Adaptation to climate change and conservation of biodiversity using green infrastructure

Adaptation au changement climatique et conservation de la biodiversité en utilisant des infrastructures vertes

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RÉSUMÉ

Dans les sociétés qui connaissent une dépopulation massive, comme le Japon, il devient de plus en plus difficile de maintenir les terres agricoles et autres infrastructures. Cependant, si le retrait humain des zones inondables devient possible en mettant en œuvre des changements optimaux d'utilisation des terres, ces zones peuvent être utilisées comme infrastructure verte pour fournir des zones de restauration de la nature aux espèces adaptées pour la colonisation des habitats nouvellement perturbés. Dans le même temps, ces zones peuvent être utilisées comme zones tampons pour atténuer le risque accru d'inondations à grande échelle qui devraient résulter du réchauffement climatique. Cet article présente un cadre conceptuel pour la prévention des catastrophes utilisant un hybride d'infrastructures vertes et d'infrastructures grises conventionnelles comme stratégie adaptative au changement climatique. Nous décrivons les changements historiques de l'infrastructure verte au Japon et décrivons les problèmes actuels en termes de sédiments et d’inondations catastrophiques ainsi que de perte de la biodiversité. Nous présentons ensuite une nouvelle stratégie pour protéger les vies humaines et les biens contre les catastrophes naturelles et conserver la biodiversité des rivières et des zones humides en utilisant l'infrastructure hybride.

ABSTRACT

In drastically depopulating societies, such as Japan, it is becoming increasingly difficult to maintain farmland and other infrastructure. However, if human withdrawal from flood areas becomes possible by implementing optimal land use changes, such areas can be used as green infrastructure to provide nature restoration areas for species adapted to colonise newly disturbed habitats. At the same time, these areas can be used as buffer zones to mitigate the increased risk of large-scale flooding expected to arise from global warming. This paper presents a conceptual framework for disaster prevention using a hybrid of green infrastructure and conventional grey infrastructure as an adaptive strategy to climate change. We outline the historical changes of green infrastructure in Japan and describe current problems in terms of sediment and flood disasters and loss of biodiversity. Then, we present a new strategy to protect human lives and assets from natural disasters and conserve river and wetland biodiversity using the hybrid infrastructure.

KEYWORDS

Green Infrastructure, Eco-DRR, Blue Infrastructure, Climate change, Biodiversity

1 CONCEPTUAL FRAMEWORK

In this paper, we use the term green infrastructure in reference to the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk, similar to the concept of ecosystem-based disaster risk reduction (Renaud 2013). Conventional grey infrastructure, such as dams and artificial levees, usually assures 100% disaster protection until the magnitude of the disaster reaches an upper limit determined by the prevention plan. However, once this upper limit is exceeded, the grey infrastructure completely loses its function; for example, floodwater spills into residential areas where artificial levees are breached. Therefore, the safety magnitude curve for grey infrastructure shows a rectangular shape (Fig. 1(a)). In contrast, the response of green infrastructure is expected to show a more gradual decreasing trend. In addition, the disaster prevention function may be sustained over a longer period than that of grey infrastructure. However, the relationship between the green infrastructure response and the magnitude of disaster is not well understood, and can vary depending on the type of green infrastructure implemented (Fig. 1(b)). Therefore, the uncertainty of the function of green infrastructure is high.

In the past, advantages and disadvantages of grey and green infrastructure have been discussed and compared to choose the best approach. However, such debates are not always productive, promoting polarised opinions between grey and green infrastructure. In this paper, we discuss combining grey and green infrastructure to apply green infrastructure as a disaster control measure in societies with a high risk of natural disasters, such as Japan. Figure 1(c) presents a conceptual diagram of a hybrid system combining these two types of infrastructure. In this conceptual diagram, GI-1 represents fundamental green infrastructure, which includes forests and wetlands in the catchment, while GI-2 represents additional green infrastructure, such as flood-control ponds, which function when floodwaters exceed the maximum high water level determined by the artificial levees.

