Research article

Comparative Assessments of Ecosystem Services between Rural and Urban Areas

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Abstract From the last century, landuse was drastically changed in both urban and rural areas. Design and planning are needed for sustainable development in not only rural area but also urban area kept being harmony with ecosystems and biodiversity. Ecosystem provides various goods and services for the human society. We carried out quantitative assessments of ecosystem services in both urban and rural areas in Japan. In a rural area, material circulations (water, carbon and wood) were estimated by a process-based ecosystem model. In an urban area, ecosystem services were estimated calculated by maps of land use classified from digital maps. From the results, both rural and urban ecosystems study areas were deeply affected by land use, provisioning service changes directly related to societal demands. Urban ecosystems might provide complementary functions for urban area residents in the condition of decreased value of provisioning service. Types of rural ecosystem services also may change for social and economic reasons. The information may be useful for environmental planning for each area but also for more large regions including urban and rural areas.

Keywords ecosystem modeling, ecosystem services, GIS, land use, urban area

INTRODUCTION

"Ecosystem Services" is a crucial keyword for sustainable development and society. After the studies of Costanza et al. (1997) and following the Millennium Ecosystem Assessment (2005), our perspective on ecosystems has changed. Ecosystems are essential to human society because they provide food, materials, and moreover services such as carbon absorption, water supply management, water quality control, disaster control, biodiversity conservation, and cultural services.

In Japan, forest and agricultural ecosystems cover over 60% and 10% of the total land area, respectively, most of which is located near urban areas that have become highly developed with the rapid Japanese economic growth. However, these ecosystems have some serious problems.

During the 1960s in Japan, a policy of converting natural forests to artificial forests was implemented (referred to as the “forest conversion policy” in this study). Today, a large portion of these artificial forests are mature. However, owing to economic reasons, these artificial forests have not been optimally managed. Imported timber and wood materials have an economical advantage when competing with Japanese forestry products. Depressed domestic forestry results in depopulation of rural areas, where forestry is the main industry, and also degrades plantation forest ecosystems.

In urban area in Japan, many cities gradually recover green space (parks, agricultural fields, and secondary forests) in contrast to the serious issues of air and water pollution experienced during rapid economic growth. The big Japanese cities of Tokyo and Osaka exceed 10% green space, and Nagoya, the chief central Japan city, exceeds 20% green space.

Over the last decade in Japan, many evaluations of ecosystem services have been conducted. Various types of ecosystems were assessed, i.e., the Sub Global Assessments (Japan Satoyama Satoumi Assessment, 2010). Several studies have also been conducted on urban green space functions (i.e., Dobbs, 2011, Ishimatsu et al., 2012, Plieninger, 2013). However, a comparison of the ecosystem type and temporal change between urban and rural areas has been lacking in these ecosystem service studies. Urban residents need more cultural and biodiversity ecosystem services and rural residents need more economic support for nearby ecosystems.

OBJECTIVES

In this study, ecosystem services assessments were conducted in both rural and urban areas. The case study areas were an upstream region of rural Toyota city and urban Nagoya city. Geographical Information Systems (GIS) data sets were compiled from various sources. Rural ecosystem services were estimated from a biogeochemical forest model. On the other hand, urban ecosystem services were estimated from land use maps and also served as preliminary results for future analysis. A comparison of these estimation results suggested that sustainable ecosystem services can be maintained in both urban and rural regions.

METHODOLOGY

Study Areas

The forest areas in Toyota city and Nagoya city were selected as the rural and urban study areas, respectively (Fig. 1). The annual averaged temperature and precipitation for these areas are 15.8°C and 1535.3 mm and 11.5°C and 1964.0 mm, respectively.

The rural study area of Toyota city (ca 18,000 ha), located upstream of the Yahagi River, includes the two communities of Asahi and Inabu. The annual averaged temperature and precipitation were 11.5°C and 1964.0 mm, respectively. The artificial and other forest (secondary or natural) covers were about 11,000 and 3,600 ha, respectively. The 2013 population was about 5,600.

