International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09, Special Issue | Feb 2022 www.irjet.net p-ISSN: 2395-0072

"Metagreen Dimensions, 2020 - 2nd International Conference on Performance of Built Environment
Organised by: College of Architecture Trivandrum, INDIA"

Blue - Green Infrastructure in Emerging Cities:

Akkulam Veli Lake Basin, Thiruvananthapuram

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***ABSTRACT**: The pace of urbanization increased many folds after the reforms of the 1990. The nation as a whole had embarked upon a new path of development wherein we have built, expanded, improved and improvised up on existing as well as created new urban settlements so as to accommodate the new settlers. The paper intends to ponder into various aspects, such as expansion of such settlements causing stress in the ecology, the depleting natural resources affecting basic delivery of municipal services like water supply and drainage. The study involves intense field work and collection of data pertaining to the land-use changes, delimitation of the study area based on ecology, literature study of comparable areas, analysis and identification of concerns and possible alternatives based on Blue -Green Infrastructure (BGI). The area of study is limited to the new developments along the rapidly expanding bye-pass area of Thiruvananthapuram City, specific to the ecologically sensitive wetland of Akkulam-Veli Lake, Thiruvananthapuram, Kerala and its catchment area. For this research, surface and ground water maps, land use maps, geologic maps, soil maps etc. are basic tools. The study intends to explore the possibility of BGI to ensure a resilient and meaningful development in urban landscape wherein sustainability will be the prime objective, in areas of ecology, culture, finance and in delivery of basic services to the city.*

KEYWORDS: Blue Green Infrastructure, Resilience, Catchment basin, Sustainable development

1. INTRODUCTION

Earth – the home to all known forms of life which have evolved and perished in definite forms of settlement defined by a conducive environment. All life forms feed and breed in such environment wherein there will be a sustainable resource of its basic need for nutrients, water and other needs.

Humans on earth in their path of civilization to urbanization have transcended quite a long path in their own way and have created a unique pattern which has led to destruction and degeneration of such habitats. The change in climate which was once a hypothesis is now not just accepted as a fact and reality but we are now looking into technologies to forgo this existential threat and possibilities to reversethe scenario.

The civilized world of humans seems to be more concentrated away from nature and is defined by more mechanical means to support life, wherein the existential needs are sourced and supplied artificially from far away sources. Humans have transformed themselves to customers of services in which all needs are delivered to the door step at the placement of an order. The "droid" life seems to be more fascinating with the cost paid by the habitat.

The basic need for water as in "Potable" grade is usually sourced from an aquifer or some other perennial source (whose replenishing capacity is not taken care of).

This paper intends to shed some light on the management of such resources within habitats where co-existence, management and economic viability will augment the drive for sustainability of all.

The area of study is limited to the urban settlement of Thiruvananthapuram city, the capital of Kerala, India which contains the catchment area of Akkulam- Veli Lake.

2. THE CONTEXT

a. Akkulam Veli Lake, Thiruvananthapuram

The 44 rivers that the state is blessed with, the backwaters, the Western Ghats and much more make Kerala a Bio hotspot of the World. The Settlement pattern which is of our concern here is also unique due to thisrichness. As mentioned earlier the human settlementpattern is also guided by these factors, because of which settlement density is much higher in the lower plains than in the hilly terrain. The state of Kerala has its administrative capital in Thiruvananthapuram and has a unique settlement pattern in this regard.

The city of Thiruvananthapuram the erstwhile Travencore (Trivandrum) is defined by the manner in which the urban settlement pattern has evolved through the ages. A city that once owed its named to the "Padmanabhaswamy Temple" now commands her place as one of the fastest growing urban agglomeration based on technology and innovation. As per the District handbook of Trivandrum the Percentage of urban population of the state is 47.7 compared to 53.66 of the district of Trivandrum (census of India 2011, Kerala, Series 33, Part XII-B). The census 2011 calls upon the need to study and understand the new settlement pattern which is referred to as Urban Agglomeration to the Core of the city. The newly added settlements are found to be profoundly more dependent on the "tech city" which is along the western side of the district. The development pattern which is of "ribbon" type is primarily defined by the NH 66 and the bypass has a proximal origin in Kazhakuttam.

