BIODIVERSITY ASSESSMENT OF JAPANESE URBAN FORESTS

—Toward a comprehensive assessment of ecosystem services of urban forests in Nagoya, Japan—

YUSUKE YONEKURA[1], KIICHIRO HAYASHI[1], YASUHIRO HASEGAWA[1], & MAKOTO OOBA[2]

[1]*Nagoya University, Nagoya, Japan,* [2]*Nationnal Institute for Environmental Studies, Tsukuba, Japan*

Abstract

Urban green space and forest provide many ecosystem services (ESs), such as CO_2 absorption, thermo-regulation, and air purification, but there are a limited number of studies that comprehensively assess the ESs provided by urban green areas. The purpose of this study was to conduct a comprehensive assessment of ESs, focusing on the supporting and regulating services of urban forests in Nagoya City, Japan. First we collected ES data through a literature survey, and then we conducted a brief field survey of the biomass, soil, and habitat of 52 forest sites one ha or larger in the eastern part of Nagoya. Finally, we conducted a comprehensive assessment by using a geographic information system to better understand the interrelationships among each forest site from the viewpoint of ES provision. The three main forest types were broadleaf deciduous forest, broadleaf evergreen forest, and bamboo forest. Large portions of urban forest areas consisted of secondary forest, mainly composed of deciduous species. We classified the urban forest in east Nagoya into 7 broad categories and 15 subcategories on the basis of ESs. These data should be useful in estimations of forest equivalence and variety, especially with respect to biodiversity policy making, including biodiversity offset programs used in urban planning.

Keywords: Biodiversity; Ecosystem services; Urban forest; Comprehensive assessment; GIS

Introduction

Urban green space and forest provide many ecosystem services (ESs), such as CO_2 absorption, thermo-regulation, and air purification (Millennium Ecosystem Assessment, 2005), but few studies have comprehensively assessed the ESs provided by urban green areas (e.g., McPhearson et al., 2013).

In Japan, urban secondary forests are becoming increasingly important with respect to biodiversity conservation because, since the end of World War II, these forests have gradually decreased in size and become fragmented as a result of urban expansion. Proper evaluations of these forests are therefore essential from the perspective of biodiversity conservation. In addition, it is very important to estimate forest equivalence and variety at each site for urban planning purposes.

The purpose of this study was to make a comprehensive assessment of forest ESs, focusing on supporting and regulating services for green space and forest in Nagoya City, Japan. This paper is a progress report of the ongoing study.

Materials & Methods

Study area

The study was conducted in Nagoya City, Aichi Prefecture, Japan. There are 239 forest sites one ha or larger in Nagoya according to local green coverage data (Nagoya City Office, 2010a). We focused on 52 forest sites located in the eastern part of Nagoya (Fig. 1). The mean annual temperature is 15.8 °C and the average annual rainfall is 1535 mm (1981–2010; data from the Nagoya Local Meteorological