With a population of about 2,260,000, nearby Nagoya (ca. 32,600 ha) represents urban Japan, and is the fourth largest city in Japan. The averaged temperature and precipitation were 15.8°C and 1535.3 mm, respectively.

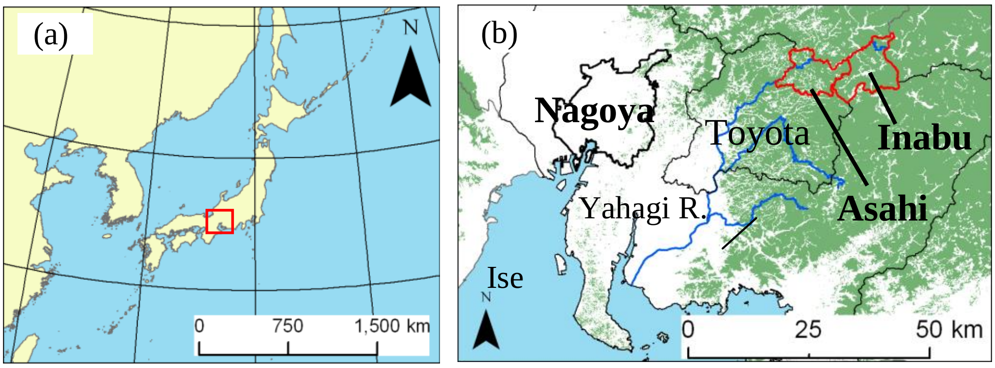

Fig. 1 Location of Japan and studied areas (a) and the studied rural and urban areas (Nagoya and two areas in Toyota) (b) (*Note: Green areas represent forest area*)

Rural Assessment

Ecosystem services related to material cycles (water, carbon, and nitrogen) were quantitatively estimated using detailed forest maps and an ecosystem model. Forest inventories, yield tables, and forest maps of Aichi prefecture were compiled. Using the methods outlined in our previous study (Ooba et al., 2010), we developed a forest GIS database that included detailed forest type and location attributes at the semi-compartment level. The total forest area has changed slightly since the forest conversion policy began (ca. 1960), but forest polygons were not changed in this study.

The BGC-ES model (version 1.1; Ooba et al., 2010, 2011) was used to simulate daily water cycles and annual carbon and nitrogen cycles. In this model, biomass growth is limited under insufficient light and low nitrogen availability conditions.

The forest ecosystem simulation unit was assumed to consist of homogeneous tree species and understory vegetation was ignored. Mixed forest stands (e.g., stands of broadleaf and needleleaf or mixed-age stands) were classified into homogeneous forest units based on crown area.

Mass cycle simulation for 1980-2060 was conducted based on current forest distribution. Before the simulation, a spin-up procedure achieved the initial condition for the model. The following proxies of forest ecosystem services were the main model outputs: timber accumulation, water runoff, carbon sequestration, and nitrogen leaching from the forest.

More detailed information about this simulation is available in our previous publications (Ooba et al., 2010, 2011, 2013).

Urban Assessment

Urban ecosystems were very disturbed by human activities. Consequently, ecosystem hysteresis effects (history) may be minor. We chose a simple and understandable urban assessment method using land use maps instead of a detailed, complicated ecosystem model. We assumed that the urban land use type (agricultural field and secondary forest) determined the type and extent of ecosystem services.

Digital land use maps from 1977 and 1997 at 10 m mesh level were obtained (Japan Map Center). Maps showed fifteen land use types that we aggregated into five types: urban area, agricultural field, forest, road, water surface. A paper land use map from 1955 was obtained from the Geospatial Information Authority of Japan, converted into digital format, and classified into five land use types using the maximum likelihood method (ArcGIS 10.1, ESRI). We manually corrected minor errors in the digitized land use map caused by the classification method.

