Two Development Scenarios for Kameoka Flood Plain, Japan: Requirements for a Paradigm Shift to Green Infrastructure

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Abstract

The local government of Kyoto Prefecture in Japan is currently planning to develop a large sports stadium in Kameoka floodplain. The floodplain is habitat to a nationally registered fish species, the Japanese kissing loach (Leptobotiacurta). However, the controversy between conservation and development is not simple because the habitat of the species is a river controlled to irrigate rice paddies. Local farmers, who are willing to develop the stadium, have been taking part in conservation activities by damming the river water to facilitate an egg-laying site for the fish. Therefore, a viable plan must preserve the habitat and be a comprehensive solution that supports the agricultural environment. Furthermore, the stadium project marks a watershed of two development scenarios of the Kameoka basin: (1) Gray Infrastructure, which is the conventional construction design used to deal with the risk of flooding and (2) Green Infrastructure, which is flexible, nature-oriented land use and design. The rare species still inhabits Kameoka basin because the basin is prone to flooding because of the narrow bottleneck, the Hozu valley, which has been providing impressive beautiful scenery and boating downstream to the nationally registered scenic beauty of Arashiyama in Kyoto.

Keywords: development scenario, green infrastructure, flood plain, nature conservation, endangered species, biodiversity

I. Introduction

The local government of Kyoto Prefecture (2012, 2013) is planning to develop a large sports stadium in the Kameoka floodplain with Kameoka City (2012, 2013). The area currently is the habitat of an endangered fish species, the Japanese kissing loach (*Leptobotiacurta*). The local governments of Kameoka City and Kyoto Prefecture are promoting the project along with a conservation plan for the species in cooperation with local people. However, academic organizations and the World Wildlife Fund (WWF)-Japan have voiced serious concerns about the survival of the fish population.

The controversy surrounding the planned development is not simply a matter of conservation versus development for two reasons. First, the habitat of the target species is not a naturally existing river; it is a human-controlled river used to irrigate rice paddies. The local farmers who support the development of the stadium have been engaging in conservation activities, such as damming the river to facilitate spawning of the fish. Second, the project might be symbolic of projects that influence the areas downstream as well as the planned area to change their beautiful natural landscapes into concrete infrastructures and degraded landscapes.

At present, the controversy and discussion on the issue apparently are polarized as pro or con positions regarding whether the development should go forward. This paper's goal is to draw each stakeholder's attention to wider and more long-term aspects of the situation by considering two development scenarios. I showed this basic idea in the process of restoration from the great earthquake disaster in Japan (Morimoto, 2012). The first scenario is the "Gray Infrastructure" type, which is the traditional structure-oriented, shortsighted method of development, whereas the second scenario is the "Green Infrastructure" type, which is oriented to utilize the function of ecosystem with low-impact land use and design. The ultimate goal of this study is to promote habitat preservation and to develop a comprehensive solution that enables continuation of the existing dynamic agricultural environment and beautiful natural landscapes, both of which are characteristically flood-prone.

II. Controversial points of conservation and disasters mitigation

A. Gray and Green Infrastructure

The Japanese kissing loach (Parabotiacurta), referred to as Ayumodoki in Japanese, is a freshwater fish species of the order Cypriniformes, family Cobitidae, and sub-family Botiinae that inhabits a limited region of western Honshu island, Japan. Before agricultural modernization, the fishwas a common species, with a population that was extensively harvested and depleted in the 1960s. It is believed that the most critical reason for the population decline was the loss of floodplain environment as the spawning ground, caused by farmland consolidation and river improvement. In 1977, Ayumodoki was named a national treasure and, in 2004, it was designated as a rare wild species by the Act for the Conservation of Endangered Species of Wild Fauna and Flora. It currently is listed as a critical endangered species (IA) by the Ministry of the Environment, Japan. At present, a very small population inhabits areas limited to the Asahikawa watershed and the Yoshii watershed of Okayama Prefecture and the Kameoka basin of Kyoto Prefecture.

