Quantitative and qualitative characteristics of greenery in suburban residential districts of Metro Manila

Yuji HARA
Project Assistant Professor, TIGS The University of Tokyo
Taku OGASAWARA
System Engineer, IBM Japan Systems Engineering Co., Ltd.
Armando M. PALIJON
Professor, College of Forestry and Natural Resources University of the Philippines Los Baños
Kazuhiko TAKEUCHI
Professor, Department of Ecosystem Studies The University of Tokyo

This case study was conducted to better understand the present situation of urban greenery in Marikina City, in the suburbs of metropolitan Manila, a typical large Asian city. A vegetation survey was conducted in residential districts of Marikina City, and the quantitative and qualitative characteristics of trees were analyzed. Lot size had some influence on the quantity of greenery in residential lots. In smaller lots, however, quantity did not increase in proportion to lot size. It appears, then, that the land-use controls for individual lots did not function effectively. Quantitative differences of greenery were related to qualitative differences, depending on the year or period of development of the residential area. In the newly developed residential lots, the greenery is comprised mostly of ornamental trees. Under the present circumstances, there is no assurance of sustaining the desired quantity of greenery in smaller residential lots. From these results, we proposed that regulations on lot size/coverage and promotion of tree planting involving local residents are needed to sustain urban greenery in residential districts.

Keywords: Urban greenery, Residential lots, Land-use change, Cadastral map, Tree survey

1. Introduction

The rapid urbanization of Southeast Asian cities has caused many environmental problems not only because of inadequate infrastructure, but also from a decrease in urban greenery. Urban greenery has diverse ecological functions in sustaining the urban environment, including abatement of air and noise pollution (Totsuka and Miyake, 1991), mitigation of the "heat island" effect (Fujisaki and Handa, 1994; Nakayama et al., 1990), and control of flooding (Terauchi, 2000). Takeuchi (2002) emphasized that mitigating adverse urban climate is one of the most important roles of urban greenery, particularly in Southeast Asian mega-cities with their year-round high temperatures and humidity. Therefore, to address diverse potential environmental problems, urban planning for Southeast Asian mega-cities must include the development and implementation of programs that conserve and create urban greenery.

To develop an appropriate urban green management plan, we have to understand the dynamics of urban greenery in Southeast Asian cities. Previous studies have assessed the distribution and transition of green space on a macro (metropolitan) scale by using satellite images (Hoyano et al., 2002; Wilson et al., 2003). However, few case studies address dynamics of urban greenery, including both qualitative and quantitative aspects, on micro (cadastral) scales. In addition to data on land use and landholding, detailed information on cadastral-scale urban green dynamics is vital for creating and implementing practical urban green management programs in the urban “fringe” areas of Southeast Asian cities. This is particularly the case where residential land uses under private landholding are dominant, in the context of land tenure history (Evers, 1984).

We undertook a detailed examination of the dynamics of urban greenery in Marikina City, a typical suburban residential district of Metro Manila, Philippines. We focused on the cadastral scale and conducted per-lot field tree surveys in residential districts. Our study provides basic and crucial information for practical urban green management in Marikina City, where private residential lots predominate, due to the absence of sufficient public urban green space. The results of this case study can be applied to other Southeast Asian cities with similar historical and geographical contexts.

2. Study area

Marikina City is one of the 17 cities and municipalities of Metro Manila (Fig. 1). This city is in a valley bounded by mountain ranges and crossed by a river. The total land area is approximately 2150 hectares, which accounts for about 3.44% of the total land area of Metro Manila. At present, the city comprises 14 barangays (a barangay is the smallest administrative unit of a municipality or city). According to the report of the City Planning and Development Office (2000), the population of Marikina City was only 40,500 in 1960 and began to increase dramatically after the 1960s. In 2000, there were 437,000 residents in Marikina City.