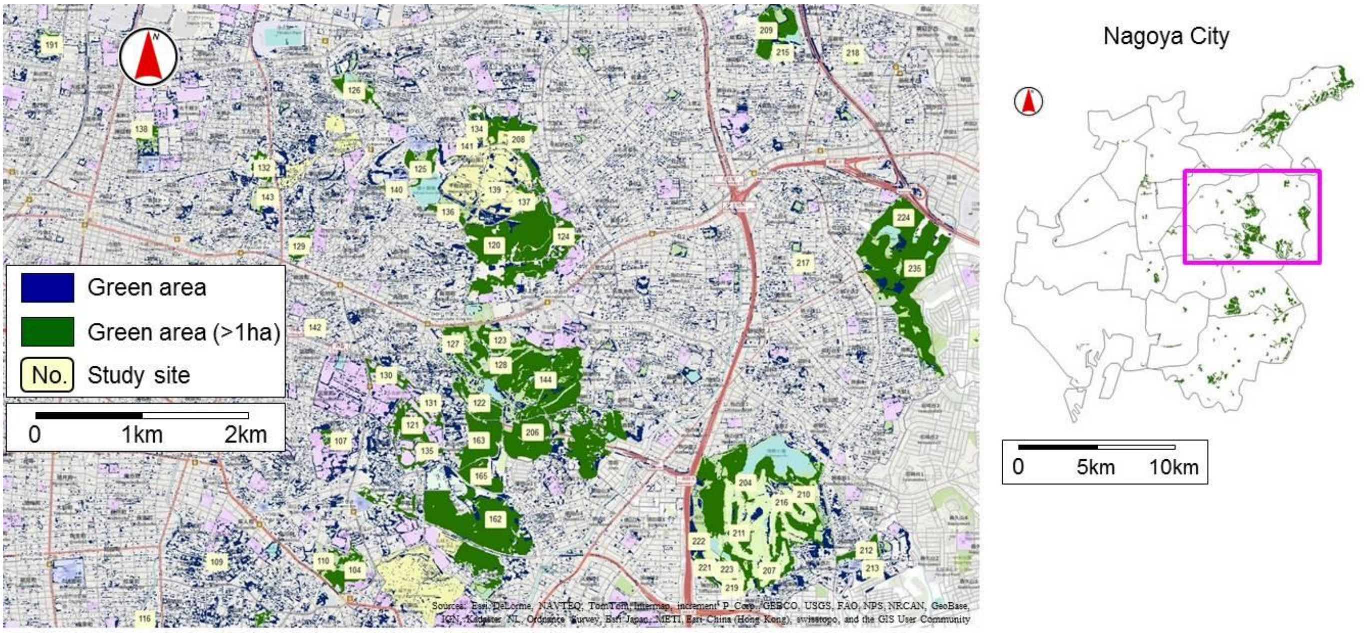

Fig. 1 Green coverage data in Nagoya City and the study sites

*Green goverage data from Nagoya City Office (2010a).

Table 1 Ecosystem services evaluated in this study

Supporting services	Indicator	Data
Primary production	Net primary production (NPP)	Using forest type (field survey data) according to Ogawa et al. (2003)
	Gross primary production (GPP)	Using forest type (field survey data) according to Ogawa et al. (2003)
Soil quality	Thickness of soil A horizon	Field survey data
Regulating services	**Indicator**	**Data**
Global climate regulation	CO_2 absorption	NPP× 1.63 ($6CO_2/C_6H_{10}O_5$ = 1.63), according to Ogawa et al. (2003)
	Biomass carbon stock	Calculated using field survey data (standing stock/100 m^2) according to Tadaki et al. (2004): standing stock of each tree = $0.0601\times(D^2H)^{0.901}$, we assumed that organic carbon was 50% of standing stock.
Local temperature regulation	Forest area	Data from Nagoya City Office (2010a)
Air purification	NO_2 absorption	Calculated using GPP and NO_2 concentration in each study area (Nagoya City Office, 2012) according to Ogawa et al. (2003)
	SO_2 absorption	Calculated using GPP and SO_2 concentration in each study area (Nagoya City Office, 2012) according to Ogawa et al. (2003)
Flood mitigation function	Leaf density	Leaf density = tall tree proportion (%) + middle tree proportion (%) + short tree proportion (%)
	Forest area	Data from Nagoya City Office (2010a)
Soil erosion prevention	Soil runoff	Field survey data (proportion of understory* and litter coverage)
Other services	**Indicator**	**Data**
Conservation target	Presence of large trees	Field survey data (presence or absence data; DBH> 50 cm)
Animal amenity	Forest area	Data from Nagoya City Office (2010a)

*Proportion of understory (%) = very short tree (0–1 m) + grass + fern + bamboo grass

Observatory). The elevation ranges from 6 to 109 m above sea level, and the topography is undulating.

Literature survey

We collected primary units of ESs (Table 1) through a literature survey, taking classification of forest in Nagoya into consideration. Wildlife distribution data (raccoon dog [*Nyctereutes procyonoides*] and weasel [*Mustela sibirica* and *Mustela itatsi*]) were obtained from the Red Data Books of Nagoya City (Nagoya City Office, 2004, 2010b), several environmental assessment reports conducted in Nagoya City, data from the Biodiversity Center of Nagoya City, and reports of sightings by Mr. Tatsuya Noro and Mr. Akira Nawa.

