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Biodiversity and Ecosystem Services: Importance of Cities for post 2010 perspective

Landscape ecology and urban biodiversity in tropical Indonesian cities

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Abstract Indonesia has recently been faced with a number of great problems: poverty, natural disasters such as tsunami, earthquakes, flooding and typhoons, volcanic eruptions, loss of biodiversity, decreasing water quality and quantity, increased pollution, and aesthetic degradation of the landscape. These disturbances have been caused by rapid changes in land use and land cover, deforestation, the application of monoculture farming systems in commercial agriculture, urbanization, industrialization, and other types of infrastructure development. The government, urban communities and companies have promoted some programs to ameliorate the problem of environmental degradation. The government has ratified law no. 26/2007 as a commitment to sustainability; this law ensures that cities are obliged to provide green open spaces covering a minimum of 30% of urbanized areas. Many metropolitan cities have feverishly enacted policies to promote greening programs, such as those applied in Jakarta. However, a new town—Sentul City—has engaged in policies that aim to create a well-designed eco-city with urban greenery and ecological networks. This new policy is supposed to herald a better future for urban quality. It is expected that green spaces will provide environmental services: water resource management, biodiversity conservation, carbon sequestration, and landscape beauty.

Keywords Biodiversity · Carbon sequestration · Ecological network · Ecosystem services · Green space · Indigenous species

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Introduction

Indonesia is a country that comprises an archipelago which stretches from the West to the East. Landscapes, land uses and land cover are changing rapidly in Indonesia in response to a variety of economic, demographic and policy factors, especially after the economic and political crises of 1997–1998. Landscape changes due to changes in agricultural activities toward industrialization, urbanization, and commercial agricultural land have become serious matters of environmental degradation (Arifin et al. 2007), and have resulted in decreased green open spaces, increased water–soil–air pollution, and a loss of agrobiodiversity in the most populated island, Java. Although urbanization is a vital process and one necessary for human development, it has been occurring much faster in developing countries, such as Indonesia, Vietnam, etc., where it has had a negative impact on city dwellers, the environment, and biodiversity (Pham and Nakagoshi 2007).

Urban and suburban parks can play an important role in the conservation of biodiversity. Such parks can have high species richness, especially if they consist of various more-or-less seminatural habitats (Cornelis and Hermy 2004). Park area is the main factor that causes variations in biodiversity, so large parks contribute more to the conservation of biodiversity than small ones. It is well known that the urban landscape depends on the surrounding area, such as suburban, rural, and bioregional landscapes that are seen in ecological watershed units. The uniqueness of urban biodiversity is influenced by the ecological networks among land uses in rural, suburban and urban landscapes. Therefore, ecological landscape management practices at rural, suburban, urban and regional scales should be integrated into planning based on the landscape unit—a landscape with a variety of physiographical characteristics within a watershed, from the upstream to the downstream regions (Arifin et al. 2009a, b).

The integration or segregation of land-use planning and management in agroforestry landscapes is driven by water resources, biodiversity, livelihoods, economic factors, land-use planning, culture, and governance (Fig. 1). Biodiversity conservation is firmly linked to ecosystem services, including GHG emissions. Changes in land use from the natural forest, which has a high biodiversity, to plantations (which mostly employ monoculture farming) have resulted in reduced C stocks. In Indonesia, monoculture systems such as oil palm and coffee plantations have C stocks that are 6–31% lower than the natural forest (Lasco 2002). By promoting land-use systems that have higher C contents than the existing plant community, net gains in C stocks (and hence sequestration) can be realized. The most significant increases in C storage can be achieved by moving from lower-biomass land-use systems (e.g., grasslands, agricultural fallows, and permanent shrublands) to tree-based systems (Roshetko et al. 2007). The objective of this paper is to review scientific publications on landscape ecology and present an overview of recent studies on urban biodiversity in a tropical country, Indonesia. This paper is a response to the continuing deterioration and fragmentation of natural areas, especially in Indonesia. We believe that it is important to conserve biodiversity through urban greening programs and ecological networks in order

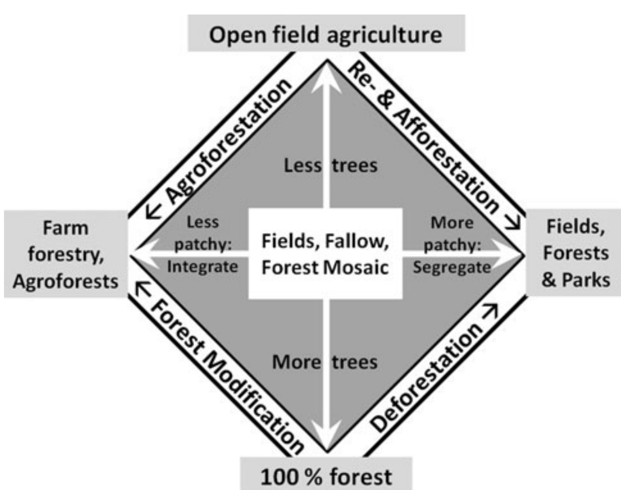

Fig. 1 Integrated and segregated planning and management in a landscape agroforestry system (van Noordwijk 2006)

