

Review of Blue-Green Infrastructure in Some Selected Countries

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Abstract: Blue-Green Infrastructures (BGI) integrate solutions implemented to enhance water management and landscape values for more climate-resilient and livable cities. It has created an opportunity to renew the natural structure of water balance in cities and rural through the increase in rainwater retention and enlargement of permeable areas. The objective of this review is to assess the blue-green infrastructures of selected countries (Ethiopia, Japan, and the USA). BGI is a driver for biodiversity and provides groundwater storage, stability for water systems, improvement in water quality, water purification, and water-related network service. It also has several benefits for enhancing inland connections and protecting marine ecological systems on a global scale. They minimize the effects of climate change, enhance water management techniques, provide important design tools for sustainable regions, increase the resilience and flexibility of infrastructure and provide an area for social and recreational activities. Currently, the selected countries have been given due attention to BGI using different methods. To ensure the efficient use of subsurface water, Japan and the USA are increasing the groundwater from the current level of thorough protection and expanding the availability of green space, green roofs, permeable paving, and other structural measures. Moreover, Ethiopia has been restored on a massive scale planting trees and wise use of forests. Japan's eco-building in Fukuoka and Nagoya Strategy for Biodiversity, the USA in Seattle cities are working on water management and urban development plans, Ethiopian's East Haarge and Tigray are some the well-known BGI. In all countries, the implementation and transformation of BGI have occurred under systematic conditions. The best practices of BGI in Ethiopia, Japan, and the USA will benefit the people of the world if it is implemented in a good manner.

Keywords: Blue-Green Infrastructure, Ethiopia, Japan, USA

Introduction

Blue-Green Infrastructure (BGI) refers to the use of blue elements, like rivers, canals, ponds, wetlands, floodplains, water treatment facilities, and green elements, such as trees, forests, fields, and parks, in urban and land-use planning (Lamond and Everett, 2019). Innovative solutions that use and deploy the properties of natural ecosystems and the services that they provide are based on nature for economic growth, creating jobs, and enhancing human well-being. The BGI can include green and blue infrastructure, green roofs and vertical walls, measuring of natural water retention, salt marshes, and

dunes, floodplains. It is the new approach and practice to deliver multiple ecological, economic, and social benefits or services (Langergraber *et al.*, 2021; Petsinaris *et al.*, 2020).

Now day's BGI has been an increasingly popular strategy in recent years by reducing polluted stormwater runoff, positively impacting energy consumption, air quality, carbon reduction, and sequestration, property prices, recreation, and other elements of community health and vitality that have monetary or other social value (Dar *et al.*, 2021; Elliott *et al.*, 2020). Droughts and floods are examples of extreme weather that are commonly seen in connected human-environment systems (Field *et al.*, 2014).

Humans are unlikely to be ready for the potential step-change in their severity and frequency brought on by a changing climate, though. The effects of recent climate-related extremes, such as droughts, floods, wildfires, and heat waves, show how many natural ecosystems and human systems are extremely exposed to and vulnerable to present climatic variability and change. Extreme weather events have a variety of negative effects on human health and well-being, ecosystems, food production, water supply, infrastructure, and human settlements. Lack of awareness and readiness for current climate variability in nations at all stages of development exacerbates these effects (Faggian *et al.*, 2009). Either human can adjust to climate change and minimize its effects, or they can fail to adapt and anticipate even worse outcomes. The way we respond to this challenge will determine how the future is shaped (Leary *et al.*, 2008).

The first step in adapting to future climate change is reducing vulnerability and exposure to current climate variability. As a result of climate change, flooding and other extreme events grow increasingly frequently. Only sustainable BGI solutions can protect people from such conditions. Actions that strengthen resilience in a variety of potential future climates while enhancing human health, social and economic well-being, environmental quality, and livelihoods may be included in BGI strategies (Field *et al.*, 2014; Gentle *et al.*, 2001; Middlemann and Middelmann, 2007). Anthropogenic environmental modification is important in response to changing climatic and meteorological conditions, as well as the creation of sustainable technical solutions. BGI, one of the options, offers a tried-and-true, sustainable foundation for growth that guards against floods and offers a variety of other benefits with no drawbacks.

