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Biodiversity and Ecosystem Services in Urban Areas for Smart Adaptation to Climate Change: “Do You Kyoto?”

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Introduction: Why Kyoto?

The local government of Kyoto, the city where the Kyoto Protocol was adopted, proposed to work towards becoming a low-carbon society by asking people, "Do you Kyoto?" (Kyoto City 2009). However, beyond the reduction of carbon dioxide emissions, we should pay more attention to the biodiversity that has been the basis of this sustainable city celebrating ecosystem services. To obtain an ecosystem-dependent design solution, biodiversity is an essential natural capital that must be reassessed from the viewpoint of smart adaptation to climate change. The "21st Century Environment Nation Strategy" (Japanese Government 2007), in which I was involved in the discussions, was the official statement of the Japanese government pointing out the importance of comprehensive measures to integrate the three aspects of a sustainable society: a Low Carbon Society, a Sound Material-Cycle Society and a Society in Harmony with Nature.

Since the year 794, Kyoto has always been celebrated as an ancient capital, but the significance is that Kyoto has so far maintained its status as a major metropolis with features unique within Japan. It has been blessed with natural beauty, which was expressed as "Sanshi-Suimei," or "blue mountains and clean water," according to Sanyo Rai, a famous Confucianist from the Edo period. However, we must note that Kyoto has several times experienced severe destructive events, such as civil wars or massive fires. Despite this, Kyoto has been a place where innovative ideas have been implemented, such as the reconstruction by Hideyoshi, the chief adviser to the Emperor in the sixteenth century, or the cutting-edge modernization taking advantage of the natural environment of Kyoto in the Meiji Era. This includes the construction of the "Sosui" canal from Lake Biwa and its use as the first commercial water power station in Japan to power the first street cars, which also allowed the development of excellent villas and provided high-quality Japanese gardens with water. These events took place at the end of the nineteenth century but have become quite important elements of the historic amenities of Kyoto today.

As a result, Kyoto is expected to offer some insight into how to create a sustainable city with resilience relevant to its historical inheritances and biodiversity. Cities need to more or less alter the original wildlife habitats into areas for human use. This process inevitably results in some sort of degradation of natural ecosystems. This paper tries to elucidate on the reality of the degradation of nature in the urbanization process, and discuss some concepts, responses, or good practices that could mitigate the negative impact of urbanization in relation to its biodiversity, ecosystems, and ecosystem services. Urbanization impacts on the natural environment in the Kyoto city area will be categorized and discussed as follows. (1) Historical responses to urban sprawl or city planning against expanding urban areas into the surrounding mountains, (2) the reality of and response to the fragmentation and isolation of natural habitats beyond the island biogeography, and (3) dealing with flooding or seeking an alternative to mitigate tradeoffs of ecosystems services.

Historical responses to urban sprawl

City planning considering natural amenities

The original city of Kyoto, the ancient capital Heian-Kyo, was constructed more than 1,200 years ago. The main structure is modeled after the ancient cities of China, and it is said that Feng-shui geomancy played an important role (Honda 1994, Huang 1996) in the city planning. Feng-shui is a theory for site selection and setting up facilities thinking of qi, or the flow of vital energies such as wind and water. The theory gives us some tips for sustainable city planning. In his famous publication “Land Mosaics (Forman 1995),” Dr. Forman mentioned the Feng-shui concept for sustainable land use considering urban forest ecosystems, which are key resources of biodiversity in the scale of urban planning.