The study intends to do a detailed observation of the possibilities in ensuring a sustainable existence in this region through adoption of technology, Sustainable Practices, and better regulations in this regard. The observations are inferred in the form of successful case studies and the scope defined through various data in the form of data sheets and other comparative studies.

b. Need of the Study

The latest and the fastest growing urban agglomeration of Thiruvananthapuram commands all its growth to the coming up of the "Technopark" which triggered this unique development. This has brought in a fresh lease of life in the region by inducing green field and brown field development in and around the surrounding rural areas which have been elevated to urban status. Lately this growth is further augmented by the redevelopment of the bypass (more lanes, flyovers), new terminal at international Airport, Vizhinjam Port and additional development of the techno-park and other private investments in this region. The sporadic development in this regard has caused a severe impact in the ecological balance of the region. The region in study has one of the bio sensitive areas of the district which is predominantly "Akkulam Lake" and which has its connection to the national water way (through the Parvathi Puthanar). The newly added settlement pattern is not just defined by the "tech city" but also incorporates industrial parks like Kinfra Apparel Park, sewerage treatment plant, educational institutions, automobile showrooms and service centres, world market, hospitals and their depended Housing in the form of detached dwellings,low rise and high-rise units.

Developments leading to Human settlement in any form in any part of earth call in for delivery of essential daily services which can be summarised to a few, like fresh water, waste treatment (solid, liquid), communication and electricity. All settlement patterns are defined by the availability of potable water – the source, quality and the quantity in which it can be economically retrieved is getting thin. The settlement in study sits in a unique place in the geographical context where it is located in the naturally evolved "sink" of the drainage pattern of water bodies that emerge from different parts of the district and then join up here before getting discharged to the Arabian Sea.This calls in for the detailed possibilities in harnessing this water resource and thereby enabling a sustainable co-existence which will ensure a better quality of life. This involves the study of drainage pattern, trends in land use development and settlement pattern, case studies and inferences from there on.

In this context, the research question is: how the active resilience could bring in urban landscapes using Blue Green Infrastructure (BGI) concepts by focusing on the importance of urban water management?

3. LITERATURE REVIEW

Blue Green Infrastructure (BGI) refers to an interconnected network of natural and manmade water features and a network of vegetal cover thereby strengthening ecosystems in urban areas. The ecological engineering replenishes the natural processes and can address the demands of potable water and management of storm water. BGI can play an important role in planning and maintaining the balance of natural resources and added settlement needs. Some of the major positive outcomes associated with the implementation of BGI in urban areas are climate change adaptation, biodiversity protection, aesthetics of city and societal benefits. This ensures a holistic approach for the sustainable development of the cities.

a. The water catchment approach in Blue-greeninfrastructures

The functional requirements of BGI systems are to capture, filter, slow down, and where possible infiltrate and store rain and storm water. BGI alters the local water cycle in a systemic way that benefits health and biodiversity for both flora and fauna, whileimproving local water security and water supply.

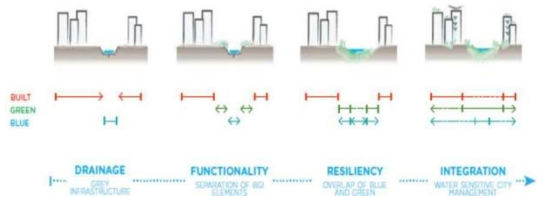

Figure 1.The process of integration (Source:https://www.zu.de/lehrstuehle/soziooekonomik/assets/pdf/Ramboll_Woerlen-et-al_BGI_Final-Report_small-1.pdf)

The process of involves multi stage intervention where in the "Flush" of the rain water to the storm leading to sea is reduced considerably. In general, elements of BGI are green roofs, bio swales, rain gardens, retention and detention swales and lakes, infiltration systems and others, which may be connected to other elements in the water catchment. Each BGI element contributes to rainwater and storm water treatment and also a network connector using blue elements and green elements thus enhancing ecological connectivity. The connected modules are commonly known as "treatment trains".