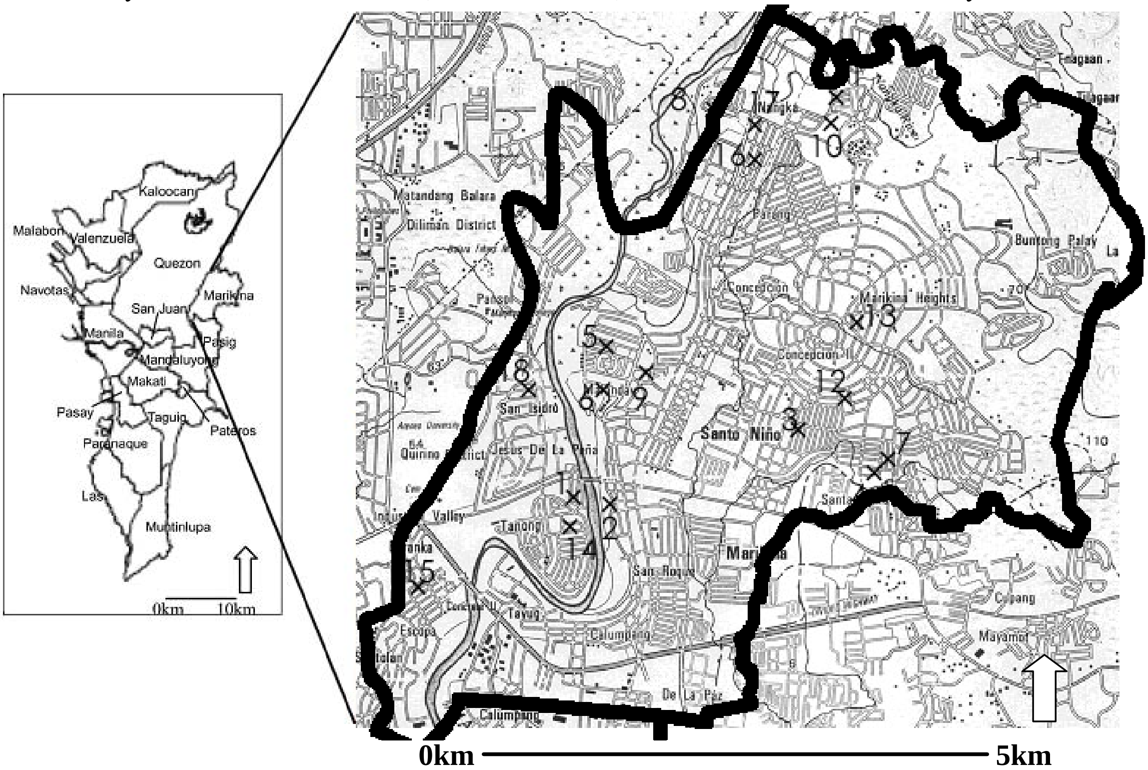

Figure 1. Location of Marikina City. Numbers (1-18) in the right map indicate the location of our vegetation survey sites.

3. Methodology

3-1. Selection of tree survey sites

We obtained all the cadastral maps that were available for Marikina City's barangays from the City Planning office (8 of 14 barangays), and digitized them in vector format using the geographic information system (GIS) software TNTmips version 6.6 (MicroImages Inc., Lincoln, NE, USA). Based on this digital cadastral map, we selected tree survey sites according to the following conditions: a) The main land use of a potential survey site must be residential use; b) The digital cadastral map must include the entire potential site; and c) The area of the candidate site must be approximately 1 hectare (calculated using TNTmips), with a uniform lot pattern. As a result we determined a total of 18 survey sites and 481 lots (Fig.1).