Despite the IA status of the fish, in Kameoka City, there are flood control projects of the Hozu area, developments of new towns in the Hozu riverbed, land readjustment of the northern area of Kameoka Station, and the development of Kameoka stadium currently in progress. Kameoka City is planning to create Ayumodoki symbiotic zones, which is its method of mitigating the impact of the sports stadium construction on the species. However, the Kameoka basin provides a unique habitat for endangered frog species and aquatic plants as well as for Ayumodoki. The traditional land use as paddy fields is quite ecologically suitable to these creatures, but the development of urban infrastructures poses a considerable risk of flooding in addition to the general ecological impact that a built environment would have on the unique and rich biodiversity of the floodplain.

Two scenarios can be considered in response to the increased risk of flooding and loss of biodiversity expected to result from the stadium's infrastructural development. First, the Gray Infrastructure plans proceed by providing a four-meter thick earthen fill for the stadium ground to avoid inundation, dredging the river channel to increase cross-sectional flow downstream, and strengthening the embankments to prevent flooding. Those measures intend to curtail the negative impacts of the development on the area's biodiversity and interaction with the beautiful landscapes, such as hozu-gawa-kudari (boating down the Hozu river valley) to Arashiyama, a nationally registered beautiful scenery site in Kyoto.

The second, and contrary, response to this conventional infrastructure features minimum and smart hardware design with a land-use design that is faithful to the natural characteristics of the floodplain, the Green Infrastructure type. This response allows flooding to occur in cases of emergency using open levees with the existing paddies acting as temporary flood basins. The Green Infrastructure type had been the traditional way of adapting to flood prone areas, such as the Hozu area of Kameoka basin. A related urban developmental design would be low impact development (LID), which minimizes the alteration of the rainwater cycle by integrating rain gardens and bio-swales into urban design (AIJ, 2011).

B. Kameoka basin as a biodiversity hotspot of flood plains

Kameoka basin is part of the Yodo River watershed. Situated upstream of the Katsura River, with the bottleneck at the Hozu valley, Kameoka basin has experienced frequent flooding (Figure 1).

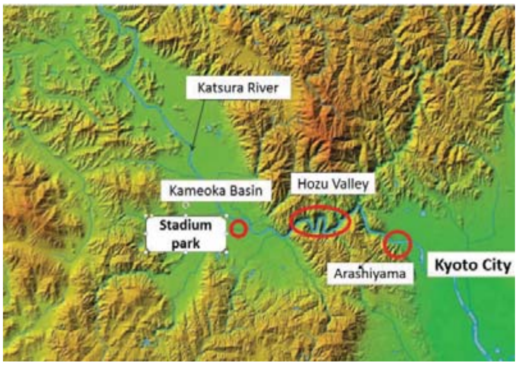

Figure1 Topographic map of the study area; the stadium development is plannd at the the Kameoka basin, which is connected to the Kyoto basin with the bottle neck of the Hozuvalley.

After a severe flood in 1953, construction was begun on the Hiyoshi Dam on the Hozu, upstream of the Kameoka alluvial floodplain, to protect it from the effects of flooding. Eleven floods were recorded between 1953 and 1997 when the Hiyoshi Dam was completed.Even after the completion of the Dam, several floods inundated the Kameoka railway station. Ironically, the frequent flooding is the main reason for the variety of fish in the basin; there are many as 50 different species of fish, which supported the survival of the Japanese kissing loach and other endangered species, such as the frog species, RanaporosaandR.nigromaculata, and the aquatic plant species, *Euryale ferox*. Thus, this area is a biodiversity hotspot among Japanese floodplains.

