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Review article

Integrating ecological perspectives into engineering practices – Perspectives and lessons from Japan

Naoya Furuta[a,*], Yukihiro Shimatani[b]

[a] IUCN (International Union for Conservation of Nature) and Institute of Regional Development, Taisho University, 3-20-1, Nishisugamo, Toshima-ku, Tokyo 170-8470, Japan
[b] Laboratory of Hydrosphere Sustainability Engineering, Department of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, Japan

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ABSTRACT

This article focuses on how ecosystem-based approaches could be mainstreamed in recovery and reconstruction after large scale, rare and infrequent coastal hazards. In doing so, this study reviews historical practices of disaster management in rivers and coasts as well as reconstruction process after the Great East Japan Earthquake (GEJE). It reveals how ecosystem approaches are integrated in river and coast works and highlights some of the relevant policies, technical guidance and guidelines and good practices on the ground. This study also documents how Eco-DRR policy evolved and implemented after the GEJE and addresses some of the challenges in its implementation. In order to draw additional insights, the reconstruction processes of Hurricane Sandy in the United States (US) was also reviewed as GEJE and Sandy shares some common features. Experience from Sandy suggests the importance of the participatory planning process rather than technical guidance or guidelines. Although it is too early to judge whether either reconstruction process was better or not, nor difficult to generalize the conclusion from only two samples, these two experiences suggest only technical guidance and guidelines is not sufficient to mainstream Eco-DRR/CCA in the reconstruction from large scale, rare and infrequent disasters. It is also suggested that the critical role of participatory planning process with cross-sector, cross-professional and interactive design approach may lead more innovative solutions.

1. Introduction

In the past few years, significant progress was made in recognizing the role of ecosystems for disaster risk reduction (DRR) and climate change adaptation (CCA) globally in terms of global policy, practice and scientific front [1]. A number of similar concepts and terminologies have also been invented and being used to articulate these efforts such as ecological engineering, natural infrastructure and green infrastructure [2]. Scientists started to argue the benefit of combining ecosystems or using ecological engineering approaches as part of disaster risk reduction and adaptation strategy instead of relying solely on conventional built structures. They argue that ecosystem-approaches can provide more cost-effective and low-regrets solutions especially in the face of uncertain climate change scenarios [3–6]. Scientific evidence has accumulated to back up these arguments [7–11].

While there are many initiatives and projects started to test these concepts on the ground such as Building with Nature and Living Shoreline [12,13], these approaches are not yet common nor mainstreamed [14]. Through a comprehensive review built on their previous work [15], Estrella et.al summarized challenges for mainstreaming Eco-DRR/CCA under three elements i.e. i) leveraging scientific knowledge to influence policy and practice, ii) re-strategizing how we develop capacities for implementing Eco-DRR/CCA and iii) scaling-up investments in Eco-DRR/CCA [14]. Among many issues identified under these three elements, one of the main constrains identified to scaling-up Eco-DRR/CCA approaches was the lack of standardized, technical guidelines for designing and using ecosystem-based measure for disaster and climate risk reduction. This was also emphasized at the third International Science-Policy Workshop convened by PEDRR (Partnership for Environment and Disaster Risk Reduction) at Bonn, Germany in 2016. The theme of the workshop was innovating engineering and ecosystem-based approaches for disaster risk reduction and developing ecological engineering standards was one of the major topics discussed at the workshop [16].

While disasters can happen in any place such as mountains, rivers, cities or coasts and can be caused by various types of natural hazards such as hurricanes, storms, flooding, tsunamis, sea-level rise, avalanches, landslides, droughts, earthquakes and volcanic eruptions [17], coastal hazards have been seen as one of the most serious issues as a number of populations and economic activities are concentrated in that

* Corresponding author.
E-mail address: naoya.furuta@iucn.org (N. Furuta).

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area with the expected sea-level rise being caused by climate change. In fact, most of the aforementioned scientific evidence and literature also focus on the coastal hazards.

Based on this background, this article addresses how ecosystem-based approaches could be mainstreamed in recovery and reconstruction from large scale, rare and infrequent coastal hazards by reviewing experiences of Great East Japan Earthquake (GEJE) in Japan. In doing so, authors apply three aforementioned perspectives i.e. i) scientific knowledge, ii) capacity development and iii) scaling-up as guiding hypothesis with a special emphasis on how technical guidance and guidelines functioned to mainstream ecosystem-based approaches. The material of this study was obtained through a policy and literature review, field visits of selected projects on the ground and interviews with key stakeholders. Additionally, the reconstruction processes of Hurricane Sandy in the United States (US) was also reviewed by using existing materials, participation in a community workshop and key informant interviews.