to mitigate global warming and global climate change. More urban green spaces in improved ecological networks ameliorate urban air temperatures. We define native or exotic species of urban trees and assume that the native species are more resistant, easier to acclimatize, and more adaptable than the exotic ones. Therefore, in this review, we consider how the biodiversity of native species can be enhanced in order to achieve better carbon sequestration in metropolitan cities, new towns, and *pekarangans* (Indonesian home gardens).

Biodiversity overview and environmental services

Indonesian biodiversity

The total terrestrial area of Indonesia is 187.9 million ha, and 137.09 million ha or 70% of the country's total area is forested. It is very important to conserve these forests, such as evergreen mountain forests, evergreen lowland forests, mangrove forests and swamp forests, in order to preserve biodiversity in Indonesia. Based on data from the Indonesian Ministry of Forestry (Departemen Kehutanan 2008), forests in Indonesia encompass conservation forests (23.54 million ha), protected forests (31.60 million ha), and production forests (81.95 ha).

Although it has only 1.3% of the world's terrestrial area, Indonesia has 17% of all of the world's species. Based on the number of flora and fauna bioresources, the United Nations Environment Programme (UNEP) has positioned Indonesia among the ten countries with mega-biodiversity; it is the world's third most mega-diverse country, after Brazil and Congo. It is also among the top five most plant-diverse countries, with more than 38,000 plant species, 55% of which are endemic species (Asis 2010; LIPI 2010). Therefore, Indonesia is one of the world's ecological hotspots. However, the deforestation rate in Indonesia is the highest in the world: forest is disappearing from Indonesia at a rate of 3.8 million ha annually or 7.2 ha per minute. The World Resource Institute (WRI) reported that only 20% of the original 130 million ha of Indonesian forest remains. About 72% of this natural forest has been converted into settlements, industrial areas, agricultural areas, estate plantations, grazing areas, etc. Forty-four percent of this natural habitat has been put to other uses in rural areas. The huge forest fires that occurred in Borneo in the second half of the 1990s have also added their share to the area affected by logging and agriculture (Roos 2003).

Biodiversity and the Green City concept

The rapidly growing world population is exerting great pressure on the lands, waters, and energy resources that are essential to tropical agricultural/rural communities and their bioresources. By 2030, more than 60% of the world population will live in cities, up from almost half now and just a third in 1950. This urban growth poses huge problems, ranging from clean water supplies to trash collection. Already, one of every three urban dwellers lives in a slum. It is therefore important for us to create green cities. Complementing this initiative is the goal of the United Nations to halve poverty by 2015. This goal will not be met unless city planning becomes less haphazard.

Indonesia's population is more than 224 million; it is the world's fourth most populous country after China, India, and the United States of America. There are more than 300 ethnic groups scattered throughout the region, with more than 60% of the population residing on Java, which only accounts for about 7% of the area of Indonesia. In the Java–Bali region, ca. 55% (2008) of the population is already living in cities. It is estimated that in 2025 65% of Indonesia's population (or around 180 million people) will occupy urban areas, primarily in 16 large metropolitan cities. Land use and land cover are changing very quickly in Indonesia. Indonesian cities have experienced a reduction in green open spaces from an average range of 35–10% during the past four decades (1970–2009).

In order to respond to this situation, the central government has enacted law no. 26/2007, in compliance with an overall commitment to sustainability. This law dictates that cities should be obliged to provide enough green open spaces in urbanized areas, as the key element of green infrastructure. Here, "enough" means a minimum proportion of 30% of the urban area (Kirmanto 2009). Such green open spaces in the urban areas include fields with vegetation and trees that can provide economic benefit for the people (Deni 2009). This new policy is supposed to herald a better future for urban quality. Green open spaces have several benefits, such as water and soil preservation, biological diversity conservation, and the minimization of air pollution.

Some green movements such as green and clean programs, eco green city campaigns and tree planting movements at local, regional and national levels are promoted by governments, nongovernmental organizations, companies, as well as community groups (Arifin 2009). These activities will only prove effective for environmental mitigation if environmental degradation and deforestation are stopped. Maintaining biodiversity in urban green spaces can help to sequester CO_2 emissions and produce O_2 (Jo 2002), purify air and water, regulate the microclimate, and reduce noise (Bolund and Hunhammar 1999).

