A Framework Study on the Methodology of Biodiversity Offset Assessment in Japan

－Hypothetical Case of GIS Screening and On-site Field Assessment－

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Abstract: In Japan, there is no legal obligation or established assessment methodologies for biodiversity offsets. In this study, a preliminary research framework of a forest assessment methodology for a biodiversity offset system was studied as a hypothetical case in Nagoya City, Japan. A three-step approach was employed. First, a wide-scale assessment of biodiversity/ecosystem services (BD/ESs) by GIS was conducted as a screening stage for prioritizing the BD/ESs in the city. Second, simple field surveys were conducted for equivalency and offset-possibility assessment in 131 forests within the city. Third, on-site field surveys that utilized biodiversity assessment methods implemented in other countries were conducted to test the applicability of these methods in Japan. At the spatial scale, the framework could be useful for identifying conservation priority areas. At the on-site scale, the individual assessment methods resulted in different viewpoints. Therefore, the selection of BD/ES assessment methodologies should be considered carefully.

Keywords: Biodiversity offset, ecosystem service, forest, Japan, Nagoya

Introduction

In Japan, the expansion of urban area has caused the degradation of forest. The extent of degradation has been remarkable, especially for large cities such as, Tokyo, Osaka, and Nagoya. For example, the forest coverage in Nagoya decreased from 29.8% in 1990 to 23.3% in 2010 (Nagoya City 2012). Forests provide a variety of benefits to human society, which are collectively termed ecosystem services (ESs) (MA 2005). The loss of biodiversity/ecosystem services (BD/ESs) are one of the important policy issues in Japan.

One of the policy instruments to compensate for the loss of BD due to development activities is biodiversity offset, which is defined in, for example, the BBOP (2013). Biodiversity offset and banking systems have been widely introduced throughout many countries (Madsen et al. 2010), such as conservation banking (CB) and mitigation banking (MB) in the USA (the State of California 2014), and BioBanking (BB) in Australia (NSW Government 2014a). However, there is no legally binding national biodiversity offset system in Japan, even though under the EIA (environmental impact assessment) law of Japan, a developer can compensate for the loss of biodiversity from a development activity with offset measures voluntarily. In addition, the Ministry of the Environment, Government of Japan (MOE-J) made a draft report on biodiversity offset (MOE-J 2014). It was a first report by the MOE-J examining the possibility of a biodiversity offset system in Japan. However, several local governments have introduced similar biodiversity offset systems, such as Aichi Prefecture (Aichi Prefecture 2013). The discussion on biodiversity offset system possibilities has gradually increased in Japan in recent years.

Many kinds of biodiversity offset and banking assessment methods have been implemented throughout the world (Quétier and Lavorel 2011), such as the HSI (Habitat Suitability Index) model (Ito and Hayashi 2014, Dhakal et al. 2014), the HH (Habitat Hectares scoring method; The State of Victoria 2014), and the BBAM (BioBanking assessment methodology; NSW Government 2014b). In discussions regarding a biodiversity offset system in Japan, the equivalency and alternativeness between the loss and gain of biodiversity were critical issues (Hayashi and Ooba 2014). Several studies were assessed to determine the applicability of biodiversity offset assessment methods implemented in other countries into Japan (Hasegawa et al. 2013, Hasegawa and Hayashi 2014, Ito and Hayashi 2014). Furthermore, several oral presentations were presented at the IAIA (international association for impact assessment) annual conferences related to Japanese examples.

For biodiversity banking, such as the CB and the MB in the US, the assessment of biodiversity components has been limited and has mainly been conducted for endangered species habitats and the ecological functions of wetlands. Ito et al. (2014b) reported that only one part of BD/ES values was included in the credit value of a MB by a contingent valuation method based on environmental economic valuation for hypothetical Californian MB sites. Most of the BD/ES values were not appropriately included in biodiversity offset and banking systems[1]; therefore, the potential scope of BD/ESs should be considered prior to implementation of a biodiversity offset and banking assessment.

