leading to practical, successful action. The LCS definition was intended to capture the perspectives and needs of countries at all stages of development (National Institute for Environmental Studies 2006). It is agreed that LCS should:

• take actions that are compatible with the principles of sustainable development, ensuring that the development needs of all groups within society are met.
• make an equitable contribution towards the global effort to stabilize the atmospheric concentration of CO_2 and other greenhouse gases at a level that will avoid dangerous climate change, through deep cuts in global emissions.
• demonstrate a high level of energy efficiency, using low-carbon energy sources and production technologies
• adopt patterns of consumption and behavior that are consistent with low levels of greenhouse gas emissions.

This research is concerned with environmental services that can be improved by revitalize *Pekarangan* systems. A *Pekarangan* has the potential to (1) improve biodiversity conservation, (2) accumulate further carbon stock, (3) increase wealth, and (4) provide additional nutrition for households. Biodiversity conservation can be achieved by managing species diversity and at the same time contribute to reducing CO_2 from atmosphere through stock and absorption. Finally, sustainable development can be obtained when a *Pekarangan* is managed properly.

Study Areas and Methods

The study areas were located within four watersheds in West Java region, Indonesia, namely Cisadane, Ciliwung, Cimandiri, and Cibuni watersheds as shown in Fig. 1 (Kaswanto *et al.*
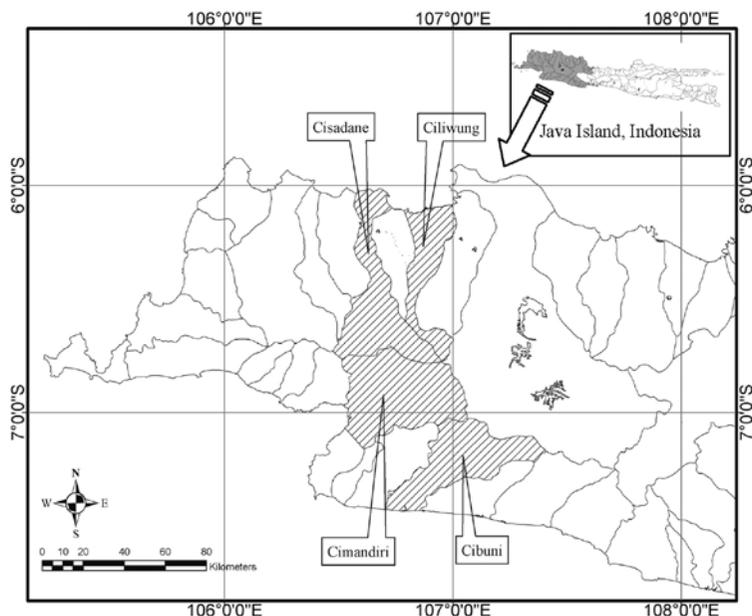

Fig. 1. The study areas locate in four watersheds, *i.e.*, Cisadane, Ciliwung, Cimandiri and Cibuni watersheds. These watersheds are situated in West Java region of Indonesia.

2010). In each watershed 24 respondents who conducted agricultural activities in *Pekarangan* were chosen. In total, 96 *Pekarangan* were investigated.

The assessment process consisted of a questionnaire, interviews and direct measurements. The method is like a tool to drill out the basic of landscape ecological perspective for LCS through micro scale on *Pekarangan* size (Fig. 2). The ob-

Fig. 2. The method is like a tool to drill out the benefits of *Pekarangan* system which are consists of the plant biodiversities, carbon stock, additional income and additional nutrition. Those four benefits are required for designing *Pekarangan* to achieve low carbon society.

