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Approaches to Implementation of Green Infrastructure and Management Practices

Antonette Varshini K[1]

Meenakshi Sundararajan Engineering College
antovarshk@gmail.com

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ABSTRACT: Urbanization is increasing at a faster pace in the recent years. Cities are becoming concrete jungles with high rise in construction of buildings and structures. It has affected the environment and our lifestyle in many ways. Urban Water logging, Flooding, increase in temperature, Pollution, Damage to natural ecosystems, reduction in green cover are some of the major issues we face in this faster growing urban Environment. This paper deals with the concept of adopting Green Infrastructure (GI) for effective storm water management for the city of Chennai, India. Green Infrastructure in gaining recognition all around the globe since it is related to Sustainable Development and Low Impact Development (LID). Chennai is a rapidly expanding metropolitan city that had and is facing many problems such as flooding, water logging and increase in temperature in the recent years. This paper gives an idea about green infrastructure, types of green infrastructure practices, benefits of adopting Green Infrastructure for the city of Chennai, the importance of adopting it and management techniques for GI.

KEYWORDS: Urbanization, green infrastructure, storm water management, sustainable development.

I. INTRODUCTION

Growing cities are in desperate need of solutions for complications they face due to urbanization. Urbanization brings about huge changes in the social, economical and environmental development. Rate of Urbanization has been massive due to increasing population, that move to cities, that provide opportunities for the people to get better jobs, live in safer environment, easier access to different resources, and good education. Cities like Tokyo, Dhaka, Shanghai, Delhi, Mexico City, Moscow, New York are some of the fastest growing urban agglomerations in the world. Urbanization has its negative impact on the society and environment. Higher cost of living, effects on economy, health complications and environmental issues. In order to face these problems countries are trying to adopt modern methods combined with technology to give green solutions and use eco-friendly options for sustainability.

Environmental issues include pollution of water bodies and air, Urban Heat Island Effect, Water logging and flooding. All these negative phenomena have been re-occurring frequently in the past decade. Global warming has contributed to climate changes leading to formation of violent storms and unusual rainfall patterns around the world.

The City of Chennai being of the rapidly concretizing cities in the country has faced water logging during the monsoon season almost every year. In 2015, Chennai was tragically hit with heavy rainfall in December that led to inundation all over the city. It has always experienced higher temperatures which has aggravated to a vast extent due to climate changes. In order to mitigate all these problems a solution is much needed, that can save the environment and help people to live better.

II. Urbanization and its Impacts

2.1. Water Logging and Flooding

Water logging has become a common occurrence in most parts of the city during rainfall. Water stagnates on roads during mild to heavy rains due to several reasons. It has become a hindrance during monsoon, to people commuting to workplaces and has lead to many water related diseases and breeding of mosquitoes. Now-a-days waters enter into homes when rains hit the maximum. It disrupts daily life of people.

In 2015, Chennai submerged in water from the rains in the first week of December. It received 1,049 mm of rainfall than usual. Rains inundated Chennai Airport, Velachery, Saidapet, Nungambakkam, West Mambalam, Adyar, Vadapalani, Guduvanchery, Perungalathur, Tambaram and many more

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locations. Many people lost their homes. Flood related losses amounted to more than Rs.1000 billion totally and over 500 people had died in Chennai alone.

Some of the causes of water logging and flooding:

- No proper design and implementation of underground storm water networks.
- Insufficient capacity of existing storm water drains.
- Improper maintenance of drainage system.
- Loss of green cover due to urbanization.
- Increase in the percentage of built-up area.
- Disposal of solid waste into drains.

2.2. Pollution

Chennai faces different forms of pollution – water, air, noise and plastic pollution. Urbanization has compelled the residents to pollute the environment. Waste water from houses, chemical effluents from factories are let into rivers. Dumping of solid wastes into the Cooum River by the locals has totally destroyed the local ecosystem.Another serious issue is air pollution. Reports have shown that Chennai's air quality is worsening with time, comparing Air Quality Index (AQI) values for consecutive months. In November, 2019 Chennai clocked air pollution levels as high as 341 in Velachery, Ramapuram, Manali, Kodungaiyur, Anna Nagar and Chennai Airport.