C. Conditions necessary for the conservation of Japanese kissing loach

A literature review was conducted and conservation specialists (Dr. NobuhiroOhnishi and the group of *Ayumodoki* conservation) were interviewed on the key points regarding the necessary habitat conditions to conserve the Japanese kissing loach (Abe 2012, 2013). It was revealed that the primary habitat area of this species is in the midsection of the river where the water flow fluctuation is very high and the riverbed materials are mostly gravel and stones. The spawning site is a temporary water body of swollen river. Currently, a sand and gravel bar with vegetation in the Sogatani River is the only spawning site in the Kameoka basin. The bar is highly influenced by the operation of the fabridam (inflatable dam) that is used to irrigate the area's rice paddies. Another distribution of the species is in Okayama; the spawning site is artificially created by pumping water into abandoned paddies. Thus, agriculture is apparently part of the ecosystem and correlations between the growing sites and spawning sites are needed.

The current conservation activities taken on by volunteers are aimed at saving fish that are downstream of the fabridam by relocating them upstream. This is an important activity because it is an opportunity to monitor the fish population and observe the water level and maintain it until the eggs hatch. In addition, these activities are natural ways to patrol the area to protect fish from poaching.

The growing habitat of the Japanese kissing loach needs gravel and space among rocks. Masonry retaining wall stone works exist in the Kameoka and Okayama habitats and apparently serve the fish as hideouts from predators and wintering sites. Further reduction of the predation pressure by large exotic fish is recommended.

D. Population viability analysis of Japanese kissing loach

The fish population fluctuates according to various conditions, including demographic factors, even where there is no development. Dr. Natuhara of Nagoya University analyzed the population viability using census data from 2004 through 2012. The data used are the middle values using the Petersen estimator obtained by Kyoto Prefecture. The fish population was highly unstable. The yearling fish population collapsed in 2008 because of exotic fish predation, but it recovered after response measures were taken to eliminate the invasive species. Although this population variation was not caused by a demographic fluctuation, the population viability was calculated considering the effect of the predator species as one of natural variation. The results found that the average number of years to extinction was 20 (if the threshold is 10 individuals) or 27 years (if the threshold is two individuals). The cumulative probability of extinction occurring within 50 years was high (0.92) in the former case. Thus, even without the stadium construction, the species faces a high risk of extinction. The high estimates of the risk of extinction are the result of high yearly population fluctuations, suggesting a need for restoration of old habitats and ex-situ conservation in addition to the current measures of habitat conservation.

III. Storm water treatment

A. Gray Infrastructure type

This section presents a schematic comparison of the Gray Infrastructure type (Fig. 2) to the Green Infrastructure type (Fig. 3).

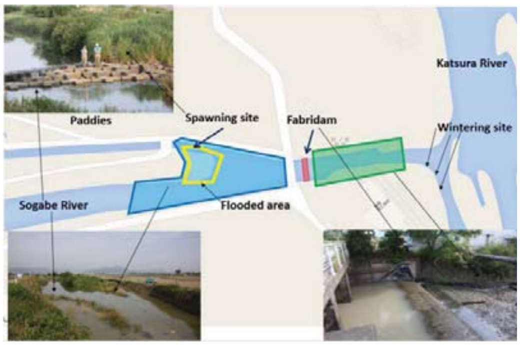

Figure 2 Current habitat of Japanese kissing loach; spawning site is the grassland flooded by dam up for rice paddies. The local community dam up the river water for the rice paddy irrigation. They help saving left population under the dam with specialists.

Figure 3 Land-use plan for the development and the core site of the fish.

The Gray Infrastructure type aims to discharge storm water as quickly as possible from the paved impermeable surfaces and roofs of urban areas to the rivers. The river water is expected to flow down quickly and empty into the ocean. Within the range of the anticipated rain intensity, rainfall would have a negligible adverse effect; urban flooding would not be expected to occur unless rainfall exceeded the planned level.

However, climate change is expected to increase the frequency of heavy rains in Japan, which would increase the likelihood of urban flooding, creating a serious problem. About 80% of rainfall in urban areas is surface runoff and the associated flood damage in Japan between 1997 and 2006 was estimated by the Ministry of Land Infrastructure and Transportation of Japanat covering an area of 200,000 ha and costing JPY 2.4 trillion. Because of the high frequency of flooding from runoff, the damage is greater than that of floods caused by the inundation of river water (110,000 ha; JPY 1.9 trillion).