3-2. Tree survey methods

For each survey site, we recorded all the trees ≥3 m in height. In accordance with previous studies by Jim (1993) and Moriwake et al. (2002) about trees in cities, we noted and recorded data for the following parameters and conditions: a) land use of the lot: Residential use, Vacant land, Public open space, or Road (Fig. 2); b) name or species of each tree; c) height of each tree; d) diameter at breadth height (DBH) of each tree; e) health condition of each tree as defined in Table 1; f) the year each sample site (residential subdivision) was developed (this information was gathered during interviews of residents); and g) whether the sample site is an exclusive habitation system (EHS; Nishioka, 1997). The tree survey was conducted in August 2003.

"Residential use"

"Vacant land"

"Public open space"

"Road"

Figure 2. Land-use categories in our vegetation survey.

Table 1. Health condition of trees.

Healthy	Trees showing luxuriant growth, no defect (e.g., dead, split, broken, and unpruned branches or tops or cavities), free from diseases and pests, and no symptoms or signs of nutrient deficiency.
Fairly healthy	Trees that are still growing vigorous growth but have some defects (like dead, dying, split, broken, or damaged branches or tops or cavities), infected with diseases or pests but can easily be corrected through appropriate arboricultural practices (e.g., pruning; wound and cavity treatment; and nutrition, pest, and disease control).
Poor	Those trees having poor growth with severe defects or that are heavily diseased or infested. The repair needed to restore the normal growth of these trees can be very difficult.

3-3. Methods of data analysis

3-3-1. Per land use analysis

We first analyzed the quantitative and qualitative characteristics of the trees in each land-use category. We adopted biomass as a quantitative indicator of the amount of trees. According to Nagumo and Minowa (1990), the shape of a trunk can be assumed to be that of a cone. The biomass of each tree was calculated using the formula:

$BM = 1/3 \times 3.14 \times (DBH/200)^2 \times H$,

where BM is the biomass in m^3, DBH is the diameter at breast height in cm, and H is the height of the tree in m. We then divided the total biomass of trees in each land-use category by the area of each land-use type to obtain the biomass per unit area.

We classified trees qualitatively according to their main function and health condition. Trees were categorized into three groups, according to function: Fruit tree, Ornamental tree, or Shade tree. Health condition categories included Healthy, Fairly healthy, and Poor (Table 1). We calculated the proportion of trees in each function category and each health condition, for each land use.

3-3-2. Per lot size analysis

Because residential use was one of the major land uses of Marikina City, we analyzed the relationships between quantitative and qualitative characteristics of trees and lot size in detail. To systematize the survey, residential lot sizes were allocated into 5 categories: 0 to 100 m^2, 100 to 200 m^2, 200 to 300 m^2, 300 to 400 m^2, and >400 m^2. Biomass was again adopted as a quantitative indicator of trees. Tree biomass was calculated for each lot and then divided by the lot area, to obtain the biomass per unit area. The difference in the amount of biomass per unit area between the five lot size categories was tested using the Kruskal–Wallis test; for multiple comparison between these categories we used the Mann–Whitney *U* test with Bonferroni's correction. SPSS ver. 10.0 (SPSS Inc., Chicago, IL, USA) was used to perform the statistical analyses.

We again adopted the main function of a tree and its health condition as qualitative indicators of trees. To understand in detail the structure and qualitative characteristics of trees in residential areas of Marikina City, we used canopy height to calculate the biomass of the fruit, ornamental, and shade trees present in each lot size category. Trees were grouped into four canopy storey categories according to their height: 3 to 6 m, 6 to 9 m, 9 to 12 m, or 12 to 15 m. We then calculated the proportion of trees in each health condition, canopy story and lot size category.

4. Results

Figure 1 includes the locations of the selected tree survey sites. Basic data of all survey sites are shown in Table 2.

Table 2. Basic data for all survey sites. “EHS” means exclusive habitation system.