Brief field survey

We conducted a brief field survey of the 52 forest sites from July to November 2013. We set a 100-m^2 and 400-m^2 investigation area at each site and conducted biomass, soil, and habitat surveys in these areas. We first measured basic survey items, including longitude, latitude, elevation, slope, topography, illumination (in- and out-canopy) using an illumination meter (LM-8000, MK Scientific, Inc., Japan), temperature (in- and out-canopy), relative humidity (in- and out-canopy), and whole-sky photography. Then we conducted the following biomass surveys in the 100-m^2 investigation area: tree species, tree height, diameter at breast height (DBH), crown area of each tree (m^2), vegetation cover (%, for tall trees [>10 m], medium trees [5–10 m], short trees [1–5 m], very short trees [0–1 m], ferns, bamboo grass, grasses, and litter), recruitment (seedling growth), and mass of dead wood (m^3/100 m^2). In the 400-m^2 investigation area, we conducted the following biomass surveys: number of gingko trees (*Ginkgo biloba*) and oak trees (e.g., *Quercus serrata*, *Quercus variabilis*, *Quercus glauca*, and *Quercus myrsinifolia*), and the number of very large trees (DBH > 40 cm). We also measured the number of very large trees (DBH > 60 cm) outside of the investigation site but within the study area.

The soil survey included following items: final infiltration capacity using a 10-cm-diameter vinyl-chloride pipe, water content (n = 3) using a soil water content meter (ProCheck, Decagon Devices Inc., U.S.A.), soil hardness (n = 3) using a soil hardness meter (Daiki Rika Kogyo Co., Ltd., Japan), surface soil and litter thickness (cm), and surface soil color using a soil-color book.

The habitat survey included human intervention, human accessibility, human and vehicular traffic, non-native species, and the number of hollow trees by visual investigation.

Mapping using GIS

We conducted a spatial analysis by using GIS to better understand the interrelationships between each forest site from the viewpoint of ES provision. We used ArcGIS 10.0 (ESRI Japan Inc.) for the spatial analysis.

(a)