B. Green Infrastructure type

In contrast, Green Infrastructure utilizes the ecosystem's regulating function in the rainwater cycle: capturing, infiltrating, holding, absorption by plants and trees, filtering, bio-processing, and groundwater recharging, which form the base flow. The cycle's processes contribute to mitigating the effects of flooding by cutting off and delaying the peak discharge even when rainfall is unexpectedly plentiful. Elements of Green Infrastructure include rain gardens, green roofs, bio-swales, permeable pavements, tanks, and ponds. There are emergency elements as well, such as paddies and grasslands. The implementation of smart land-use designs for public parks serve as emergency storm water facilities, which should be further studied. Moreover, smart designs, such as high-floored buildings or piloti (piers or supports) architecture, are useful for damage mitigation in emergency flooding situations.

Katsura Detached Palace, adjacent to the Katsura River, is one of the most beautiful examples of Japanese architecture and Japanese gardens with ponds.

flooding. However, the house, garden, and bamboo grove on the Katsura River bank have lasted for 400 years. This is one of the smartest examples of Green Infrastructure in Japan. Applying these design techniques to the construction of Kameoka Sports Stadium, not filling the ground, incorporating high-floored essential architectural facilities, and so on, should be studied as a viable way to avoid the negative influence of development on the river flow.

Considering the type of floods experienced in the Kameoka basin, it is not a problem of the tractive force of the dam breaking the river water; it is the inundation of the rising water level caused by the bottleneck at the Hozu valley. The rice plants are safe in most cases of inundations because the water level gradually rises and gradually recedes and the rice plants survive the floods. Moreover, because the flooding process is relatively easy to forecast, evacuation processes are expected to function smoothly with minimum risk to human life. The traditional open levee system in the Kameoka basin works as a mitigation method for flood management of the watershed, including the Arashiyama area and the nationally registered beautiful landscapes located at the end of the Hozu valley at the Kyoto basin.

V. Backgrounds to be considered

A. Climate change and Cost of Gray Infrastructure

The Japan Meteorological Agency estimated the long-term trends in concentrated heavy rain (> 50 mm/hour) and torrential rain (> 80 mm/hour) in Japan. The trend is believed to continue along a path of increase in correlation with the process of global warming. Many local level governments have adapted their drainage systems to accommodate a rain intensity of 50 mm/hour. It is very expensive to facilitate a Gray Infrastructure drainage system to meet this standard, such as larger diameter sewage pipes, underground reservoirs, and underground rivers. For example, Osaka Prefecture originally aimed to accommodate an intensity of 80 mm/hour; but, when it considered the cost and time required for completion, it selected limited areas at this level and others were set at the lower level goal of 50 mm/hour. Additionally, a Gray Infrastructure approach must be periodically serviced and refurbished after several decades. Currently, the majority of Japan’s infrastructures are Gray Infrastructures that were constructed during the Bubble Economy period; those infrastructures are in need refurbishment, which will create major financial debts. For example, Kanagawa Prefecture estimates that its infrastructure refurbishment will cost 1.8 times it total budget, not including any new construction, until 2024.

B. Multi-function of Green Infrastructure

In addition to the costliness of Gray Infrastructure measures, they are mostly single function applications. On the other hand, Green Infrastructures are multi-functional, utilizing ecosystem services. For example, rain gardens are a typical Green Infrastructure in urban areas that have many functions: biodiversity conservation, storm water management, mitigation of heat island phenomena, groundwater recharging, drainage water purification, landscaping enhancement, nature experience opportunities, and so on.

V. Comparison of the expected outcomes of the two scenarios

A. Outcomes of Gray Infrastructure

There are five main consequences of implementing Gray Infrastructure for mitigation. Severe tradeoffs would exist between a short-term economic stimulus derived from construction and a long-term deficit in the area's natural capital: biodiversity, and ecosystem services.