Recognizing that natural beauty is a basic component of the historical quality of the city, the local government of Kyoto has been a front-runner in the field of city’s landscape amenity governance (Morimoto 2009), beginning with the first city ordinance to control urban sprawl into the surrounding mountains, “Scenic Landscape Districts,” which was established in 1930. A person wanting to build a house in the designated area is required to consider the environment including trees and shrubs. However, this ordinance only intended to create well-considered developments and was ineffective in conserving the natural environment in the face of rapid urbanization during the rapid economic growth after the 1960s. Citizens' earnest protests against the destruction of natural and historic environments in Kamakura, an ancient city like Kyoto, pushed the government to establish a powerful new law, the "Special law for the preservation of historical features in ancient capitals," which enables land acquisition by local authorities. This buy-out system to deal with rapid economic growth was an emergency procedure. The "Special Preservation Areas of Historical Landscape" ordained by this law and another powerful law that designated "Preservation Areas of Green Spaces" and "Special Preservation Areas of Suburban Green Space" succeeded in keeping the isolated, precious forested hills in the urban areas of Kyoto, Narabigaoka, and Yoshidayama, untouched (Table 1).

However, more discussion is required to ascertain whether compensation for landowners is necessary. The landscape area as well as the zoning code for urbanization constraint private right, but the compensation is not prepared. It is very natural for people in the current generation to consider the excellent natural and historical amenities that have been nurtured and taken over from our ancestors to make some decision on the land use. This zoning is limited to the core areas of amenities such as shrines, temples, and the foothills of surrounding mountains.

Another city ordinance that intends to conserve the whole forested mountain scenery as the basic backdrop of Kyoto, "Preservation Areas for Natural Scenery,", was adopted as a response to illegal development and dumping. The designated area extends to more than 25 thousand ha, and the landscaping is recommended to consider regionally specific landscape and plant materials. The ordinance stipulates not only punishment by fee but prison for the violators, for the purpose to ensuring the effectiveness of the ordinance. Kyoto is likely to be conceived as a green city, but contrary to expectations, the actual coverage of greenery is rather low in the city area.

However, because of the green mountains in the surrounding area, citizens' level of satisfaction with the aspect of greenery is very high (Nagayama et al. 1992).

Down zoning and vistaed view preservation: new ordinance

Kyoto established several other townscape zoning systems within built-up areas in order to revitalize the areas while considering historical traditions. Moreover, for the purpose of keeping beautiful natural and historical "vistaed views" or "borrowed scenery," down-zoning of building heights and design control systems were established based on the intensive discussion at the special council, in which I participated. Thirty-eight vistaed views were designated for preservation, as follows:

① On-site views: 14 World Heritage Sites, Kyoto Imperial Palace Park, Shugakuin Imperial Villa, Katsura Imperial Villa

② Street Views: Oike St. etc.

③ Waterfront Views: Hori and Uji River, Lake Biwa Sosui canal

④ Borrowed Views of Gardens: Entsuji Temple, Shosei Garden

⑤ Mountain Views: Higashiyama and Kitayama from the Kamo River, Nishiyama from the Katsura River banks

⑥ Bonfire Character Views: Daimonji Bonfire as seen from the Kamo River, etc.

⑦ Lookout Views: Arashiyama range as seen from Togetsu Bridge downriver

⑧ Bird's-Eye Views: Cityscape seen from Daimonji-yama

Despite the protest by residential developers, the fact that all political parties agreed to this innovative landscape ordinance clearly shows the socio-economic value of cultural landscape with trees, vegetated mountains, and gardens. The price of condominiums is higher with a view of Daimonji Bonfire, one of the bio-cultural landscape elements of Kyoto. Using CVM and the conjoint method, the benefit of the designation of "Special Preservation Areas of Ancient Capitals" is estimated at 2.4 billion yen, while the amount paid for acquisition to protect the scenery was much lower at 1.1 billion yen

(Aoyama et al. 2000). Thus, down zoning and the vista preservation policy are expected to increase the asset value of Kyoto city, which could enjoy the ecosystem services of surrounded mountains.

Beyond the theory of "Island Biogeography"

Fragmentation and isolation of habitats in Kyoto

Kyoto has had a unique structure of urban greenery since the Edo period, including shrine forests and trees in the traditional courtyards of town houses. Following is the summary of our survey on the reality of biodiversity in the fragmented greenery areas inside the city area of Kyoto.