Table 1 Ratios of land use types in Nagoya city at 3 different years (%)

Year	1955	1977	1997
Water surface	5	6	5
Residential and industrial area	36	53	57
Road	2	17	19
Agricultural field	38	10	6
Forest	17	13	10
Green area	55	23	16

Green area = Agricultural field + Forest

RESULTS AND DISCUSSION

Rural Ecosystem Services

Time series of timber accumulation, water runoff, carbon sequestration, and nitrogen leaching from the all forests in the studied area are shown in Fig. 2.

The accumulated trunk (timber) volume of the study area forests was averaged over 10 years to represent a saturated level. However, the 10 year average carbon sequestration rate was the maximum at the 1990s, and then continuously decreased. This was caused by the extensive conversion from natural to artificial forests. Young artificial forests are strong carbon sinks (Ooba et al., 2010). Post-1970s, low forestry disturbance (thinning and regeneration rates) provided effective carbon accumulation. The models predict that the carbon sequestration rate will not rise again after 2050, due to forest aging and lack of plantation forest regeneration. Model-predicted spatial distributions of carbon sequestration for three decades are shown in Fig. 3.

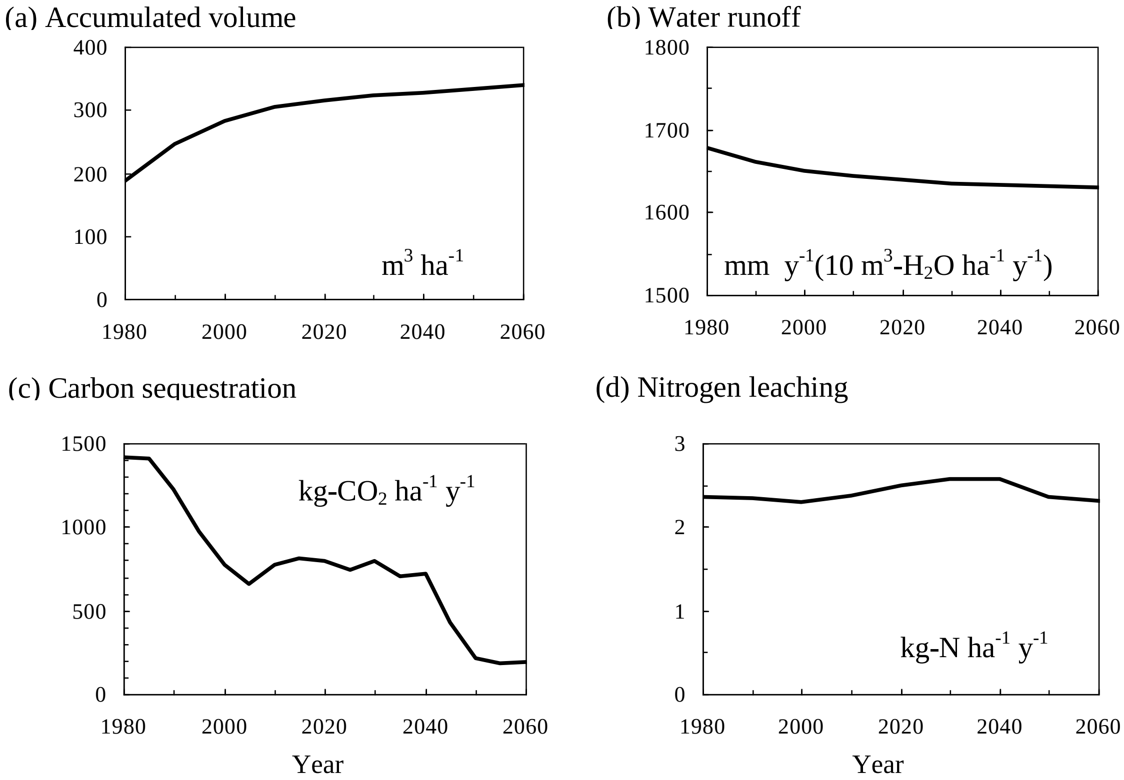

Fig. 2 Time series estimated by the BGC-ES model from 1980 to 2060 in the all forests of studies areas (Inabu and Asahi areas)