The tasks involved in urban water management are the alteration of the local water cycle, reduced infiltration, corresponding reduction in local groundwater availability, increases the risk and intensity of flooding and increases pollution of surfacewater.

The challenges in implementing sustainable urban storm water and environmental management systems, using BGI infrastructure involve a paradigm shift in vision, policy, design, and the urban planning/ design culture with respect to spatial, social, economic and temporal context. This may thus call in for a more holistic approach in the treatment/engineering techniques, treatment of grey water/ residual waste water treatment methods suitable to the ecosystem.

Inferences from BGI Case studies

Figure 2: Bishan-Ang Mo Kio Park , Singapore Source: http://the-southern-cross.com/awordortwo/wp-content/uploads/2013/11/RiverPlains_070612.jpg

Literature case studies such as Bishan-Ang Mo Kio Park, Singapore, Copenhagen, Denmark etc. were analysed and the inferences are as follows:

Cities dual need of fresh water supply and flash flood management could be achieved in a sustainable manner.

BGI approaches ensure that water falling on the road network flows into infiltration drains, thus protecting the water bodies from pollution and recharging our water table.

The water catchment approach will yield more to the cities maintaining the natural processes and hence integrated water management approach is required.

The ecology of the fragile areas can be restored and balance of ecosystem services can be ensured.

Healthy living and aesthetical values of the urban areas can be ensured and recreation spaces.

Socio economic values of cities could be increased in a positive manner.

BGI approaches involve shifts in vision, policy, design, and the urban planning culture.

4. THE AKKULAM VELI LAKE.

The backwater of Akkulam-Veli, adjoining the Arabian Sea in the south-west part of Indian Peninsula, is a coastal wetland system with tropical humid climate and forms an integral part of the local ecosystem.

The Veli-Akkulam Lake, a famous tourist destination, is located about 8 km north of Thiruvananthapuram and fringes the Arabian Sea in the western coast of India It is situated between 8°31′14″ and 8°31′52″north latitudes and

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76°53′12″ and 76°54′06″ east longitudes.

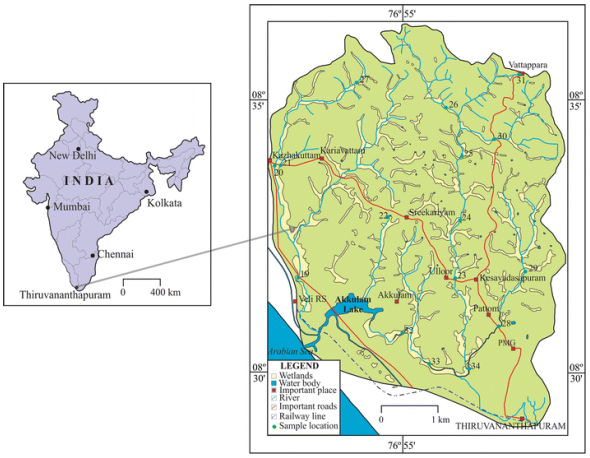

Figure 3: Catchment area of Akkulam Veli Lake Basin (Source: Applied Water Science. 2017 retrieved from https://link.springer.com/article/10.1007/s13201-015-0333-8.)

The lake occupies an area of 1.16 km2. AV Lake has a maximum length of 3.2km and a maximum width of 0.52km with a mean depth of 0.9m.

The Catchment basin

The Akkulam-Veli lake basin consists of six sub-basins, namely, the Amayizhanchan basin, Pattom basin, Ulloor Basin, Medical College basin, Kulathur basin and the TS canal basin (Figure 4).

Among these, Ulloor basin (19.71%), the Pattom basin (10.8%), the Amayizhanchan basin (6.11%) and the Medical College basin (5.65%) together constitute the Kannamoola basin making it the largest basin (42.27%) of the AV Lake.