2.3. Degeneration of Green Cover

Construction projects have greatly occupied open spaces and agricultural lands. Green Cover is very important for environmental balance, as it regulates temperature, water cycle and air quality.

Chennai's green cover dropped from 79 km^2 in 2005 to 64 km^2 in 2017. According to a study conducted by Care Earth Trust, Adyar has the highest percentage of green cover with 30 %, least being Tondiarpet and Perungudi with 8.37% and 5.31% respectively.

2.4. Water Scarcity

In the year 2019, the summer had dried up the wells of the city. June 19, 2019 was declared as "Day Zero" by the government. Deficient monsoon rainfall in the consecutive years of 2016 - 2018 and failure in managing water is said to have caused the water crisis. Many disputes arose among locals over the water crisis.

Government took measures to deal with this problem by bringing-in water from Jolarpet. Rain Water Harvesting (RWH) systems were prioritized and were implemented in many places. Restoration of Tanks, Ponds and lakes all around Chennai started in 2018, initiated by The Greater Chennai Corporation.

2.5. Urban Heat Island Effect (UHI)

A city/area becomes warmer than the surrounding unconstructed area, converting it into an Urban Heat Island. The increase in temperature is due to human activities such as:

- Deforestation.
- Increased number of construction activities.
- Reduction in the number of open spaces and agricultural lands.
- Residential, commercial and industrial construction causes energy production.

This phenomenon reduces the quality of air and water quality. Soaring temperatures increases air pollution with pollutants like ozone. It also affects rainfall patterns and quantity of rainfall. Studies and reports concluded that rapid urbanization has led Chennai to become an Urban Heat Island.

III. Planning and Implementation of Green Infrastructure

Green Infrastructure (GI) is a method of changing the existing urban environment to cope up with fast rates of urbanization. It combines both environmental management and water management. Green Infrastructure can be done both at smaller and larger scales, from houses to whole cities. These practices

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improve quality of life by providing clean air, water and good shelter for everyone. It is a great tool for effective, sustainable and cost-effective storm water management.

Any project consists of a series of steps preceding one another. Green Infrastructure implementation needs much planning and assessment before any actual task is undertaken. The whole process involves a number of tasks and resources that are to be carefully planned, executed/used, and managed for better outcomes. This Implementation process consist four steps: Planning, Implementation, Monitoring and Management.

Planning involves setting objectives and goals for the future and identifying strategies and techniques to achieve them. Goal for a GI project is to make it beneficial for the environment and humans as well as to make the project cost and time efficient. With set objectives tasks are identified and schedules are formed. Stake holders are identified in this stage and may include local authority, land owners, contractors, ecologists, horticulturists, wildlife charity and more. Planning of resources needed is also done based on budget, and equipments are procured. Planning strategies must be adopted such that certain aspects are given importance: preservation of existing land features, reduction of impervious cover, reducing run-off volume and downspout disconnection.

Zoning is a technique to be used to separate regions in order to construct different types of Green Infrastructure. The different zones are shown in Figure 1.Different GI practices can be implemented based on these zones. Zoning will also help identify type of labor, equipment, cost required and the size of the project.

Implementation will include survey of the land and preparation of the site before installation. Following procedures and inspection during construction are given importance. Project manager and the contractor take charge of the entire process from start till completion, in case of large scale projects. Smaller installations can be done by the local community or authorities with help of non-governmental organizations.