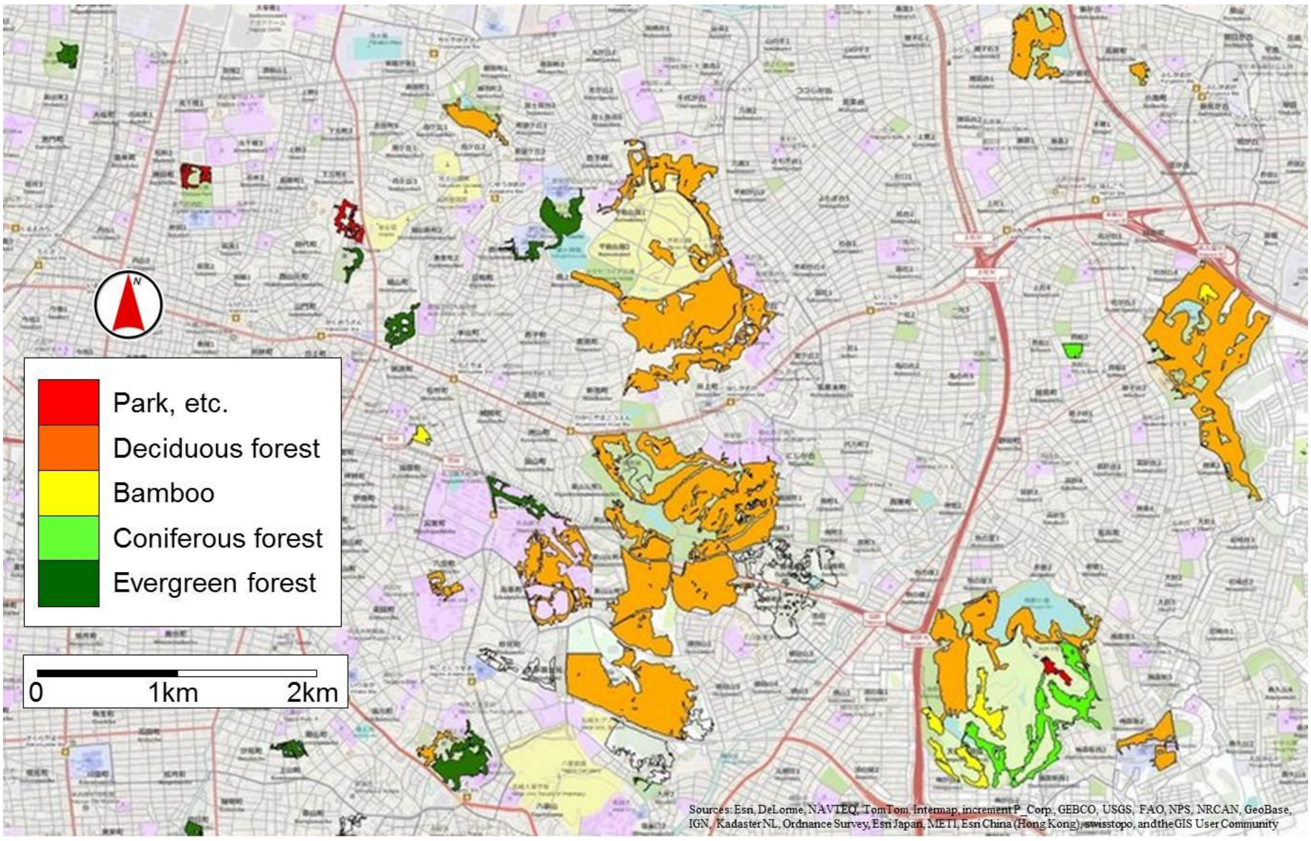

Fig. 2 Forest type (a) and ecosystem service units (b) in East Nagoya based on the field surveys

(b)	NPP ($t\ ha^{-1}\ yr^{-1}$)	GPP ($t\ ha^{-1}\ yr^{-1}$)	CO_2 absorption ($t\ ha^{-1}\ yr^{-1}$)	Carbon sequestration ($t\ ha^{-1}\ yr^{-1}$)	SO_2 absorption ($kg\ ha^{-1}\ yr^{-1}$)	NO_2 absorption ($kg\ ha^{-1}\ yr^{-1}$)
Park, etc.	5	10	8	1.5	0.21	2.0
Deciduous forest	9	18	15	2.7	0.37	3.6
Bamboo	10	20	16	3.0	0.41	4.0
Coniferous forest	14	47	23	4.2	0.97	9.4
Evergreen forest	20	67	33	6.0	1.38	13.4

