“GREEN INFRASTRUCTURE” AS AN IMPORTANT PART OF NATURAL RISK MANAGEMENT

Dr. Elena Petrova[1]

[1] Faculty of Geography, Lomonosov Moscow State University, **Russia**

ABSTRACT

"Green infrastructure" plays a very important role in the concept of sustainable development. Various components of "green infrastructure" provide a range of ecosystem services including provisioning, supporting, regulatory, and cultural. The study proposes a complex approach to the management of "green infrastructure", which foresees multifunctional use of its components. Among other ecosystem services, forests, coastal landscapes, green levees, and other components of "green infrastructure" perform protective functions. They can successfully complement the engineering protection measures against natural hazards and disasters, and become part of natural risk management.

Keywords: Green infrastructure, Sustainable development, Regulatory ecosystem services, Protective functions, Natural hazards

1. INTRODUCTION

The concept of "green infrastructure" originated in the mid-1980s as part of urban green spaces management. This concept has been actively working out in the spatial planning of many developed countries since the early 1990s (Klimanova et al., 2016). The "green infrastructure" approach is developing within the framework of the strategy of sustainable development, since the "green infrastructure" can be considered as a kind of Sustainable and Resilient Infrastructure. The main components of "green infrastructure" include both natural (such as forests, meadows, wetlands, coastal landscapes) and semi-natural habitats (parks, gardens, agricultural fields, green levees, hedges, and other man-made green spaces and cultivated lands). These components range in their size, shape, and “naturalness”, depending on the type of provided functions and services (Escobedo et al., 2011) and the scale of relevance (Lafortezza et al., 2013). The elements of the so called "blue infrastructure" such as canals, harbors, ponds can be also considered as part of "green infrastructure".

Various components of "green infrastructure" provide many important ecosystem services including provisioning, regulatory, and cultural, as well as supporting services that are necessary for the production other ecosystem services. Ecosystem services are defined as "the benefits people obtain from ecosystems" (MEA, 2005). In the context of this research, the regulatory services are especially relevant. Regulatory ecosystem services include global and local climate control, climate adaptation, disease control and preservation of health, river flow regulation, floods prevention, groundwater retention and accumulation, purification of air and water, prevention of soil erosion, stormwater

management, protection against tsunami, strong winds, and other dangerous natural processes, and many other social, economic, and environmental functions.

The main objectives of this study are to analyze the protective functions and services of "green infrastructure" in context of natural hazard impacts on the technological systems and people. The paper considers protective functions and services, which various components of "green infrastructure" can offer, their possibilities, and advantages as an important complement to methods and means of engineering protection.

2. METHODOLOGY

The methods used in this research are field studies and a literature review. The author examined in practice various components of "green infrastructure" and their ecosystem services and functions during the field studies in various regions and landscape types of Russia and Japan (Petrova et al., 2015). Additional information has been obtained from the analysis of publications on the topic in scientific journals, conference proceedings, book chapters, and mass media.

The main methodology proposed in the present paper is a complex approach to the management of "green infrastructure". This approach assumes that multifunctional usage of various components of the "green infrastructure" should be developed for better protection of ecosystems and their services. An ecosystem does not necessarily provide all four types of services mentioned above simultaneously; but humans benefit from a combination of these services. It is very important to preserve natural environment and consider ecosystems and various elements of the "green infrastructure" not only as provisioning material resources such as food and raw materials, but also as sources of non-material, but no less significant intangible services such as cultural and regulatory. Such an integrated approach to "green infrastructure" is an important part of the concept of sustainable development.

3. RESULTS AND DISCUSSION

The services offered by diverse types of ecosystems and components of the "green infrastructure" (forests, coastal landscapes, etc.) differ in their nature and in consequence. The results below show the important role of the "green infrastructure" components as providing many significant and not-replaceable services including their protective functions against natural hazards and disasters. Many negative consequences of natural hazard impacts on people and economics can be prevented or significantly reduced by "green infrastructure".

Protective functions of some important components of the "green infrastructure" are discussed below. Forest ecosystems, coastal landscapes, and ecosystems of paddy fields are considered.