Arifin (2009) stated that "green city" is a term applied to a sustainable city or an ecological city. Activists mark June 5, the date of the first environmental summit in Stockholm in 1972, as UN World Environment Day. The 2005 theme for UN World Environment Day was "greener planning for cities." Many cities have been hit by air pollution, fouled rivers, and poor sanitation. In San Francisco, the main host of the 2005 event, mayors from more than 50 cities, including Shanghai, Kabul, Buenos Aires, Sydney, Phnom Penh, Jakarta, Rome and Istanbul, planned to sign up for a scheme setting new green standards for cities. Cities would be ranked from zero to four stars according to their compliance with a set of 21 targets. All around the world, from Australia to Zimbabwe, activists staged rallies, cleaned up litter, organized poetry competitions or planted trees.

The green city theme is related to urban environmental management and ISO 14001 at the level of a city. The development and implementation of an environmental management system (EMS) at the level of a city is a complex task involving a myriad of tasks and actors. UNEP's International Environmental Technology Centre recommends three steps when extrapolating ISO 14001 to the level of a city (Srinivas 2006): step 1 (promotion of eco-offices): reduction of energy use, reduction of water use, reduction of solid wastes, promotion of recycling, and green procurement; step 2 (promotion of eco-project): use of e-friendly materials, use of e-friendly equipment, acceleration of the use of recycled materials, green public engineering works, the development of green technology, and the promotion of greening; step 3 (green city planning): the setting of green guidelines for public works, the setting of green guidelines for housing, enhancement of public transportation, capacity building, and the application of an environmental management system to the whole city. Recently, a new city in Indonesia—Sentul City in Bogor, West Java—has been promoting policies aimed at creating an eco/green/sustainable city, which is in line with ISO 14001.

Singapore, a developed country, has grown into a vital global city housing a population of more than 4 million residents. Since it is a city state with an area of 682.7 km^2 and a population of 4.17 million in 2002, Singapore ranks as one of the most densely populated cities in the world (Tan 2006). The greenway movement in Singapore began in the late 1980s as a proposal for an island-wide network of green corridors. The Singapore experience provides a model for greenway planning and implementation for other rapidly urbanizing cities in Asia. Singapore's greenways play a vital role as vegetated linkages that provide a protected path and cover for wildlife to move from one habitat to another, thereby increasing biodiversity throughout the island.

Pekarangans (Indonesian home gardens), a traditional biodiversity–low carbon system in Indonesia that establishes green procurement, promotes greening, species diversity and biodiversity, and sets green guidelines, plays an important role in sustaining the ecosystem at present (and will do in the future). Pekarangans are a common smallholder agroforestry system used in Indonesia and throughout the tropics, from the rural to urban areas (Arifin 1998). These species-rich, tree-based systems produce non-wood and wood products for both home use and for selling at markets. High biodiversity is an intrinsic property of these home gardens (Kumar 2006), which presumably favors greater net primary productivity (NPP) and higher C sequestration potential than monospecific production systems. The projections of Roshetko et al. (2002) reveal that, depending on the management options employed, the time-averaged aboveground C stocks of pekarangan systems can vary from 30 to 123 Mg C ha^{-1}. These projected time-averaged aboveground C stocks of pekarangans are substantially higher than those of *Imperata* cassava systems (2.2 Mg C ha^{-1}), which is a vegetation type grown extensively in the Lampung study area. Pekarangan research (Roshetko et al. 2002) showed that, due to their high biomasses, these systems simultaneously offer the potential for carbon storage. While their small sizes limit 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 region's carbon budget while simultaneously enhancing smallholder livelihoods. A field study in Lampung, Indonesia indicates that pekarangans with an average age of 13 years store 35.3 Mg C ha^{-1} in their aboveground biomass, which is on a 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 the use of pekarangan systems and other smallholder tree-based systems was to expand in currently degraded and underutilized lands, such as *Imperata* grasslands, the C sequestration potential would be about 80 Mg C ha^{-1}, although this would vary considerably depending on species composition and management practices. A clear opportunity exists to induce management that leads to higher C stocks at the systems level. However, incentive mechanisms are needed to ensure that smallholders will benefit from selecting management practices that favor higher C stocks.

Payment for environmental services (PES) schemes are being proposed and tested in different contexts as a way to involve the local people in conservation practices (Nurhariyanto et al. 2010). Rapid agrobiodiversity appraisal (RABA) is a diagnostic tool that is designed to measure the perceptions of different stakeholders related to conservation in a target area and to assess the feasibility of a PES mechanism (Kuncoro et al. 2006). A quick biodiversity survey (QBS) of indicator plant animal groups may provide sufficient information necessary for a RABA.

Urban biodiversity and green network studies

Metropolitan Jakarta

The capital city, Jakarta, is a trendsetter for the other metropolitan cities in Indonesia. Any attainment of Jakarta progressiveness would generally be tracked by the other cities. Kim et al. (2006) classified the urban green spaces in Jakarta into four types based on land-use type and function: public park, village green space, nursery, or roadside green space. Based on the research results from 11 urban spaces in Jakarta, a total of 80 woody species were found in the tree layer.