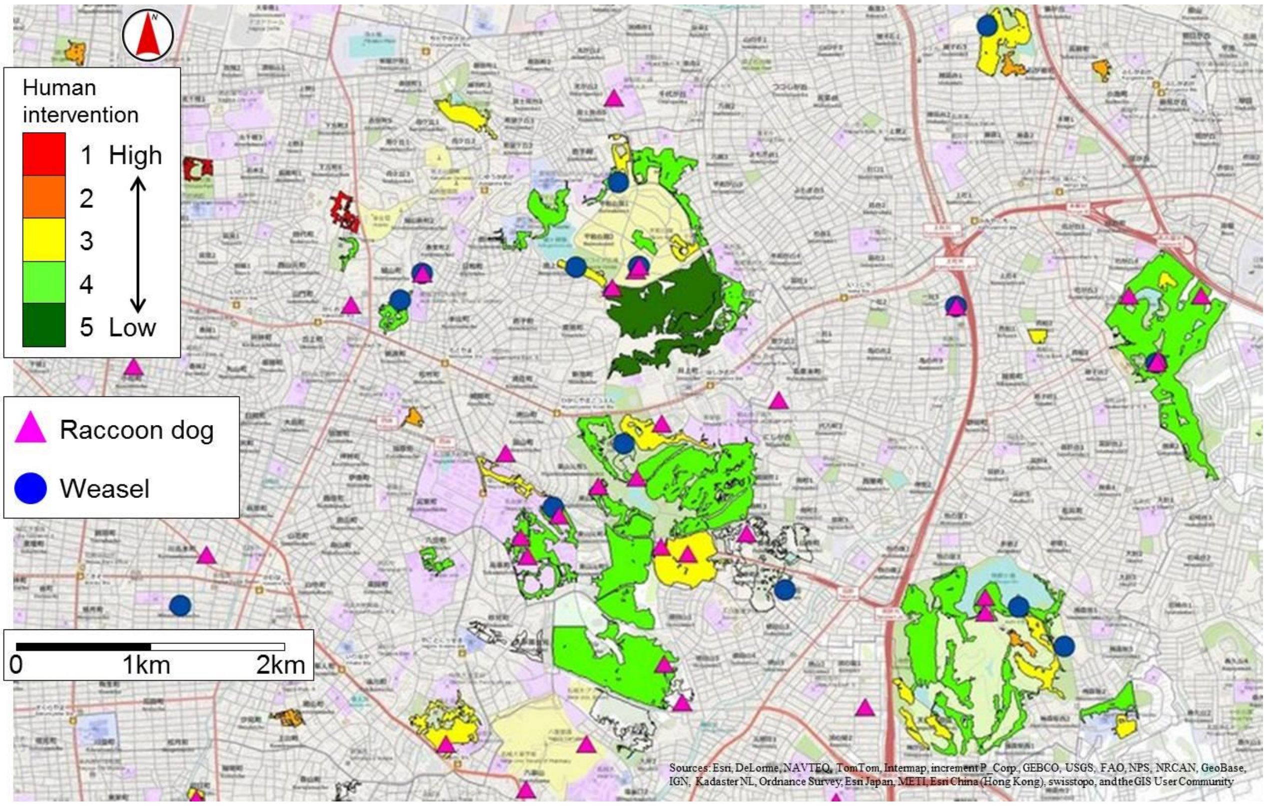

Fig. 3 Human intervention and wildlife distribution in East Nagoya

*Wildlife distribution data from the Environmental Agency and Biodiversity Center (Nagoya City Office), Mr. Tatsuya Noro and Mr. Akira Nawa (Report of sightings), and a camera trap survey by the authors.