tained data on the structure of *Pekarangan*s was divided into four groups referring Arifin *et al.* (2001). Those groups are G1 (< 120 m² *Pekarangan* with no other agricultural land: OAL), G2 (< 120 m² *Pekarangan* with < 1,000 m² OAL), G3 (120 – 400 m² *Pekarangan* with no OAL) and G4 (120 – 400 m² *Pekarangan* with < 1,000 m² OAL). Represented samples were obtained by 1) random village selection, 2) evaluating the *Pekarangan* intensification practices, and 3) defining the sampling frame of households holding *Pekarangan* ownership and dominant land use types, such as rice production + horticulture, other crops + animal husbandry and/or fishponds and absence of *Pekarangan*. Prior to collecting respondent's data, a sample frame was made. A sample frame is the number of households at each hamlet which are appropriate with the criteria of sampling procedure. This number is should be representative as well as the statistical reason requirement. It can be represented as purposive random sampling.
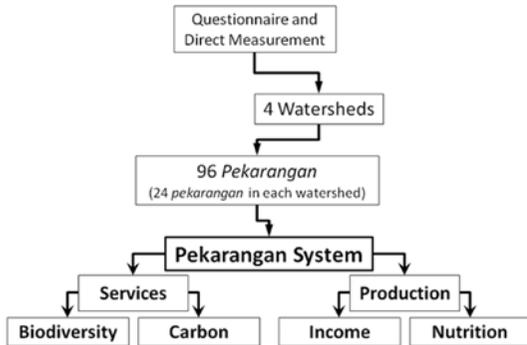
Results

General condition of respondents

The average *Pekarangan* household member consisted of 4.6 people, with a range between 1
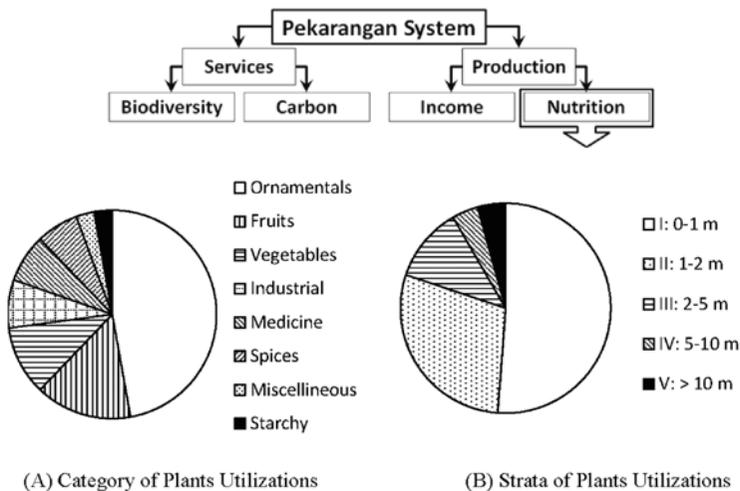

Fig. 3. Plants compositions in *Pekarangan* were divided to 8 categories and 5 strata. Plants in *Pekarangan* are predominantly in ornamental utilization (47.2%) (A) and in 0-1 m height (51.2%) (B). In addition, plants with height more than 2 m occupied 19.9% of total which means *Pekarangan* allows plants to grow without vertical limitations.

and 10 people. Males were the head of 93.8% of households, with females the head of the other 6.3%. This indicates that community was predominantly patriarchal. The average age of household head is 48 years old, with age of household head ranging from 24 to 90 years old. The vast majority (93.1%) of household heads are married. Of remaining 0.7% were single, 4.9% widows/widowers and 1.4% divorced/separated. In general, there are much potential human resources (productive age) in the studied rural villages.

There were nine occupation types found in study areas. Agricultural labors accounted for 26.4% of total and 25.0% owned farm land. Others occupations were non-farmers (13.2%), petty traders (4.2%), house wives (4.2%), drivers (3.5%), tenant farm land (1.4%), village officers (0.7%), and village elders (0.7%). Agriculture labor was predominant in G1, while farm land owners were greatest in G4. The remaining 20.8% of household heads undertook a range of supplementary occupations. It can be concluded that the agriculture based occupations were prospective as initial capital for local development.