The cause of climate change and rising extreme weather requires the adoption of BGI-style systems for resilient and sustainable settlements (Bibri and Krogstie, 2020; Rowan and Casey, 2021). Green and blue infrastructure are viewed as all-natural and partially-natural landscape components that make up a green-blue network in the context of an urbanized environment. It can relate to landscape features at many spatial scale levels, from isolated tree rows to entire valley systems. Hedgerows, copses, bushes, orchards, forests, natural grasslands, and ecological parks are examples of green landscape elements. Blue landscape elements are those that are connected to water, such as swimming pools, ponds, pond systems, wadis, constructed buffer basins, or watercourses. Consequently, their union creates a green-blue infrastructure (Mertens *et al.*, 2022; Sowińska-Świerkosz *et al.*, 2021).

Countries around the world are implementing the BGI for different purposes. Among these countries Japan, USA and Ethiopia are giving due attention to BGI to sustain the aesthetic aspects of their cities, creating a

conducive atmosphere for life, facilitating the tourist to visit the area, and preventing climate change. Ethiopia has a vast natural forest in different parts of the country that are home to animals, birds, and plants themselves like coffee. However, some people use the economy trees unwisely or cleared from the land for grazing and timber. Through a course of time and repeated training for these people, now a day, they understand the impact of deforestation and degradation in global greenhouse gas emissions. The country designed a pilot and other intervention areas of the region, cultivated land is protected through stabilizing terraces by planting multipurpose trees, grasses, and legumes and constructing trench bunds to capture both water and soil. These activities have resulted in quick overall land rehabilitation and marked increases in productivity per unit area and encourage blue-green infrastructure. The main objective of this review is the contribution of BGI concepts in nature-based solutions for pollution control of the environment in some selected countries.

Purpose of the Review

The review was analyzed in the context of published articles, strategies, and the availability of related literature on BGI from Japan, the USA, and Ethiopia. The main purpose of the review is to assess the best practices of BGI of the selected countries that will be valuable to other international cities in urban water management and climate change adaptation strategies. Furthermore, the comparison of the three cities will create a nuanced understanding of how the socio-political, geographical, and climatological similarities and differences between these cities influence perceptions of BGI. Promoting cooperation and knowledge exchange is an effective way to connect the nations with various resource usage strategies and manage their limited resources. Social inclusion and full community engagement are crucial to the development and management of the urban BGI because they ensure success by enabling people to contribute their ideas from the planning stage through to the conclusion. Therefore, a coordinated planning strategy involving open space, landscape and urban planning, nature conservation, the management of water resources, transportation, energy supply, real estate, and social institutions (interdisciplinary planning) are required between developed and developing countries to develop and manage urban BGI sustainably. As a result, in addition to government representatives, a wide spectrum of actors participate in BGI.

Methodology

Assessing the adequacy of BGI components for a specific setting is a crucial step in applying the BGI idea. To make this assessment, a decision framework that

comprises two main components-the adaptation components and the evaluation tool was created. Different elements of adaptation components and evaluation tools were described in this section. Under adaptation components: Practical feasibility, site feasibility, and integrated evaluation were the main parts. For evaluation, collection of environmental and watershed data while ecological features: Ecological characteristics of the watershed include geomorphologic conditions that define the amount of infiltration and retention in the soil and climatic conditions that impact the process of evapotranspiration and cooling (Fletcher *et al.*, 2013; Fryd *et al.*, 2012; Roldin *et al.*, 2012).

Results and Discussion

Based on existing BGI information or literature, the analysis and implementation were sectioned as Japan, the USA, and Ethiopia.

