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Planning of Green Infrastructure for an Urban Area – A Case of Visakhapatnam

K.N. Deepak Sarma¹, K.S.R. Kutumba Rao², K.S. Jaya Surya³, Dr. Vidya V.Ghuge⁴

Principal Consultant, n-PLASeS Consultancy India, Guntur, A.P, India¹

Chief Consultant, Sri Sai Architects, Guntur, A.P, India²

Consultant, n-PLASeS Consultancy India, Guntur, A.P, India³

Assistant Professor, Visweswaraya National Institute of Technology, Nagpur, India⁴

ABSTRACT: With the rapid growth in urban and suburban communities across the world, available rainwater infiltration and natural groundwater recharge areas are declining. Storm water runoff is becoming a problem as the conventional methods are failing in capturing the generated storm water. Increased impervious cover decreases the amount of rainwater that can naturally infiltrate into the soil and increases the volume and rate of storm water runoff. There are two definitions of “storm water management”; first one explains about the Traditional storm water management design that has been focused on collecting storm water in piped networks and transporting it off site as quickly as possible, either directly to a stream or river, to a large storm water management facility (basin), or to a combined sewer system flowing to a wastewater treatment plant. The second one explains about the Low impact development (LID) and wet weather Green Infrastructure which addresses the problems related to storm water management through a variety of techniques, including strategic site design, measures to control the sources of runoff, and thoughtful landscape planning. The study was conducted in 3 stages; in the initial stage literature review was conducted by considering the successful foreign case studies. In the second stage, city (Visakhapatnam) was selected based upon the coastal climatic conditions as GI plays an important role in reducing runoff. Visakhapatnam; the coastal city was taken as a case study for planning of Green Infrastructure. There are 72 wards present in the city. GVMC has divided into 6 zones. The city has tropical climatic conditions; and clayey type of soils and the topography of the city is ranging from very steep to steep slopes.. There are 55 major industries present in the city; and Vizag steel plant was the primary economy generation for the city and this was also the major emissions generating in the city. A pilot study and visual survey was conducted in the CBD area and in the lower topographical areas of the city. After conducting the pilot study; issues are identified based upon the questionnaire responses from people and the questionnaires are finalized. Three questionnaires (Household, Industrial and Government official) are drafted based upon different target groups for each questionnaire to identify the severity and intensity of the problem. Household questionnaire was conducted with people as target group for identifying and analyzing the people perception regarding the runoff management, cyclone effects, pollution effects and awareness programs in the city. Industrial questionnaire was conducted with each Industrial management officers as target group for assessing and reducing the emissions from the industrial belt. A primary survey sample of 531 questionnaires are conducted for household based upon the population density, number of households and issues identified in the zone, 18 industrial questionnaires are conducted based upon the highest CO and SO₂ emissions generation and 9 Government Questionnaires are conducted pertaining to storm water and industrial management.

I. INTRODUCTION

Green infrastructure is the latest term for techniques that have been employed for over 100 years that use the land's natural drainage capacity to both management storm water and provide beautiful public amenities. Due to the rapid urbanization and development, the quality of oceans, seas, rivers, streams, lakes are depleting. 35% of jobs in the developed countries depend upon the ecosystem services only. Today more than 50% of the world's population lives in

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urban areas, making the urban environment the most common environment for man, thus, leading to increase in size of urban areas due to increase in number of residents. Present urbanization trends shows that an additional 3 billion people will be living in cities by 2050, leading to increase the urban share to two-thirds of the present population. Certain trends and events (For Ex: Bhopal Gas Tragedy) affecting our lives have already made us to re-think the importance of nature. With the rapid growth in urban and suburban communities across the world, available rainwater infiltration and natural groundwater recharge areas are declining. The shrinking and destruction of natural environment caused by urban sprawl, destruction of forests along rivers due to floods, indicates that we have limited resources to mitigate flooding and lack of climate-cooling, vegetation in cities causes extreme heat waves to occur, showing the relevance of Green Infrastructure.

II. METHODOLOGY

The methodology included three stages. To start with, it was needed to study the global meaning of Green Infrastructure. As a result of this study, the concept evolution, major benefits and barriers were identified and highlighted. The target of stage one was achieved by listing out the major issues and understanding the global and Indian scenario about GI techniques. And then, it was apt to study the Green Infrastructure in the study area too.

