Temporal and Spatial Assessment of Ecosystem Services in 1955 and 2008: Case study in Nagoya and its suburbs, Japan

Wataru Kobayashi[1], Kiichiro Hayashi[2], Makoto Ooba[3]
1: Master student of Nagoya University, 2: Nagoya University, 3: National Institute for Environmental Studies

Abstract: Global environmental problems have become a serious issue because of the expansion of the scale and scope of human activities. Decrease in the forest area has directly led to the deterioration of the quality and quantity of benefits provided from the forests, i.e., ecosystem services (ESs), which have been summarized in the Millennium Ecosystem Assessment carried out in 2005. In recent decades in Japan, continuous development has been one of the major reasons for the loss of natural resources, especially of urban forests in large cities, such as Tokyo, Osaka, and Nagoya. It has led to the decrease in the potential ES supply in these areas. Therefore, effective forest conservation in urban regions is important for the conservation of a variety of ESs provided from the forest area. In this study, the digital land-use maps in the 10-m grid scale were developed by classifying satellite images from 2008 and the old land-use maps from 1955 of the northwestern part of Aichi Prefecture, Japan. Then, by using the ES unit values, the potential provisions of several ESs were estimated.

INTRODUCTION

In recent decades, environmental problems, caused by the demand for urban development and human activities, have become serious issues. One of the problems is decrease in forest in large cities and its suburbs. This has led to the deterioration of the quality and quantity of the benefits provided by forests, i.e., ecosystem services (ESs). These effects have been summarized in the Millennium Ecosystem Assessment carried out in 2005 (MA, 2005). In Japan, the demand for urban development has contributed to the loss of natural resources, especially urban forests in large cities. The loss and degradation of forests as a result of urbanization has been recognized as a serious issue in the highly populated areas, such as Tokyo, Osaka, and Nagoya; Nagoya's population is 2.3 million as of April 1, 2016 (Nagoya City, 2016). Vegetated areas in Nagoya City have decreased from 29.8 % to 24.8 % from 1990 through 2005 (Nagoya City, 2011), leading to the decrease in several ESs. Therefore, the conservation of the forest ecosystem is necessary for sustainable provisions of the ESs. This paper presents a study of the temporal and spatial changes of potential provisions of ESs based on the land-use changes from 1995 to 2008 in Nagoya City and its surrounding areas.

MATERIALS & METHODS

Study area

Nagoya City is located in Aichi Prefecture, Japan (the city hall is located at 35.181°N, 136.906°E) (Figure 1(a) to (c)). The total area of the city is approximately 326 km^2. The average annual temperature in 2015 was 16.6°C, and the average precipitation was 1803 mm (Japan Meteorological Agency, 2015). Nagoya is the third most populated metropolitan area in Japan, after Tokyo and Osaka. This study also covers the suburban area of Nagoya City. The estimated population in the study area is around 3.6 million people, as roughly estimated by population statistics (Aichi Prefecture, 2015).

Materials and methods

Referring to Ooba et al. (2015) and Kay Khaing Lwin (2015), in this study, digital land-use maps were developed by classifying satellite images and old land-use maps in the northwestern part of Aichi Prefecture, Japan. Then, by utilizing the ES unit values from a filed survey of the Nagoya forests, the potential provisions of several ESs were estimated as a methodology development case study.