Japan

The BGI of Japan's threats of climate change and the loss of green spaces in the city, Nagoya has undertaken various measures to create more sustainable lifestyles. The Nagoya Strategy for Biodiversity, which acknowledges the connections between the green space cover and the urban heat island effect, is the main program that seeks to expand green space. The Nagoya Water Cycle Revitalization Plan is another component of this approach and it tries to restore the natural water cycle that has been disrupted by ongoing urban expansion. By 2050, it seeks to lower runoff levels from 62 to 36% and boost groundwater infiltration from the current level of 24 to 33%. This will be accomplished by safeguarding and increasing the amount of green space, installing green roofs, using permeable paving, and using other structural measures that allow rainfall to infiltrate and ensure the efficient use of subsurface water (Fig. 1, 2, and 3). It provides a multi-functional and cross-sectoral approach to increase the blue-green spaces in the city and, as a result, the sustainability of the city (Kazmierczak and Carter, 2010).

The United States

The USA of delta city of Hoboken was susceptible to floods caused by extreme storm weather events as well as coastal flooding (Crujisen, 2015; Showstack, 2014). A BGI strategy was developed to provide a sustainable urban water management system and lessen the city's vulnerability to extreme water events (Crujisen, 2015). This illustrates how the retention and infiltration obtained by a BGI-influenced approach affect water drainage (Fig. 4). The climate of the Earth has changed in the past and is changing now and it appears that more changes are inevitable shortly. As a result, it is crucial to plan for climate change, predict changes and create and put into practice

adaptation measures. Bates (2008); Meehl *et al.* (2007); Rahman *et al.* (2012); Wenger *et al.* (2013).

Because of the growing scarcity and competition for natural resources like water in a changing climate, environmental management will be very difficult. Managers and planners of natural resources must adapt to these new problems. They will need to combine blue-green bodies with land-use planning to create an environment that is suitable for the predicted future climate (Falkenmark and Rockström, 2006; Lawson *et al.*, 2014; 2015; Preston and Jones, 2006; Thorne *et al.*, 2018).

Mitigating the effects of climate change entails doing ongoing, thorough assessments and social research. Here, constantly refers to the necessity of society to continue to monitor the full range of climate change risks. Schanze (2006). In contrast to short-term mitigation of climate change impacts, long-term management emphasizes the creation, oversight, and application of policies to address the long-term effects of climate change.

Environmental managers must therefore learn about the dynamics of the environment and its consequences to judge whether a different strategy is necessary for the future. However, because the future is so unpredictable, the managerial process will need to adapt (Schanze, 2006). As an increase in the variability and potential impact of climate change in the future is predicted, we can expect more environmental damage (Lawson *et al.*, 2015; Thorne *et al.*, 2018). The anticipated rise in urbanization and economic expansion will intensify the effects of climate change even more. As a result, there will always be a need for fresh and creative research to lessen the effects of climate change. Additionally, the research should aid in the creation of climate change-resistant zones that take economic development into account (Bates, 2008; Lawson *et al.*, 2014; 2015).

One of the most promising strategies for adapting to rapidly changing human and environmental conditions is the innovative use of blue-green infrastructure. This must be taken into account during the planning process, particularly when developing regional (spatial) development strategies. Above all, the development of this significant idea can be a crucial part of reducing current and probable future effects of climate change, guaranteeing water for regional and agricultural development, and generating economic activity in urban and rural areas. Only well-considered systemic intervention practices that are ethical, take into account multiple points of view and are sensitive to the ecology we are a part of would offer hope of successfully resolving the problematic situations that face regional systems, their human communities, and natural ecosystems (Sposito *et al.*, 2014).

Water quality, recreation, health, city livability, and property value are among the advantages of green infrastructure that cities have cited in their plans. Social advantages were mentioned in plans the most frequently across cities, followed by the environmental, economic, built environment, and ecological benefits. Additional benefits that some cities have highlighted are recovery from major weather catastrophes, new business opportunities, and social rejuvenation, for example, Washington, DC, Miami, and Atlanta (Zhongming *et al.*, 2022). Cities such as Seattle and New York in the USA have good practices in using the BGI (Fig. 5 and 6).