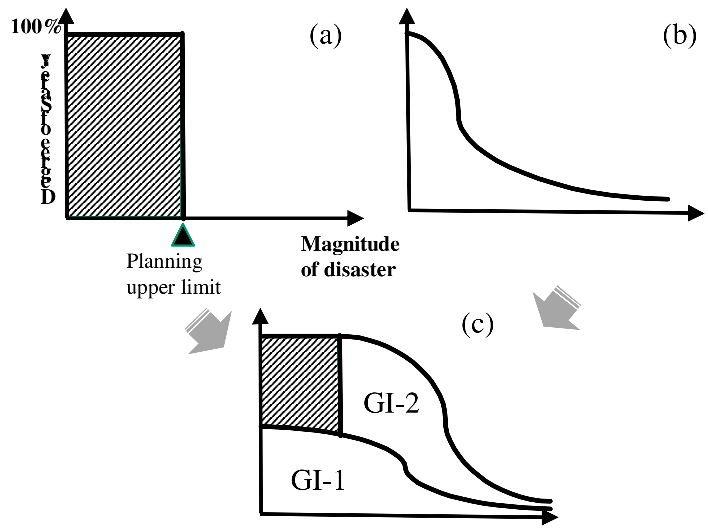

Figure 1 Conceptual framework for (a) grey, (c) green, and (c) hybrid infrastructure. The shaded and white areas denote the safety zone created by grey and green infrastructure, respectively. The area denoted by GI-1 represents fundamental green infrastructure, whereas GI-2 represents additional green infrastructure. See text for details.

2 PAST AND CURRENT STATE OF GREEN AND GREY INFRASTRUCTURE IN JAPAN

Human influence in Japan has changed the mountainous landscape drastically over the past 100 years. From the beginning of the 20th century to the 1950s, overharvesting of and failure to re-establish forests, and air pollution caused by mining and processing of mineral resources, denuded extensive areas of land in Japan, resulting in the transportation of a large amount of sediment to streams and rivers (Nakamura et al. 2017). Thus, a large extent of GI-1 infrastructure was lost.

Since the 1950s, many flood- and debris-flow disasters have occurred in Japan, caused by the loss of

GI-1 infrastructure in basins. The Japanese government initiated re-vegetation efforts for mountains and built many flood control dams and check dams (sabo dams) in streams and rivers to control water and sediment discharge. Thus, by losing GI-1 infrastructure, additional grey infrastructure had to be implemented at an extra cost (shaded area in Fig. 1(c)).

The loss of GI-1 infrastructure and increase in grey infrastructure has altered the water and sediment regimes in river-floodplain systems. The first half of the 20th century was a period of high sediment production in response to land use practices beyond the river and riparian areas. Then, a major shift occurred in river-floodplain systems with dam construction and gravel mining, causing channel incision and forest development on gravel bars and floodplains. Such changes can alter the assemblages of aquatic and terrestrial organisms, mostly resulting in a loss of biodiversity.

3 FUTURE PERSPECTIVES USING HYBRID INFRASTRUCTURE

Despite recognising the utility of implementing hybrid infrastructure, the question of by how much grey or green infrastructure should be expanded or reduced remains. To determine the optimal combination in a given area, the effectiveness of hybrid infrastructure in disaster prevention and biodiversity protection, as well as the social and economic costs, must be evaluated. For example, expanding the area of grey infrastructure can yield get high levels of disaster control, but may also result in the loss of biodiversity and hometown landscapes, while increasing maintenance costs.

In drastically depopulating societies such as Japan, it will become more difficult to maintain grey infrastructure. However, if human withdrawal from flood areas becomes possible, these areas can be used as nature restoration areas to promote the colonisation of endangered species that are dependent on newly disturbed habitats. At the same time, such areas would be used as buffer zones to accommodate large-scale flooding that is expected to increase with global warming. This would represent a shift from grey infrastructure to green infrastructure.

As an example of GI-2 infrastructure, in the Chitose River watershed in Hokkaido, Japan, six large flood control ponds with areas of 150–280 ha were constructed to control large-scale flooding. These flood control basins have created a wetland landscape home to swans, greater white-fronted geese, and bean geese in early spring. These areas are also expected to function as important breeding grounds for Japanese cranes (i.e., red-crowned cranes), a protected species.

We investigated the biodiversity in the flood control ponds of the Chitose River and found that the ponds provided important habitats for fish, aquatic invertebrates, birds, plants, and bats. Moreover, the abundance of plants and animals was higher in the ponds than in other water bodies.

Figure 2 A flood control pond built in the Chitose River, as an example of GI-2

LIST OF REFERENCES

Nakamura, F., Seo, J. Il., Akasaka, T., and Swanson, F. J. (2017) Large wood, sediment, and flow regimes: Their interactions and temporal changes caused by human impacts in Japan. Geomorphology, 279, 176–187.

Renaud, F.G., Sudmeier-Rieux, K., and Estrella, M. Eds. (2013) The role of ecosystems in disaster risk reduction, United Nations University Press, Tokyo (2013).