GEJE and Hurricane Sandy share several common features, such as large scale, rare and infrequent coastal hazards; both occurred in developed countries; both happened in similar timing namely 2011 and 2012; both reconstruction processes applied "build back better approaches" to increase resilience and incorporate ecosystem perspectives rather than rebuilding what had been in place before the disasters. However, the reconstruction process, in particular the role of technical guidelines was completely different in these two events, therefore they faced different challenges. By reviewing these two experiences, this article draws lessons in mainstreaming ecosystem approaches in recovery and reconstruction from large scale disasters with a special focus on the role of technical guidelines and guidance; and contributes additional insights and perspectives to this emerging field.

2. Eco-DRR concept introduced and evolved in Japan

The concept and basic elements of ecosystem based DRR (Eco-DRR) were systematically introduced for the first time after the GEJE when IUCN (International Union for Conservation of Nature), UN Environment and UNU (United Nations University) organized an experts' workshop on "Ecosystem-based Disaster Risk Reduction for Resilient and Sustainable Development" in Sendai, Japan in 2012 [18]. After this workshop, the Ministry of the Environment of Japan (MOEJ) was particularly interested in the concept of Eco-DRR as they had just established a national park called Sanriku Fukko (Reconstruction) National Park along the coastline affected by tsunami at the GEJE [19]. Backed by this strong interest from MOEJ, national and global policy related Eco-DRR were mutually reinforced and have since then co-evolved.

In November 2013, the first Asia Parks Congress was organized by MOEJ and IUCN in Sendai, Japan, where about 800 participants from 40 countries and one of the six themes featured there was disasters and protected areas [20]. Based on the interest shown and success of the Asia Parks Congress, MOEJ and IUCN also organized a series of sessions on disaster risk reduction and protected areas at the IUCN World Parks Congress in Sydney, Australia in November 2014. "Promise of Sydney Vision", the outcome document from the Congress, recognized the role of protected areas for disaster risk reduction for the first time in the history of the Congress [21].

An important milestone was also reached at the 12th meeting of the Conference of Parties (COP12) of the CBD in October 2014 in Pyongchang, Korea. The importance of Eco-DRR was recognized for the first time by parties through the adoption of decision XII/20 Biodiversity and Climate Change and Disaster Risk Reduction which also gives a strong mandate to the CBD secretariat to start working on this issue. In June 2015, the Ramsar Convention COP12 in Uruguay also recognized the importance of Eco-DRR by adopting decision XII.13 on Wetlands and Disaster Risk Reduction. The Third UN World Conference on Disaster Risk Reduction (WCDRR) held in March 2015, Sendai, Japan adopted the Sendai Framework for Disaster Risk Reduction 2015–2030, which recognized the positive role of ecosystems for DRR [22].

These national and global policy developments also stimulated actions by different groups in Japan such as the scientific community, the private sector and the development community. In September 2014, the Science Council of Japan published a recommendation on "Encouragement of the Use of Ecological Infrastructure in Reconstruction and National Resilience" [23]. This recommendation proposed to promote the use of ecosystem infrastructure for post-disaster reconstruction and for enhancing resilience in Japan. MOEJ also started to invest in research activities on Eco-DRR and two research projects titled "Green Infrastructure in the Depopulated Society under the Climate Change, Evaluated by Biodiversity, Disaster Prevention and Social Acceptance" and "Development of Ecosystem-based Disaster Risk Reduction Methods Based on the Processes of Habitat Loss and Comprehensive Cost-benefit Evaluation Methods" were proposed by groups of scientists and started for implementation since 2015 [24].

Tokio Marine, a Japanese insurance company group that has been implementing mangrove reforestation in developing countries since 1999 recently started to recognize the importance of DRR value of their activities such as coastline stabilization and erosion prevention, coastal hazard mitigation as well as other benefits to the local livelihood in addition to the conventional value they emphasized i.e. CO_2 absorption. As of March 2016, a total of 9474 ha of mangrove forest were planted in nine countries. Tokio Marine commissioned an economic study of this mangrove plantation and found the total economic value created by this project from April 1999 to the end of March 2014 was 338.8 million USD in which coastline stabilization and erosion prevention function was estimated at 71.1 million USD and functioning as a refuge shelter from extreme weather (damage mitigation) was estimated as 55.8 million USD while the Carbon sequestration (climate change mitigation) function was estimated at only 3.3 million USD. Tokio Marine is actively communicating this result in their CSR report [25].