Key Issues

The key issue identified is severe anthropogenic pressure in the lake. The eutrophication and immense growth of water hyacinths in the lake, induced by the continuous inflow of effluents from the streams

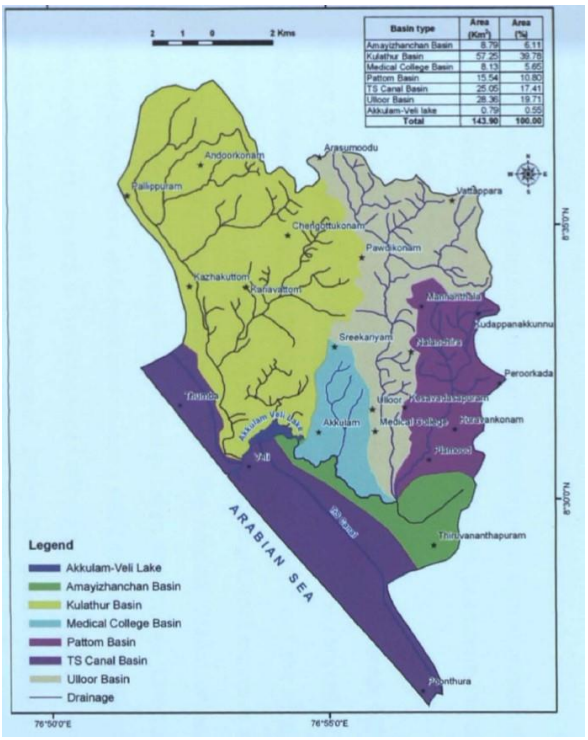

Figure 4: Akkulam Veli lake and sub drainage basins (Water quality modelling of a lake system using remote sensing and GIS. 2011 retrieved from http://shodhganga.inflibnet.ac.in:8080/jspui/handle/10603/74065)

been elevated to urban status. Lately this growth is further augmented by the redevelopment of the bypass (more lanes, flyovers), new terminal at international Airport, Vizhinjam Port and additional development of the techno-park and other private investments in this region. The sporadic development in this regard has caused a severe impact in the ecological balance of the region. The region in study has one of the bio sensitive areas of the district which is predominantly "Akkulam Lake" and which has its connection to the national water way (through the Parvathi Puthanar). The newly added settlement

Figure 5: Akkulam Veli lake and water depth (Water quality modelling of a lake system using remote sensing and GIS. 2011 retrieved from http://shodhganga.

inflibnet.ac.in:8080/jspui/handle/10603/74065) draining the urban agglomerate, are deteriorating the lake day by day.

Numerous dwellings, slums, hospitals, commercial areas etc. are situated all along these rivers. Improper management of sewage waste from the dwellings, domestic waste and other industrial waste have resulted in direct disposal and pollution

of these drainages and Akkulam- Veli Lake.

a. Drains connecting the lake

The streams that drain into the Akkulam-Veli lake include the Kannamoola stream and the Kulathur stream.

Figure 6: Akkulam Veli lake and streams joining the lake (Water logging in parts of Thiruvananthapuram city and an overview of 'operation anantha'.2017 retrieved from http:// cds.edu/wp-content/uploads/2017/03/Water-logging_ Shaji.pdf)

The Kannamoola stream is formed by the confluence of the Ulloor stream, Pattom stream and the Amayizhanchan canal near Pattoor. The Amayizhanchan canal starts from Vellayambalam (backwash of filters from the water treatment plant of Kerala Water Authority) and it passes through Thampanoor, EastFort, Vanchiyoor and Pattoor through the Thiruvananthapuram city.

The Ulloor stream originates from Vattappara and Arasumud area and it flows through Paudikonam, Ulloor and Kesavadasapuram and joins the Pattom stream near Pattoor.

The Pattom stream originates from the Kudappanakunnu-Mannanthala area and it flows through Kuravankonam, Plamood, and Gowreeshapattom and meets the Ulloor stream and the Amayizhanchan canal at Pattoor. Thus the Pattom stream, the Ulloor stream and the Amayizhanchan canal join to form Kannamoola stream and it then flowsthrough Kannamoola, and joins with the upstream portion of the Akkulam Lake. Medical College channel joins the Kannamoola stream before it joins with the Akkulam lake.

5. LAND USE CHANGES

Land use is one of the essential and the basiccharacteristics of a catchment basin that affects the infiltration and other hydrological processes like waterflow, runoff, and soil erosion.