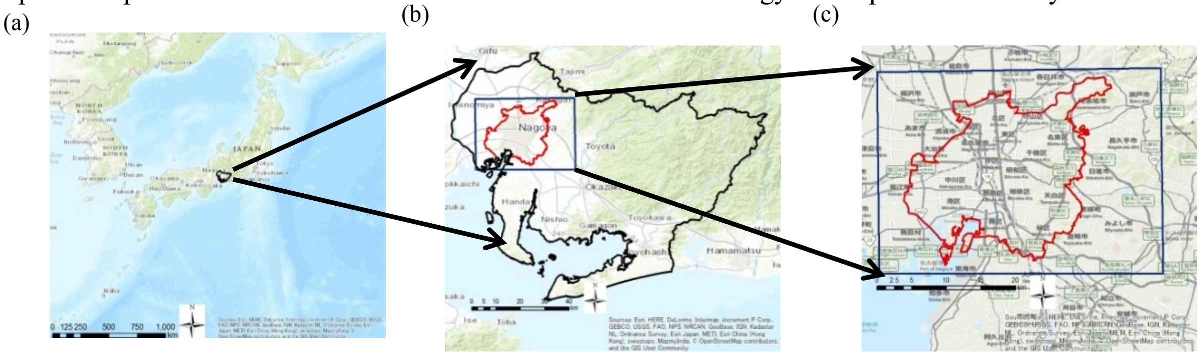

Figure 1. Maps of the study area: (a) Aichi Prefecture in Japan, (b) Aichi Prefecture outlined in black, the study area outlined in blue and Nagoya City outlined in red, and (c) the study area

Advanced Land Observing Satellite (ALOS) images captured by JAXA in 2008 were used for developing the current land-use map of the Nagoya area. The first step in the process was to distinguish the forest area from the non-forest area using Normalized Difference Vegetation Index (NDVI) analysis (Manandhar et al., 2009; Kay Khaing Lwin, 2015). After conducting the NDVI analysis, the NDVI values of each cell was used to classify them into two categories, namely, forest and non-forest areas. In the frequency distribution graph of the NDVI values, 800 samples of NDVI values were used to determine the threshold value of forest and non-forest areas, which was finally determined to be 0.25. In the second step, the forest area was classified into four categories: (1) evergreen coniferous forest (CF), (2) broad-leaved deciduous forest (DF), (3) broad-leaved evergreen forest (EF), and (4) bamboo forest (BF). The classification was carried out by the supervised classification method, using a forest field survey data in Nagoya City (Hayashi laboratory, 2015) to validate DFs, EFs, and BFs, and Google Earth images were used for CFs. The main species of trees found in DFs include *Quercus serrata* and *Quercus variabilis*, EFs include *Cinnamomum camphora* and *Castanopsis sieboldii*, and CFs include *Cryptomeria japonica, Chamaecyparis obtuse*, *Pinus densiflora*, and *Pinus thunbergii*. Subsequently, the non-forest area was categorized into three land-use types—(1) farmland, (2) water body, and (3) urban area—by the supervised classification method validated by the ALOS satellite images. The accuracy of the supervised classifications was around 81% for the total land-use categories by using 200 points validated by Google Earth. ArcGIS10.2.2 (ESRI) and ERDAS IMAGINE 2014 (Hexagon Geospatial, Intergraph) were used for GIS analysis and satellite image analysis.

Until 1955, land-use maps were digitized from original paper maps for GIS analysis in the 10-m grid scale. Then, the land-use categories were classified into nine land-use types, including CF, BLF (including DF and EF), mixed forest (CF and BLF), farmland, water area, bare-land, clear-cutting area, urban area, and grassland by the supervised classification method. The accuracy was around 85% for the total land-use categories by using 500 points validated by the original land-use maps.

Finally, the ES unit values were developed based on the Nagoya forest field survey data (Hayashi laboratory, 2015), with the support of literature review as listed in Table 1. Since 2012, field surveys have been conducted in many forests in Nagoya City. According to the Nagoya vegetation coverage GIS data (Nagoya City, 2010), there were around 240 forest (more than 1ha) in the city. Until June 2016, over 190 forests had been investigated in the surveys. In each forest area, a 100-m^2 and a 400-m^2 survey sites were set up for vegetation, soil, and habitat surveys, the detailed methods for which were presented in Yonekura et al. (2014), Hayashi and Ooba (2015), and Hayashi laboratory (2015). In this study, the ES unit values were developed based on around 170 forest data from the field survey (Table 1). The field survey has not finished yet so that the ES unit values presented here are tentative version estimated by the limited number of sites as a test case. The values will be updated after completion of the whole area of the field survey.