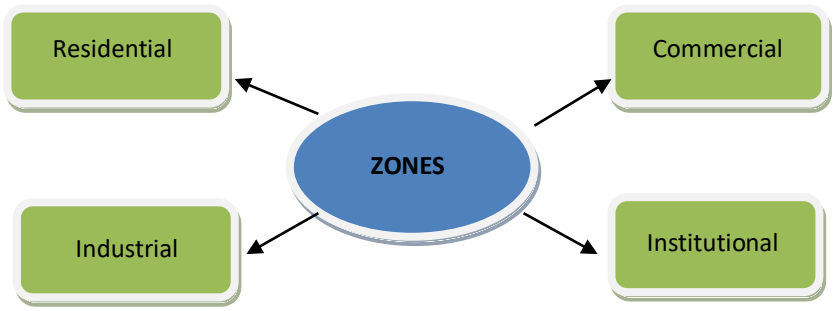

Figure 1. Zoning of the City

Monitoring the processes are done by the managers and stake holders are periodically informed of the status of the project and any changes to the GI plan is made if necessary. GI plan can be amended in order to yield higher levels of benefits from the project.

Management phase involves handling costs and equipments for the various tasks. A proper management strategy will help save money and time. In order to avoid any cost over runs, GI plan must be good and adaptable to future change in tasks, during sudden emergencies, if need arises. Managing GI tasks can prevent any delay in work or overcome any resource constraints, thereby mitigating losses.

IV. Green Infrastructure Practices

4.1. Rain Garden

A rain garden is a piece of land with a depression of certain inches depth that can catch hold of run-off from roofs, roads, parking lots etc., Rain Gardens have planted shrubs, flowers and other water-loving plants, in them. The depression allows flowing water to stagnate and infiltrate to the underground thereby recharging groundwater.

Before designing a rain garden certain considerations have to be made: Location, rainfall, soil type, garden depth and size, type of vegetation to be planted.

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Rain garden must be located where the run-off would flow easily into – a low lying area. It would be proper to locate it in a natural slope. A slope of 1 in 41/2 is required for water to flow into the garden. It is difficult to construct rain gardens in steeper slopes, which would need additional support structure.

The type of soil also plays a major role in retention of run-off. Soil testing must be done in order to find out the percolation rate and the clay content of the soil. Percolation rate of the soil is important for design depth. When percolation of the soil is low, additional drainage system has to be provided. When clay content is more the soil can be amended with organic matter and sand for better infiltration.

The size and depth of the garden depends on the volume of water that is going to get infiltrated from a particular catchment area, from which water has to be saved. Plants can be native to that region which would thrive during both monsoon and dry weathers.

Components of the rain garden include: freeboard, top soil and drainage sub base. The depth of each layer varies, were freeboard depth must be between 200-300 mm to allow for water flow and silt accumulation. The top soil must be a minimum of 300 mm depth. The drainage sub base must be 100 – 500 mm deep. In cases where the soil infiltrates freely, the depth of the sub base can be reduced or even the layer can be eliminated.

4.2. Green Roofs

Green roofs are vegetated roofs, either partially or completely. They are planted and maintained for aesthetic purpose, for irrigation and most essentially for reducing high temperatures. Plants are grown on a medium with water proofing membrane for the roof, in order to prevent structural damage to the building. Green roofs hold storm water and release it back through transpiration and evaporation. It can drain excess run off and reduce Urban Heat Island Effect.

Green roofs can be installed in small structures to big commercial and industrial buildings. They provide many benefits such as reducing run – off, the temperature of the building, stress level of people, providing clean air, new habitat for wildlife and serve aesthetic purposes.

4.3. Bio Swale

Swales are natural or artificially created structures with side slopes and made of soil. It consists of thick vegetation occupying the full section of the swale. Swales act as infiltration medium for storm water and reduce the velocity of flow. It is designed in such a way that water stays in the swale for longer periods of time resulting in pollutants and dirt getting trapped in the swale. Bio swales can be located where percentage of impervious surface is more: roads, parking lots. Bio swales are generally designed to take in first flush of the rain.