Ethiopia

Landscapes in Ethiopia's Eastern Hararge and Tigray regions have been extensively restored because of the usage of BGI. The transformation took place in a fairly organized manner by modifying unfavorable circumstances. Groundwater levels were refilled as a result of the methodical management of slopes and hillsides using stone walls and trenches. From 5,000 ha in 2000 to 30,000 ha in 2008, the area that is irrigated has grown and is still growing. According to Haregeweyn *et al.* (2012), since 1991, soil and water conservation actions have been carried out on 960,000 ha and 1.2 million hectares have been blocked off to allow for the regrowth of vegetation. By utilizing integrated watershed management, erosion has greatly decreased (Fenta *et al.*, 2016; Gashaw, 2015). Furthermore, Entoto and the unit park of Ethiopia are the best-known green infrastructure that attracts many tourists and residents from the capital city (Addis Ababa) and elsewhere from different regions of the country. The two parks indicate the current initiative of the country to implement the BGI into practice (Fig. 7 and 8).

Land rehabilitation in the districts of Hararge and Tigray is one more example of green infrastructure in Ethiopia (Fig. 8). Changes in crop cover (48%) and conservation practices (29%) that limit land degradation led to a decline in sheet and rill erosion in these two regions. Additionally, the local community's engagement in 20 days for free has changed the landscape (Haregeweyn *et al.*, 2016). According to Fenta *et al.* (2016) study, erosion rates along the sheet and rill have decreased, which has improved infiltration, vegetation cover, and crop output. Improved plant cover and the installation of physical conservation features are both responsible for the recovery. Figure 9 depicts the green infrastructure that is restored in Hararge (Oromia regional state) and the Tigray region (Tekla *et al.*, 2020).

Even though the review has been looking at three different countries like Japan, the USA, and Ethiopia, the list of one hundred countries with the total number of planted plants was placed based on the descending

order in Table 1. Plants make forests that can provide natural filtration, increase the water quality, decrease soil erosion, lower stormwater runoff, air quality improvement, a new habitat for wildlife, control temperatures, and carbon sequestration (Madalcho *et al.*, 2022; Oguns, 2019; Stanton, 2020).



Fig. 1: The eco-building in Fukuoka, Japan boasts one of the world's most famous green roofs. Fenta *et al.* (2016); Showstack (2014)



Fig. 2: Asian green-blue infrastructure Sanya Mangrove Park/ Kongjian (Yu, 2021)

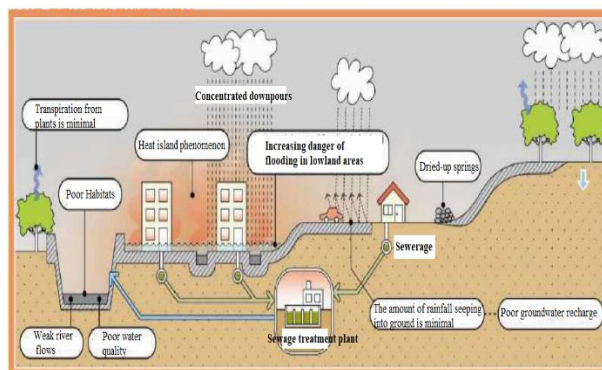


Fig. 3: The BGI in Nagoya (Kazmierczak and Carter, 2010)

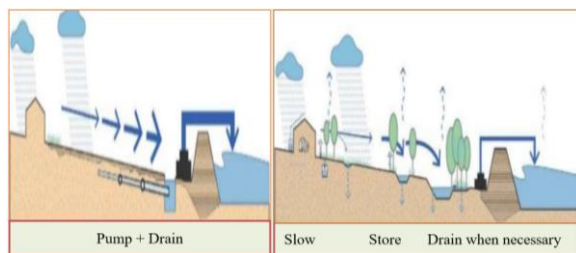


Fig. 4: A BGI-Inspired Approach Achieves Retention and Infiltration (Crujisen, 2015)