The application of island biogeography (MacArther & Wilson 1967) has been a major theory for urban landscape ecological analysis, considering built-up areas as matrices like an ocean and forested areas as patches of islands for wildlife habitats. Species diversity in a remnant patch or a created park is expected to be determined by not only planting or species introduction but also the dynamics of natural colonization and extinction in a long history. Kyoto is a kind of matured city, where there are a considerable number of isolated forests, including shrine forests that have been sustainably managed through traditional culture with trees and plants. Those matured greeneries could be, therefore, at near the steady state of colonization/extinction dynamics.

Island biogeography suggests the importance of the patch size and the distance from source patches; however, different types of responses were found in each taxonomic group.

Woody plant species (Murakami and Morimoto 2000) respond to the patch size most clearly. The species richness of ants has a considerably weak response to the patch size and depends strongly on microhabitat diversity (Yui et al. 2001): features such as soil surface conditions and the existence of fallen tree trunks. On the other hand, as pteridophyte species generally respond to micro-relief, the species diversity is also affected by the microhabitat diversity. As the shrinkage of a forest patch size in an urban area may result in a drier environment, making the habitat for ferns very severe, the slope of the regression line for the species-area relationship is steeper and wider scattered than the line is for woody plants. Smaller and more isolated patches seem to have more severe conditions for fertilization by sperm in case of diploid ferns (Murakami et al. 2005), which are sensitive to urbanization. As a result, large patches could be the refuge of red-list species such as *Epipogium roseum*, an orchid, *Asplenium oligophlebium*, a fern, and *Leskeella pusilla*, a moss species. If we look into the meaning of the size of an isolated patch, avi-fauna may be convenient for characterization. Our research (Hashimoto et al. 2003, 2005a) suggests that the insect-eating bird, Great Tit needs 1 to 3 ha, while the large beetle- and frog-eating Brown Hawk Owl needs 3 to 10 ha. A pair of Northern Goshawks, which prey on crows, have successfully nested for four consecutive years in the Osaka EXPO '70 Park (about 100 ha of forested area) (Inoue et al 2010).

However, small habitats prove to be a matter to be reckoned with. When we tried to conserve all the plant species found in the Kyoto shrine forests, we found that the largest forest has more than 50% of tree species; however, the ratio of herbaceous plants to fern species is only 20–30%. Moreover, red-list-species are found in small patches (Imanishi et al. 2005a,b). Thus, the so-called SLOSS (Single Large Or Several Small) issue is also an important topic for greenery planning (Morimoto 2004, 2007a). We examined the reality in Kyoto, and found both cases: a large forest on a hill of bedrock, Narabigaoka, and another on an alluvial fan, Tadasu-no-mori, showed that four or five small patches have much more woody and fern species, including rare species, than one large area (Murakami et al. 2005).

Role of management

Therefore, is it enough if one large patch and several unique small patches are protected? The answer is no. As mentioned above, Kyoto has been a front-runner in terms of landscape governance. However, the reason why the "Council for Kyoto Traditional Forest Culture" was established is, according to the charter (Yamaore 2007), "The background forest landscape has been gradually changed to create not a few environmental and ecological problems during recent years." Currently, the ecological integrity of forest ecosystems in and around Kyoto is threatened by unusual mass dieback of Pines and Oaks. Mosses in Japanese gardens are also part of the crisis. These phenomena might be examples of typical biodiversity crises in Japan (Japanese government 2008). The moss withering mainly because of urban heat island phenomena (Iida et al. 2010), is an example of Crisis 1, "habitat degradation due to excessive human activities;" the background of Oak wilt disease is Crisis 2, "degradation due to an insufficient level of management;" and Pine wilt disease is Crisis 3, "Invasive alien species." Other examples of Crisis 2 include drastic landscape changes and forest floor vegetation dieback by succession to even-aged evergreen *Castanopsis* forest, and abnormal population outbreak of wildlife such as shika deer, wild bore, common raccoon, and monkey. These problems are detrimental to traditional cultural events, including the Daimonji Bonfire and Gion festival, the most important attractive festivals of Kyoto. The surrounding green mountains are suffering from "metabolic syndrome," or accumulating materials without adequate use.