Bio Swales are of many types: vegetated swales, low water, low grass and wet bio swales. Depending on the location, the type of bio swale to be installed can be decided. Bio swales require soils with lower clay content. A longitudinal slope is provided for settlement of dust and pollutants. Filters must be used in order to prevent blockage of inlets.

Bio swales greatly help in preventing water logging and improving water quality by filtering pollutants from street run-off. They reduce the stress on storm water drains and help in recharging ground water.

4.4. Urban Forestry

Urban Forestry involves planting and taking care of urban trees. Trees clean out toxins from the air and prevent erosion. Urban Forestry also involves taking care of already existing local trees and plantation. Practicing urban forestry will regulate rainfall patterns and provide clean air to the community.

4.5. Eco Ponds

Eco ponds can be created artificially both at smaller and larger scales. It has its own eco system and water quality is good all the time. Figure 2 shows an Eco pond. Eco ponds require low maintenance, low costs and is naturally thriving, with self-sustaining life forms.

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Figure 2. Eco Pond

Eco ponds are usually created for aesthetic purposes and can be created using rockery, sand, vegetation and organic matter or with wood, stainless steel and stones. Regular inspection would be needed to check growth of algal forms, aquatic life and vegetation growing in the pond. Eco ponds can also be used for recreational purposes. Eco friendly materials for construction can be opted for added advantages.

4.6. Green Spaces/Alleys/Streets/Parking

Planting trees, shrubs, grass along the streets and in open areas is called Green Spaces. It greatly reduces pollution levels and control Urban Heat Island Effect. They are aesthetically pleasing and are beneficial in many ways to the environment.

Green streets and Green parking uses green practices such as permeable pavements, planter boxes, rain gardens, and other eco friendly methods such as solar lighting, using recycled materials for various purposes, in order to manage storm water.

4.7. Rain Water Harvesting

Rain Water Harvesting setup captures water from roofs of buildings and recharge it to the ground through a recharge well. This helps save large amounts of water without going for a waste. It improves ground water levels and prevents water scarcity.

Rain water harvesting has been around hundreds of years in Tamil Nadu. It has been a potential solution to water scarcity problems. Rain water harvesting along with other GI practices will provide additional benefits to the society.

4.8. Land Conservation

Land conservation refers to protection of existing greenery and reclaiming lost land cover. This can be done in many ways by preservation, remediation and restoration. It is useful in flood control, storm protection, recreation and much more. Land conservation makes sustainable development more effective. Figure 3.shows the restored Creek and Estuary in Adyar.

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Figure 3. Restored Creek Estuary, Adyar

4.9. Restoration of Lakes, Rivers and Ponds

Most of the water bodies get polluted from chemical effluents let into them, by factories and by other pollutants, such as untreated raw sewage, plastics, fecal matter and other undesirable substances. Polluted waters spread diseases like typhoid, cholera, E-coli infection, Botulism and Dysentery.

Pollution can be reduced by treating waste water from factories, agricultural lands and municipal waste disposal before discharging in water bodies. By formulating strict rules and regulations for preventing effluent discharge into water bodies, water pollution can be minimized. Awareness programs, workshops, meetings, messages through social media can be effective in increasing knowledge of the locals on water pollution, its effects and preventive measures.

4.10. Constructed Wetlands

Constructed wetlands can be implemented in large open areas where natural water sources are available. Wetlands include swamps, marshes, bogs etc. They are usually made of brackish, fresh or saltwater and have their own unique ecosystem.

V. Benefits and Importance of Implementing Green Infrastructure

5.1. Benefits

Green Infrastructure offers multiple benefits to us. It can not only be used for effective storm water management but can also give social, economic and environmental benefits.

