Chapter 1

Introduction

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Abstract Worldwide, Green Infrastructure (GI) has mainly been discussed from an adaptation strategy perspective in cities and urban areas. However, we believe that GI can also function in rural and suburban areas where depopulation is prominent. From 2015 to 2021, my colleagues and I have launched two projects, titled “Green Infrastructure with a Declining Population and Changing Climate: Assessment of Biodiversity, Disaster Prevention, and Social Values” and “Complementary Role of Green and Gray Infrastructures: Evaluation from Disaster Prevention, Environment, and Social and Economic Benefit,” which were supported by the Environment Research and Technology Development Funds (4-1504 and 4-1805) of the Ministry of the Environment of Japan. This volume introduces some of our achievements in the projects. Additionally, I invited active foreign scientists from the United Kingdom and the United States to contribute their experiences and knowledge to this volume. As suggested by the studies, one of the important characteristics of GI is multifunctionality, which maintains biodiversity and traditional landscapes. Using a natural and seminatural GI network in a watershed, we are able to adapt to elevated disaster risks in a changing climate while sustaining traditional land use and restoring natural ecosystems that provide a suite of ecosystem services and human welfare.

Keywords Hybrid infrastructure · Flood control · Climate change · Ecosystem services · Biodiversity · Multifunctionality

The global average air temperature has been increasing over the long term; since the 1890s, it has risen at a rate of 0.72 °C per 100 years (Ministry of the Environment et al. 2018). The IPCC (2013) showed that precipitation is different from air temperature, revealing an increasing trend across the Earth and increases in North

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America and Europe at the midlatitudes in the Northern Hemisphere since the 1900s. In Japan, the fluctuation of yearly precipitation has increased since the 1970s, and the frequency of hourly heavy rains of 50 mm or more has also increased (Ministry of the Environment et al. 2018). The climate projections for the twenty-first century in Japan indicate that the mean precipitation may increase by more than 10% (Kimoto et al. 2005), and other projections predict an increase in the frequency of high-magnitude floods and a reduced discharge from snowmelt floods.

The Japanese archipelago frequently suffers from not only climate disasters but also geological disasters, such as earthquakes and volcanic eruptions. In 2011, a large-magnitude tsunami hit Tohoku district following the Great East Japan Earthquake in 2011 and caused more than 30,000 people to die or go missing. In 2018, an earthquake struck the Iburi district in southern Hokkaido and triggered numerous landslides, reaching 44 km² in total area, killing 43 people and injuring 782 people. After the Great East Japan Earthquake, Japan enacted a basic law for National Resilience Contributing to Preventing and Mitigating Disasters for Developing Resilience in the Lives of the Citizenry in 2013. Since then, fundamental plans and action programs for national resilience have been established at the national, prefectural, and local government levels.

The world's population growth rate is slowly falling, and the population is projected to level off or decrease before the end of this century (United Nations 2019). In particular, in at least 55 out of 235 countries or areas, including Japan, populations are predicted to decline between 2019 and 2050. The United Nations (2014) has provided estimates showing that population decline has already been occurring in Germany since 2005 and in Italy and Japan since 2010. In a drastically depopulating society such as that in Japan, it will be more difficult to maintain engineered gray infrastructure with limited tax income.

Considering the above-described circumstantial background together with the importance of biodiversity conservation and the United Nations Sustainable Development Goals in Japanese society, national policies for disaster risk reduction have started to change from gray measures using artificially structured facilities such as dams and dikes to more environmentally friendly measures such as green infrastructure (GI) and nature-based solutions. In 2014, the former Prime Minister Shinzo Abe announced that the “application of the concept of green infrastructure using our rich natural environment is socially and economically effective and of great importance. We should preserve the natural environment and ecosystem services for future generations and use their functions for disaster risk reduction.”

Japan has been developing traditional measures for disaster prevention since the sixteenth century. These are nature-friendly technologies and are recognized as GI from the present perspective (Nakamura Chap. 2). Unfortunately, the significance and necessity of these measures have been forgotten since modern technologies were introduced from European countries in the Meiji era (1868–1912). However, these modern technologies are vulnerable to extraordinary events such as megatsunamis and floods. Thus, we need to learn more about the wisdom and philosophy of traditional knowledge and technology. This volume includes those contents.

Worldwide, GI has mainly been discussed from an adaptation strategy perspective in cities and urban areas (e.g., Gill et al. 2007; Keeley et al. 2013; Netusil et al. 2014). However, we believe that GI can also function in rural and suburban areas where depopulation is prominent (Nakamura et al. 2020). Moreover, to protect cities, which are generally situated at lower, downstream elevations, we should explore the preservation and restoration of forest GI in headwater basins and floodplain wetland GI along rivers from a catchment perspective. Additionally, disaster risk reduction by a hybrid of green and gray infrastructure has been examined for stormwater, floods, and coastal flooding (Keeley et al. 2013; Sutton-Grier et al. 2015; Zelner et al. 2016), but very few studies have quantitatively examined flood risk, biodiversity, and socioeconomic benefit by defining existing GI (e.g., forest and wetland in a catchment) and additional layered GI (e.g., flood control basin along a river).