Roadside green spaces consist of linear corridors between sidewalks. *Pterecarpus indica* is the predominant roadside tree species, but we also found some flowering shrubs and palmae in the medians of roads (Fig. 2). Curbs of islands at crossroads were planted with relatively few tree species due to the need for lower plants, such as flowering annual plants and bushes. One hundred nineteen tree species were identified among 25,706 individual trees located in 113 roadside green spaces of five municipalities in Jakarta. Eighty-three tree species were recorded in South Jakarta, 59 species in Central Jakarta, 70 species in West Jakarta, 69 species in North Jakarta, and 69 species in East Jakarta (Nasrullah et al. 2009).

According to the above study, ten tree species were the species most frequently found (78.8% of population) in the roadside green belts: *Swietenea macrophylla*, *Pterocarpus indicus*, *Mimusops elengi*, *Polyalthya fragrans*, *Cerbera manghas*, *Ficus benjamina*, *Diallium indum*, *Ryostonea regia*, *Polyaltya longifolia*, and *Bauhinia purpurea*. Furthermore, nine tree species were found to be the most common in Central Jakarta (*Canarium indicum*, *Tamarindus indica*, *Khaya senegalensis*), West Jakarta (*Ficus lyrata*, *Artocarpus integer*, *Samanea saman*, East Jakarta (*Areca catechu*, *Mangifera indica*), and North Jakarta (*Tamarindus indica*, *Cocos nucifera*). Tree species mobility, dynamics and transportation are faster and easier in the global era. However, for biodiversity conservation programs, indigenous species are better than exotic ones.

Fig. 2 Green spaces at the sides and medians of roads containing trees species in Jakarta (*left–right Pterecarpus indica* is the predominant roadside tree species; a multi-strata of trees, shrubs and bushes; small flowering trees and shrubs; and palmae in the median of the road landscape)

Table 1 The most frequent species of roadside trees in Jakarta and their origins

No.	Species[a]	Origin	Exotic/native
1	*Swietenea macrophylla*	Latin America	Exotic
2	*Pterocarpus indicus* Willd.	Indonesia	Native
3	*Mimusops elengi* L.	Indonesia	Native
4	*Polyalthya fragrans*	India	Exotic
5	*Cerbera manghas* L.	Indonesia	Native
6	*Ficus benjamina*	Indonesia	Native
7	*Diallium indum*	Indonesia	Native
8	*Ryostonia regia*	Latin America	Exotic
9	*Polyaltya longifolia*	India	Exotic
10	*Bauhinia purpurea*	Asia Continental	Exotic
11	*Canarium indicum* L.	Indonesia, New Guinea	Native
12	*Tamarindus indica* L.	Tropical Africa, West Asia	Exotic
13	*Khaya senegalensis*	Africa	Exotic
14	*Ficus lyrata* Wareb.	Africa	Exotic
15	*Artocarpus integer* (Thunb.) Merr.	Thailand, Malaysia, Indonesia	Native
16	*Samanea saman* (Jacq.) Merr.	Tropical America	Exotic
17	*Cocos nucifera* L.	Pantropical	Native
18	*Areca catechu* L.	India–Indonesia	Native
19	*Mangifera indica* L.	India–Burma	Exotic

[a] Nasrullah et al. (2009)

Therefore, we identified the origins of these species (Table 1). Among 19 species that were recognizable, only nine (47.4%) were native species of Indonesia. The use of native or indigenous species in urban greening programs is encouraged in order to maintain species conservation ex situ.

As a comparison, Pham and Nakagoshi (2008) performed research in the downtown area of the ancient city of Hanoi, Vietnam. There are a variety of higher plant species in Hanoi: 644 species belonging to 247 genera and 157 families. In particular, there are 13 valuable and rare plant species and 150 non-native species belonging to 78 genera and 54 families.

Bogor City and the Botanic Garden

Based on regional planning regulations, the Bogor Municipality will be developed as a growing center of the VII Region (the Bogor Regency context). This region supported a population of 1.5 million in 2009 (the Jakarta–Bogor–Depok–Tangerang–Bekasi region context); it acts as a buffer zone for Jakarta and a recreational resort for Jakarta's citizens (the Indonesian context); and it provides a center for International Conferences (the international context). Therefore, it is proposed that Bogor should become a trading and services city, an industrial city, a settlement resorts city, a scientific tourism city, and an educational city.