JICA (Japan International Cooperation Agency) has also become interested in Eco-DRR since GEJE. Their Forest and Natural Environment Group under the Global Environment Department actively participated in various workshops and meetings on Eco-DRR since then and integrated Eco-DRR as one of the four pillars in the Strategic Plan 2014–2020 in JICA's nature conservation sector [26]. After that, JICA conducted a basic study on Eco-DRR [27] and also started to provide an Eco-DRR capacity development training courses in Japan by inviting government officials in developing countries.

Several large scale disasters followed by GEJE such as landslides in Hiroshima in 2014, a flooding in Kinu River in 2015 and an earthquake in Kumamoto in 2016 also reiterated the importance of ecosystem-based approach to DRR. Some of the perceived common causes of these recent large scale disasters were inappropriate land use together with over reliance on built infrastructure that increased exposure to natural hazards and worsened damages caused by these disasters. For Hiroshima landslides in August 2014, more than 70 people lost their lives due to landslides primarily triggered by a concentrated heavy rain in the region. The main underlying cause of this disaster, however, was identified as inappropriate sprawling housing developments at the valleys in foot of mountains with fragile geographical soil structure [28].

In September 2015, heavy rain caused by a typhoon hit a wide range of Japanese islands and the bank of Kinu River was broken in Joso city in Ibaraki prefecture. This led to floods which inundated 40 km^2 and more than 5000 houses, caused two deaths, and injured 40 people [29]. An analysis of historical place names and changes of settlements locations in the area suggested that the people started to settle in areas with lower likelihood of hazards then started to settle in more hazard-prone areas for flooding as the population grew [30]. In April 2016, a series of large earthquakes called the 2016 Kumamoto Earthquake with the maximum M7.3 occurred in Kumamoto prefecture, Japan causing 69 deaths, injuring 1663 people and damaging more than 100,000 houses. Many land liquefactions occurred along with old river channels and natural levees which now serve as built-up areas [31]. The Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLITJ) recommended to take into account the location of active faults for the reconstruction activities in the most affected areas [32].

As was seen above, significant progress was made in terms of promoting Eco-DRR at global and domestic policy levels after the GEJE. It is, however, also becoming evident that there remain gaps and challenges with respect to the implementation of these policies on the ground [12,33]. Furuta and Seino [34] analyzed some of the reasons behind this policy/implementation gap. To build on that, this study firstly reviews the history of the policy and implementation of river and coastal engineering works in Japan from an ecosystem-based perspective.

3. Historical background of river and coastal engineering works in Japan

Japan is a disaster-prone country and disaster management has been one of the important agendas for the governments all times in history. Particularly in the river flooding management and coastal zone management, ecosystem-based approaches had been used before the modern Western science and technology came into Japan in the late 19th century. For example, at Shiotagawa River in Saga prefecture, a famous flood control facility called “wing of bird” was built in 18th century. In this facility, a series of bird wing shaped flood control basins were constructed along the curved sections of the river (Fig. 1). One of the major design features of this facility was setting up water intakes at the downstream side of the river so that overflow water can enter the flood control basins very gently. These flood control basins are used as rice paddies during normal times and overflow water can deposit sediments on fertile soils in rice paddies. Because of this design feature, this flood control facility not only reduces flood risks in the downstream of the river but also enriches the fertility of the rice paddies in the area [35].

Another famous example from historical practices in Japan is a combination of water control facilities and discontinuous open levee system called Shingen Levee at Kofu Basin in Yamanashi prefecture (Fig. 1) [36]. The Shingen Levee was named after a famous samurai warrior, Shingen Takeda who built this levee in 16th century. Shingen Levee is a combination of various types of natural and built infrastructures to control floods. Kofu Basin was created by sediments from several rivers flowing into the basin and the Kamanashi River that runs from north to the south in the western edge of the basin is one of the major rivers that created this basin. In the northwest part of the Kamanashi River, another river called Midaigawa river flows into the Kamanashi River running from west to eastward. Originally, this Midaigawa River flows into the Kamanashi River much more southern part that means Midaigawa River originally flew towards southeast direction instead of eastward as we observe today. At that time, when heavy rain falls, the strong stream water from the Midaigawa River often pushed the river course of Kamanashi River eastwards and serious and unpredictable flooding occurred quite often in the basin.

The basic idea of the Shingen Levee is, first of all, to change the route of Midaigawa River towards north by using series of structures built by stones and diverge and converge the stream in order to attenuate the stream energy. The water was led directly to hit the huge natural rock wall called Takaiwa and further reduced the water energy before flowing into the Kamanashi River [37]. As the water from Midaigawa River vertically hit the Kamanashi River, it also has an effect to attenuate the water energy of the Kamanashi River. In addition, a series of discontinuous open levees were constructed along the river banks. These discontinuous open levee structures act as multiple defence system and guide flooding water go back into the Kamanashi River again. It also allows some floodwater to gently flow into the surrounding paddy fields which act as temporal flood control basins in order to prevent unpredictable and devastating damages [37].