Moreover, farmlands, especially paddy fields, are one of the prevalent land uses in Southeast Asian countries, including Japan, which has an Asian monsoon climate, and play vital roles in providing various ecosystem services, such as biodiversity conservation and rain and floodwater retention, in addition to rice production (Natuhara 2013). We interpreted this type of seminatural environment as GI and evaluated its functions in this volume. Recently, some of these farmlands have been abandoned in the depopulating society. These abandoned farmlands may lose ecological and hydrological functions or may succeed in quasi-original natural environments after abandonment where various ecosystem services are provided (biodiversity, water retention, water quality, and recreation) (Queiroz et al. 2014, Koshida and Katayama 2018, Hanioka et al. 2018).

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In Part I, the concept, history, theoretical approach, and practical model of green and hybrid infrastructure (i.e., the combination of green and gray infrastructure) are introduced. Nakamura (Chap. 2) presented a conceptual model of GI and gray infrastructure based on the model introduced by Onuma and Tsuge (2018) and then developed a hybrid model by combining these two models. He also introduced historical GI for floodwater management in Japan, which still provides important insights for current river management in a changing climate. Onuma (Chap. 3) developed an optimal hybrid model by economically maximizing social net benefits. Taki (Chap. 4) introduced one of the most advanced flood management policies in Shiga Prefecture, Japan, implementing GI at the watershed scale. Osawa and Nishida (Chap. 5) classified the types of GI (natural, seminatural, and artificial) and presented the principle to evaluate the implementation potential of GI.

In Part II, the forest ecosystem as a GI is the focus. Forests cover 67% of the land area in Japan, and 40% of the forests are plantations. There is a long history of forest studies examining the effects of forests on hydrological cycles, including rainwater storage and floodwater discharge attenuation. One of the current major concerns in Japan is the abandonment of artificial forest management, which results in high-density and thin-diameter trees. Unmanaged plantations are very vulnerable to windthrow and landslides; therefore, they may not be able to sustain forest GI functions. Nakamura (Chap. 6) focused on riparian forests as an interactive zone of green and blue infrastructure and discussed adaptation strategies to climate change using riparian forest GI. Tamura (Chap. 7) examined the effect of forest management on water discharge using a runoff model, focusing on the evaporation of intercepted rainfall and water storage in forest soil. Nisbet et al. (Chap. 8) provided guidance on designing appropriate and cost-effective forests for water payment schemes in the United Kingdom that support tree planting and forest management to protect and improve water quality.

In Part III, river and floodplain GI, including paddy fields and other farmlands, are the focus. Muto and Yokokawa (Chap. 9) built a hydraulic simulation model that is able to calculate both surface water flooding and river flooding, and functions for reducing flood risks by paddy fields with proper land-use management were evaluated. Imai et al. (Chap. 10) examined the negative impact of floodwater retention function after the abandonment of a paddy field. Osawa et al. (Chap. 11) reviewed the effects of the consolidation and abandonment of paddy fields in recent years on ecosystem services represented by habitat provision and regulating services (i.e., flood control) besides rice production.

In Part IV, the flood control basin (FCB) in an agricultural landscape that provides habitats for wetland flora and fauna was studied with special reference to biological conservation. In the past, flood control dams and diversion channels were dominant measures to prevent flood disasters. However, these engineered gray infrastructures have a detrimental influence on river and floodplain biota and have recently tended to be avoided by managers and practitioners. In contrast, FCB can be regarded as GI, functioning by attenuating peak discharge during a flood and providing wetland environment for a wide array of plants and animals and recreational opportunities for people during ordinary times. Ishiyama et al. (Chap. 12) introduced a case study in the Chitose River, Japan, which features a network of FCBs, regarding how FCBs and their networks contribute to the regional species biodiversity of various taxa. Morimoto et al. (Chap. 13) studied the succession of wetland vegetation in the FCB and proposed management practices to enhance the species diversity of wetland vegetation. Nishihiro et al. (Chap. 14) highlighted the need for human intervention and activities to maintain the FCB function of biodiversity.