Some of the advantages of introducing Green Infrastructure in Chennai would be:

- Better storm water management and water conservation.
- Reduction in peak run-off rates.
- Reduction in storm water pollution of rivers, lakes due to decreased amount of run-off.
- Recharge of groundwater by infiltration
- Mitigates water logging and related problems.
- Reduces Urban Heat Island (UHI) effect and minimizes higher temperatures.
- Flourishes old and new ecosystems.
- Reduces potential risk of flooding
- Enhancement of environment aesthetically.
- Prevents sewage overflow from drains.
- Improves air quality and provides the community with clean air.
- Forms additional recreational spaces for the community to enjoy.
- Improvement in water quality due to reduction in water pollution.
- Reduces spread of water borne diseases, diseases related to air pollution and much more.

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5.2. Importance of Implementing Green Infrastructure

Green Infrastructure is **multifunctional**, with many advantages to the society. It can solve modern problems of urbanizing cities, in water management. Different methods can be adopted according to site conditions and amount of space available. It is favorable as it can serve various purposes of managing the urban environment. It particularly aims to reduce, re-use and recycle water that might go for a waste if not taken care of. It brings solutions to problems, helping create self-sustaining cities with beautiful landscapes.

VI. Maintenance and Management Techniques

Green Infrastructure project requires precise planning and management of resources. Resources include labor, equipment, money and time. Resources management is crucial to bring out maximum benefits from the project in the long term.

Much skilled labor is not required as the tasks are simple and procedures are easy-to-follow. Labor education and training is an essential part of implementation process. Equipments required for the processes are smaller equipments: shovels, rakes, ladders, back hoe, loaders. Equipments are readily available, easy to procure and require less maintenance.

Installing GI components in a proposed locality/region will require less time compared to constructing bigger water storage systems or new drainage lines. Green Infrastructure practices are time-saving and reliable.

Cost is an important aspect to be considered in GI. Cost for each project depends on its scale and size. Most projects are funded by the government, non-governmental organizations and even local communities. Costs for rain gardens, green spaces, urban and few other practices can be adjusted to suit size constraints and budget. Costs can be reduced by using alternate procedures, multi-purpose equipments and good management schemes.

Maintenance of GI is necessary, so as to reduce overall costs of the projects. Projects must be planned and designed keeping maintenance in mind. The type, staffs and regularity of maintenance, must be decided during the planning stage itself.

Maintenance procedures should be written in advance. Personnel chosen are briefed about it and issues such as siltation, damaged pipes, accumulation of garbage, erosion, plant diseases, overgrown vegetation, structural damage, will be identified by them. Remedial measures are taken with help of volunteers.

Planning and design standards should be established for Green Infrastructure, to guide planners in all future projects. Regulation and inspection manuals are to be devised for proper operation and maintenance in the long-term.

Aim of any project would be cost efficiency and on-time completion. Proper implementation only, is not imperative but operation and maintenance too. Good management and maintenance techniques of different resources for Green Infrastructure will yield gains, in many ways to both the environment and the public.

VII. Conclusion

We are in search of sustainable and enduring methods, at present, as development and growth is inevitable. With new inventions in different fields of science, technology and construction, growth has fastened in the past decade. Management of different resources needs to be prioritized, in order to avoid any adversity that could take place due to lack of proper management tactics.

Pollution, Global Warming, Floods have been identified as **man- made** activities that could be possibly taken care of, with new perception in planning, designing, monitoring, execution and management with sustainability in mind. Sustainable development is being considered in order to cope up with the rapidly developing urban environment. Major issues are related to water management. Hence, Countries are adopting Sustainable Water Management practices, Smart city concepts, Greening cities and Integrated Storm Water Management systems. Conservation of existing water bodies, wetlands and green cover are being emphasized now.

Green Infrastructure can solve Chennai's water crisis, temperature climb, water stagnation problems and pollution. Proper planning and implementation of green infrastructure in the city would be beneficial to the community and the environment. Management is equally as significant as planning and execution, because when it is done correctly, it can reduce costs of maintenance and can be rendered fruitful for a longer period of time.

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