The land use of Thiruvananthapuram Municipal

Corporation has changed due to urbanization; physical, social, political and economic factors have played theirroles in changing the city's land use pattern.

Land use changes and its impact on AV Lake

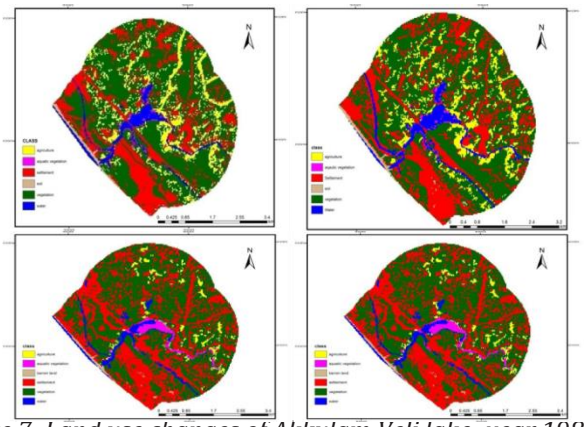

Figure 7: Land use changes of Akkulam Veli lake -year 1989,2006, 2018(Land Use Change Detection in Akkulam-Veli Lake, an Analysis using Remote Sensing and GIS Tools.2018 retrieved from https://www.ijraset.com)

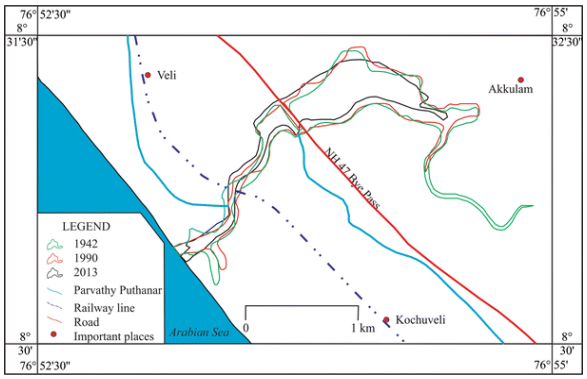

Figure 8: Shrinkage of Akkulam lake over a period of time (Applied Water Science. 2017. Retreived from https://link. springer.com/article/10.1007/s13201-015-0333-8)

The settlement density increased exponentially during the period, from 1989 to 2006 and aquatic vegetation has been increased from 0.45% to 6.94% due to eutrophication. The increase in settlement area by replacing agricultural and vegetated areas led to the inefficient land use pattern observed.

The infrastructure developments such as widening and construction of new bypass road and many multistoried buildings, industrial establishments such as Techno park, Info park, Vikram Sarabhai Space Centre (VSSC),KIMS hospital, factories, Air Force Academy and Boat Club etc. that offered various employment opportunities resulted in the migration of people from nearby suburban or rural areas. This increase in population resulted in the rise in land value and thus the change of land use pattern.

Thus, large scale construction activities occurred and haphazard filling of low lying areas leading to blockage of natural drains, reclamation of water logged areas and reduction in ground water recharge. Thus land and water, which are prime natural resources, are under severe stress in the capital of Kerala state, Thiruvananthapuram.

The demand for fresh water supply increases with the fast-growing population and the source remains the same, the water from Peppara dam and Aruvikkara reservoir which creates severe shortage of water in summer season and the quality of drinking water is also a matter of concern.

Issues identified due to land use changes

The area of lake has substantially reduced over a period of time. The reclamation of paddy fields leads to flooding during rainy season and causes lowering of water table in the area. The condition of existing water bodies as natural

Table 1: Shrinkage of Akkulam lake over a period of time (Applied Water Science. 2017 retrieved from https://link.springer.com/article/10.1007/s13201-015-0333-8.)

Year	Area (Sq.Km)	% change with respect to 1942
1942	1.608	-
1990	1.576	2
2013	1.157	28.05

drainage for storm water is deteriorating due to siltation and reclamation activities. This has resulted in the occurrence of flash floods.

Dumping of solid waste from markets, hotels, apartments, houses, shops etc., and discharge of untreated sewage directly into the water bodies lead to contamination of water and foul smell.