1. Burdensome monetary expenses for the maintenance and refurbishment of the infrastructures are forwarded to our descendants together with potentially huge risks in the event of unexpectedly high levels and numbers of floods.

2. The rare and uniquely beautiful rural landscapes of the alluvial plain with its endangered species will degrade into common suburbanized landscapes. This change may negatively influence the tourism economy, the potential for ecologicallybranded tourism, and agricultural production.

3. The unique biodiversity of the floodplain will degrade, as will the ecosystem services of flood regulation by the paddy fields and open levee.

4. The development at the Kameoka basin and the stadium and town at the northern side of Kameoka station may increase the flood discharge on the lower stream area, the Hozu valley, and Arashiyama.

5. The estimated operating revenue of the stadium, presented by Kyoto Prefecture at the joint research workshop of Kameoka City and Kyoto Gakuen University, is not optimistic, but rather negative, particularly if the Kyoto soccer team, Kyoto Sanga F.C., remains in the minor league of the Japan Professional Football League. KameokaCity takes this risk, although Kyoto Prefecture covers the construction cost.

B. Outcomes of Green Infrastructure

In contrast, the Green Infrastructure scenario comprises: (1) low impact development (LID) of the sports stadium with no soil mounding, high-floored architectures, and town development with rain gardens, bio-swales, and minimum soil filling; (2) conventional river water management by open levees and conservation of the Hozu valley and Arashiyama landscapes; (3) restoring and creating spawning habitats and securing the connections among growing sites, spawning sites, and wintering sites for the Japanese kissing loach; (4) continuing rice paddy cultivation that accounts for the function of the spawning habitats of various fish species; and (5) organizing a supervisory committee for the conservation of biodiversity with eco-friendly tourism and production.

Kawai (2012) presented a landscape design for the core habitat, in which there was 2.9 times the growing areas and 5.0 times the spawning sites. The Green Infrastructure solutions are expected to be relatively low cost, highly adaptable to climate change (JMA 2014), and able to sustain the unique amenities of the area's rural landscapes, including *Satoyama* (socio-ecological production landscape), which is believed to be a way to live in harmony with nature, as discussed at the 10th Conference of Partners of the Convention on Biological Diversity (S-CBD 2010).

Table 1

Comparison of the two scenarios

<table>
<tr><th></th><th>1: Gray Infrastructure "Fortress"</th><th>2: Green Infrastructure "Willow"</th></tr>
<tr><td>Stadium & Sports Ground</td><td>Filling soil 4m thick
Conventional sports ground
Conventional stadium</td><td>Leveling with limited filling
Ground that inundated in a storm
High floored or Piloti architecture</td></tr>
<tr><td rowspan="2">Conservation</td><td>Sanctuary creation</td><td>Preservation of current site and previous habitat restoration</td></tr>
<tr><td colspan="2">Establish the "Biodiversity Center" for conservation
Facilitate also the ex-situ conservation</td></tr>
<tr><td>Related projects</td><td>Land use change of paddies that had been retarding ponds.
Close the open levee.
Digging Hozu-Valley, and digging and banking in Arashiyama</td><td>Low impact urban design that recharges ground water.
Watershed storm water management by the Hozu-Valley and Arashiyama, win-win solution</td></tr>
<tr><td>Expected consequences</td><td>Hugemonetarycost forthe maintenance and renewal
Potential huge risk of flooding
Severe tradeoffs between the short term benefit by construction and the long term deficit of ecosystem services</td><td>Low cost, natural capital oriented responses are win-winsolutionsamongthe trilemma: climate change, aging shrinking society and financial debts</td></tr>
</table>