The results were averaged for 10-years at a unit area

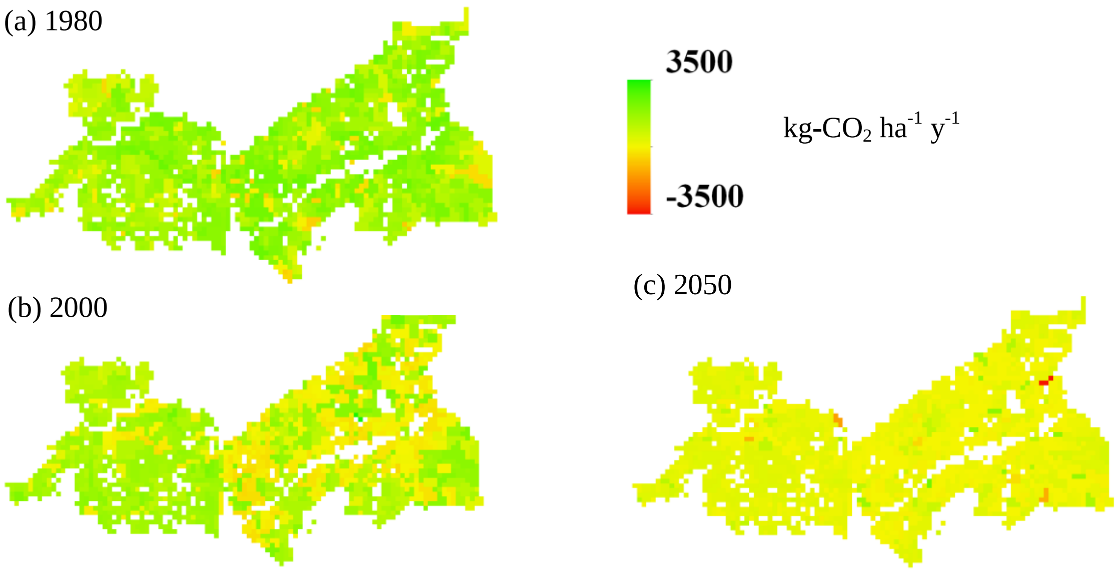

Fig. 3 Carbon sequestration rate in forests of studies areas (Inabu and Asahi areas)

(a) 1980 (b) 2000 (c) 2050 at 250 m mesh

No remarkable variation in water runoff or nitrogen leaching from the forest was observed among the model scenarios (Fig. 2b and 2d), similar to our previously published results (Ooba et al., 2010, 2011, 2013).

Urban Ecosystem Services

A comparison of the urban land use in 1955 and 1977 showed that green space decreased drastically (Figs. 4a and 4b), including agricultural fields and forests in Nagoya city. In contrast, the urban green space slightly decreased between 1977 and 1997 (Figs. 4b and 4c, Table 1).

28% of agricultural fields were converted into urban area in northern and western parts of Nagoya city. The largest land use change from 1955 to 1977 affected provisioning services (agricultural products). However, valuation of agricultural ecosystem services in urban area obviously declined during rapid economic growth, resulting in economic benefit from residential, or industrial, land use.

Urban forest area also decreased from 1955 to 1977 (4%), reducing ecosystem services related to carbon sequestration. Urban forests had been an important fuel source before the end of World War II. After the war, firewood and charcoal use gradually declined in favor of fossil fuel use. Urban forests were also converted to urban land use for economic reasons. It is notable that area of forest decreased (3%) from 1955 to 1977, in contrast to the change in agricultural field.