Plants biodiversities

Comparatively high biodiversity was found in *Pekarangan* predominantly due to the large number of ornamental plants, therefore *Pekarangan* can be more adaptive to human disturbance. Plants were predominantly ornamental (47.2%) and less than 1 m in height (51.2%). However, plants more than 2 m in height occupied 19.9% of total flora, thus *Pekarangan* is able to allow plants to grow without any vertical limitations (Fig. 3). In total, 214 plant species and 11 livestock species were found in the 96 *Pekarangan* plots. Most of the *Pekarangan* structures were found to be imitated the forest land, where the vertical and horizontal plant diversities were very high based on biodiversity indices.

Carbon stock

The carbon stock in *Pekarangan* varies from 3.49 to 10.84 Mg/ha in G1 and G2, while for G3 and G4 ranges from 6.54 to 22.23 Mg/ha (Fig. 4). In total, the average carbon stock of *Pekarangan* is 9.90 Mg/ha. Nevertheless the carbon stock in *Pekarangan* is also estimated to account for 20% of natural forest. This means plant density and

growth in *Pekarangan* has the ability to mimic natural forest conditions. In term of carbon stock, there were significant correlations among groups, the four groups differentiate as predicted early within the sample frame method. However, there is no correlation between respondents who have OAL and those who do not.

Additional income

Income derived from *Pekarangan* came from selling plants and livestock (Table 1). It can be concluded that the households who do not have OAL (G1 and G3) tend to obtain higher income both from plants and livestock than those who have OAL (G2 and G4). The average highest income was in G3 which had open area size larger than G1. In term of productivity, G1 and G2 were different to G3 and G4, as small *Pekarangan* were more productive. This is because *Pekarangan* management was more intensively in small areas. Small *Pekarangan* (G1 and G2) tend to improve their open space by cultivating more crops and raising more livestock. However, the productivity for those who have not OAL was indeed higher
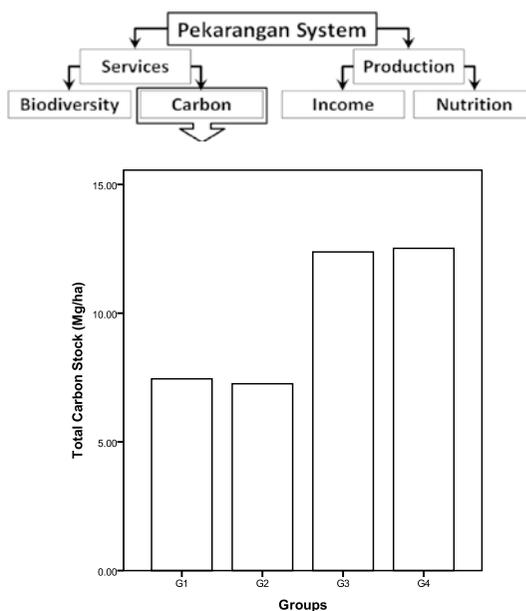

Fig. 4. The amount of carbon stock (Mg/ha) in *Pekarangan* (from plants and soil) based on groups classification. It showed that even small scale *Pekarangan* can store large amount of carbon. It may account for up to 20% of forest landscape carbon stock.