Site	Area (ha)	No. of lots	No. of species	No. of trees	Developed period	EHS
1	0.54	28	21	35	Spanish time	no
2	0.58	29	44	133	1950s	no
3	1.26	52	43	140	1965	no
4	0.73	31	29	72	First half of 1960s	no
5	1.14	35	41	128	Second half of 1950s	no
6	1.43	47	35	112	1970s	no
7	0.93	22	43	115	1960s	no
8	1.15	32	41	169	1980s	yes
9	1.23	42	39	97	1960s	no
10	1.37	35	38	158	1960s	no
11	0.69	18	30	103	1970s	no
12	1.03	14	42	151	1979	no
13	1.20	16	67	302	1950s	no
14	1.48	24	55	161	1970s	yes
15	1.27	19	72	312	1970s	yes
16	1.95	18	43	132	1980s	no
17	1.99	8	44	144	1970s	no
18	0.91	11	40	205	1980	yes

4-1. Results of analyses for each land use

The amount of biomass (m^3) per unit area (ha) in each land use is shown in Table 3. Notably, this measure is high for both Public open space and Vacant land but low for the Residential use.

Figure 3 shows the ratio of trees in each land-use category in terms of their main function. Fruit and ornamental trees both account for a significant percentage of the total in Residential use, while fruit trees predominate in Vacant land. Fruit, ornamental, and shade trees are equally represented in the Public open space category. Ornamental and shade trees both account for large percentages in the Road.

Figure 4 shows the ratio of trees in each land use in terms of their health condition. The health condition of trees was worst in Vacant land.

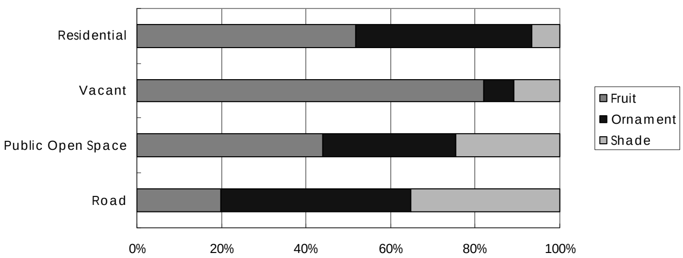

Figure 3. Ratio of trees divided by the main function in each land use.

Table 3. Amount of biomass per unit area for each land use.

Land use	Amount of biomass (m^3/ha)
Residential use	8.3
Vacant land	17.6
Public open space	20.2
Road	12.3

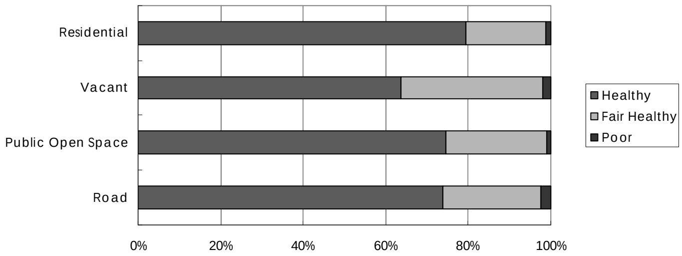

Figure 4. Ratio of trees divided by the health condition in each land use.

Table 4. Characteristics of residential lot-size groups. Lowercase letters indicate groups with similar ranges of biomass according to multiple comparison using the Mann–Whitney's *U* test with Bonferroni's correction ($P < 0.05$).

Group	No. of lots	Mean biomass ($10^{-4}m^3/m^2$)	Multiple comparison*
0–100 m^2	32	15.6	a
100–200 m^2	112	19.1	a, b
200–300 m^2	179	22.2	b
300–400 m^2	47	21.8	a, b
>400 m^2	69	29.3	c

4-2. Results of analyses of residential lot size

Of the 481 lots surveyed, 439 were residential lots. The characteristics of lots of various sizes, grouped in 100-m^2 intervals, were analyzed; in particular, biomass per unit area differed significantly (Kruskal–Wallis test, $P < 0.01$) between the five residential lot-size groups (Table 4). The multiple comparison analysis (Mann–Whitney *U* test; Table 4) revealed significantly increased biomass per unit area for lots of 300 to 400 m^2 and >400 m^2, compared with that of the two adjacent lot size groups.