The council has expert panels to discuss cultural ecosystem services as well as forestry technology panels; however, adequate ecosystem management is only on the way to being developed.

Role of design: Ferns and mosses

Another factor affecting the biodiversity of the city is the nature-oriented design. Biodiversity is not only a resource of culture, but also the result of culture. We can point out characteristic biodiversity (Morimoto 2007a,b), which has been nurtured by culture in Kyoto.

For example, Japanese gardens play an important role in providing urban wildlife habitats for ferns and moss. Our researches (Murakami et al. 2004, Ohishi and Morimoto 2003) clearly showed the characteristics. Species richness of ferns is significantly greater than in other fragmented forests. Another characteristic is the high occurrence of forest edge species. Japanese gardens are famous for the moss landscape, and traditionally, the moss garden is one of the design styles of Japanese gardening. However, consciously introduced species of ferns and moss are quite limited to only several species. Therefore, species richness in these taxonomic groups is the result of natural colonizing and extinction, which are expected by “island biogeography” as well as the garden design and its maintenance.

While the moss garden or Saiho-ji temple garden was originally a dried-up garden with sand and stones, the wet climate of Kyoto and the maintenance required, including sweeping falling leaves and pruning branches to keep the garden half-shaded made the garden a refuge of moss (Morimoto 2007a). Well-maintained gardens are treasure houses of moss. An endangered (category VU, Ministry of Environment) species, *Monosolenium tenerum*, was confirmed at three imperial gardens in Kyoto city. This species was once recorded at the Moss Garden, but is listed as most threatened by Kyoto Prefecture because it was not found during the red-list species survey (Kyoto Pref. 2002). We also found *Riccia fluitans* (category CR+EN) at the same places, and *Taxiphyllum alternans* (listed as endangered by Kyoto Pref.) was found in some imperial gardens, including the Katsura detached palace garden.

Role of design: Fish fauna

A garden pond is not always just a water body or a live-box of carp. For example, a kind of cyprinid fish, *Acanthorhodeus cyanostigma* (red-list category CR) (MOE 2004) inhabit the sacred garden pond of the Heian shrine that was constructed about a hundred years ago. The fish lay eggs into large bivalves, and the bivalve larva need small fish to parasitize. Therefore, there exists a small but well-organized ecosystem. The above-mentioned “Sosui” canal is regarded as an ecological network to connect Biwa Lake and gardens in Kyoto. We completed a research project (Ito and Morimoto 2003) on the garden ponds designed by Ueji, an excellent gardener, using the water of the canal from Biwa Lake. About a hundred years from construction could be sufficient to analyze the time-proven relationship between fish fauna and the design. We clarified the parameters such as microhabitat diversity, depth, area, shape complexity, and turnover rate of water, which strongly affect the fish fauna. For example, a different fish composition of diverse species was found in the Shokuhoen garden pond, where greater turnover rate of water was recorded, including eel, the nesting fish *Pelteobagrus nudiceps* and *Tridentiger brevispinis*, and the brood parasite *Pungtungia herz*. Thus, garden ponds are now a refuge of these species, because some of the species became quite rare at the original habitat of Biwa Lake (Morimoto and Natuhara 2005), the largest in Japan.

Of course, the purpose of these Japanese gardens is not to grow fish or moss; however, the design effort to realize the sense of nature at the foot of the Higashiyama Mountains may have led to the development of the garden as ecologically sustainable and well organized in terms of an ecosystem. The reason we feel these Japanese gardens to be important amenities is thus that they provide biodiversity nurtured by the environment as well as skilled maintenance.