Table 1. Additional incomes derived from *Pekarangan* came from selling plants and animals (livestock) production. Productivity is estimated by divided incomes to open space areas.
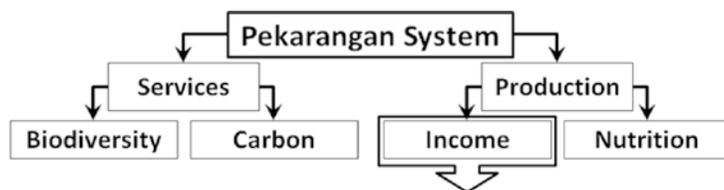
| Source of income	G1	G2	G3	G4	G1&G3
Income (IDR/year) from a *Pekarangan* production					
Plants	$1,247,923_a$	$1,124,172_a$	$2,173,335_b$	$1,610,421_{a,b}$	$1,710,633_a$
Animals	$4,214,292_a$	$2,980,770_a$	$4,700,003_a$	$4,690,002_a$	$4,530,005_a$
Total income	$5,462,215_a$	$4,104,942_a$	$6,873,338_a$	$6,300,423_a$	$6,240,638_a$
Income productivity (IDR/year/m^2) from a *Pekarangan* production					
Plants	$11,999.26_a$	$10,506.28_a$	$7,960.93_b$	$5,350.24_b$	$9,099.11_a$
Animals	$40,522.04_a$	$27,857.66_a$	$17,216.13_b$	$15,581.40_b$	$24,095.77_a$
Total income	$52,521.30_a$	$38,363.94_a$	$25,177.06_b$	$20,931.64_b$	$33,194.88_a$
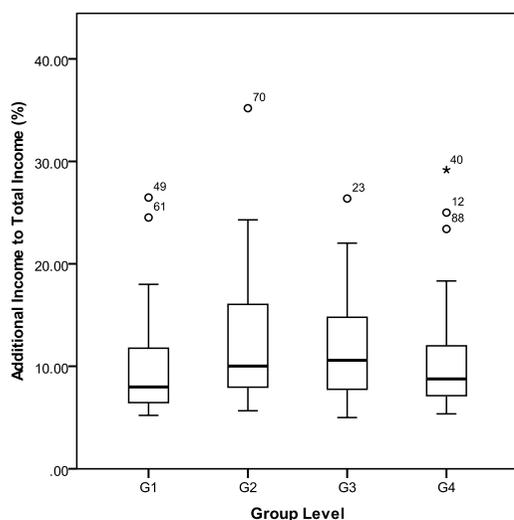
Fig. 5. Percentage of additional incomes to total income derived from *Pekarangan* productions. In average, additional incomes could be increased by up to 12.9% of total income.

compared to the other areas. Those respondents cultivated their *Pekarangan* intensively because they did not have OAL to manage.

It was found, total annual income from selling livestock is higher than selling crops. The non-OAL groups tend to have income higher than the OAL groups, because respondents tried to improve and increase the productivity of *Pekarangan*. Income from *Pekarangan* accounted for 12.9% of total household income (Fig. 5).

Additional nutrition for human

Plants and livestock raised in *Pekarangan* provided multiple types of nutritions that significantly enriches family's health. Four nutrition types were investigated in order to determine the contribution of *Pekarangan* to each family's diet through the Recall method (Hebert *et al.* 1997; Jonnalagadda *et al.* 2000; Domel Baxter *et al.* 2003). Those contributions were counted from calories (2.1%), protein (2.5%), vitamin A (12.7%) and vitamin C (23.1%) of total consumption (Table 2).

Discussion

High biodiversities in Pekarangan

There are few studies on flora and fauna in *Pekarangan* related to the conservation of protected area. The *Pekarangan* diversity has high values which were represented by Margalef, Shannon-Wiener, Simpson and Sorenson indices. The ecological condition of both horizontal and verti-

Table 2. The value of family consumption derived from *Pekarangan* per day. Nutrition contribution derived from *Pekarangan* is estimated to total consumption (%) and to recommended dietary allowance (RDA) (%).

Pekarangan System
→ Services ↓	Production ↓
↓ Biodiversity ↓ Carbon	↓ Income ↓ Nutrition
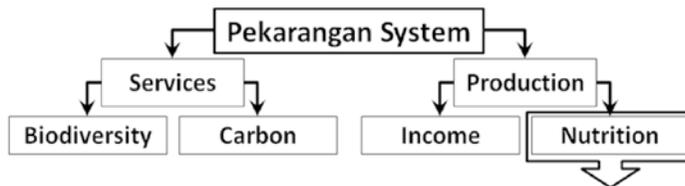
Group	Calorie			Protein			Vitamin A		
	kcal	To total (%)	To RDA (%)	gram	To total (%)	To RDA (%)	IU	To total (%)	To RDA (%)
G1	60.1	0.93	1.05	2.1	1.13	1.27	67.9	8.71	9.79
G2	95.6	1.50	1.45	2.5	1.20	1.41	78.2	8.68	10.19
G3	201.8	2.87	2.32	6.7	3.74	3.02	105.7	17.11	13.77
G4	220.3	3.22	3.06	8.2	3.75	3.58	114.2	16.12	15.36
Average	144.5	2.13	1.97	4.9	2.46	2.32	91.5	12.65	12.28