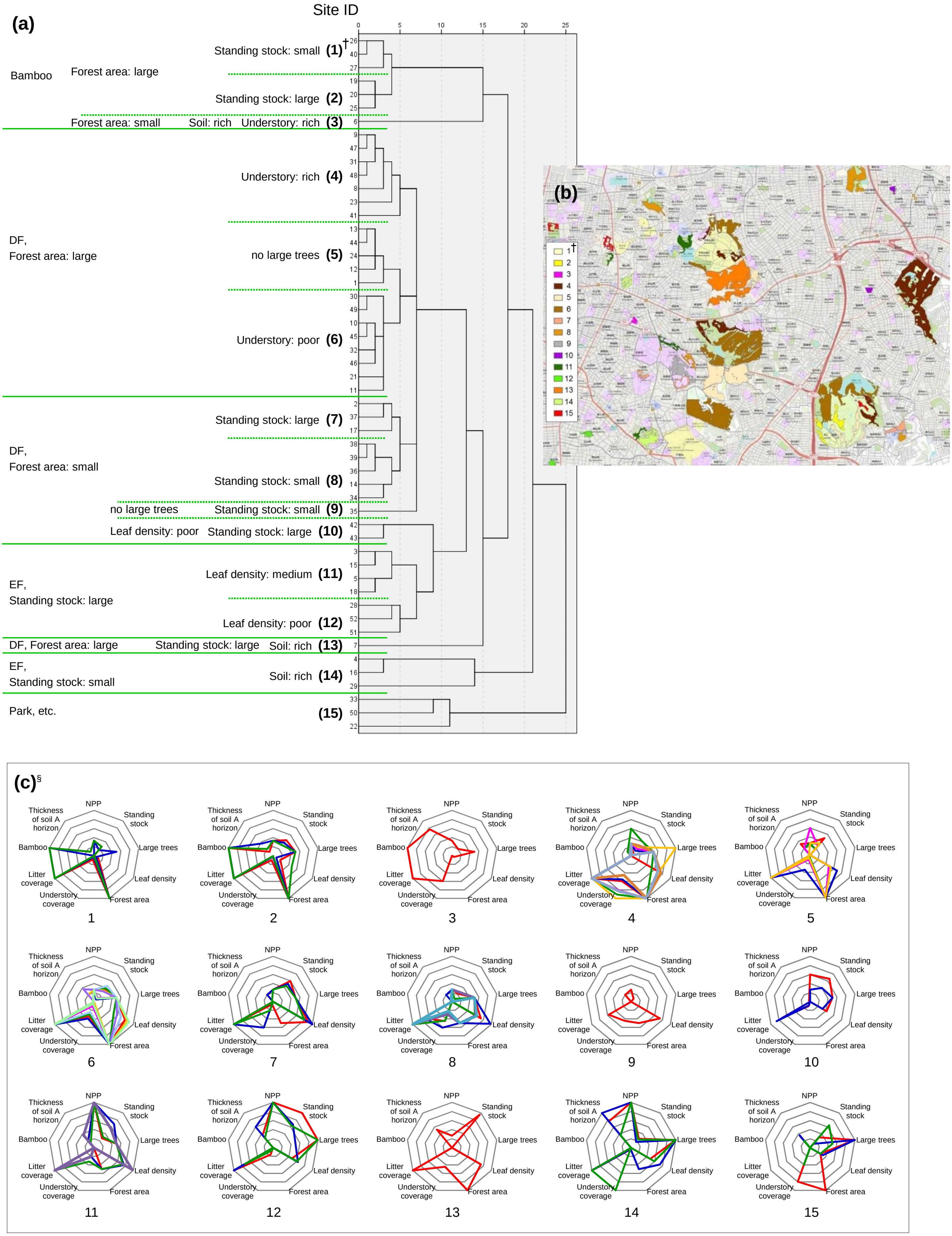

Fig. 4 Categorization of urban forest in East Nagoya (a, b) and ES parameters in each subcategory (c)

*We selected the following parameters for cluster analysis: (1) NPP, (2) standing stock, (3) presence of large trees¶, (4) forest area (unrelated to polygon size), (5) proportion of understory and litter coverage, (6) bamboo forest, (7) thickness of soil A horizon, and (8) leaf density.

†The numbers indicate subcategory (1-15).

‡DF, deciduous forest, EF: evergreen forest.

§Different color indicates each study site.

¶Presence of large trees: (1) no large trees, (2) medium (DBH 50–80 cm), and (3) large (DBH >80 cm).

Categorization of forest

To classify these urban forests, we first selected the following parameters: net primary production (NPP) as an indicator for CO_2, SO_2, and NO_2 absorption (because there were strong correlations among forest type, NPP, and GPP [Table 2], we used NPP in this analysis); standing stock as an indicator for carbon stock, presence of large trees as an indicator for *conservation targets (we divided study sites into three* categories of tree size [Table 1]: small [no big trees], medium [DBH = 50–80 cm], and large [DBH > 80 cm]); size of contiguous forest area which was unrelated to each polygon size as an indicator for wildlife amenity, flood mitigation function, and local temperature regulation; proportion of understory and litter coverage as an indicator for soil erosion (understory coverage [%] = very small trees (0–1 m) + grass + fern + bamboo grass); area of bamboo forest (bamboo forest is disparate compared with the other forests); thickness of soil A horizon as an indicator for soil quality; and leaf density as an indicator for flood mitigation function (Table 1). We then performed a cluster analysis using these parameters under the group-average method and the squared Euclidean distance method. We also evaluated forest equivalence for these same subcategories. We used SPSS 22.0 for windows (IBM Japan, Ltd.) for all statistical analyses.

Results and Discussion

Brief field survey combined with literature survey

Figure 2 shows the forest types in the study area based on the results of our brief field survey. The vegetation types of urban forest sites in the east part of Nagoya were mainly classified as (1) broadleaf deciduous forest dominated by *Q. serrata* and *Q. variabilis*, (2) broadleaf evergreen forest dominated by *Q. glauca* and *Cinnamomum camphora*, and (3) bamboo forest. Biomass standing stock was 113–494 t ha^{-1}, and the corresponding carbon stock in this biomass was 56–247 t ha^{-1}.

Deciduous forests covered the largest area of urban forest in the east part of Nagoya. These deciduous forests were mainly composed of secondary forest, whereas evergreen forests were mainly located in temples, shrines, and other cultural heritage areas (e.g., museum).