In this study, as a test case, the following three ES unit values were selected: forest canopy volume and NO_2 absorption for the regulating services and number of trees of acorn for the provisioning services. Forest canopy volume is estimated by using the average tree height multiplied by each vegetation coverage of high trees (more than10 m), moderately high trees (5-10 m), and short trees (1-5 m) based on the idea of Hiruta and Ishikawa (2012) and Iwai (2015) taking into consideration avoiding the overlapping of each vegetation coverage. NO_2 absorption was estimated by using gross primary production (GPP), NO_2 atmospheric concentration data in each forest type (Ogawa et al. 2000, Totsuka and Miyake, 1991) and forest categories based on the land-use maps. Acorn was potentially used as a raw material for personal ornaments. Therefore, the supply of acorn was considered to be one of the indicators for the provisioning services. These were estimation based on the field survey results. Then, the potential provisioning maps of the selected ESs were developed by using the land-use maps and the ES unit values. Moreover, the differences between the potential provisions of ESs in 1995 and 2008 were compared.

Data used in this study

- ALOS satellite images by JAXA
  - Two ALOS images, dated 20080527 and 20080225, of 10 m × 10 m resolution were used.
- Land-use maps constructed in 1955 by Geospatial Information Authority of Japan (GSI)
  - Four old land-use maps were used, namely, northern part of Nagoya City, southern part of Nagoya City, Koromo, and Seto. The maps were scanned and digitized for GIS analysis.

Table 1. ES unit values used in this analysis (tentative)

ES	Regulating services		Provisioning service
Contents of ES	Adjustment of micro climate	Adjustment of air quality	Ornaments
Indicators	Forest canopy volume ($10^2 m^3$/ha)	NO_2 absorption (kg/ha/yr)	Acorn (number of trees/ha)
BF	931	12.2	10.1
CF	1,128(1,128)	28.6(28.6)	6.7(6.7)
EF	1,204	40.8	18.4
DF	1,133	11.0	27.7
BLF	(1,169)	(25.9)	(23.1)
Mix CF and BLF	(1,148)	(27.3)	(14.9)
Farmland	0(0)	11.6(11.6)	0(0)
Water area	0(0)	0(0)	0(0)
Urban area and others	0(0)	0(0)	0(0)
Source	Estimated by using Hiruta and Ishikawa (2012), Iwai (2015), and Hayashi laboratory (2015)	Estimated by using Ogawa et al (2000), Totsuka and Miyake (1991), and Hayashi laboratory (2015)	Developed based on Hayashi laboratory (2015)

Note: The unit values used this study were tentative version because the field surveys for all Nagoya forest have not finished yet.
The 2008 ES values are listed on the left of bracket and the 1955 ES unit values are in each bracket.
The BF and CF meant main forest types with small number of different type of trees including acorn trees.
The BF and CF were dominant in bamboo and conifer trees with some other types of trees.
The Forest canopy volume of BF was calculated by only three BF sites. The surveys for other BF sites are on-going.
The unit value of NO_2 absorption for farmland is calculated by the average of rice and crop in Ogawa et al (2000).

RESULTS & DISCUSSION

Figure 2(a) showed the digitized land-use maps in 1955 and figure 2(b) was the result of the 2008 land-use map from the ALOS satellite images. Figure 3 showed the land-use change between 1955 and 2008. Figure 4 to Figure 6 showed the potential provisioning maps of selected ESs in a 1-km grid scale.

According to the results, urban areas have expanded greatly in this half century. Both farmland and forest areas have been converted to urban area. Additionally, land-use changes from forest to bamboo were observed in some areas. In the course of these changes, a variety of ESs have deteriorated and decreased in urban areas, especially in Nagoya City and its suburban area.

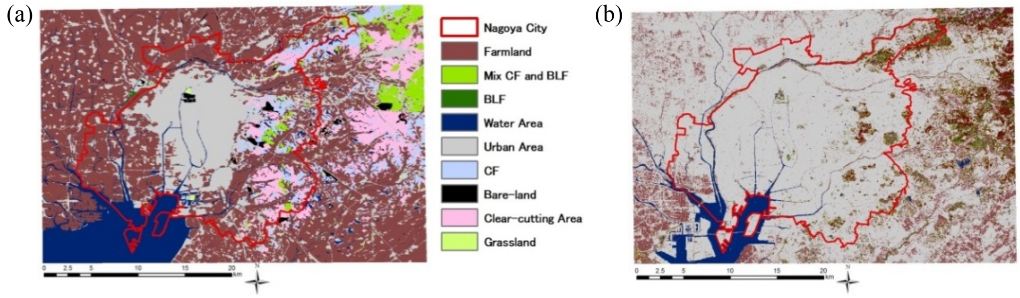

Figure 2. Land-use maps (a) the digitized land-use map originally constructed in 1955 (left) (b) the 2008 land-use map (right)