3.1. PROTECTIVE FUNCTIONS OF FOREST ECOSYSTEMS

Forests occupy a central place among ecosystems of the Earth. The Forest provide various important ecosystem services including not only the support material or so-called provisioning services such as the production of timber and other natural

materials, but also intangible services and functions such as regulatory, supportive, and cultural.

A very important role of forest ecosystems is to offer a range of regulatory ecosystem services. These services include: global and local climate control, surface runoff regulation, groundwater retention and storage, flood protection, soil erosion prevention, carbon dioxide absorption from the atmosphere, which in turn leads to a reduction in the greenhouse effect, and many other useful and indispensable functions (Ninan and Inoue, 2013).

It is difficult to overestimate the protective functions of forests against various types of natural hazards. Trees growing on mountain slopes are the most effective protection against slope erosion, rock falls, and other natural hazards. Tree roots hold the soil, strengthen slopes, and prevent the development of soil erosion and the formation of ravines. Deforestation in the mountain regions significantly increases the risk of landslides, debris flows, snow avalanches, and other hazardous slope processes. Forests regulate river flow, filter rainwater, and accumulate groundwater, thereby significantly reducing the risk of flooding compared to treeless areas.

In the sustainable and environmentally friendly management of forests their protective and cultural role should prevail over their productive functions.

3.2. PROTECTIVE FUNCTIONS OF COASTAL LANDSCAPES

Coastal landscapes such as sand dunes, coral reefs, and mangroves (Figure 1) are other important components of "green infrastructure". Their regulatory ecosystem services include performing various protective functions such as protecting coastal settlements from tsunamis, storm surges, and strong winds; purification and accumulation of groundwater; performing functions of biological drainage (bioswale); prevention of advancing sand to settlements.

Figure 1 – Mangroves in Okinawa, Japan.

Such countries as Japan, which consist of many islands, have a much-extended shoreline including diverse coastal landscapes. Due to the geographical position of Japan in the subduction zone prone to earthquakes and tsunami, protective functions of coastal landscapes are especially relevant. In coastal areas of Japan, sand dunes are a very important element of the "green infrastructure". Many studies have shown that preserving coastal sand dunes and planting trees and shrubs on them significantly reduce the risk of tsunami waves moving inland (e.g. Hayasaka et al., 2016). For example, a sand dune near the village of Shinai, Yamagata Prefecture with a pine forest planted on it serves as a kind of bioprotective screen that prevents the onset of sands, protects the village from strong winds and tsunamis. According to Tanaka et al. (2013), the coastal vegetation is widely recognized to reduce tsunami damage to people and buildings. Compared with artificial measures, sand dunes and coastal vegetation require relatively little capital investment, provide human-friendly beach fronts, and enhance inter-relationships with other ecological systems. Irtem et al. (2009) examine the effects of a coastal forest on tsunami run-up heights. Their results have shown that in the case when the trees were placed in the dense rectilinear pattern and close to the still water level, the run-up height was reduced by approximately 45% compared with the case without trees. In many cases, natural coastal ramparts in the form of sand dunes are more effective barriers than engineering structures. However, sand dune may be used as tsunami protection as long as its crest is high enough not to be overtopped (Triatmadja et al., 2014). Additionally, beneath the coastal forest and sand dunes, there is a freshwater aquifer that is very suitable for the production of traditional Japanese sake (Kaneko and Matsushima, 2017). Thus, coastal sand dunes offer not only regulatory, but also cultural ecosystem services.