A preliminary research framework for a forest assessment methodology of a biodiversity offset system was examined as a hypothetical case study in Nagoya City, Japan. A three step approach was employed. First, the wide-scale assessment of BD/ESs by GIS (Geographical information systems) was conducted as a screening stage for the conservation priority of BD/ESs in the city. Second, simple field surveys of forests were conducted to perform equivalency and offset-possibility assessments in the city. Third, on-site field surveys utilizing biodiversity assessment methods implemented in other countries were conducted to test the applicability of these assessments in Japan. Through this approach, the site selection method, the spatial assessment of BD/ESs, and the preliminary research framework were tested.

Methodology

Study area

Nagoya City is located in Aichi Prefecture (Figure 1(a) and (b)), and the City hall is located at 35.181°N, 136.906°E. The average annual temperature for the city in 2014 was 16.1°C and the average precipitation was 1505.5 mm (Japan Meteorological Agency 2015). The area of the city is approximately 326.43 km^2 and the population was 2.27 million as of April 1, 2014, making Nagoya City the third largest city in Japan (Nagoya City 2015).

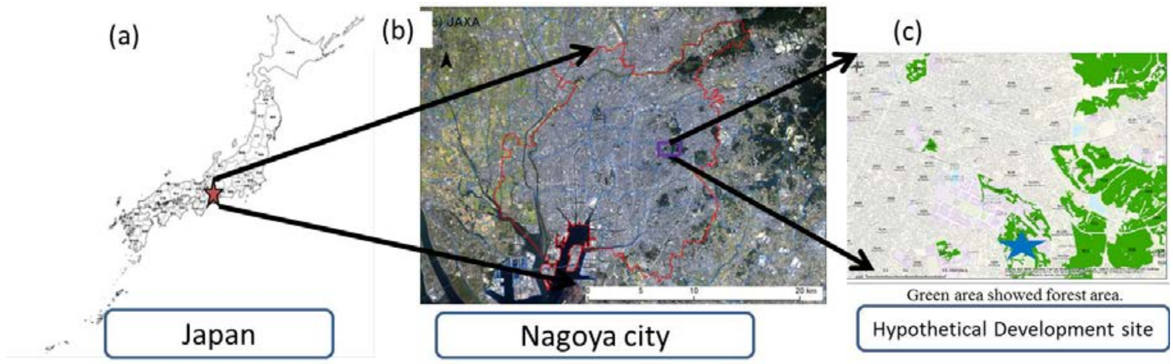

Figure 1. Maps of the study area, (a) Japan with Nagoya City in the star symbol, (b) Nagoya City outlined in red, (c) the hypothetical development site in the star symbol

Source: (b)ALOS Satellite image by JAXA/Distribution RESTEC, (c) Hypothetical development site in the star symbol and forest area in green colour by Nagoya green coverage GIS data (Nagoya City 2010)

Methods

A hypothetical development activity was setlected to potentially damage a forested area in Nagoya City (Figure 1(c)). The hypothetical development site (4.05 ha) was a typical secondary broadleaf deciduous forest dominated by *Quercus serrata* and *Q. variabilis* in the east part of Nagoya City, namely, on the Nagoya University campus. To compensate for the hypothetical loss of the BD/ESs, this study evaluated potential offset sites. In this case, the boundary of the site selection area was limited to within the city.

The first step was to grasp the BD/ES provisioning potential in Nagoya City utilizing GIS as a screening stage. Detailed methods to estimate the general tendency of the BD/ES provisioning potential for each area were presented in Ooba et al. (2015). Based on GIS data from the Nagoya land use metric

[1] To overcome this issue, there are several related approaches implemented: such as, the Cap-and-Trade program under AB 32 (namely, the California Global Warming Solutions Act of 2006), implemented in California, USA, which expanded its scope of greenhouse gas emissions (GHGs) to include a forest program(ARB 2014).

provided by Nagoya City(2007), six land use categories were developed—urban areas, forested areas, urban parks, water areas, paddy fields, and agricultural lands. Ecosystem services were then selected for the BD/ES estimation by utilizing unit value assessments from existing studies. The ESs included the following: carbon sequestration, food supply, soil erosion control, recreation index, and biodiversity index. The conservation priority areas could be identified based on the analysis from the perspective of five ESs.