Bogor exhibits diverse land utilization: irrigated rice fields (100.6 ha), dry fields (147.97 ha), plantation estates (30.96 ha), forests (15.0 ha), lakes and fish ponds (11.47 ha), pekarangan/home gardens (86.83 ha), settlements (621.73 ha), and other land uses (CBD, recreational resorts, industrial estates and cemeteries: 170.67 ha). Agricultural biodiversity is mostly found in urban agricultural areas such as farmlands for rice (*Oryza sativa* L.), corn (*Zea mais* L.), soybean (*Soya max* Piper), cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomea batatas* Lamk), groundnuts (*Arachis hypogaea* L.), yams (*Colocasia esculentum* Schott), tomatoes (*Lycopersicum esculentum* Mill.), long beans [*Vigna sinensis* (L.) Savi ex Hassk], and red chilies (*Capsicum annuum* L. forma typica).

Some research, especially that related to pekarangan (Indonesian home gardens), which has focused on biodiversity in urbanized vegetational structures, has been held in the landscape ecological unit of the Ciliwung watershed (Fig. 3) and the Cianjur watershed, which covers the Bogor–Puncak–Cianjur (BOPUNJUR) region (Arifin 2004; Arifin et al. 2001). We elucidated the species richness of pekarangan from the upstream to the downstream regions of each watershed. Furthermore, we analyzed plant species number among the most rural, the intermediate, and the most urban pekarangan. Pekarangans are generally regarded as being very complex, species-rich agroforestry systems that have been managed in a sustainable manner over decades or even centuries. 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 structures, serve as an important habitat for wild flora and fauna. Pekarangans fulfill not only important ecological functions but also many social and cultural functions (Kehlenbeck et al. 2007).

Plant species in the pekarangan were divided into ornamental plant species and non-ornamental plant species. The ratio of ornamental to non-ornamental species and the ratio of the number of individuals of each were calculated for each site (Arifin 1998). In the Bogor–Puncak–Cianjur (BOPUNJUR) region, changes in pekarangan plant diversity were studied along an urban–rural continuum, as well as along an elevation gradient. To investigate the effects of urbanization, the vegetative structures and compositions of 115 pekarangans in six villages were studied (Arifin et al. 1998). The six villages differed in their urbanization levels: one was a rural village, three were characterized as being intermediately urbanized, and two were urban villages. In each pekarangan, both ornamental and crop plants were inventoried. Pekarangan size ranged from 30 to 4,000 m^2; the mean size was 270 m^2. A total of 440 plant species were grown in the 115 pekarangans combined, with about half of these species being ornamentals. The number of species in a pekarangan varied from place to place according to the local physical circumstances, the ecological characteristics of the plants, animal species, socio-economic factors, and cultural factors (Abdoellah 1991).

Arifin (1998) and Arifin et al. (1998) showed that the number of plant species present varied widely among the

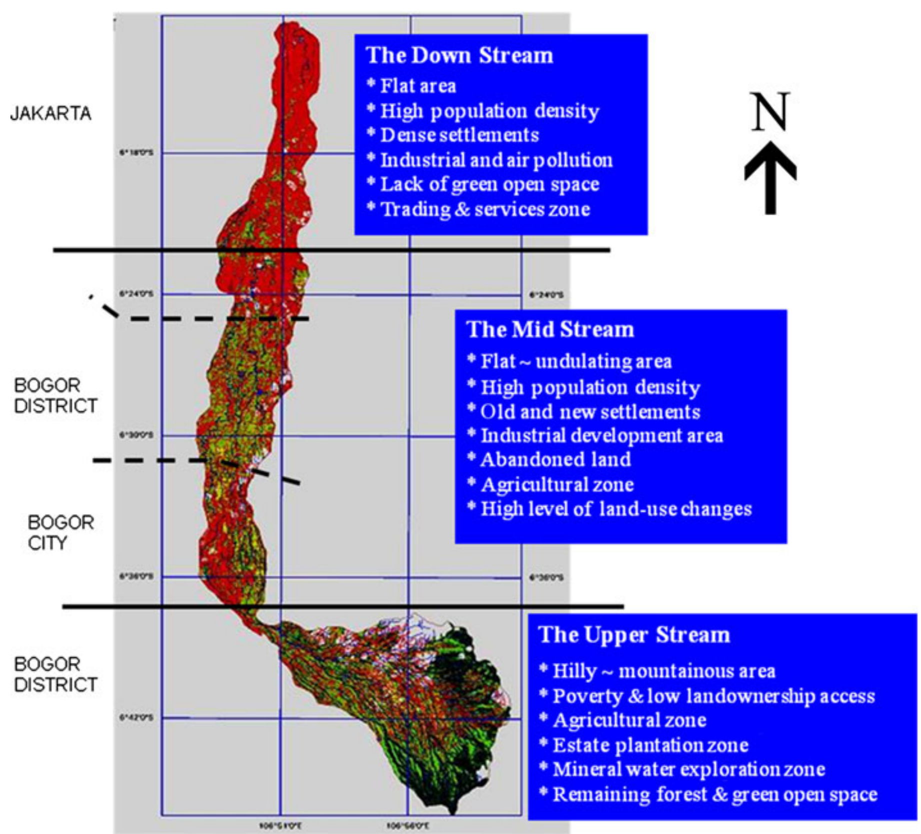

Fig. 3 Bogor land use in the unit of the midstream of the Ciliwung watershed (image from the Urban Forest and Spatial Analysis Lab., Faculty of Forestry, IPB)