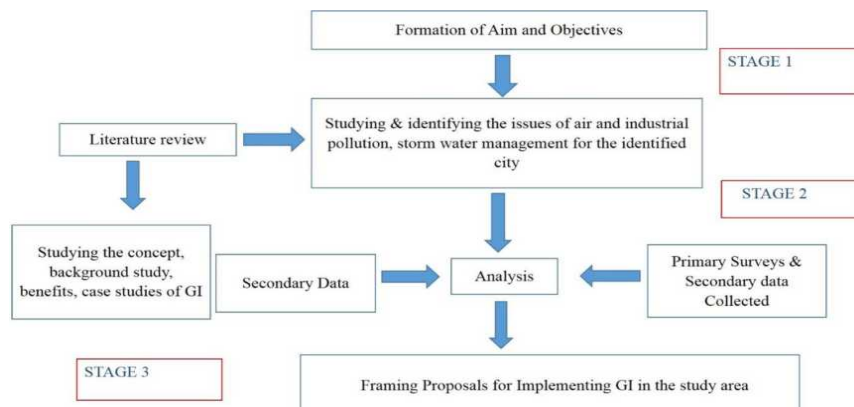


Figure 1 Showing Methodology

III. LITERATURE REVIEW

Green infrastructure was used to describe a network of green spaces that were connected, offering multiple ecosystem services. Due to the rapid development, the benefits of Green Infrastructure have expanded for storm water management, climate change adaption, management of run-off and eco-system services.

Definition of Green Infrastructure

Green infrastructure is the network of natural and semi-natural areas, features and green spaces in rural & urban, and terrestrial, freshwater, coastal & marine areas, which together enhance ecosystem health & resilience, contribute to biodiversity conservation & benefit human populations through the maintenance & enhancement of ecosystem services.

Elements of Green Infrastructure

A. Green Roofs

These are the roofs of buildings covered with vegetation and soil either fully or partly covered. These are in layers, having waterproof membrane, drainage mat, root barrier and growing media. Due to exposure of plants to sun and wind, evaporation of water from soil takes place making the roofs cool.

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Figure 2 Showing Hamilton Green Roof



Figure 3 Showing Burnsville Rain Gardens

B. Rain Gardens

Rain Gardens are also called as Bio-Retention Basins. These are designed to absorb rain water that drains from impervious areas (roofs, parking areas, streets, lawn areas). These will reduce run-off because storm water drains into soil leading to reduction in erosion, water pollution etc. These are shallow vegetated basins which can be installed in any unpaved space.

C. Porous Pavements

Porous pavements are permeable pavements which allow rainwater to infiltrate into the soil and these can be used as pavements, parking lots and pedestrian pathways instead of conventional pavements. These are also the cost effecting and can be used in the areas where flooding is a problem.



Figure 4 Showing Porous Pavements



Figure 5 Showing the installation of vegetated Swales

D. Vegetated Swales

These are the linear features which have wide and shallow channels present on side slopes with natural vegetation to promote infiltration & reducing flow velocity of runoff. These can be used in parking lots, since storm water picks pollution from vehicles and these can be treated before entering the watershed.

E. Green Parking

These are used in parking lot designs which incorporates green infrastructure also in its functional requirements. This also helps in management of storm water and reduces heat land effect. These can be used in parking lots, cycle tracks and in pedestrian walkways.

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Figure 6 Showing Heifer Parking Lot Area



Figure 7 Showing Green Streets

H. Green Streets

Green Streets help in integrating all the green infrastructure elements to store, infiltrate and evapotranspire storm water. Planter boxes, pervious pavements, bio swales can be used in the design of Green Streets.

IV. CASE STUDIES

URBAN HEAT ISLAND EFFECT IN STUTTGART-IMPLEMENTATION DATE: 2008

PROJECT TYPE: Reducing Heat Island Effect by preparation of Climate Atlas. CITY EXTENT: 207.4 km².

SCALE: City Level, Impacts Addressed: Poor air quality and high temperatures.

Issue: Development on the valley slopes have made the situation worse by preventing air from moving through the city, which contributes to the urban heat island effect.

Key aims of the Plan: Purpose of Atlas was to make available basic materials required for the proper consideration of all climatic and air-related issues during planning process. Aimed for providing strategically environment assessment.