Second simple field surveys were conducted on forests in Nagoya City. Surveys were conducted because the quality of biodiversity was noted as an important consideration in the offset site selection and by the above mentioned GIS analysis it is difficult to analyze a variety of factors, including the quality of forests, different tree species, the understory and litter layer composition, and cultural service use. According to the Nagoya green coverage GIS data (Nagoya City 2010), there were approximately 240 forests (≥ 1 ha) in the city. In this study, a forest was defined as a continual tree crown area of 1 ha or more occupied by any tree species. Among the selected forests, simple field surveys were conducted for 131 forests in the city from 2013 to 2014. The survey items were listed in Table 1. After conducting simple field surveys, forests were tentatively categorized into several types and compared with each other for equivalency and offset-possibility of the ES provisioning potential. In this categorization of forests, the following parameters were used in a cluster analysis using the group-average method and the squared Euclidean distance method: (1) supporting services (e.g., soil formation, carbon stock), (2) regulating services (e.g., NO_2 absorption, climate regulation), (3) provisioning services, (4) cultural services (e.g., spiritual value, aesthetic value, education value, recreation), and (5) habitat (e.g., forest size, naturalness). These similarities or equivalencies of forest BD/ESs should be considered as a biodiversity surrogate for development sites.

Third, detailed field surveys were conducted to test a variety of biodiversity assessment methods including the HSI, the HH, and the BBAM with several diversity indices (Simpson's diversity index, Shannon-Wiener's index, etc.). Biodiversity items for the biodiversity offset study included forest ecosystem, species diversity, and species habitat. Four forests near the hypothetical development site in the east part of Nagoya City were selected. Vegetation surveys were conducted in a 400-m^2 area and included tree species, tree height, diameter at breast height (DBH), crown area, vegetation cover (for over-story tall trees, medium-story trees, short trees, ground cover short trees, ferns, grasses, and litter), number of hollow trees, and mass of dead wood. In addition, a quarter of each 400-m^2 site was intensively sampled to identify every tree species, including young trees. These data were utilized for the HH, the BBAM, the HSI, the Simpson's diversity index, and the Shannon-Wiener index. Detailed methods for the HH and the BBAM analyses were summarized by Hasegawa et al. (2013) and Hasegawa and Hayashi (2014). Similarly, Ito and Hayashi (2014) developed a forest HSI model by combining integrated SI models for the firefly (*Luciola parvula*) (Ito and Hayashi 2014), large Japanese field mouse (*Apodemus speciosus*) (Ueno et al. 2011), and northern goshawk (*Accipiter gentilis*) (Higuchi et al., 2009). The authors determined the characteristics, limitations, and problems for each assessment and outlined their potential application in Japan.

The statistical analysis was conducted using Excel ver. 2010 (Microsoft corp.), SPSS statistics ver.22 (IBM corp.). The ArcGIS 10.1 (ESRI Japan Inc.) was used for the spatial analysis.

Table 1. Simple field survey items by survey size

	In 100-m^2 area	In 400-m^2 area	Entire forest area	Outside of forest
Basic survey items	Longitude, Latitude, Elevation, Slope, Topography, Temperature+, Relative humidity, Whole-sky photography++, etc.			Temperature, Relative humidity
Biomass surveys	Tree species, Tree height, DBH Crown area of each tree, Vegetation cover (tall trees, medium trees, short trees, very short trees, etc.), Recruitment (seedling growth) Mass of dead wood, etc.	Number of gingko trees (*Ginkgo biloba*) Number of large trees (DBH ≧ 40 cm) Number of oak trees (e.g., *Quercus serrata*, *Quercus variabilis*, *Quercus glauca*, and *Quercus myrsinifolia*)	Number of large trees (DBH ≧ 80 cm)	
Soil survey	Water content+++, Soil hardness++++, Surface soil and litter thickness, etc.			
Cultural survey			Aesthetic value, Recreation, Spiritual value, Cultural heritage value, etc.	
Habitat survey	Human intervention, Human accessibility, Human and vehicular traffic, etc.			
Other	Non-native species, Number of hollow trees			

+: illumination meter (LM-8000, MK Scientific, Inc., Japan); ++: fish-eye lens(IDF-3, Izawaopt, Japan); +++:soil water content meter (ProCheck, Decagon Devices Inc., U.S.A.)
++++: soil hardness meter (Daiki Rika Kogyo Co., Ltd., Japan); DBH means Diameter at Breast Height.

