Development of Blue-green infrastructure framework to restore nallahs (dirty drains) to nadis (streams), in India.

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Abstract. The rivers and streams serve as important life support systems for helping in recharging the aquifers and regulating the hydrological cycle besides providing habitats and breading grounds for birds, fish and aquatic life. However, these are always becoming targets of adverse effects of development around the streams particularly in urban areas due to presence of human activities like urbanization and climate change. As a result of these activities, most of the urban streams have got degraded due to encroachment, siltation discharge of domestic sewage, surface drainage caring sand and silt and other chemical pollutants. Literature review is conducted to study how resilience and ecosystem services can play important role in climate change adaptation and to keep balance between nature and society. This review paper is to analyse the Green Infrastructure (GI) and the recent Blue-Green Infrastructure (BGI) are the multidisciplinary approaches to combat the negative impact of urbanization and climate change on urban streams and revive the condition totally. Identification of the need of development of Blue-Green infrastructure framework to transform nallahs (dirty drains) to nadis(Streams) in India. Keywords— [Climate change, Resilience, ecosystem services, green infrastructure, blue-green infrastructure]

1 Introduction

As stated in the first sentence of the World Water Development Report 2015, "water is at the core of sustainable development and the latter is strongly connected to the availability and access to sufficient quantity and quality of water for the preservation of healthy ecosystems and is critical for socio-economic and human development" (1).The cities are depending mainly on the water for survival and sanitation, economy and ease of connectivity (2). Water plays a central role in any environment along with public open spaces and vegetation whether it is in the urban or rural area (3). The degraded quality of water with its harmful impact on unsustainable socio-ecological systems is the main issue of concern globally (4).

1.1 Background

The urban environment and quality of life are mostly influenced by management of urban water, especially stormwater management (5). The conventional urban infrastructure with a typical grey approach i.e., to discharge a large volume of rainwater into pipes to solve hydro-climatic problems generated due to haphazard urbanization, high density of buildings, and

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maximum impervious land cover (3). Also disregard many socio-economic benefits of storm-water near people's neighbourhoods. Grey infrastructure fails to take additional stresses induced by climate change along with expeditious urbanization and impervious land covers (3).

The significant challenges cities facing in the 21st century is to secure clean and sufficient freshwater and making aware people about it (3). Unintended urbanization and land-use changes in urban areas have changed the natural water cycle drastically and now it has been replaced by the urban water cycle which is not balanced as heavy volumes of surface runoff from impervious urban surfaces aggravated along with degraded water quality persistent due to point and non-point source pollutants from nearby residential communities (6) (3). However, the most essential natural resource i.e. storm water is pushed underground, out of sight out of mind or in the form of open drains constructed and culverted as a part of grey infrastructure flowing through urban streams with unhygienic condition (7).In developing countries like India, most of the rivers and streams have been polluted to such an extent that here we call it a dirty stream (ganda nallah) (4).

When, I tried to find etymology of the word nallah I found few interesting facts that, Nala is a Persian word predominantly used and well-known in South Asia meaning small streams, small creek, canal, rivulet, or ravine (4). Similarly, Nahal is a Hebrew word meaning a stream in a subtropical climatic region with wet conditions during monsoon and remains dry in summer (4). In the 17th century, Jahangir predominantly used the word nallah in his memoirs. From the 19th century onwards, nallah word has been transliterated as a drain. So, Nallah or the drain is a natural or artificial channel draining urban or rural runoff (4).

2 Methodology

This review paper is to study, the consequences of urbanization and climate change on these nallahs and whether those can be radically transformed to nadis (streams/rivers). Extensive literature review conducted by using keywords, storm water management, grey infrastructure, urban degraded rivers, etc.

In 1st part of the paper, I have discussed, how resilience and ecosystem services play important role in solving this problem in the context of climate change, and in the second part, I have systematically reviewed various approaches especially green infrastructure and blue-green infrastructure for transforming these dirty nallahs to streams. At the end, I have discussed how resilience theory and ecosystem services are embedded to develop a framework of blue-green infrastructure strategies to solve stormwater problems created due to urbanization and climate change, in India

3 Climate change impact on urban streams

Readily available vital natural resource water has been widely exploited and overlooked its necessity for several socio-ecological benefits (8). Climate change exerting additional stresses upon natural streams along with population growth and urban development pressures (8). There is an immediate need of developing strategies that could solve the problems related to the water crisis in urban areas, especially in developing countries, like India created not only drastic changes in aquatic systems caused by high evaporation due to climate change but also increased water demand for agriculture and human activities (9). Threats of climate change are having direct or indirect implications. Direct impacts are in the dual form of shocks such as storms, typhoons, and heatwaves, whereas indirect impacts of climate change can be seen and observed gradually over time such as sea-level rise, general temperature rise, changes in rainfall pattern, etc (10).