Shingen Takeda also introduced several soft mechanisms to maintain these facilities sustainably. Firstly, he established a new village adjacent to this levee and asked the villagers to take care of these facilities in exchange of exempting their tax. He also established a shrine on the levee and created a system of festival twice a year. In that festival more than 500 villagers carry heavy Mikoshis, miniature shrines, and walk on the embankment so that soil of the levee was tightened twice a year before and after the flooding season [37]. The function and the history of the Shingen Levee is still under investigation but modern computer simulation techniques recently underscored how these facilities functioned in the past [38].

After the Meiji revolution in 1968, a modern river administration system was established by introducing the River Law in 1896 in Japan.

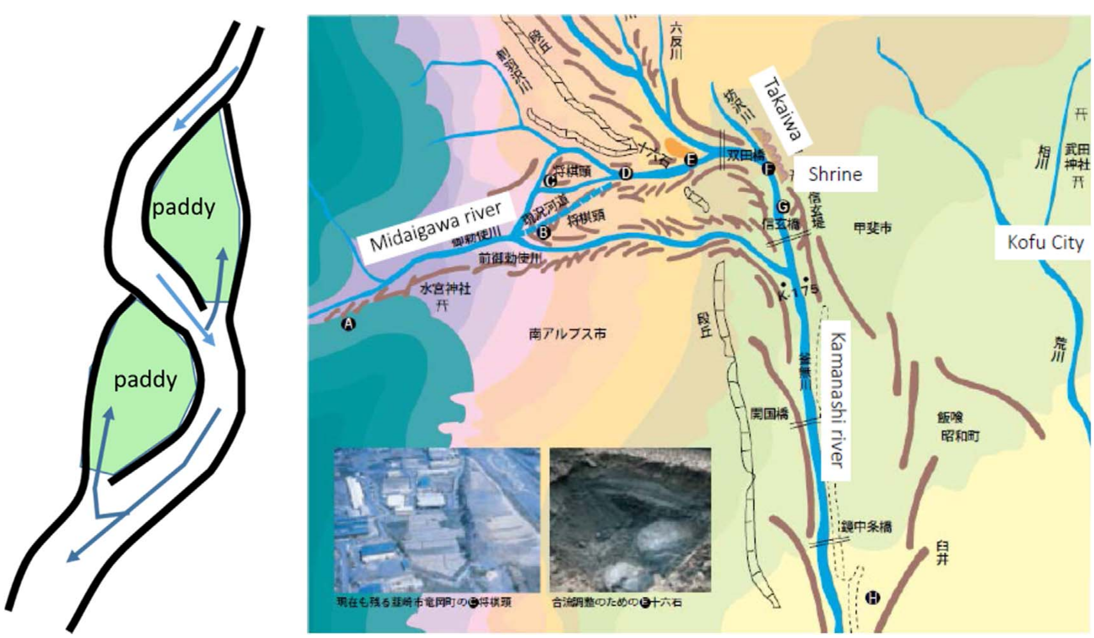

Fig. 1. A schematic diagram of “wing of bird” at Shiotagawa river (left). (Source: Yukihiro Shimatani) and Shingen (discontinuous) levee (right). (Source: MLITJ).

The objective of the law was flood control. The law was amended in 1964 to add water use as the second objective [39]. In the 1980's, with a rise of an environmental awareness in the civil society, many conflicts started to happen in the river engineering works that might have negative impacts on the environment. In the same period, MLITJ started to pilot quasi-natural river engineering projects in 1990 and gradually applied this approach widely. The number of such projects amounted to 28,000 sites by 2002 [40]. The concept of quasi-natural river engineering was originally imported from Europe. The concept was quite new to most of the river engineers and government officials in Japan and no technical guidelines was provided from the government. It was reported that the most of the engineers working on implementing projects were confused [41].

In this context, MLIT amended the River Law again in 1997 to add environmental conservation as additional objectives of the law and also incorporate participatory planning and management principles. They also started various scientific studies on river environment since 1990s and also released Basic Principles for Disaster Reconstruction Works to Conserve Landscape Beauty for river engineering works in 1998 that was built on the concepts of quasi-natural river engineering. This technical document was updated in 2014 to further mainstream ecosystem-based approaches in the reconstruction works in rivers [42]. In 2005, the Ministry commissioned to an experts' committee to review the past quasi-natural river engineering projects. The committee found that most of the works were "un-natural" by applying inappropriate design or materials [41].