Results and discussion

The five ES provisioning potential maps were calculated (detail parameters, figures and results are presented in the IAIA15 proceedings by Ooba et al. (2015)). Ooba et al. (2015) estimated the priority area within the city in 1997 by using Zonation which is a conservation priority software (Moilanen et al. 2012), and compared it to the prioritized area in 1955 to identify the change of the conservation priority region. These results allowed easy identification of the type of ES provisioning potential that was compared to the hypothetical development site when considering conservation priority for BD/ESs. Furthermore, the trade-off and synergy of ES provisioning potential among ESs could visually be identified by GIS. Based on Ooba et al. (2015), the hypothetical development site was recognized as one of the high priority areas in the city for both 1955 and 1997.

For the second step, forests were categorized into several groups utilizing simple field survey data. The tentative cluster analysis results showed that forests were classified into 13 categories (Iwai and Hayashi 2015). These broad categories included bamboo forests, deciduous forests (5 sub-categories), evergreen forests (5 sub-categories), and urban parks (2 sub-categories). The development site was classified as one of the deciduous forests with relatively high soil erosion control services and recreational/educational services, and low in air regulation service. The detailed results will be summarized in future publications. Based on this analysis, the forest quality of potential offset sites could be compared with the hypothetical development site at this stage.

As for the third step, a detailed biodiversity assessment was conducted at field sites (Table 2). Regarding the SI model, only the average score of the SI model from site D was lower than the hypothetical development site. This resulted from the SI model scores for firefly and large Japanese field mouse being lower than those of the development site. As for the BBAM assessment, the score of site C was lower than the development site and the score of site D was highest. Regarding the HH assessment, the score of site C was similarly lower than the development site, and site B resulted in the same score as the development site. The score of sites A and B for the HSI, the HH, and the BBAM were higher or equal to the development site; therefore, sites A and B could be potential offset sites. However, other indices (i.e., individual number and aboveground biomass, which was related to one of ESs, namely, carbon stock) indicated that the scores of sites A and B were lower than those of the development site. Considering the individual assessment methods and indices having different viewpoints, the priority of the site assessment for BD/ESs should be considered carefully. More detailed results can be found in Ito et al. (2014a), Ito and Hayashi (2014), Hasegawa et al. (2013), and Hasegawa and Hayashi (2014).

Table 2. On-site biodiversity assessment results of the hypothetical development site and four hypothetical potential offset sites(A-D)

	Development site	A	B	C	D
HSI model assessment					
SI for firefly(*Luciola parvula*)	0.92	0.92	1.00	0.92	0.47
SI for northern goshawk(*Accipiter gentilis*)	0.39	0.37	0.47	1.00	0.67
SI for large Japanese field mouse(*Apodemus speciosus*)	0.80	0.83	0.67	0.80	0.55
Average of three SI models	0.70	0.71	0.71	0.91	0.56
Inhabitation of mammals	raccoon dog	raccoon dog	raccoon dog	raccoon dog, weasel	raccoon dog, weasel
BBAM	145	190	208	125	210
HH	56	64	56	54	63
Individual number	289	127	215	179	167
Species numeber	21	12	23	34	17
Simpson *λ*	0.77	0.83	0.87	0.94	0.88
Shannon-Wiener *H'*	2.99	3.23	5.20	4.70	4.47
Above ground biomass(kg/400㎡)	5,243	4,751	3,169	7,888	6,869

Source: Ito et al. (2014a) revised

Note: BBAM means BioBanking assessment methodology; HH means Habitat Hectares scoring method; Index species for HSI model included firefly (*Luciola parvula*) (Ito and Hayashi 2014), northern goshawk (*Accipiter gentilis*) (Higuch et al. 2009) and large Japanese field mouse (*Apodemus speciosus*) (Ueno et al. 2011).

Conclusion

This study developed a preliminary research framework of a biodiversity offset assessment methodology. The framework was tested for a site selection by a spatial GIS assessment and an on-site assessment with the inclusion of BD/ESs comprehensively. At the spatial scale, the framework could be useful for identifying conservation priority areas and to grasp the characteristics of each forested area from the perspective of BD/ES potential provisions beforehand. At the on-site scale, individual assessment methods and other indices resulted in different viewpoints. Therefore, the selection of BD/ES assessment methodologies should be considered carefully. Future studies should attempt to understand the linkage between spatial ES assessments and on-site assessments. The results presented here are tentative and will be updated in the future.

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