Through our field survey, we assumed that the year or period during which the lot was developed may have caused the difference in the amount of greenery, particularly for residential lots of the same size. To clarify this potential effect, we first identified the old residential lots, using a 1955 map of Marikina City (1:50,000, prepared by U.S. Army). We included results of resident interviews regarding the year or period of development of each sample site (Table 2). Because there were few large, old residential lots, the size groups of 300 to 400 m^2 and >400 m^2 were excluded from the analysis. We tested the difference in the amount of biomass per unit area between old and new residential lots in the three smaller groups using the Mann–Whitney *U* test, and found a significant ($P < 0.05$) difference for the lot-size group of 200 to 300 m^2. Thus the amount of biomass per unit area is higher in old residential lots than in new ones.

The biomass of fruit trees, ornamental trees, and shade trees in each canopy story of every residential lot having at least one tree in each lot-size group was compared (Fig. 5). Whereas the proportion of fruit trees is almost equal to that of ornamental trees (Fig. 3), biomass is mostly composed of fruit trees (Fig. 5). Two additional features can be noted. The first is the rapid increase of biomass of higher canopy trees in residential lots larger than 300 m^2. The second is that the biomass of ornamental trees increases in residential lots larger than 300 m^2 and is well distributed in lower as well as higher canopy stories.

We conducted a similar analysis to understand the differences between old and new residential lots in the 200 to 300 m^2 lot-size group (Fig. 6). Although fruit trees account for most of the biomass in both old and new residential lots, fruit and shade trees predominate in old residential lots, whereas fruit and ornamental trees are typical in new residential lots.

The proportion of trees in each lot-size group was calculated according to health condition (Fig. 7). Overall, larger lots are associated with healthier trees; however, few trees exhibited poor health, regardless of lot size.