3.1 Resilience

Resilience in the context of cities has been defined as "the degree to which cities are able to tolerate alteration before reorganizing around a new set of structures and processes which can be measured by how well a city can simultaneously balance ecosystem and human functions" (11). Resilient society is that which not only is adaptable and adjust under uncertainty and the extremity of various types of events but also take advantage and find opportunities from the variety of conditions and achieve a better position for a sustainable future (11). Resilience can be achieved by adopting a system approach i.e. to understand the interdependencies of various components of water systems which plays a very important role in the functioning of the entire system (12).

Thus, resilience is that capacity of any system, which can be sustained adaptable to any kind of pressure, absorb all the ill effects and reorganize itself and be ready to change by keeping basic function structure, identity as it is (13). The main characteristics of resilient urban systems are flexibility, redundancy, resourcefulness, safe failure, responsiveness, capacity to learn, and most important is a dependency on local ecosystems as per table no. 1 below (14). A multidisciplinary approach of bridging the fields of ecology, urban design, urban planning, ecology, and sociology while understanding city can be proved to be the best from a resilience point of view (9).

TABLE NO. 1 Characteristics of Resilient Urban Systems (14)

Sr. No.	Characteristics of resilience	
1	Flexibility	The ability to change, evolve and adopt alternative strategies (either in the short or longer-term) in response to changing conditions.
2	Redundancy	Redundancy is the ability to adopt a variety of options through the provision of multiple Pathways.
3	Resourcefulness	The ability to mobilize assets (Financial, physical, social, environmental, technology, and information) and human resources to meet established priorities and achieve goals.
4	Safe failure	Resilient network infrastructures are designed for safe failure with minimal impact on other dependent systems.
5	Responsiveness	The ability to re-organize, to re-establish function, and sense of order following a failure.
6	Capacity to Learn	Direct experience and failure play a key role in triggering learning processes.
7	Dependency on local ecosystems	Resilient urban systems exercise a greater degree of control over the essential assets required to support well-being

Grey stormwater infrastructure reduces ecosystem services from stormwater by reducing infiltration and groundwater rechanging and adding more pollutants and contaminants from impervious surfaces can carry is to streams to pollute water bodies (15). Cities are indeed seeking a large demand for ecosystem services (16). Unprecedented environmental impacts can be observed besides the known nexus of the relationship between citizen and nature (16). Significant challenges and opportunities are posed by unplanned rapid agglomeration of urban cities to design liveable, healthy, and resilient cities (16).

4 Discussions

4.1 Green infrastructure (GI)

The term Infrastructure has its revised meaning which plays an important role. Very well planned and maintained natural and semi-natural network which is multifunctional and provides a wide range of benefits to nature and society both is called Green Infrastructure (17). Multiplication of open spaces and porous surfaces like parks, river corridors, greenways, urban forests, community gardens, green roofs, and biofiltration facilities. Green infrastructure offers mainly 3 benefits 1. Groundwater and water table protection 2. Maximize evapotranspiration 3. The collection, reuse, detention, filtration, treatment, and infiltration of rainwater on-site (18).

Green infrastructure facilitates ecosystem services for healthy environment and hygienic surroundings necessary for both mental, physical and psychological health along with recreational amenity and visual pleasureful improvements (19). Green infrastructure serves as a backbone of the green economy and ecological restoration is one of the most important phenomena required for green economy (19). A multi-scale approach to preserve the urban environment by applying key principles of landscape ecology with a keen emphasis on the natural process, system, and interrelationships of various components in that system (7). Infrastructure development by mimicking natural processes to allow natural water flow into rivers can be termed as green infrastructure (19). The GI approach is different from open space planning as it is with hidden agenda of nature conservation, specific objectives for land development, and infrastructure planning Predominantly, other nature conservation approaches are in isolation or opposition of development (7).

Low impact development principles of green infrastructure unable minimization of environmental impact giving full justice to natural systems that allow stormwater to flow infiltrate into the ground and can help to balance the water cycle up to some extent (20). This definitely will provide opportunities to convert grey to green and hard to soft in turn to preserve valuable water resources (20). Recharging of groundwater, mimicking natural systems not only improve the stream water condition but also improve quality of life and increase property value (20).

In April 2011, U.S. Environmental protection agency (EPA) published the strategic agenda of implementing green infrastructure to protect water and build more liveable communities (21). Green infrastructure here refers to a stormwater management system that uses vegetation, soil, and natural processes. In England, a new framework for climate change adaptation and mitigation through the planning of green infrastructure into the city by the National Planning Policy 2012 (22). The primary initiatives taken by road authorities in land management and planning to overcome the impact of climate change on the environment is the green infrastructure (GI) (22).