Based on the review, the expert committee prepared a set of recommendations and basic principles to upscale and improve the quasi-natural river engineering works [43]. MLITJ decided to apply these basic principles for every river engineering works since 2006 that means ecosystem-based approach is "mainstreamed". In addition, the ministry developed technical guidelines to implement these basic principles that can be applied to small to medium size rivers in 2010 [44]. These guidelines were communicated to the ministry's local offices and river engineering departments of the local governments throughout Japan.

As mentioned above, quasi-natural river engineering works started without enough technical guidance, scientific knowledge nor capacity thus created confusion at the beginning. With more than 25 years of experiences and accumulation of basic scientific knowledge with revisiting the historical experiences, the concept was becoming mainstreamed and various good examples were also developed on the ground (Fig. 2).

For example, the Azamenose Riverine Wetland Restoration Project in Saga prefecture used similar techniques of "wing of bird" flood control basin that was created by transforming rice paddies into wetlands. By doing so, this project was able to reduce the flooding risks as well as restore nature in the area. The Azamenose project was appreciated not only by its design and function but also its participatory planning, monitoring and management process with the local residents and also its function for environmental education for children. This project was recognized as Outstanding Civil Engineering Achievement Award in 2008 by Japan Society of Civil Engineers [45].

Another example is a stream restoration project at Kamisaigo River in Fukuoka prefecture [46]. The Kamisaigo River used to be a typical urban river characterized by its straight-shaped river channel and its fully concrete-covered banks that disconnect people, river and nature. By applying quasi-natural river engineering standards, the river stream was widened and its shape was transformed into more natural shape. River banks were also restored by using natural materials such as soil, rocks and vegetation. This project not only reduced the flooding risks but also significantly improves its landscape value that has been already reflected into the property prices in the area. This project was awarded the Civil Engineering Design Prize in 2016 [47].

The Japanese archipelago has a long coast line and coastal areas have been utilized for various ways from the ancient age [48]. Reclamation to expand farm lands in the coastal areas started in 14th century using natural materials such as stones and vegetation which can be regarded as ecological engineering techniques nowadays. Salt farm development had been also very active in many coasts but it started to decline since 1970's after industrial salt production technology was widely introduced. After that land fill for industrial developments became dominant since 1960s until 1980s. Japan also has a long history of planting forests since 16th century along the coast line to mitigate coastal hazards from farmlands and other human activities.

Historically, coastal areas had been mainly managed by the private sector in Japan but gradually government started to intervene and take responsibility for the management particularly after disasters through providing necessary resources for reconstruction [48]. This was one of the reasons why it took longer time, compared to the River Law, to introduce the Seacoast Act, which was enacted in 1956. The objective of the law was to protect seacoast from hazards such as tsunamis, high tides, ocean waves. In order to do so, the law allows the government to designate Coastal Protection Zones along coast lines and build coast defence facility such as dykes, levees, sea walls etc. in the zones. Because of this law, the coastal defence projects progressed dramatically throughout Japan. For example, the annual budget to build the coastal defence facility increased more than 20 times 10 years after the introduction of the law [48].

While the coastal protection facilities were constructed systematically, there has been a growing concern for their negative impacts on the environment at the same time the coastal use was diversified such as marine sports. That led to an amendment of the Seacoast Act in 1999 to add environmental conservation and use as the additional objectives of the law. After this amendment, many coastal management plans were developed by local governments by taking into account their unique local environmental and social conditions. In addition to that, various technical guidance, guidelines and best practices were introduced [49] and some good projects that integrate ecosystem consideration for coastal management projects were implemented through participatory research and planning with local stakeholders.

For example, at the Kinoppu Coast project in Aomori prefecture, the local government originally constructed concrete slopes along the coastline without appropriate consultation with the local residents.

Fig. 2. Azamenose Riverine Wetland Restoration Project in Saga prefecture (left) and Kamisaigo River in Fukuoka prefecture (right) (Photos taken by Naoya Furuta).

Fig. 3. Kinoppu coast project in Aomori prefecture (left) and Nakatsu Tidal Flat in Oita Prefecture (right) (Photos taken by Naoya Furuta).

Local residents strongly opposed to this solution after the construction as it destroyed the landscape beauty. After a series of consultations between local residents and local government, the concrete structure was demolished [50]. Debris and a number of large natural rocks were placed in the sea to create an artificial rocky shoreline (Fig. 3). The technique of putting rocks in the ocean was traditionally practiced in this area but had not been applied since the modern engineering technology came in. This project not only enabled to mitigate coastal hazard risks but also enhanced habitats for aquatic creatures so they contributed to local livelihoods. This project won the Civil Engineering Design Grand Prize in 2006 [51].