115 pekarangans studied (Table 2). Mean species number per pekarangan did not differ markedly between the rural, intermediate and urban pekarangans. However, the mean number of non-ornamental plant species per pekarangan was markedly higher in rural than in urban gardens. The proportion of ornamental species among all plant species increased with the level of urbanization (40% in rural; 70% in urban pekarangans). Pekarangan size decreased continuously from rural to urban sites.

Bogor is surrounded by four mountains and tropical rainforests: Mt. Salak, Mt. Gede, Mt. Pangrango, and Mt. Pancar (Fig. 4). Some urban forests are available in or close to the city, such as the Forest Research and Development Agency (FORDA) forest, the Bogor Agricultural University Campus forest, the Cibinong forest, the Indonesian Institute of Science (LIPI) Ecopark, and the urban greenery of Sentul City.

The Bogor Botanic Gardens (BBG), with an area of 97 ha, contributes a large green open space to the center of Bogor City. It was established in 1817 by Casper Georg Carl Reinwardt. BBG is an ex situ flora collection, with a total of 2,972 species from 55 families. It provides shelter and habitat for wildlife such as birds, small mammals, and insects. There are more than 50 well-known species of birds that live in the BBG (Levelink et al. 1997), such as the kepodang (*Oriolus chinensis*), walik kembang (*Ptilinopus melanospila*), kutilang (*Pycnonotus aurigaster*), kucica (*Copsychus saularis*), and cinenen kelabu (*Orthotomus sepium*). Others include the cinenen biasa (*Orthotomus sutorius*), kowak (*Nycticorax nycticorax*), kuntul perak (*Egretta internedia*), kuntul perak kecil (*Egretta garzetta*), and burung udang/cekakak (*Halcyon chloris*). Good ecological connectivity among the BBG and other green open spaces such as urban forests, parks, mixed gardens and pekarangan occur in Bogor as well as in its vicinity. Habitat diversity in BBG—i.e., riparian zones, ponds, lawns, dense bushlands and high trees—is very important for the sustainability of birds and other wildlife.

Table 2 Mean sizes and mean diversity characteristics of useful and ornamental plant species (ranges in parentheses) of 115 home gardens studied in six villages with different urbanization levels in Cianjur and Bogor, West Java, in 1995

Village urbanization level	HG size (m^2)	Mean plant spp. no. per HG (range)	No. of ornamental spp./HG	No. of total plant individuals per 100 m^2	No. of ornamental individuals/100 m^2
Rural ($N = 30$)	530	36 (6–82)	14	63	29
Intermediate 1 ($N = 21$)	380	49 (32–79)	25	72	40
Intermediate 2 ($N = 10$)	190	32 (7–85)	14	107	59
Intermediate 3 ($N = 20$)	130	20 (2–53)	11	58	34
Urban 1 ($N = 10$)	70	34 (18–63)	24	280	233
Urban 2 ($N = 24$)	90	37 (16–78)	26	240	201