VI. Conclusion

The Kameoka basin has been a rural area adjacent to the major city of Kyoto. However, it seems to be at a critical point in its development. Two different approaches to development in the area, Gray Infrastructure and Green Infrastructure, are summarized in Table 1. The decision about how to proceed should be made only after careful discussion that considers the risks and the costs over the long term and which parties take on the burden of the risks, the costs, and who reaps the benefits. Unlike Osaka, Shiga, and Hyogo, Kyoto Prefecture has no natural history museum to deal with species conservation. Regardless which scenario to select, an agency, organization, or institute comprised of specialists, facilities, and resources is necessary to manage the habitat area to conserve and protect the nationally registered fish species. The stadium project is an opportunity to shift the paradigm in Japan toward Green Infrastructure as an ecosystem-based solution for disaster risk reduction now and in the future (UNISDR, 2011).

References

Abe, T. (2012). Adaptation of Japanesekissingloach (Parabotiacurta) to floodplain environment and conservation and restoration of their spawning ground. *Ecol. Civil Eng*, *1* (2), 243-248. (In Japanese with English Abstract)

Abe, T. (2013). The difficulty of the conservation of Japanesekissingloach (Parabotiacurta). *Bulletin of Kansai Organization for Nature Conservation, 35*(1), 23-32 (in Japanese).

Archtectural Institute of Japan. (2011). *AME-NO-KENCHIKUDO* (Architectural principles to deal with rain). Tokyo: GIHODO SHUPPAN. (In Japanese).

Japan Meteorological Agency. (2014). Long-term changes in the concentrated heavy rain occurrences observed by AMeDAS. Retrieved from http://www.jma.go.jp/jma/kishou/info/heavyraintrend.html

Kameoka City. (2012) *KYOTO-KAMESUTA* (Kyoto-Kamesuta, the symbiotic stadium with nature that Kyoto is proud of). Retrieved from http://www.pref.kyoto.jp/sposyo/news/general/2012/5/documents/1335923406206.pdf

Kameoka City. (2013). *KAMEOKAEKI-KITACHIKU NIOKERU TOSHIKEIKAKU KETTEI/HENKO NITUITE* (Decision/revision of the city plan of the northern area of Kameoka station). Retrieved from http://www.pref.kyoto.jp/spo-syo/news/documents/3kai-siryou3-5.pdf

Kawai, Y. (2012) Landscape desgin study on the symbioses area of the Kameoka sports studium. Graduate thesis of the faculty of Bio-environmental science, Kyoto Gakuen University.

Kyoto Profecture. (2012). *HOZUGAWA KAWA-MACHIZUKURI* (Town development of the Hozu-river). Retrieved from http://www.pref.kyoto.jp/nantan/do-kikaku/1261008745651.html

Kyoto Profecture. (2013). *KYOTO-Stadium NO SEIBINIMUKETE* (Draft plan on the Kyoto stadium). Retrieved from http://www.pref.kyoto.jp/spo-syo/news/documents/stadium.pdf

Ministry of Land, Infrastructure, Transportation and Tourism of Japan. (2013). Manuals for the hazardmaps of inlandflooding. Retrieved from http://www.mlit.go.jp/common/000037234.pdf

Morimoto, Y. (2012). *KEIKAN-NO-SEITAI SHIKAN* (Ecological history of landscapes). Kyoto: KYOTO TSUSHIN SHA. (In Japanese).

Secretary of the Convention on BiologicalDiversity. (2010). Convention on biological diversity. Retrieved from http://www.cbd.int/convention/

Yodogawa river Office of Ministry of Land, Infrastructureand Transport Kinki RegionalDevelopment Bureau. (2013) *KATSURAGAWA ARASHIYAMA-CHIKU-NO-CHISUITAISAKU NITUITE* (River water management of the Arashiyama area, the Katsura-river). Retrieved from http://www.yodogawa.kkr.mlit.go.jp/activity/comit/arashiyama-workshop/report/img/2-11.pdf

UNISDR. (2011). Global assessment report on disaster risk reduction. Geneva, Switzerland: United NationsInternational Strategy for Disaster Reduction.