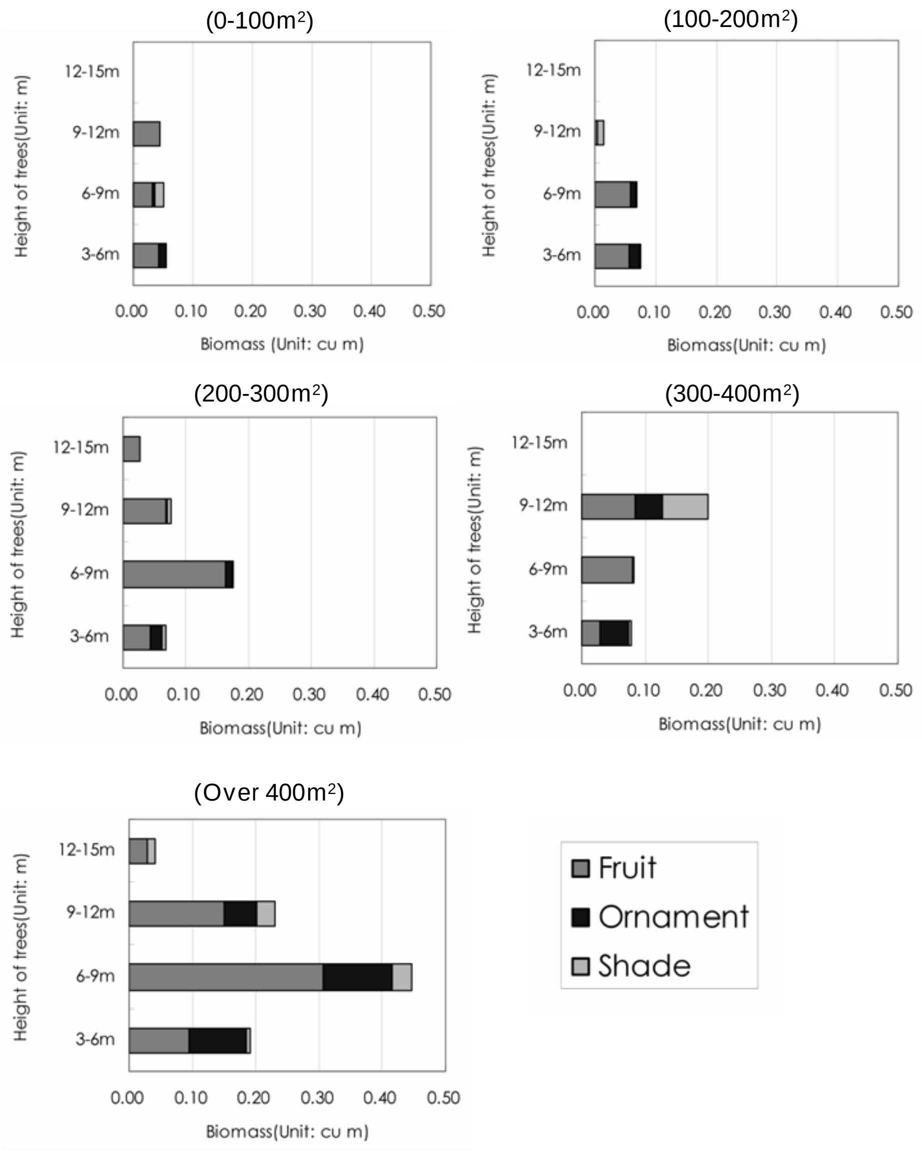

Figure 5. Biomass of each story per residential lot.

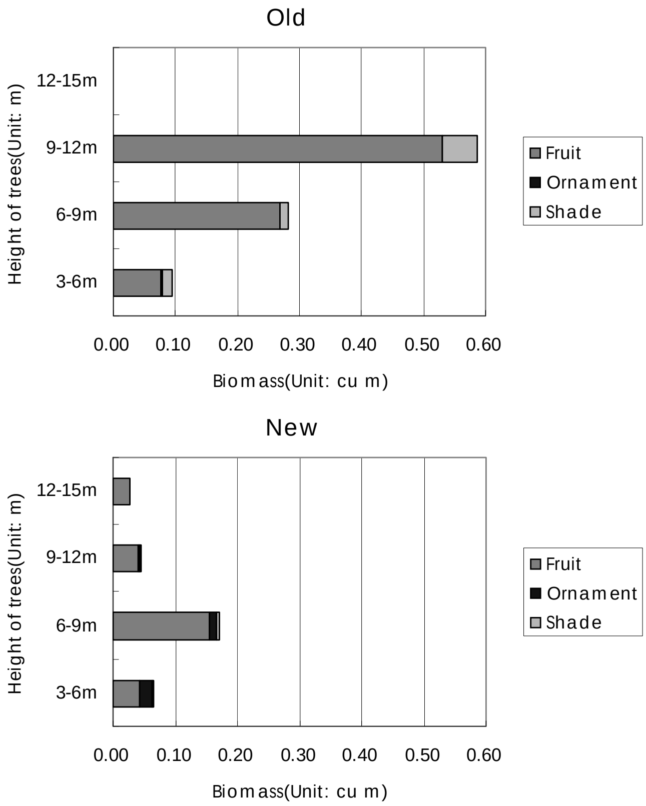

Figure 6. Biomass of each story in old/new residential lot with 200-300m^2.

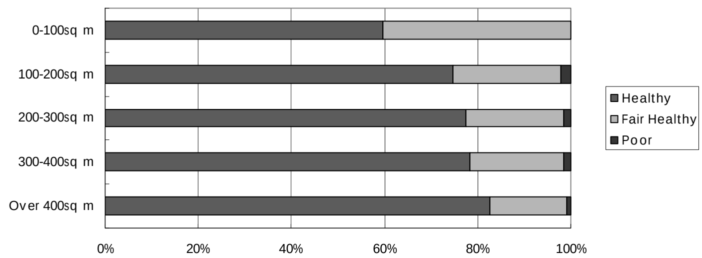

Figure 7. Ratio of trees divided by the health condition in each group by residential lot size.