Sand dunes, coral reefs, and mangroves act as protection against wind, tide, and tsunami waves not only in Japan, but also in other countries such as India, Sri Lanka, Indonesia, Thailand, New Zealand (e.g. Arun et al., 1999; Rajani Priya et al., 2010; Handunnetti, 2019). These coastal ecosystems cannot fully stop destructive actions of tsunami waves especially those of very high magnitude; but sand dunes, coral reefs, and mangroves have a major role in lowering the damage and destructive force of tsunami waves. Field investigations and remote sensing imagery of the coastal regions of India after the destructive tsunami of 2004 in the Indian Ocean clearly indicated that in places where natural barriers were present, the degradation and destruction was minimal, whereas the places that lost these barriers were seriously affected (Rajani Priya et al., 2010). The lessons from the tsunami disaster of 2004 in Sri Lanka have shown similar results: intact coastal ecosystems helped to buffer against the tsunami waves; those who lived behind the lush vegetation of mangrove swamps were better shielded from the destructive impacts. The government of Sri Lanka intends to further expand the island's coastal green space, creating a chain of mangrove swamps that limits the damage and disruption of tsunami waves. The government of this country plans to rehabilitate about 10,000 hectares of mangrove swamps to the island’s current mangrove cover of 15,670 hectares, mainly by reclaiming fish farms and salt-drying pools (Handunnetti, 2019).

Thus, the preservation and rehabilitation of coastal ecosystems such as sand dunes, coastal vegetation, coral reefs, and mangroves make it possible to significantly decrease negative consequences of the impacts by strong winds, storm surges, tsunami, and other natural hazards specific to coastal areas.

3.3. PROTECTIVE FUNCTIONS OF PADDY FIELDS

Paddy fields can be considered as a kind of man-made wetlands, that is why they perform a number of ecosystem services peculiar to these landscapes.

Paddy fields are probably the most characteristic type of cultural landscape in Japan (Figure 2). Historically, they served not only for their intended purpose - the production of the main Japanese food crop - rice, but also provided a whole range of diverse ecosystem services.

Figure 2 – Paddy field, Japan.

Regulatory ecosystem services of paddy fields include: flood control; replenishment of groundwater; water purification including nitrates removal; prevention of soil erosion; prevention of landslides; climate regulation: rice paddies on the outskirts of large cities have a cooling effect, which is directly proportional to the area of the fields (Yokohari et al., 1997).

Especially important among the protective services of paddy fields is flood control. Paddy fields increase the water storage capacity of river basins; lower the peak flow of rivers, and work as a buffer for down-stream areas during heavy rains (Natuhara, 2013). The total flood-storage capacity of paddies in Japan is estimated between 4.4 and 5.2 billion m^3 (NRIAE, 1998).

Japan has a long tradition of integrated, multifunctional use of various components of the green infrastructure, including paddy fields. The current intensification of the Japanese economy, along with such processes as population decline and aging, especially in rural areas, leads to a significant loss of many important ecosystem functions and services. At the present stage, much attention is paid to the maintenance

of traditional methods of nature management in order to preserve ecosystems and their services. Farmers are supported by the administrations in their efforts to develop traditional rice production, which simultaneously helps to maintain the regulatory functions of paddy fields. For example, the administration of Ichikawa City pays the owners of lowland paddy fields to preserve the fields for flood control (Yoshikawa et al., 2010).

CONCLUSIONS

It can be concluded that diverse components of the "green infrastructure" play a very important role as protection against a wide range of natural hazards and disasters. Forests, coastal landscapes, paddy fields, and other ecosystems offer various regulatory services including floods prevention, prevention of soil erosion, storm water management, and protection against strong winds, tsunami, and other dangerous natural processes. "Green infrastructure" can serve as an important addition to engineering protection methods. Thus, it can be a part of natural risk management. Compared to conventional engineering protection, the "green infrastructure" requires less capital investment, provides human-friendly environment, and improves interconnection with other ecological systems. Scientifically and practically well-performed "green infrastructure" can provide real economic, ecological, and social benefits.

ACKNOWLEDGEMENTS

The work described in this paper was supported by the Lomonosov Moscow State University (grant I.7 AAAA-A16-116032810093-2 “Mapping, modeling and risk assessment of dangerous natural processes”).

REFERENCES

Arun A., Beena K., Raviraja N., Sridhar K., 1999, Coastal sand dunes – A neglected ecosystem, Current Science, 77(1), pp 19-21.