The Nakatsu Tidal Flat is one of the few natural tidal flats remaining in inner bay in Japan, which provide habitats for various endangered species such as horseshoe crab. In late 1990s, the local government developed a plan to fill Nakatsu Tidal Flat by excavated mud and sand from an adjacent port and construct sea walls along the coastline. Concern about negative impacts on the environment was raised and a biological survey was conducted by local citizens in cooperation with scientists and NGOs [52]. The survey revealed the importance of the tidal flat as habitats for various endangered species and several alternative development options were discussed in participation of various stakeholders. Finally, a greater emphasis and value were placed on the protective function of the natural coast and seawall line was retreated to landward than the originally plan so that natural tidal flat and beaches were preserved [53].

As was seen above, similar to the river works, the Seacoast Act also incorporated environmental perspectives in the 1990s and various initiatives started as a result. In that sense, ecosystem-based approaches had already been incorporated to a certain extent and experiences and knowledge were accumulated in the coastal management works in Japan even before the GEJE without using the term Eco-DRR. In the meantime, several challenges were also identified in promoting environmentally friendly coastal management works on the ground such as narrowness of legally defined coastal protection zone i.e. maximum 50 m from the shoreline, lack of knowledge about the coastal ecosystems, limited funding, lack of human resources and capacity working on coastal management, potential trade-offs among objectives i.e. coastal defence, environment protection and sustainable use [54].

4. Lessons learned from the reconstruction process of the GEJE

GEJE took place on March 11 in 2011, triggering a gigantic tsunami which struck the Pacific Coast of Japan with waves as high as 40.1 m. The area affected by tsunami waves of more than 10 m stretched 530 km from north to south along the coastline facing the Pacific Ocean [55]. As most of the damages were created by this tsunami at the GEJE, several technical guidelines and standards were quickly developed after the GEJE to reconstruct coastal areas. Examples include "Technical Investigation on Countermeasures for Earthquakes and Tsunamis based on the lessons learned from the 2011 Tohoku Pacific Coast Offshore Earthquake". The important principle presented by this policy document was recognizing the limitation of built infrastructure to prevent large scale natural hazards. This report defines Level 1 and Level 2 scale of tsunamis depending on their magnitude and frequency and provides basic principles how to cope with these two levels of tsunamis [56]. Based on this basic policy orientation, other important technical standards were developed such as the Tsunami City Planning Act [57] that provides policy frameworks for land use regulation and the Technical Standards for Sea Wall Heights that provides standards to calculate the appropriate heights of sea walls to be reconstructed based on Level 1 criteria mentioned above [58].

In addition to that, MLITJ issued a Landscape Consideration Manual for the Recovery and Coastal Protection Facilities Damaged in the Great East Japan Earthquake in 2011 [59]. The objective of this manual was to provide practical technical guidelines for the reconstruction works of coastal protection facilities such as sea walls, water gates and other structures in the coastal area and river mouths in order to ensure the landscape beauty and integrity to the local environmental conditions. In order to achieve this goal, this manual provides five elements that need to be taken into account namely landscape beauty, locality, ecosystems, sustainability and costs. It was an epoch-making effort that this kind of design guideline was prepared right after the large scale disaster. It also has a particular importance for Eco-DRR point of view because it provides various design principles and practical examples to integrate Eco-DRR perspectives on the ground. Examples include retreated levee construction that allow harmonization of hazard mitigation and nature conservation in reconstruction projects form the GEJE.

Development of this Landscape Consideration Manual was built on the past experiences of quasi-natural river engineering and environmentally friendly coastal management. It was however observed in many places that huge sea walls were constructed just in front of the shoreline, contradicting recommendations made by the guidelines (Fig. 4). It was also observed that in some rivers close to the coastlines, a completely opposite approach to the quasi-natural river engineering guideline in 2010 was applied by building concrete river banks such as the Okinota River in Miyagi prefecture (Fig. 5). One of the reasons why this type of reconstruction works occurred is an apparent misuse of the design guidelines. For example, the design guidelines for the coastal sea walls seemed to be applied for building river banks in Okinota River.