cal biodiversity, showed that *Pekarangan* highly contribute to helping the environment remain sustainable (Kaswanto and Nakagoshi 2011). Hylander and Nemomissa (2009) concluded that the species composition of the home garden plots were sometimes more similar to the forest plots than plantation plots and sometimes vice versa.

Nevertheless, the diversity is impacted by people who neglected *Pekarangan* area then tried to encroach protected area. Therefore *Pekarangan* might be one solution which would limit infringement on protected areas. People will not encroach into protected area to look for more incomes and food production, because *Pekarangan* itself could provide significant additional incomes and food for consumption. In some cases, it has be recorded that population and economic pressures force households to resettle in forest margin area or in protected areas. Offering *Pekarangan* areas to landless families can reduce the pressured caused by people encroaching on forest areas. It helps both families remain in their historical area and also reduces forest conversion. In addition, distribution of *Pekarangan* may reduce the need for land-poor families to gather fodder and fuel-wood from marginal lands, contributing to the sustainability of protected area (Mitchell & Hanstad 2004). These situations made the biodiversity value increasing, indirectly.

Carbon stock in Pekarangan: *20% of natural forest stock*

According to biomass estimation in Java by Jensen (1993a, b) around 16.0 Mg/ha of carbon can be stored when rice paddy fields were changed to *Pekarangan*. This statement was confirmed by the carbon stock data in *Pekarangan* which had changed from paddy field. There were five new *Pekarangan* sites, which were built less than 10 years ago. For large *Pekarangan*, the carbon stock value is similar to normal sized *Pekarangan* (Roshetko *et al.* 2007).

The OAL ownership did significantly impact on carbon stock in *Pekarangan*, this is mainly because the household without OAL more concerned with ornamental plants cultivation, which do not have significant carbon stock values. In addition, carbon sequestration in farmlands may contribute to mitigate CO_2 concentration in the atmosphere, greater agrobiodiversity may ensure long term stability of carbon storage in fluctuating environments (Henry *et al.* 2009).

Additional income derived from Pekarangan productivity

The household may sell the products produced

in *Pekarangan*, including fruits, vegetables, animal products and other valuable materials such as bamboo and wood for construction or fuel. Some of the respondents also obtained incomes from renting *Pekarangan* area to be used for drying harvest product or as land for kiosks, repair shops, craft shops, *etc*. Mitchell and Hanstad (2004) also stated that *Pekarangan* can contribute to household income in several ways

Through this research, it was found that *Pekarangan* contributes up to 12.9% of total income, therefore *Pekarangan* can have greater economic benefits for households in the future. As stated by Soemarwoto (1987) *Pekarangan* is a traditional agroforestry system with a promising future. Other research supports the statement that *Pekarangan* in rural areas are an important factor in the economy and self-sufficiency of many households. The degree to which the *Pekarangan* contribute to the provision of the household food varies a lot and can only be tentatively (Wezel & Bender 2003).

The livelihoods benefits of *Pekarangan* actually go well beyond those related to nutrition and subsistence. In many cases, the sale of products produced on *Pekarangan* significantly improves the family's financial status (Mitchell *et al.* 2004). Furthermore, *Pekarangan* fulfils not only important for ecological, but also many social and cultural functions (Arifin *et al.* 2001). Currently, the main 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. Nevertheless, small *Pekarangan* should be considered as a model for sustainable small agroforestry systems, integrating both economic and ecological benefits that will help local communities to a better future. Sustainable development planning, particularly in rural area, must be based on environmental and biophysical indices that effectively define comparative development potential and environmental constraint as stated by Schultink (2000).