CASE STUDY 2:

Liverpool- LOCATION: England Population: 15, 13,086 Density: 10186/sq. mi

Goal: Planning of Green Infrastructure in Liverpool is to support a safe, more inclusive, sustainable and enjoyable city; to provide essential life support functions for a world class city that is adapted to climate change and where healthy living is a natural choice.

Methodology Adopted by the city: A 5step approach was followed by Liverpool City which was derived from North West Green Infrastructure Guide that helped as a good basis in managing and developing the Green Infrastructure framework effectively. For better understanding; a matrix was prepared with parameters on y axis and cities on x axis; 3 International and one Indian city was considered for analyzing the GI. The red color marking will show the lowest level and Green color marking shows the highest marking achieved by the city when compared to others. Green Infrastructure framework development was identified as a key theme by Emerging Environment and Waste Board.

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They proposed and identified certain priorities for the city of Liverpool.

Priority	Issues
Setting the Scene for Growth	Improving quality of place for projected housing growth Encouraging people to live and work in the city as well as increase the number of visitors to Liverpool. Increasing levels of productivity across the city. Developing a low carbon economy, Including improving the opportunities for walking and cycling as part of everyday life in the city.
Providing access to high quality region	Reduce the high levels of poor mental health and reduce levels of air pollution.
Adapting to and Mitigating Climate Change	Managing storm water runoff to protect the lower areas and to provide irrigation for drought susceptible areas of green infrastructure to sustain their cooling function for the city. Provision of corridors for species movement as climate changes.
Safe Guarding and enhancing the ecological framework of the city	Protecting core biodiversity areas. Creating expansion areas and wildlife corridors. Ensuring that green infrastructure delivery programmes contribute to the delivery of biodiversity action plan habitat targets

V. REGIONAL SETTING OF VISAKHAPATNAM

Visakhapatnam is the country's largest city in terms of land and Andhra Pradesh's second largest urban agglomeration in population. The reconstituted Greater Visakhapatnam Municipal Corporation has an area of 540 sq.km with a population of more than 1.8 million. On account of rapid industrialization, there has been significant migration into the city. The city of Visakhapatnam has implemented a number of reforms including e-governance and citizen-friendly initiatives. Vizag has been the first city in the country to implement e-governance and still leads in offering a variety of services to its residents online.



Figure 8 Location Map of Visakhapatnam City

Geographical Data and Topography: The Topography like a spoon shaped basin surrounded by hill ranges on three sides and sea on the other side and is often called as bowl area for assessment of environmental related issues.

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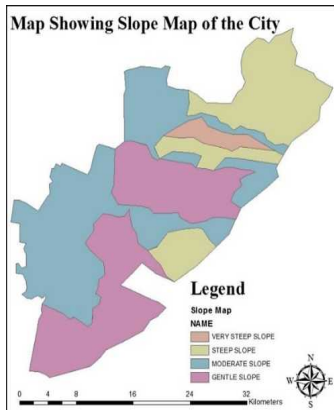