Direct sewage disposal to drains and thereby to lake is not only a source of environmental degradation to the lake and surrounding ecosystem but also a major health hazard for the local population.

Degradation of ground water quality and open wells and open water sources are dependable for drinking water supply.

Unscientific and indiscriminate methods of sand mining have resulted in erosion of river banks.

Reclamation of water logged areas and natural drains for high density development.

Severe shortage of fresh water supply due to increasing population and dependency on the source exceeds its carrying capacity. Increased impervious areas in the drainage basin, resulting in increased peaks and volumes of runoff.

Table 2 Population of Thiruvananthapuram Municipal Corporation (Census of India 1981,1991, 2001, 2011)

Year	1981	1991	2001	2011
Population	4,83,086	6,46,372	8,89,635	10,48,283
Area in sq.km	147.74	177.77	217.36	

6. BGI AS A TOOL.

Blue green Infrastructure has evidently widened its scope from mere a "micro" level, problem specific intervention to a macroscopic form. The change in character is evident in the recognition of the need for centralized waste water treatment plants to preservation and planting of sedge's for root zone treatment (which will help in Water Resource Recovery Facility (WRRF)) to fight pollution. There are various models available whose combinations are tried out to suite the demand of time. The direct benefits being

- Better surface and subsurface water.

- Reduced pollution (air, noise, glare)
- Overall betterment of living condition (outdoor)
- Reduced stress on other species mainly due to reduction in Urban heat islands and better green cover.

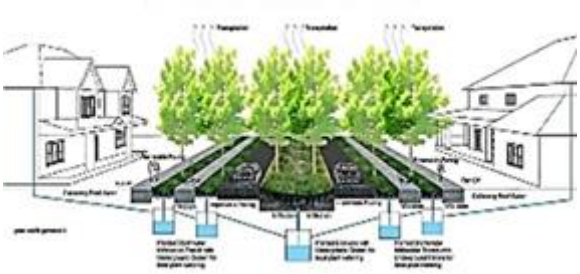

Figure 9: Integrating Blue green Infrastructure into street retrieved from https://www.umass.edu/larp/file/ meilan2jpg

Incorporation of natural design elements into storm water control plays a critical role in mitigating flooding, controlling runoff, and removing harmful contaminants from storm water with systems that can withstand and rebound from extreme storms and changing conditions.

Blue green infrastructure can improve water quality through a variety of treatment mechanisms, but can also provide substantial pollutant load reductions by

Figure 10 Stormwater management using BGI as a tool Retrieved from https://www.umass.edu/larp/file/ meilan2jpg

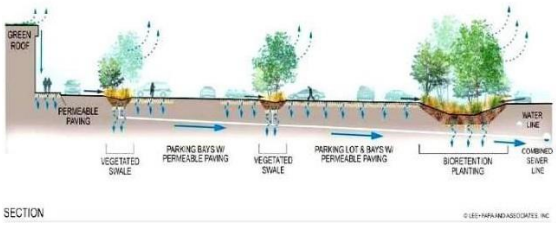

Figure 11: Treatment train retreived from Low Impact Development / Green Infrastructure retreived from https:// www.slideshare.net/mclarchick/low-impact-development- green-infrastructure)

infiltrating runoff and reducing the volume discharged to receiving waters.

Once the green infrastructure is implemented, it can then be monitored, yielding valuable information regarding potential CSO reductions and pollutant loadreductions.

The cost so incurred in the installation, maintenance of such infrastructure will surely too small compared to the reduced carbon sink savings and environmental benefits. After all how much can one pay for a healthy living ensured by a healthy environment.

Private development standards and design guidelines should be refined to reinforce district- scaled strategies. Consider ways to encourage green roofs and other on-site infrastructure features.

7. CONCLUSION

Man, who is an integral part of nature, is not meant to be a threat or not to be threatened by the either of them. The need for preservation of resources has become the need of the time and requires the will of the time and must be induced by the system. The awareness so generated as a part of such deliberations generate serious approaches to this perspective and will surely point towards a path for more sustainable practices and possibilities so as to ensure mutual co-existence. So let us make it believe that "better late than never".

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