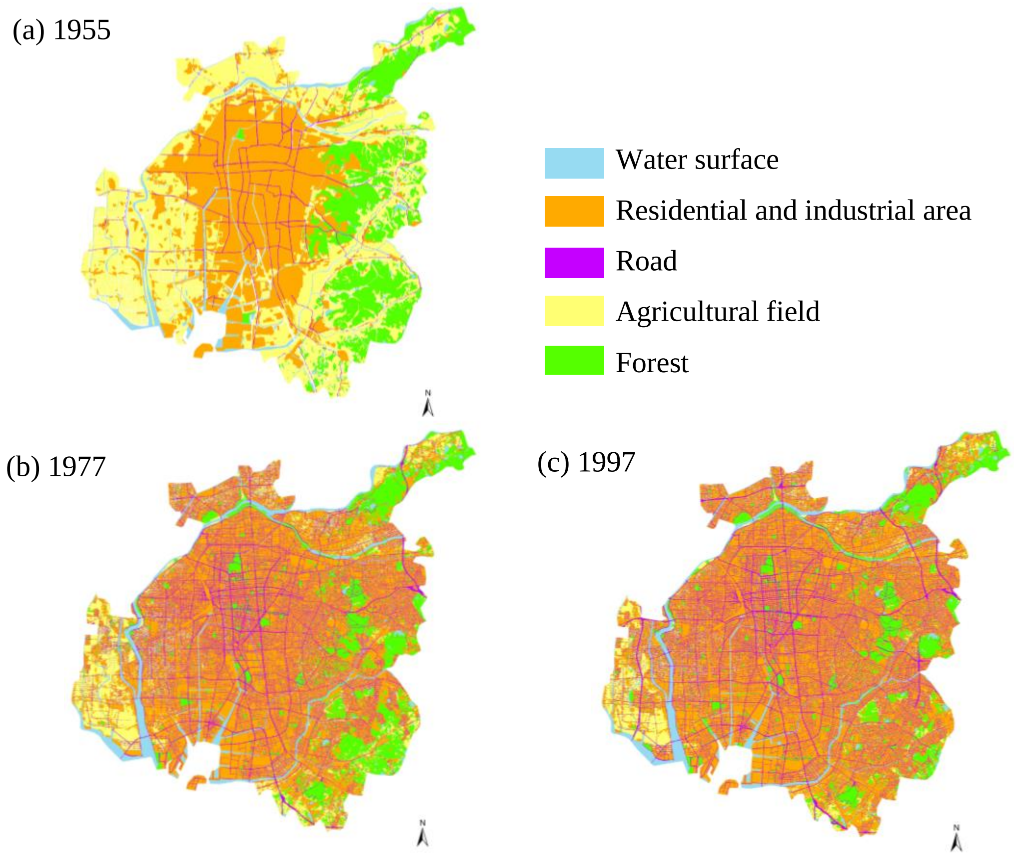

Fig. 4 Land use types in Nagoya city at 3 different years
(a) 1955 (b) 1977 (c) 1997

Ecosystem Services Comparison between Rural and Urban Study Areas

Ecosystem characteristics essentially differ between the rural and urban study areas. Rural ecosystems have broad spatial and temporal extents, contribute such regional mass cycles as hydrological and climatological circulations, and provide such goods as water, wood, and agricultural products. Urban ecosystems are relatively small and fragmentized.

Initially, both rural and urban ecosystems study areas were deeply affected by land use provisioning service changes directly related to societal demands on estimating ecosystem services. The shift from wood to fossil fuels as an energy source resulted in large carbon emissions in the urban study area, but more carbon storage in the rural study area. From this, we deduce the necessary ecosystems services for residents of both the rural and urban areas have changed since 1955. Urban ecosystems might provide complementary functions for urban area residents, including aesthetic, cultural, and biological values. Types of rural ecosystem services also change, for social and economic reasons.

This study indicates both rural and urban areas undergo spatial distribution and temporal changes in ecosystem services. A future study incorporating the systematic and integrated evaluation of ecosystem services would improve upon this study's shortcomings.

CONCLUSION

Rural forest ecosystems provide many ecosystem services; demand is less to provisioning services such as wood biomass and carbon sequestration. In urban areas, needed ecosystem services shifted from provisioning to other services. Our results are useful for rural and urban area environmental planning, particularly on a regional scale.

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