In Part V, GI adaptation strategies in cities and urban areas are the focus. Cities and urban areas are vulnerable to heavy rains associated with climate change. Roads, buildings, and parking lots are paved and covered by impermeable surfaces, which increases surface runoff, leading to poor water quality and elevated peak discharge in urban streams. Additionally, most urban residents are eager to relax in green space after their hard official work. In this regard, Fukuoka (Chap. 15)

introduced GI projects in various countries from the site scale to the urban land-use scale and discussed GI visions and frameworks that are needed to provide broader perspectives, ranging from urban heat mitigation and water disaster reduction to healthy and walkable cities. Interestingly, Ueno et al. (Chap. 16) paid attention to the use of GI before and during the COVID-19 pandemic in Japan and found that GI plays a role in maintaining health and refreshment during the pandemic. Watanabe and Ishida (Chap. 17) proposed a comprehensive land-use plan combined with GI, considering flood risk reduction in a depopulated local town on Shikoku Island, Japan. Finally, a case study of Portland, Oregon, which has a long history of implementing GI, was introduced by Shandas and Hellman (Chap. 18). They discussed the potential for activating a “green grid” in Portland that may help alleviate ongoing socioeconomic disparities.

In Part VI, GI and hybrid infrastructures in coastal and estuary ecosystems are studied. Since the Great East Japan Earthquake in 2011 and the subsequent tsunami disaster, disaster risk reduction in coastal zones has been a major nationwide concern for Japanese people (Suppasri et al. 2013). In addition to tsunamis triggered by earthquakes, high tidal waves associated with the rising sea level in the changing climate and their combinations are also anticipated disasters that Japan will certainly face in the future. Yamanaka and Nakagawa (Chap. 19) examined the effects of hybrid infrastructure consisting of a seashore, coastal embankment, coastal forest, and dunes on the spread of tsunamis and/or tidal waves in combination with the rising sea level. Matsushima and Zhong (Chap. 20) examined the effects of sand coverage on seawall slopes with the aid of local citizens on vegetation establishment. Kawata (Chap. 21) recognized mangrove forests in Jakarta as a GI mitigating flood damage and noticed floating garbage problems that may hinder the growth and regeneration of mangrove forests. Kuwae et al. (Chap. 22) summarized the current status of “blue carbon (carbon captured by marine organisms)” initiatives and reviewed three carbon offset projects in Japan.

In Part VII, public preference and willingness to pay (WTP) regarding GI and hybrid infrastructure are investigated. Shoji et al. (Chap. 23) found heterogeneous responses of the general public depending on their background knowledge of GI. Tsuge et al. (Chap. 24) conducted a survey in areas where giant seawalls were constructed after the Great East Japan Earthquake and found that citizens were strongly concerned about the negative impact of higher seawalls on the natural environment. Omori et al. (Chap. 25) quantified the economic value of coastal ecosystem services, including species richness, landscape, recreational services, and disaster risk reduction. They found that a hybrid infrastructure (seawalls + coastal forests) received higher positive responses. Valatin (Chap. 26) evaluated the climate change mitigation benefit of carbon storage in wood products and of carbon substitution associated with the use of wood instead of more fossil energy-intensive materials in the United Kingdom.

In Part VIII, governance systems to maintain and manage GI by various sectors and their collaborations are introduced. Asanami and Kamada (Chap. 27) studied the key role of the NPO group in maintaining collaborative activities for restoring and conserving pine forests in Kyushu, Japan. Kamada et al. (Chap. 28) introduced

the Yolo Bypass Wildlife Area in the United States as a good example of GI governance through the collaboration of various sectors, such as federal, state, and local governments, landowners, NGOs, and citizens. Masuda et al. (Chap. 29) investigated the administrative plans of local governments across Japan to determine whether the plans contain the multifunctional features of farmland GI. They suggested effective strategies to implement GI, considering population, financial strength, extent of farmland and abandoned farmland, and flood risks.

As suggested by the above studies, one of the important characteristics of GI is multifunctionality, which maintains biodiversity and traditional landscapes. Using a natural and seminatural GI network in a watershed, we are able to adapt to elevated disaster risks in a changing climate while sustaining traditional land use and restoring natural ecosystems that provide a suite of ecosystem services and human welfare (Nakamura et al. 2020). In contrast, if we heavily depend on engineered gray infrastructure for disaster risk reduction, it may ruin biodiversity and traditional landscapes, as experienced with the seawall construction after the Great East Japan Earthquake. Even if the seawall guarantees safety against tsunamis in a return period of once every several decades to centuries, the local people who lost their houses to the tsunami would not return to live in a hometown where the original landscapes were destroyed by seawalls. The populations of Iwate, Miyagi, and Fukushima prefectures, where the tsunami disasters had prevailed in 2011, have rapidly decreased by approximately 15% between 2011 and 2020. Without considering an appropriate balance between gray and green infrastructures, we may create unacceptable land-use recovery plans for residents after such disasters. A land-use plan for adapting to climate change should be devised to allocate GI and gray infrastructure to function complementarily and comprehensively and to nurture local and regional landscapes in which GI contributes to an improved quality of life.

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