Figure 9 Slope Map

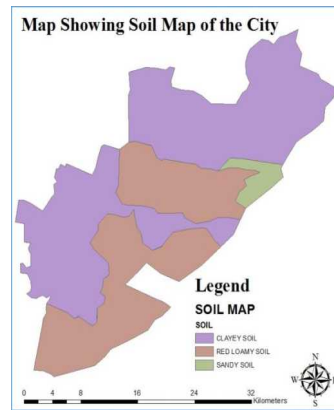


Figure 10 Soil Map

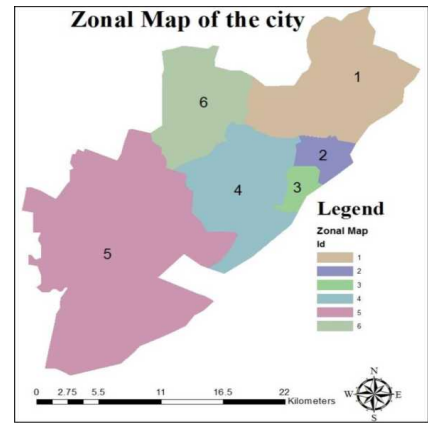


Figure 11 Zonal Map

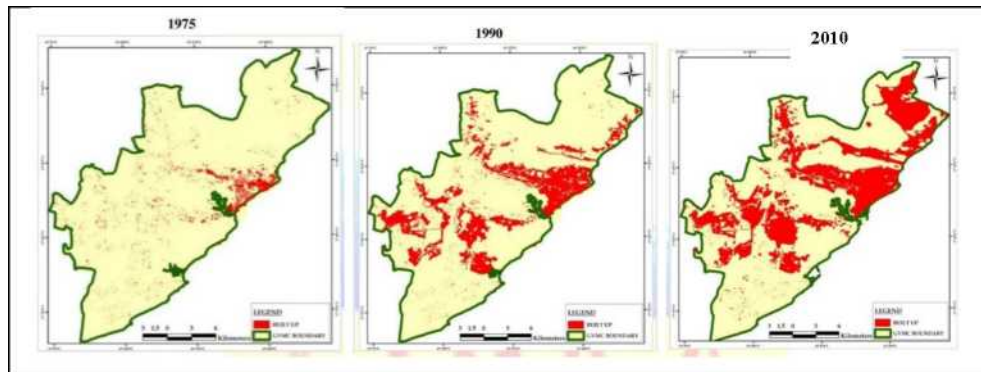


Figure 12 Built-Up Density Maps

From City development plan and Cyclone Warning Centre data; areas are identified which are more prone to cyclones. These maps are generated based upon severity of cyclone on a particular zone and these are marked with respective colour coding to identify the major effected zones in the city. Cyclone density maps have shown that the green colour patches are more prone to cyclones and are affected. It was observed that the total coastal zone area is being affected during the cyclones.

Cyclone Affected Areas Density Maps

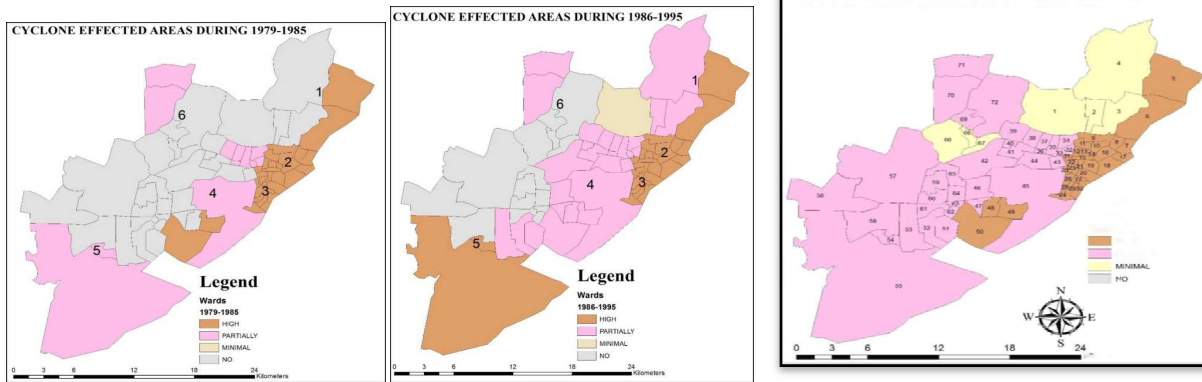


Figure 13 Cyclone Effected Areas during 1979-2016

VI. ANALYSIS

After conducting the pilot study with a preliminary sample; issues were identified from each zone. At the time of preliminary survey, topography, green cover, land use type, Issues of Storm Water Runoff, Industrial Pollution and health was observed to be the critical issues in the city. So to study the issues in the city in detail and to know the severity of these issues in 6 zones of the city; A primary survey was conducted with household, Government and Industrial Questionnaires to identify the severity and intensity of the problem. During the primary surveys; the functionality of the area was considered primarily to assess its characteristics and land-use. After identifying the issues; analysis was carried out for each addressed parameters in the questionnaire and 3 major priorities (Storm water, Industrial and Health) are considered. From case study 2; Likert scale ranging method was considered for analysing the city. Scoring Rates are given ranging from 0 to 1 (0- no targeting area and 1 - highest targeting area) for each priority and targeted zones are identified through the scoring rates obtained from the questionnaire results.

HOUSEHOLD QUESTIONNAIRE ANALYSIS: With the sample of 531; the age comparison analysis was carried out to identify the percentage of people present in the city. The below chart shows the age percentage comparison analysis of the sample considered.