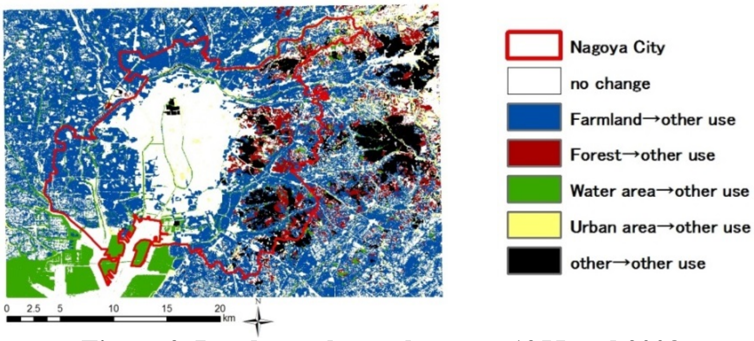

Figure 3. Land-use change between 1955 and 2008

Note: City Park, temple and shrine, etc. were classified in the public area category in the 1955 land-use maps. However, some of these were categorized as forest by satellite images. Therefore, it seemed that there might be cases classified as "urban area changed to other use."

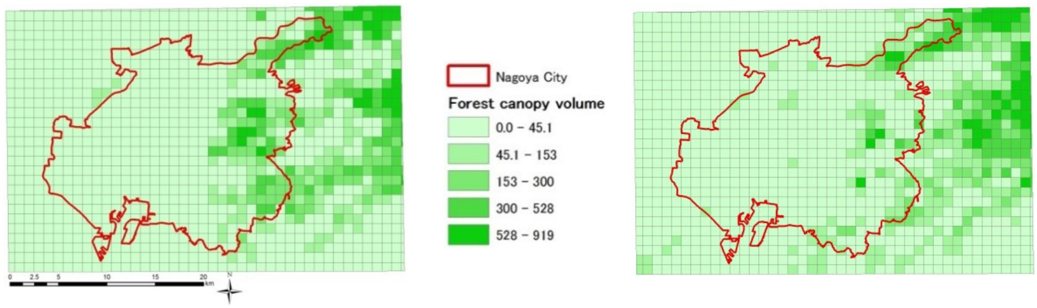

Figure 4. Supply potential maps of Forest canopy volume: 1955 (left) and 2008 (right) (unit: $10^2 m^3/ha$)

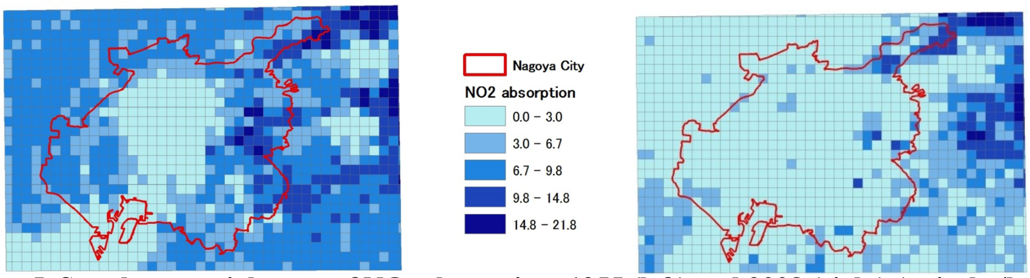

Figure 5. Supply potential maps of NO_2 absorption: 1955 (left) and 2008 (right) (unit: kg/ha/yr)