Several scientists and local residents also started to question this situation and openly discussed it at various occasions such as symposiums and conferences in order to analyse and understand the underline causes [60,61]. Some of the common underlying causes identified in these discussions and analysis are as follows:

- Responsibility for the reconstruction planning process was delegated to each local government and had to be bottom-up after the GEJE. However, the number of reconstruction works was overwhelmingly large, also considering that many local government officials had been killed or went missing during the disaster. It had become very difficult for local governments to spend enough time to develop locally appropriate plans in a participatory manner by appropriately applying all the technical guidelines and guidance provided [34].
- The situation was worsened by the fact that there was no legal

Fig. 4. Sea walls constructed just in front of the shorelines in Miyagi prefecture (Photos taken by Naoya Furuta).

obligation for full informed consent or participation of the local community in the planning process as legally speaking these were reconstruction projects to rebuild what existed before the disaster although in fact that was not the case [49].

- It was also pointed out that local governments had to rush in completing the reconstruction projects by the end of 2015 as local governments was able to obtain 100% grants from the central government if they complete them by 2015. Only by that time, many people started to recognize what had been built and question about the projects [49].
- It was also observed that the silos of different line ministries administrating different sections such as shorelines, coasts, rivers, forests, farms, roads were a big challenge in realizing more holistic ecological engineering or Eco-DRR solutions on the ground such as retreated levee particularly in the coastal areas in Japan under the current legal and institutional arrangement [49].

As described above, Eco-DRR was promoted in the national policy in Japan after the GEJE and various technical standards were provided from the government to support the implementation. These were based on 25 years of experience in river engineering and coastal management works to incorporate ecosystem considerations into hazard mitigation in Japan. Nevertheless, the Japan has failed to mainstream Eco-DRR in the reconstruction of coastal defence facilities and many contradictory cases have been implemented in the field. This poses a serious question to the current hypothesis drawn from the previous studies in order to mainstream and scale-up Eco-DRR/CCA on the ground particularly through utilization of technical guidance and guidelines. This also suggests that Japan may need a different approach for the reconstruction process from large scale rare and infrequent disasters such as GEJE.

5. Insights from the Hurricane Sandy reconstruction in the US

In order to draw insights to the challenges faced in the reconstruction process from GEJE to mainstream ecosystem-based approach, the reconstruction process of Hurricane Sandy in the US was reviewed based on existing materials and information obtained from participating in a community workshops by the East Side Coastal Resiliency Project for Hurricane Sandy recovery. As GEJE and Hurricane Sandy share several common features, such as large scale, rare and infrequent coastal hazards; both occurred in developed countries; both happened in similar timing 2011 and 2012; both reconstruction processes applied “build back better approaches” to increase resilience and incorporate ecosystem perspectives rather than rebuilding what had been in place before the disasters, it would be useful to compare these two different experiences to draw insights.

Hurricane Sandy occurred in 2012 and impacted 13 states, costing more than US $65 billion in damages [62]. Green options or approaches that are aligned with Eco-DRR concept were incorporated in several recommendations in the Hurricane Sandy Rebuilding Strategy [63] and an international competition to select Sandy recovery plans was organized under these recommendations (Table 1). This international competition process called Rebuild by Design was characterized by multi-staged process with in-depth research, cross-sector, cross-professional collaboration, and interactive design. Participants for the Rebuild by Design collaborated with community and local government stakeholders to ensure each stage of the competition were based on the best knowledge and talent and final proposals would be realistic and replicable [62].

Participants to the Rebuild by Design were encouraged to think big and be innovative in proposing plans without following conventional technical guidelines nor approaches. This is an opposite approach by the conventional Federal disaster recovery programs that were originally designed to help communities rebuild what had been in place before disasters [64]. Ten interdisciplinary teams were selected out of 148 submissions and they engaged with more than 500 community organisations, held dozens of public workshops, toured hundreds of cities and neighbourhoods, and met with almost 200 government agencies during the planning process. After that, six winning designs were selected in 2014 and awarded US$930 million to state and local governments for their implementation [65].

Rebuild by Design Hurricane Sandy Design Competition has changed the way the federal government responds to disasters and has become a model for other regions and cities in the US to increase community resilience for future uncertainties [66]. In the meantime, the Rebuild by Design projects are now facing various challenges in the project implementation phase such as funding challenges, legal challenges, land-use challenges [64]. For example, one of the challenges

Fig. 5. Constructed section (left) and unconstructed section (right) at Okinota River in Miyagi prefecture (Photos taken by Naoya Furuta).

Table 1
Hurricane Sandy Rebuilding Strategy (2013) Recommendations on Ecosystem Services. Source: Hurricane Sandy Rebuilding Task Force 2013.