In the deciduous forests, the understory condition across large areas was poorly developed and the soil A horizon was relatively thin. In addition, the tree size levels (Table 1) were either small (no large trees) or medium (DBH = 50–80 cm). Whereas the litter thickness was relatively thick and the level of human intervention was relatively low, indicating that these forests remained largely untouched. In this context, these forests appeared to be represent good habitat for middle-sized mammals (raccoon dogs and weasels; Fig. 3).

Categorization of urban forest in East Nagoya

We divided the forests into 7 broad categories and 15 subcategories. The broad categories were bamboo forests, deciduous forests (3 types: large, small, and large with rich soil), evergreen forests (2 types: standing stock large and small), and parks or other similar areas. Many of these were then subdivided on the basis of size, standing stock, and soil quality as shown in Figure 4.

The bamboo forest were subdivided into 3 categories: large areas with a large standing stock, large areas with a small standing stock, and small areas with a rich understory and soil.

The evergreen forests were mainly located in temples, shrines, and other cultural heritage areas. Therefore, most of these forests were relatively small and the understory vegetation was sparse because of intensive management. The large standing stock category was subdivided by leaf density (medium and poor).

The deciduous forests could generally be divided by forest area, and most these forests were classified as large (Fig. 2). These large-area forests were subdivided into 3 types: (1) rich understory, (2) poor understory, and (3) no large trees. In addition, a separate broad category was created for large areas with a large standing stock and rich soil (number 13 in Fig. 4). The small area category also had 4 sub-categories: (1) large standing stock, (2) small standing stock, (3) small standing stock with no large trees, and (4) large standing stock with poor leaf density.

Conclusions

We conducted a brief multipoint survey for an ES assessment. A large portion of the urban forest areas consisted of secondary forest, which was covered mainly by deciduous trees. We categorized the types of urban forest in the east part of Nagoya into 7 broad categories and 15 subcategories. These data should prove to be useful in estimations of forest equivalence and variety with respect to biodiversity policy making, such as in biodiversity offset programs in urban planning.

In the future, we plan to conduct brief surveys of the remaining forest sites in Nagoya. Additionally, it would be better to segment forest polygon by plant community. Thus far, we have not developed a well-established comprehensive forest assessment method and need to address this in the future.

Acknowledgements

The authors thank Nagoya City Greenification & Public Works Bureau for providing green coverage data; Higashiyama park, Chikusa, Showa, Tenpaku, Midori and Meito branch; Nagoya City Biodiversity Center, Shiroyama shrine, Mitsuke elementary school, Kosho-ji, Nanzan University, Nittai-ji, Aichi Urban Development Association, Owari Construction Office, Aichi Prefectural Government, Aichi Country Club, Yagoto shrine, Touzan-sou, Katayama shrine, Kibune shrine, Nagoya City Waterworks & Sewerage Bureau, Aichi Shiroyama Hospital, Higashi Nagoya National Hospital, Showa museum, and Tokugawa garden for their permission for our field survey; Natsuko Yoshino, Ayumi Kawajiri, Yuri Inagaki, and Shimpei Inoue for their assistance in the survey. This study was granted by the Japan Society for the Promotion of Science through the "Funding Program for Next Generation World-Leading Researchers".

References

McPhearson T., Kremer P., Hamstead Z.A. (2013) Mapping ecosystem services in New York City: Applying a social-ecological approach in urban vacant land. *Ecosystem Services*, 5, 11–26.

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Nagoya City Office (2004) Red data book of Nagoya City (in Japanese).

Nagoya City Office (2010a) Green coverage data in Nagoya city. Greenification & Public Works Bureau, Nagoya City Office.

Nagoya City Office (2010b) Red data book of Nagoya City (in Japanese).

Nagoya City Office (2012) Annual environmental report of Nagoya City. pp 26–27 (Information section) (in Japanese).

Ogawa K., Miwa M., Shimada T., Ogawa S. (2003) Air purification function of green area and its economical evaluation in Japan. *Bulletin of Center for Environmental Science in Saitama*, 1, 1–12 (in Japanese).

Tadaki Y., Hirano A., San-nabe H., Kawaguchi J., Hiraizumi T., Hoshino D. (2004) Net production of a secondary broadleaf forest on Nagoya University campus. *Nagoya University Forest Science*, 23, 9–13 (in Japanese).