Fig. 5: Seattle is working on increasing the level of green infrastructure in its water management and urban development plans



Fig. 6: Enabling BGI opportunities in complex social-ecological systems in New York, USA



Fig. 7: Entoto park situated in Addis Ababa, Ethiopia



Fig. 8: Unity park situated in Addis Ababa, Ethiopia



Fig. 9: Rehabilitated land of Hararge in Oromia (Left) and Tigray regions, Ethiopia

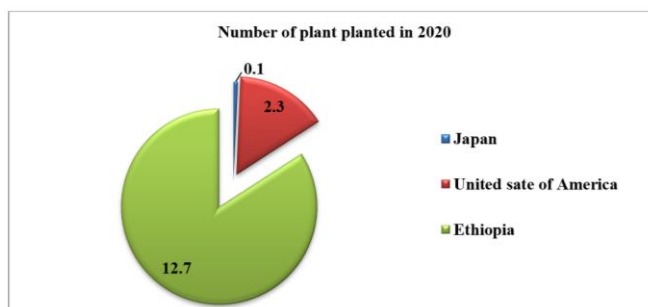


Fig. 10: The percentage of tree plantations in Japan, the USA, and Ethiopia in 2020

The following figure shows the percentage of trees planted in Japan, the USA, and Ethiopia among one hundred countries in the world in the year 2020 (Fig. 10). Accordingly, the percentage of trees planted in Japan and the USA was relatively lower than in Ethiopia. Although Japan and USA are developed in economy and technology, more plant biodiversity is expected from them to absorb the dumped carbon dioxide from the atmosphere. Relatively Ethiopia planted more plants than the two countries (USA and Japan) to sustain the climate change.

Table 1: Tree planting order for one hundred different countries of the world in the year 2020

Ranking	Country	Trees planted	In %
1	China	2,407,149,493	17.7090
2	India	2,159,420,898	15.8860
3	Ethiopia	1,725,350,234	12.6930
4	Pakistan	1,006,776,724	7.4066
5	Mexico	789,307,032	5.8067
6	Turkey	711,103,088	5.2314
7	Peru	646,502,236	4.7561
8	Nigeria	626,725,667	4.6106
9	Kenya	534,680,609	3.9335
10	United States	315,586,982	2.3217
11	Ghana	220,571,208	1.6227
12	Italy	211,269,211	1.5542
13	Myanmar	192,154,935	1.4136
14	Philippines	187,393,371	1.3786
15	Tanzania	159,635,654	1.1744
16	Brazil	144,078,245	1.0599
17	Cuba	137,476,944	1.0114
.	.	.	.
.	.	.	.
.	.	.	.
41	Japan	14,093,513	0.1037
47	.	.	.
48	.	.	.
49	.	.	.
97	Haiti	423,243	0.0031
98	Zimbabwe	408,356	0.0030
99	Togo	367,165	0.0027
100	Brunei	336,459	0.0025
Total tree planted			13,593,004,090.0000

Conclusion

BGI improves land connectivity and secures marine ecological biodiversity and provides groundwater storage, stability for water systems, quality, and purification. In Ethiopia, Japan, and USA BGI mitigate the climate change effects and better water management methods. Ethiopia currently implemented the BGI in Hararge of Oromia region, Tigray region, Entoto, and unity park in Addis Ababa (Capital city of Ethiopia). BGI is also implemented in the eco-building of Fukuoka and Nagoya in Japan and the cities of Seattle and New York in the USA. In the selected countries BGI brings tangible changes and people are benefited directly or indirectly in many ways.

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Availability of Data and Materials

The datasets analyzed during the current study were available online or getting from the corresponding author upon reasonable request.

Author's Contributions

Tariku Neme Afata: Developed the idea, looked up relevant literature, and composed the first version.

Seyoum Derib: Research relevant literature.

Reda Nemo: Draft, revise, and reviewed the article.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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