4.2 Blue-green infrastructure

Blue-green infrastructure (BGI) is the natural extension of the green infrastructure concept since green vegetation depends upon water and indirectly affect local hydrology (3). BGI is a paradigm shift that highlights the important role of the urban hydrological cycle in Urban water management especially stormwater. Here blue represents water and green means vegetation system in urban waterscape design (3). BGI is the process of integrating to blue i.e. water or hydrology and green i.e. ecology to treat water, where blue and green are gelled very well (23). Blue-green infrastructure is an interconnected network of natural areas with designed landscape elements that include both streams and flowing green spaces as an

interface development provides multiple benefits than green infrastructure such as 1) water storage for various uses 2) flood control 3) wetland areas for water purification and many others (23). Blue-green infrastructure absorbs the maximum of surface runoff by recharging groundwater and also reduces pollution of streams to a great extent (23).

4.3 CLIMATE CHANGE AND BGI

The impact of climate change and urbanization has been recognized and accepted that the heavy rainfall causing urban flooding with high water flows in many parts of the country (5). The prevalent situation of tremendous drought and extreme floods as a unpredictable consequence of climate change and the only sustainable solution is Blue-green infrastructure (BGI) (5). BGI is the best approach that provides co-benefit to offer resilience also at the same time help to improve human health, social, and economic wellbeing (24).

5 RESULTS AND RECOMMENDATIONS

Along with the assessment of the impact on nature by environmental pollution and other issues persistent due to climate change and urbanization, it's advisable to assess the existing infrastructure practices in India before planning for a Blue-green infrastructure approach as a sustainable facility (25). In case of any infrastructure project, Environmental Impact Assessment (EIA) report has to be submitted to Govt. of India to get Environmental Clearance (EC) before the commencement of any new urban infrastructure project and also have to take permission from the Ministry of Environment and Forests (MOEF) (25). Green infrastructure is a nation's life-supporting system with a triple bottom line framework that fulfils all the sustainability pillars i.e., economic, ecological, and social (25).

Restoration, protection and rejuvenation of green infrastructure and ecosystem services in urban areas is not only socially acceptable and environmentally viable but also proves to be economically feasible. With added benefits to society, community, and to the people (18). So now we can admit conventional approaches are where anthropocentric (weak to sustainability), whereas BGI would prove to be an eco-centric approach (strong approach to sustainability where the integration of social and ecological systems can be facilitated also can have a balanced healthy environment for social well-being and quality of life expected in nearby neighbourhoods (26). An eco-centric approach was initiated by ecologists by keeping in mind resilience theory (27). This resilience theory is an approach that suggests a management action plan to balance natural resource systems by using some equilibrium centre theories and models (28). Thus, resilience theory very well establishes the prominent role of people in shaping the ecosystem processes and also ecosystem services (29). In this context, social-ecological systems recognize the integrated concept of humans and nature for the benefit of a balanced urban ecosystem (30).

Blue-green infrastructure strategies must be included in the overall governance mechanism so that all domain experts like landscape designers, urban designers, urban planners, architects, ecologists, public policymakers as well as other remaining stakeholders also can get benefited (16). Besides, all the benefits of green infrastructure, how BGI would prove important in the climate change adaptations also underlined (7). BGI can be extended further at a various level from micro to macro-level (site, area, city, region, watershed, etc.) (31) Land use and land cover (LULC) optimisation as per BGI will provide new opportunities for the green economy. This can only be possible with the appropriate implementation of BGI for multifunctional land use planning and optimum and efficient use of - natural resources along with resilience in extreme events (13).

6 CONCLUSION

"There is a phenomenal resiliency in the mechanisms of the earth. A river or lake is almost never dead. If you give it the slightest chance then nature usually comes back."---Rene Dubos (1981). Liveability can be achieved by planning urban open spaces that it reflects cultural and sacred environment, which will also help to achieve equity, accessibility, participation, etc (32). BGI always has played its role in increasing resiliency in an urban setting. Thus, BGI helps to reduce dependence on grey infrastructure. It has shown promise to minimize adverse impacts of urbanisation on natural streams, and rivers and also helps to reduce the risks associated with mitigate risks by climate change adaptation (10). Urbanisation, besides putting number of challenges in front of experts of varied domains, also increased possibilities of development opportunities to enhance resilience and offer ecosystem services for efficient working of urban systems (33). For example, Blue-green infrastructure can play crucial role in resilient society to cope will climate change. Cities can actively participate in United Nation's agenda on green economy for 21st Century and sustainable development goals (SDGs) by formulating and implementing Blue-green infrastructure framework to radically transform nallah's to nadi (streams /rivers) (34).

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