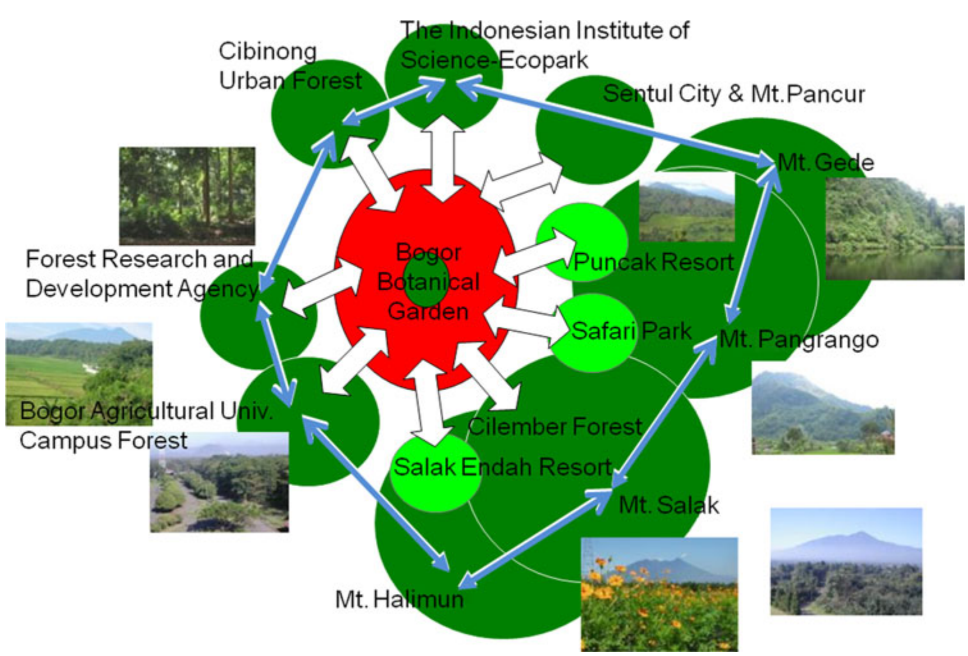

Fig. 4 Ecological network in Bogor City and its vicinity

Much of the wildlife of the region—avian, insect, mammal, reptile, amphibian, and fish species—migrate from one habitat to the other through the green corridors in Bogor (i.e., river greenways, highway greenbelts, green railways among the mosaic landscapes). From the perspectives of landscape ecology (landscape structure, function, and dynamics) and the realization of functional space structure in urban areas, in many cases greenways provide a culturally and aesthetically pleasing network of green spaces, and represent areas where the urban population can mentally unwind (i.e., relax) (Tashiro 2009).

Sentul City

Sentul City is a township development with an area of ca. 3,000 ha that is located 5 km from the city of Bogor. This city was established in 1994. It is 300–600 m above sea level and located on a hilly area surrounded by mountains, forests and waterfalls. The average daily air temperature is a minimum of 22°C and a maximum of 30°C. This city has a green area that is 65% of its total area (Utama 2009).

In order to bring renewal to Sentul City, the "City of Innovation" has defined four pillars of development that should enable the growth of Sentul City to be more comprehensive and rapid, in accordance with today's demands as well those of the future. One of these pillars is an eco-city concept, which is reflected in a plant biodiversity approach to gardens along 6.2 km of the main road (Fig. 5). This diversity of plant species can be seen in each settlement gate, traffic island, roadside and median landscape. With an area of 27 ha, there are 6,518 trees comprising 49 species. This does not include small trees, shrubs, bushes, herbs, lianas and grasses. Indonesia's World Record Museum (MURI) awarded Sentul City's street garden with the title of the "Largest Street Garden for Township Development" in November 2008. In August 2007, in collaboration with the Indonesia Tree Planting Foundation (YTPI), the Go-Green Program was launched with the planting of 15,000 trees. This shows the level of active participation associated with increasing the quality of the area in Sentul City (Utama 2009).

To strengthen the Eco-City and Education City pillars, on July 21, 2009, Sentul City signed an MOU with Bogor Agricultural University (IPB) to cooperate in four fields: the development of the eco-city concept; the development of a green implementation for buildings; the development of environment management methods; and the development of the IPB Education Facility in Sentul City. The first step was to conduct an inventory of the urban biodiversity by land-use units. Various land uses such as the Central Business District, settlement and housing complexes, recreation resorts, parks, golf courses, forest and catchment areas were identified. We found high biodiversity, with 76 species of trees present, and a total number of 32,876 individual trees in green open spaces (29.66 ha). However, only 68 of these species were identified (Table 3). Most of them were exotic species; there were only 27 native Indonesian species (39.7% of all species).

According to the Environmental Impact Assessment in 1994, Sentul City was considered a rubber plantation estate. It was found to contain 7 amphibian species, 23 avian species, 6 mammalian species, 7 reptilian species, and 7 fish species. More than 15 years later, Sentul City now has greater diversity in places and varied corridors of land use. It is thought that biodiversity has risen significantly from its previous status of a rubber plantation. Therefore, we need deeper landscape ecological research in order to elucidate biodiversity structure, function, and related dynamics.

Conclusion

There is no doubt that the importance of biodiversity in urban areas should be kept in mind. So why not start to re-establish biodiversity in the city in the literal sense (Rekittke 2009)? The awareness of stakeholders (i.e., the government, communities and companies) is very important if we are to gain the same perception of the eco-green concept and the implementation of eco-green projects directly in the environmental field. Money, time and power are all expended in order to preserve biodiversity by

Fig. 5 Plant biodiversity in the gardens along 6.2 km of the main road of Sentul City (*left–right*: diversity of plant species in a settlement gate; multi-strata of plants in the main traffic island; each traffic island in each settlement cluster contains a sculpture that reflects the diversity of animal species present in the cluster; evergreen at the roadside and the median)