Creating a new island: Inochi-no-mori, urban wildlife habitat

A drastic change in the transportation system in Japan is the basic reason why Umekoji park (with a significant space of 12 ha) was established near Kyoto Station. The former fright train yard was transformed into a park as part of Heian-Kyo's 1,200th anniversary celebrations. A portion of the park (0.6ha) was designed as an urban wildlife habitat, "Inochi-no-mori," where human use is restricted. The project team, in which I am involved, discussed making the goal of the area to be a refuge of wilderness like what was found in Kyoto before urbanization. Although it is a very limited area and there is limited connectivity from the nearest core natural areas (2 km from the Kamo river and 3 km from the Higashiyama mountains), we tried to realize a miniature Kyoto basin, including shrine forests and aquatic environments. In the Edo period, several hundred years ago, sight-seeing guidebooks for Kyoto, such as "Miyako-meisho-zue" and "Kyo-habutae" introduced about 40 urban forests (Shidei 1993). The new project expects to add a landmark or a green island inside Kyoto.

By monitoring the process of species colonization and extinction for 14 years, from construction up to now, we have been able to figure out the characteristics of each taxonomic group (Morimoto & Natuhara 2005, Murakami et al. 2004, Hashimoto et al. 2005, Imanishi et al. 2007, KRGB 2010). Following is a tentative summary of our ongoing research.

Generally, the initial several years were quite astonishing in terms of recording new species, and the maximum or a plateau value of the number of species was detected in most taxonomic groups. In the second year, an impressive 14 species of dragonfly were recorded; however, aquatic insects were almost replaced by invasive alien species such as American bullfrog and red swamp crawfish. The peak of species richness of herbaceous species was the fourth year, and gradually declined. The same trends were observed in woody plant species, but the year when species number peaked and the decline are delayed and gentler than for herbaceous species. The number of seedlings taller than 0.5 m is still increasing, and *Celtis sinensis* var. *japonica* is most dominant, as expected, because of the site's natural quality of being a floodplain like Tadasu-no-mori. However, *Ligustrum lucidum*, (listed as a suspicious invasive alien by MOE) is increasing even in the shade conditions. Fern species richness increased gradually, but seems to be already at its peak. Avifauna recorded in a year is almost steady at 30–34 species after the third year. There are still limited nesting species; however, a pair of *Alcedo atthis*, a beautiful fish-eating species, has become an attractive target for nature watching. The peak of mushroom diversity was observed in the fifth year, in relation to the decay process of woods introduced at the first stage. However, mycorrhizae species are gradually increasing.

In general, however, growing trees, homogenization of the forest floor light environment, plant succession, and invasive aliens are considered negative factors for species diversity. Global warming might be another threat in relation to invasive aliens (Murakami and Morimoto 2008, Horikawa et al. 2008, Ooishi et al. 2008). In spite of these limitations, species richness of the above taxonomic groups in this wildlife habitat park is still significantly higher than the standard species-area curve derived from isolated greenery in the Kyoto basin. This site became a unique site in the heart of the city area, where nature observation and education projects are undertaken frequently.

Getting along with flooding

Alteration of natural water ecosystems

As part of the process of modernization, Kyoto is no exception to the trend of losing natural water ecosystems, including small rivers inside the city area and wetlands. From 1931¬¬–1976, 24% of the total length of rivers was lost (Yoshimura 2006). Almost all small rivers became concrete-covered. The major rivers, the Kamo and the Takano had their cross sections improved to go down the water table. As a result, the small ponds and rivers in Tadasu-no-mori, the largest shrine forest in Kyoto, lost water with Futabaaoi or Asarum caulescens, the symbol herb of this shrine (Shidei 1996). Natural springs stopped, and they drilled a well to pump up water for a shrine purification ceremony—the Mitarashi ritual, quite a popular traditional event. An endemic fish species, Pungitius kaibarae, also became extinct from Japan. The most serious impact for biodiversity and ecosystem services could be the reclamation of the Ogura-ike pond wetland system (800 ha in 1910), which had been the symbol of the southern side of Heian-Kyo. Not withstanding that the wetland was designated as a national monument of the habitat of a rare aquatic plant species, the largest inland marsh with the largest wetland biodiversity in western Japan, which had aquatic production and was a famous place for lotus watching, Ogura-ike was reclaimed for rice production. Ninety-one aquatic plants, including endemic species, were lost (Hatcho et al. 2007, Matsumoto et al. 2009).