- Recommendation 19 - Consider *green options* in all Sandy infrastructure investments.
- Recommendation 20 - Improve the understanding and decision-making tools for *green infrastructure* through projects funded by the Sandy Supplemental.
- Recommendation 21 - Create opportunities for innovations in *green infrastructure* technology and design using Sandy funding, particularly in vulnerable communities.
- Recommendation 22 - Develop a consistent approach to valuing the benefits of *green approaches* to infrastructure development and develop tools, data, and best practices to advance the broad integration of green infrastructure.

they face is the delay of government permitting process. This was caused partly because lack of experiences of these kinds of innovative solutions.

Although six proposals were awarded grants as mentioned above, these grants cannot cover the full costs to implement these proposals. In the meantime, conventional federal disaster recovery funds can only restore communities as they were before a disaster and not cannot be used for these innovative plans. Other types of federal program funds are also constrained by programmatic silos where certain sources can only be used for specific types of project [64].

The Sandy Recovery process, particularly the Rebuild by Design was very successful in developing innovative ecosystem-based rebuilding solutions by applying an experimental and innovative design competition process without detailed technical guidance nor guidelines. This seems to be an opposite approach to the reconstruction from the GEJE and conclusions from the previous studies. The experience of the reconstruction from Hurricane Sandy poses a very important question about the role of technical guidance or standards to mainstream Eco-DRR/CCA and also suggests the importance of the innovative planning process itself rather than technical guidance or standards.

6. Discussions and conclusions

This article focused on how ecosystem-based approaches could be mainstreamed in recovery and reconstruction for large scale, rare and infrequent coastal hazards. In doing so, this study reviewed relevant policy and literature, conducted field visits for selected projects and interviews with key stakeholders in terms of historical background of disaster management in rivers and coasts as well as reconstruction after the GEJE. It revealed that although the term and concept of Eco-DRR was introduced after the GEJE, Japan has a historical and relatively long experience in mainstreaming ecosystem perspectives into river and coastal engineering works. In addition, various technical guidance and guidelines were developed and applied. After the GEJE, additional technical guidance and standards were developed to support reconstruction. Those were built on the previous experiences and took also ecosystem perspectives into account. Nonetheless, huge built infrastructures were constructed, contradicting recommendations made by several technical guidelines nor based on well-established ecosystem-based practices.

A comparison with the Hurricane Sandy reconstruction process suggested the importance of participatory planning processes rather than technical guidelines. However, this process is now also encountering various difficulties in translating innovative ideas into implementable projects on the ground such as funding and government permitting processes etc. Although previous studies identified the lack of standardized, technical guidelines is one of the most critical obstacles for mainstreaming and scaling-up of Eco-DRR/CCA [14], experiences from GEJE poses serious questions about this hypothesis and the effectiveness of such technical guidance or guidelines particularly in the reconstruction from large scale disasters. On the other hand, experiences from the Hurricane Sandy reconstruction process suggests the importance of participatory planning with cross-sector, cross-professional and interactive design approach. There are a couple of potential reasons that may explain these findings.

For example, after large scale disasters such as GEJE, it is very difficult to disseminate and build capacity for newly developed technical guidance and guidelines within a short period of time. As previously mentioned, after the GEJE, the number of reconstruction works was overwhelmingly large and many local government officials themselves had been killed or went missing during the disaster. It had become very difficult for local governments to spend enough time to develop locally appropriate plans in a participatory manner by appropriately applying all the technical guidelines and guidance provided.

It is also important to point out that various technical guidelines developed before and after the GEJE do not go beyond their sectoral silos such as river, coast, forest and farmland. In order to achieve better solutions, it is important to go beyond these sectoral silos with cross-professional approach but this does not happen usually.

During the immediate aftermath and recovery period right after the emergency period of a large scale disaster, saving of human lives and assets are given the highest priority and other values of the society that are equally valued in the normal time such as education, environment, convenience, welfares etc. tend to be significantly undervalued [67]. In the meantime, reconstruction plans are usually developed in the short period of time just after the disaster under a big societal pressure for quick recovery, the reconstruction plans tend to place a disproportionate emphasis on securing human lives and assets and that can create conflict between environment conservation and disaster management.

It is too early to judge whether either reconstruction process was better or not as both GEJE and Hurricane Sandy reconstruction process are still underway. It is also very difficult to generalize the conclusion from only two samples on what would be the best way to mainstream Eco-DRR/CCA in the reconstruction process. In addition, Japan and US have differences in land use, regulations/laws in coastal area, and responsible organization for the reconstruction process that may also affect the differences. However, these two experiences suggest only technical guidance and guidelines is not sufficient to mainstream Eco-DRR/CCA in the reconstruction from large scale, rare and infrequent disasters. The critical role of participatory planning process with cross-sector, cross-professional and interactive design approach has to be more emphasized as that may lead to more innovative solutions.

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