Additional nutrition from Pekarangan production

There were no statistically significant differences between G1, G2 G3 and G4 in family consumption from *Pekarangan*. Nevertheless, it can be concluded that *Pekarangan* contrib-

utes significantly to vitamin A and C intake. On average, vitamin A derived from *Pekarangan* contributes up to 12.7% to total consumption and 12.3% to recommended dietary allowance (RDA) equivalent to 91.5 IU/day. While vitamin C derived from *Pekarangan* contributes up to 23.1% of total consumption and 22.7% to RDA which was equivalent to 38.7 mg/day. Vitamin A and C were mainly derived from fruits, vegetables and spices. Therefore, *Pekarangan* should be recommended as a strategy for addressing malnutrition and micronutrient deficiencies, particularly for people in forest margin areas or at the buffer zone of protected areas. Several studies also have found that *Pekarangan* produce a significance percentage of household consumption (Niñez 1985; Soemarwoto 1987; Marsh 1998; Mitchell *et al.* 2004; Abdoellah *et al.* 2006; Wiersum 2006).

Others indirect benefits from Pekarangan

There are also some benefits that could be derived indirectly from *Pekarangan* other than those mentioned above. They are wage security, the increasing of social status, wealth or position in labor markets and women emancipations.

Wage security and social status for the households

Pekarangan provided the collateral needed to obtain credit or loans from formal financial agencies (*i.e.*, village bank, Koperasi Unit Desa (KUD) - village cooperative system) or informal lenders. Nevertheless, those with regular employment do not relay on *Pekarangan* for credit or loans. Furthermore, *Pekarangan* also provided the opportunity to derive additional income home industries.

In some cases, the size of *Pekarangan* also implies to the social status of the household. The larger the *Pekarangan* area, the greater the respect and honors bestowed on the *Pekarangan* holder. Large *Pekarangan*, particularly with flat open area, frequently hold neighborhoods activities, *i.e.*, social gathering, wedding ceremony, harvesting ceremony. The status of *Pekarangan* can lead to improve trading relations within the villages. In addition, it increase access to government programs serving village households (Mitchell *et al.* 2004).

Wealth in labor markets

Labor forces influence the condition of *Pekarangan*. In large scale *Pekarangan* households were noted to cultivate commercial plants to be sold at the market, however for small scale *Pekarangan* households only tried to fulfill their subsistence needs. When households achieved higher production, they exchanged or donated leftovers to their neighbors. Some respondents said that *Pekarangan* have been also used for post harvesting activities such as drying and threshing. Funds could be obtained by those who used *Pekarangan* open space for such activities. *Pekarangan* also provided space for storing farming related materials.

The role of woman in Pekarangan

The role of women in *Pekarangan* impacts on the selection of plants and animals, which indirectly impacts the biodiversity inside *Pekarangan*. The majority of women when involved attempted to introduce new species to *Pekarangan*. The cause of this can be explained by the tendency of women in this study to seek to beautify the *Pekarangan* by introducing colorful exotic species. *Pekarangan* also represents the woman's individuality, they tried to show the ability to develop *Pekarangan* into beautiful places and suitable for many kinds of social gatherings.

Designing Pekarangan *for LCS concept*

Of upmost importance in designing *Pekarangan* for LCS is that there a close link between the LCS concept and the sustainability development principles. Through designing *Pekarangan*, it has been confirmed LCS are achievable, yet a major coordinated effort at national level is required in order to achieve this vision. Revitalizing *Pekarangan* as promising cultural landscape is a recommendation for developing countries, particularly those in tropical regions, because advanced technology and knowledge is not required. The combination of simple technology and local knowledge is adequate to revitalize *Pekarangan*. Skea and Nishioka (2008) stated that although advancing the technological frontier will be vital, changes must go to a deeper social level if development goals are to be reconciled.