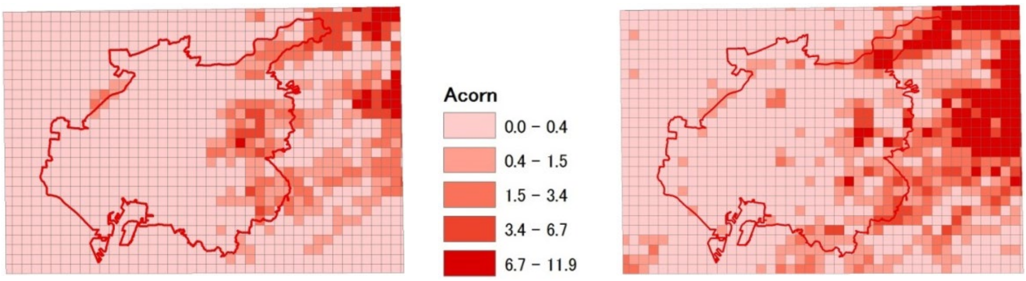

Figure 6. Supply potential maps of Number of acorn trees: 1955 (left) and 2008 (right) (unit: number of trees/ha)

The Nagoya forest field survey data was used as the training sample of the supervised classification of the 2008 satellite images. However, the field survey was conducted only in Nagoya City. Therefore, further field surveys are needed to cover the suburban forest areas surrounding Nagoya City. In addition, the ES unit values estimated for 1955 were based on the 2008 field survey results because it was difficult to get ES unit values for 1955. However, more effort is needed to determine the appropriate ES unit values for the 1950s in the future.

CONCLUSION

In this study, digital land-use maps of 10-m grid scale were developed by classifying the satellite images in 2008 and digitizing the old land-use maps of 1955 for the northwestern part of Aichi Prefecture, Japan. By utilizing the land-use maps and ES unit values, the potential provisioning maps of the selected ESs were estimated.

In future, high-resolution land-use maps will be needed for more detailed assessments. Moreover, to develop the 1955-based ES unit values and use those, a variety of multiple ESs are needed in a future study. Then, compiling the results of each ES supply potential map, a conservation priority map will be constructed for this area. Based on the results, the conservation priority map can be utilized for a biodiversity/ES assessment, an avoidance assessment of the potential biodiversity offset project, etc.

ACKNOWLEDGEMENT

The authors thank: Nagoya City Greenification and Public Works Bureau (Agriculture Centre, Higashiyama Park, Midorigaoka Park, Shonai Park, Tsuruma Park, Atsuta, Chikusa, Higashi, Kita, Meito, Midori, Minami, Minato, Mizuho, Moriyama, Naka, Nakagawa, Nakamura, Nishi, Showa, and Tenpaku branches); Nagoya City Biodiversity Center; Nagoya City Waterworks & Sewerage Bureau; Nagoya City Housing and Urban development Administration; Nagoya City Mizuhoundojo; Aichi Urban Development Association of Aichi Prefectural Government (Odaka Park, Obata Park and Makinogaike Park); Aichi Shiroyama Hospital; Aichi Prefectural Gymnasium; Aichi Country Club; Aichi-ken Jinjya-cho; Atsutajingu shrine, Atsutajingu Park, Gokoku-jinjya shrine, Hakusan-gu shrine, Harina-jinjya shrine, Hachiken-jinjya shrine, Higashi Nagoya National Hospital, Ikutamainari-jinjya shrine, Katayama-jinjya shrine, Kinjo Gakuin University, Kosho-ji temple, Myochu-in temple, Mitsuke Elementary School, Nagoya Castle, Nanzan University, Narumi-jinjya shrine, Nittai-ji temple, Takakuramusubimiko-jinjya shrine, Tobe-jinjya shrine, Toho gas Co. Ltd., Tokugawa garden, Toray Industries, Inc., Tozan-so, Showa museum, Shiroyama-hachimangu shrine, Suwa-jinjya shrine, Tachibana-jinjya shrine and Yagoto-jinjya shrine for their permission for our field survey. Also the authors thank Natsuko Yoshino, Masaki Iwai, Kay Khaing Lwin, Yusuke Yonekura, Yasuhiro Hasegawa, Hiroaki Sumi, etc. for their assistance to the survey. This research was supported by the 'KAKENHI' 15K00622 from JSPS, Japan and the fund from the 'Funding Program for Next Generation

World-Leading Researchers' from JSPS and MEXT, Japan and the 'Environment Research and Technology Development Fund (1-1401)' from MOE-J, Japan.