Escobedo F.J., Kroeger T., Wagner J.E., 2011, Urban Forests and Pollution Mitigation: Analyzing Ecosystem Services and Disservices, Environmental Pollution, 159, pp 2078-2087. https://doi.org/10.1016/j.envpol.2011.01.010

Handunnetti D., 2019, Sri Lanka wields mangroves, its tsunami shield, against climate change, https://news.mongabay.com/2019/09/sri-lanka-wields-mangroves-its-tsunami-shield-against-climate-change/

Hayasaka D., Yamada K., Uchida T., 2016, Susceptibility of Sandy Beach Flora to the Great East Japan Earthquake and Tsunami in Northern Tohoku, Japan. In: Urabe J., Nakashizuka T. (eds) Ecological Impacts of Tsunamis on Coastal Ecosystems, Ecological Research Monographs, Springer, Tokyo. https://doi.org/10.1007/978-4-431-56448-5_17

Irtem E., Gedik N., Kabdasli M.S., Yasa N.E., 2009, Coastal forest effects on tsunami run-up heights, Ocean Engineering, 36(3-4), pp 313-320.

Kaneko K., Matsushima H., 2017, Coastal sand dune ecosystem services in metropolitan suburbs: effects on the sake brewery environment induced by changing

social conditions, Progress in Earth and Planetary Science, 4, 28, https://doi.org/10.1186/s40645-017-0142-9

Klimanova O.A., Kolbovskiy E.Yu., Kurbakovskaya A.V., 2016, Assessment of geoecological functions of green infrastructure in Canadian cities, Geography and natural resources, 2, pp 191-200.

Lafortezza R., Davies C., Sanesi G., Konijnendijk C.C., 2013, Green Infrastructure as a tool to support spatial planning in European urban regions, iForest 6: pp 102-108. https://10.3832/ifor0723-006

Millennium Ecosystem Assessment (MEA), 2005, Ecosystems and Human Well-Being: Synthesis, Washington: Island Press.

Natuhara Y., 2013, Ecosystem services by paddy fields as substitutes of natural wetlands in Japan, Ecological Engineering, 56, pp 97-106.

Ninan K.N., Inoue M., 2013, Valuing forest ecosystem services: Case study of a forest reserve in Japan, Ecosystem Services, 5, pp 78-87.

NRIAE, 1998, The result of evaluation of public benefit accompanying agriculture and rural area by a replacement cost method. J. Agric. Econ., 52(4), pp 113-138 (in Japanese).

Petrova E.G., Mironov Y.V., Aoki Y., Matsushima H., Ebine S., Furuya K., Petrova A., Takayama N., Ueda H., 2015, Comparing the visual perception and aesthetic evaluation of natural landscapes in Russia and Japan: cultural and environmental factors. Prog. in Earth and Planet. Sci. 2, 6. https://doi.org/10.1186/s40645-015-0033-x

Rajani Priya K., Santhi Kiran K., Pema U., 2010, Role of Sand Dunes and Mangroves in the Mitigation of Coastal Hazards with Reference to 2004 Tsunami. In: Ramanathan A.L., Bhattacharya P., Dittmar T., Prasad M.B.K., Neupane B.R. (eds) Management and Sustainable Development of Coastal Zone Environments. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-3068-9_16

Tanaka N., Yagisawa J., Yasuda, S., 2013, Breaking pattern and critical breaking condition of Japanese pine trees on coastal sand dunes in huge tsunami caused by Great East Japan Earthquake, Nat Hazards, 65, pp 423–442. https://doi.org/10.1007/s11069-012-0373-4

Triatmadja R., Hijah S.N., Azizah N., Kuswandi K., Dewanti I., 2014, Simulation of sand dune as a tsunami protection, Proceedings of the 19th IAHR-APD Congress, Hanoi, Vietnam.

Yokohari M., Brown R.D., Kato Y., Moriyama H., 1997, Effects of paddy fields on summertime air and surface temperatures in urban fringe areas of Tokyo, Japan, Landscape Urban Plan., 38, pp 1-11.

Yoshikawa N., Nagao N., Misawa S., 2010, Evaluation of the flood mitigation effect of a Paddy Field Dam project, Agr. Water Manage., 97, pp 259-270.