These changes in biodiversity and ecosystem services should be reconsidered from the viewpoint of smart adaptation to climate change. Biodiversity issues contain critical natural capital, which is not renewable but is essential for sustainability. Species extinction in the wild is an indicator of this issue. Ecosystem services issue should be studied as an issue of tradeoffs and benefits and sharing. The main tradeoff of provisioning service in the reclamation process of Ogura-ike is between rice production of about 4000 t a year and fish production of about 160 t a year. However, we must pay attention also to the cultural function of Ogura-ike as a famous lotus-watching site, as in the travel writing before reclamation in 1926 by Tetsuro Watsuji (1951), the famous philosopher. Moreover, Ogura-ike's regulating service as a flood control basin is a fundamental tradeoff with dams and levees (Okuma 2007, Miyamoto 2007), which keeps leading waterside ecosystems towards deterioration.

There should be more discussion on long-term adaptation scenarios considering the increasing risk of flooding (Hamada et al. 2008). Ideal land use, including flooding basins with optimized greenery planning and design, are expected to contribute to disaster management considering ecosystem services from the viewpoint of smart adaptation to climate change. As the Millennium Ecosystem Assessment (2005) and the report by the Science Council (2007) suggested, one of the most endangered habitats is the wetland of floodplains.

Biodiversity-conscious solutions

The above discussion is summarized for biodiversity-conscious urban design as shown in the middle row of Table 2. Biodiversity is an essential resource for human use as well as the indicator for the sustainability of the resource and land use. Urban design without extinction of the species that originally inhabited the area could be the goal for a sustainable city. I would like to propose this concept as a bio-culturally diverse city, because biological sustainability would not be guaranteed without cultural sustainability.

At the scale of site planning and design, Japanese gardens suggest good solutions for land use, taking advantages of the environment. Katsura detached palace, one of the excellent examples of architecture with a garden, which was introduced to the western world by Bruno J. F. Taut (1880¬–1938), suggests a harmonious coexistence between culture and nature. Most of the materials for its construction, such as the wood and stones, are common in and around Kyoto, but the composition and the design were unique. It was constructed at the alluvial plane just along the Katsura River. That gave it the advantage of bringing water from the river for attractive garden ponds, but also created the risk of flooding. The solution for this tradeoff was to make the main building high-floored. We can notice several signs of the water levels of the floods on the posts under the floor (Okuma 2007). Moreover, the unique design of bamboo fences in the garden and the bamboo grove along the riverbank could have played a good role in mitigating the damage by filtering garbage so it could not get into the garden. The history of 400 years from its construction shows the significance of this smart adaptation to live in harmony with nature that provides us ecosystem services and also natural hazards. Considering that the waterside eco-tone is one of the key habitats for species threatened by urbanization (Washitani et al. 2007), and that there is an increasing risk of extraordinarily heavy rain in the urban climate (Mikami et al. 2005), we need to seek an alternative system of design and planning to mitigate tradeoffs of ecosystems services and biodiversity. There are still many attractive landscapes being nurtured as part of the long history of land use and landscape design and management (Morimoto 2008). Thinking of the multilevel mosaic city of Kyoto, I would like to suggest that "Do you Kyoto?" should ask everyone to engage in not only ethical behavior, such as "Mottainai," but also innovative design with nature for a society with bio-cultural diversity.

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