REFERENCES

1. Aichi Prefecture (2015): Aichiken Zinkou Doukou Chousa (Population Statistics in Aichi Prefecture) URL, http://www.pref.aichi.jp/soshiki/toukei/0000077326.html, accessed in June 22, 2016. (in Japanese)
2. Geospatial Information Authority of Japan (GSI) (1955): Tochiriyouzu (Land-use maps), Nagoya City north, Nagoya City south, Koromo and Seto. (in Japanese)
3. Hayashi K., Ooba M. (2015): A Framework Study on the Methodology of Biodiversity Offset Assessment in Japan -Hypothetical Case of GIS Screening and On-site Field Assessment, IAIA15 web proceedings, http://conferences.iaia.org/2015/final_papers.php.
4. Hayashi laboratory (2015): Nagoya no morino seitaikei sabisu chousa ver.1.0 (Ecosystem service survey for Nagoya forest), Nagoya university EcoTopia Science Institute Hayashi laboratory. (in Japanese)
5. Hiruta Y., Ishikawa M. (2012): Research on indicators for evaluating the heat-reduction effect of spaces, Journal of the City Planning Institute of Japan, Vol.47, No.3. (in Japanese)
6. Iwai M. (2015): Equivalency and Diversity Assessment of Forests based on Ecosystem Services: A Case of Urban Forests in Nagoya City. (unpublished) (in Japanese)
7. Japan Meteorological Agency (2016): Kakono Kishou deta kensaku (Search for past climate data). http://www.data.jma.go.jp/obd/stats/etrn/index.php.
8. Kay Khaing Lwin (2015): Spatial Assessment of Ecosystem Services in Nay Pyi Taw, Myanmar. (unpublished)
9. Manandhar R., Odeh, I. O. A., and Ancev, T. (2009): Improving the Accuracy of Land Use and Land Cover Classification of Landsat Data Using Post-Classification Enhancement: Remote Sensing 2009, 1, 330-344. ISSN 2072-4292.
10. Millennium Ecosystem Assessment MA, (2005): Ecosystems and human well-being: synthesis. a report of the millennium ecosystem assessment. Island Press, Washington D.C.
11. Nagoya City (2011): Nagoya Midorino Kihon Keikaku 2020 (Nagoya greening basic plan 2020) URL, http://www.city.nagoya.jp/ryokuseidoboku/cmsfiles/contents/0000029/29836/NagoyaGP2020-1-honpen.pdf, accessed in February 27, 2016. (in Japanese)
12. Nagoya City (2012): Midorino Genkyou Chousa (Green Coverage Research in Nagoya). URL, http://www.city.nagoya.jp/shisei/category/53-3-3-1-0-0-0-0-0-0.html, accessed in August 30, 2015. (in Japanese)
13. Nagoya City (2010): Nagoyashi Ryokuhi Deta (Nagoya vegetation coverage GIS data).
14. Nagoya City (2016): Toukei Nagoya web ban (Statistic Nagoya web version). http://www.city.nagoya.jp/shisei/category/67-5-0-0-0-0-0-0-0-0.html, accessed in June 25, 2016. (in Japanese)
15. Ogawa K., Miura M., Shimada T., Ogawa S. (2000): Nihonniokeru Ryokuchino Taikizyoukakinouto sono Keizaitekihyouka, (The atmosphere purification function of the green tract of land and the economic evaluation in Japan), Center for Environmental Science in Saitama, No.1, pp. 106-117. (in Japanese)
16. Ooba M., Hayashi K., Ito H., Fujii M., and Hasegawa Y. (2015): Assessment of ecosystem services using land-use maps, IAIA 15 web proceedings, http://conferences.iaia.org/2015/final_papers.php.
17. Totsuka T., Miyake H. (1991): Ryokuchino Taiki Zyoukakinou (Atmosphere purification function of the green land), Journal of Japan Society of Air Pollution, Vol. 26, No. 4, pp. A71-A80. (in Japanese)
18. Yonekura Y., Hayashi K., Hasegawa Y., Ooba M. (2014): Biodiversity assessment for Japanese urban forest, IAIA 14 web proceedings, http://conferences.iaia.org/2014/final-papers.php.