Table 3 List of tree species found in Sentul City and their origins

No.	Species	Origin	Exotic/native
1	*Acacia mangium*	Maluku Indonesia	Native
2	*Alstonnia scholaris*	Indonesia	Native
3	*Araucaria heterophylla*	New Zealand	Exotic
4	*Areca cathecu*	Malaysia, Philippines	Exotic
5	*Artocarpus altilis*	Pacific Islands	Exotic
6	*Barringtonia asiatica*	Indian Ocean	Exotic
7	*Bauhinia blakeana*	Continental Asia	Exotic
8	*Bismarckia nobilis*	Madagascar	Exotic
9	*Brassaia actinophyla*	Australia	Exotic
10	*Calliandra calothyrsus*	Central America, Mexico	Exotic
11	*Callistemon citrinus*	Australia	Exotic
12	*Cassia fistula*	Indonesia	Native
13	*Casuarina sumatrana*	Indonesia	Native
14	*Cerbera odollam*	Indonesia	Native
15	*Chrysalidocarpus lutescens*	Madagascar	Exotic
16	*Cinnamomum burmanni*	Indonesia	Native
17	*Cocos nucifera*	Pantropical	Native
18	*Cryota mitis*	Indonesia	Native
19	*Cymbopogon nardus*	Sri Lanka	Exotic
20	*Cyrtostachys lakka*	Indonesia	Native
21	*Delonix regia*	Madagascar	Exotic
22	*Dillenia obovata*	Indonesia	Native
23	*Diospyros philippensis*	Philippines	Exotic
24	*Elaeis guineensis*	West Africa	Exotic
25	*Elaeocarpus grandiflorus*	Indonesia	Native
26	*Erythrina crista-galli*	South America	Exotic
27	*Ficus benjamina*	Indonesia	Native
28	*Ficus elastica*	Indonesia	Native
29	*Ficus lyrata*	Africa	Exotic
30	*Filicium decipiens*	Sri Lanka	Exotic
31	*Gmelina arborea*	India, Burma, Sri Lanka	Exotic
32	*Gnetum gnemon*	Indonesia	Native
33	*Hevea brasillensis*	Brazil	Exotic
34	*Hibiscus tiliacecus*	Indonesia	Native
35	*Hopea odorata*	Myanmar	Exotic
36	*Lagerstroemia indica*	China and Japan	Exotic
37	*Leucaena leucocephala*	Tropical America	Exotic
38	*Livistonia decipiens*	Australia	Exotic
39	*Livistonia rotundifolia*	South East Asia	Exotic
40	*Manilkara kauki*	Indonesia	Native
41	*Maniltoa schefferi*	Pacific Islands	Exotic
42	*Mascarena lagenicaulis*	Mauritius	Exotic
43	*Melia azedarach*	Indonesia	Native
44	*Michelia champaca*	India	Exotic
45	*Mimusops elengi*	Indonesia	Native
46	*Morinda citrifolia*	Indonesia	Native
47	*Pandanus tectorius*	Malaysia, Eastern Australia, Pacific Islands	Exotic
48	*Pandanus utilis*	Madagascar	Exotic

Table 3 continued

No.	Species	Origin	Exotic/native
49	*Paraserianthes falcataria*	Indonesia, Maluku and Papua	Native
50	*Phoenix roebelinii*	Middle East	Exotic
51	*Pinus merkusii*	Indonesia	Native
52	*Pisonia alba*	Indonesia	Native
53	*Plumeria rubra*	Tropical America	Exotic
54	*Podocarpus macrophyllus*	New Zealand	Exotic
55	*Polyalthea fragrans*	Tropical and subtropical	Exotic
56	*Polyalthea longifolia*	India	Exotic
57	*Pometia pinnata*	Indonesia	Native
58	*Pterocarpus indicus*	Indonesia	Native
59	*Ravenala madagascariensis*	Madagascar	Exotic
60	*Roystonia regia*	Cuba	Exotic
61	*Samanea saman*	Tropical America	Exotic
62	*Sandoricum koetjape*	Indonesia	Native
63	*Spathodea campanulata*	Africa	Exotic
64	*Swietenia mahagoni*	Tropical America	Exotic
65	*Syzygium polyanthum*	Indonesia	Native
66	*Tamarindus indica*	n.a.	Native
67	*Tectona grandis*	Indonesia	Native
67	*Uraria lagopodioides*	Indonesia	Native

27 species are native to Indonesia

improving environmental quality. The utilization of indigenous species for greening programs has been suggested, due to the propensity for native species to have high rates of successful adaptation, low maintenance due to their high suitability to local biophysical conditions, and their preservation of genetic resources. It would not perturb anyone living in the city from ecological, economic and sociocultural perspectives if native animals and plants were to recolonize the city. Finally, we reached the following conclusions:

1. The use of native or indigenous species is encouraged in urban greening programs in order to maintain ex situ species conservation. Native species are inherently well suited to their original habitat.
2. Urban open space is a potential landscape for biodiversity conservation when supported by a good ecological network.
3. Good green space management should promote tropical evergreen design; it contributes to reducing emissions.
4. In aggregate, pekarangan agroforestry systems can contribute significantly to a region's carbon budget while simultaneously enhancing the livelihoods of rural and urban communities.

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