The schematic design of *Pekarangan* as small scale agroforestry landscape for developing the low carbon societies is shown in Fig. 6. It is recommended that these eight plants categories and five strata are introduced in *Pekarangan* sized less than 400 m². This recommended in order to
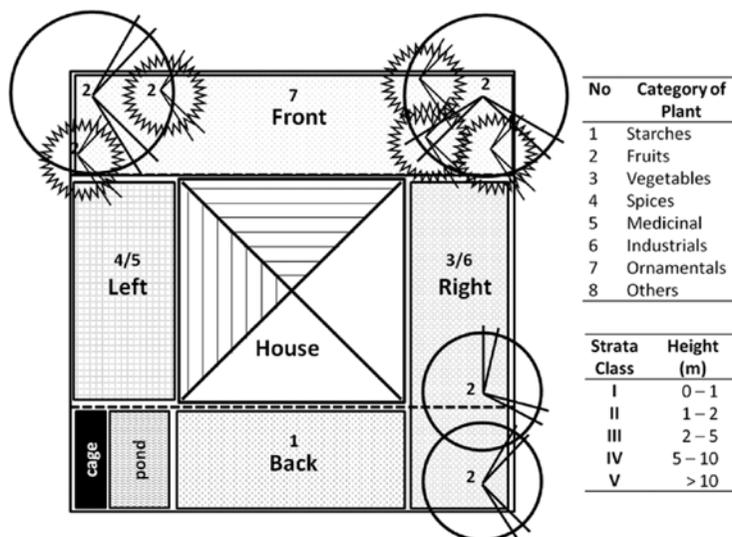

Fig. 6. The schematic design of *Pekarangan* as small scale agroforestry landscape for developing the low carbon societies. The eight categories and five strata of plants should be implemented in *Pekarangan* sized 20 m × 20 m (400 m²).
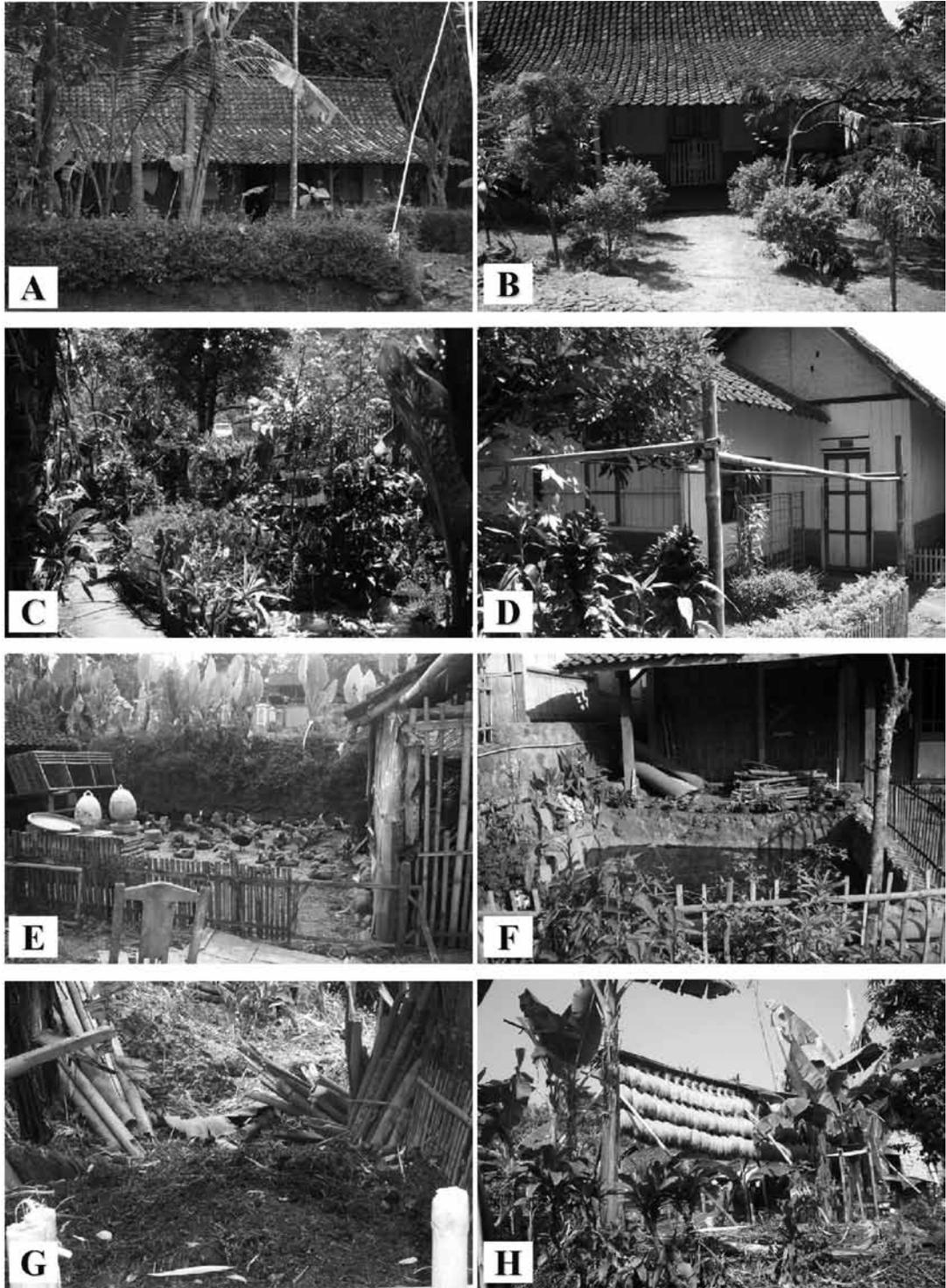
Fig. 7. *Pekarangan* provides many benefits for household and environment, *i.e.*, high carbon density derived from plants and soils (A and B), high biodiversity from various kind of plants (C and D), additional nutrition and income by selling plants and livestock production (E and F), recycling system by composting household waste (G), and also other benefits by utilize the open space for drying agriculture products (H).