5. Discussion

Our results show that the characteristics of vegetation in each land-use category differ quantitatively and qualitatively. In each land-use category, trees appear to be chosen according to function. For example, for the Road land use, the proportion of shade trees is higher than that of fruit trees. This difference arises because providing shade for pedestrians is necessary, whereas in this land use, fruit trees are hazards. This is particularly the case during the fruiting season, because people attempt to collect the fruit by climbing or throwing stones or pieces of wood, in the process endangering lives and property. The situation is quite similar in the Public open space category. In Residential land use, the proportion of ornamental trees is higher because residents want to decorate their houses with attractive plants. In Vacant land, fruit trees account for a large percentage of the trees because residents of adjacent lots plant banana (*Musa sp.*) and malunggay (*Moringa oleifera*), which are maintained as sources of food until development in Vacant lot is introduced.

In residential lots, lot size has a great effect on the greenery within the lot. The amount of biomass per unit area is significantly increased in residential lots >400 m^2. Many of these lots are in Village land, an exclusive residential district that is surrounded by walls or fences. This association means that the greenery of residential lots is not sustained except in Village lots. The system of urban planning in the Philippines has some bearing on this situation. Kidokoro (1994) stated that residential zones defined by zoning ordinances of Metro Manila has made lots of low, medium, and high greenery density distinct from each other. However, such zoning fails to control for the size of each individual lot, such as by legislating the proportion of land area to be planted with greenery. As a result, the coverage of residential lots by buildings tends to be high, leaving very little space for greenery.

In addition, lot size influences the height of canopy trees. Tall trees are very important for improving urban environments (Takeuchi, 2002). For residential lots <300 m^2, it is necessary to introduce plans that facilitate growing taller trees. In addition, lot size has a remarkable influence on qualitative aspects. The biomass of ornamental trees increases in residential lots with a lot size of >300 m^2. It seems that lot size reflects the income of the resident, and it can be assumed that groups with more income and bigger lots are willing to plant ornamental trees to make their surroundings aesthetically pleasing. For both land-use type and individual residential lots, trees are chosen based on their function.

Furthermore, our data suggest that the period or year when a residential area was developed is an important factor that significantly influences greenery in residential lots. Residential lots developed when Marikina City was still a municipality and considered to be a rural settlement had more greenery, as compared with lots developed recently under the pressure of urbanization. This difference is particularly pronounced when lots of the same size are compared; this emphasizes the possibility of having more greenery in individual residential lots through conscious planning. Differences in qualitative characteristics that result from the development period impact upon the quantitative characteristics, and it is necessary to sustain the quantity of greenery in residential lots. We previously mentioned the importance of fruit trees as a source of food. Recently, it has become important to sustain the quantity of greenery, not only because of its use as a food source, but also because of the highly desirable ornamental use or value of trees.

6. Proposals for sustaining urban greenery in residential districts

One important aspect that has been clarified in our study is that there is no assurance that greenery in the new, smaller residential lots will be sustained, although they may show increases in greenery with respect to lot size. There are many low-rise houses, and building coverage of residential lots tends to be high in Marikina City. It is necessary to enhance the control of building coverage for individual lots. Osakaya (2000) pointed out that urbanized land uses had expanded only in a horizontal way. During our study, it was also observed that there are many single-story houses. In the future, it will be necessary to change the form of urban development, from horizontal to vertical, through the implementation of appropriate land-use controls on a district scale.

To promote land-use planning on a district scale, it is necessary to facilitate consensus building with local residents, and to seek their voluntary contribution to the conservation and creation of green spaces. We hope that the Marikina City government will develop a consensus-building system, and also suggest a master plan for greening that is informed by the results of this study, in order to ensure that green spaces among small residential lots will increase in the future.

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