develop the ecological, subsistence, commercial, and socio-cultural aspects that will in turn produce numerous many benefits for the households. This schematic design is achievable and convincible for rural communities to make LCS reliable when accompanied through sustainable practices in the near future. Harashina *et al.* (2003) stated that the sustainable managed *Pekarangan* play a significant role in the environment. In addition, landscape management in rural landscape has positive correlation with the sustainability of the ecosystem as an agroforestry practice (Kaswanto *et al.* 2008). Existing *Pekarangan* conditions are shown in Fig. 7.

Perspectives

Pekarangan has high biodiversity and carbon stock even in small plots less than 400 m². In term of biodiversity, *Pekarangan* has high biodiversity, while carbon stock in *Pekarangan* has the potential to account of up to 20% of natural forest. Therefore, it can be concluded that even a small *Pekarangan* could contribute to environment conservation while also increasing the household prosperity. Since *Pekarangan* has such potential, its management in rural communities needs to be encouraged.

Although *Pekarangan* system in the tropics are claimed to sustain the basic needs of communities without environmental deterioration (Schultink 2000), the ecological rationalities of the harmony between humans, *Pekarangan* and the environment could be more clearly understood (Gajaseni & Gajaseni 1999). Designing LCS synergy with stakeholders in rural communities could be further develop environmental friendly activities through passing down local wisdom to future generations. Rural LCS community, particularly those in remote areas are still undisturbed by modern activities, have critical on sustainable system management knowledge. The community should consider suitable agroforestry practices rather than agricultural land practices, utilizing indigenous species heterogeneously (Kaswanto *et al.* 2010).

This research concludes that *Pekarangan* has excellent biodiversity and carbon density, and ability to provide income and nutrition in sustainable system that is compatible with LCS principle. Thus *Pekarangan* is an appropriate agroforestry

for West Java.

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