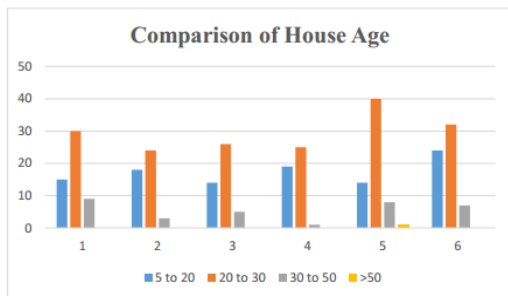


Figure 14 Comparison of House age

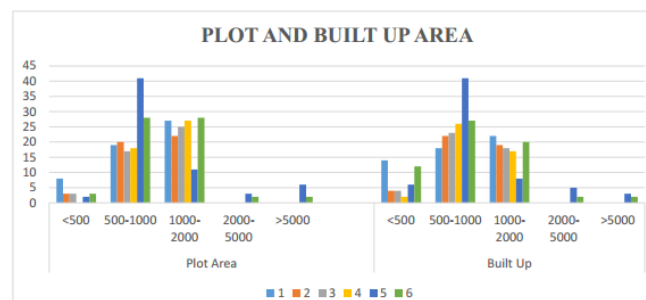


Figure 15 Plot and Built up Area Comparison

All the zones constitutes majorly with 20-30 years of house age. Zone 5 area has the highest range due to the presence of industrial quarters present in the area. Built up area of 500-1000 Sq. ft. has its major share even though the plot areas are of 1000-2000 sq. ft. Hence there is a possibility of using the remaining area for improving the green vegetation. Plot areas of 1000-2000 Sq. ft. are observed to be highest in all the zones except the industrial zone area.

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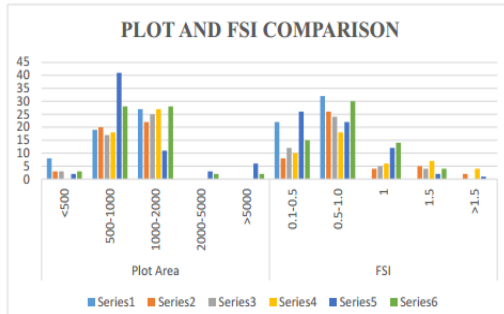


Figure 16 Plot and FSI Comparison

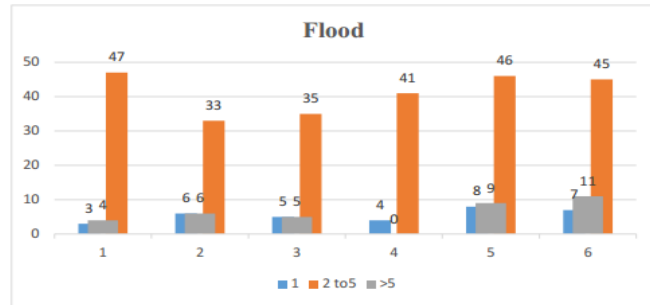


Figure 17 Rate of Flooding in the city (in Number/year)

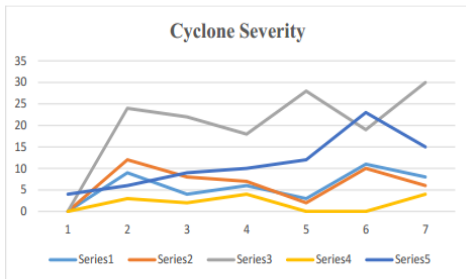


Figure 18 Cyclone Severity

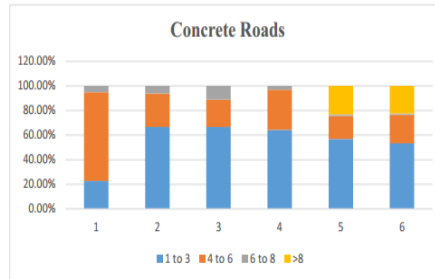


Figure 19 Flooding in Concrete and Bituminous Roads

PRIORITY MAPS

After analysing the various parameters; the priority maps are prepared based upon the questionnaire results generated. These will help in preparing priority maps to identify the critical severity zone of each criteria considered.

S.NO	PRIORITY
1.1	Topographical Influence was the major issue for flooding in the zone
1.2	Poor maintenance of storm water drains or drainage network in the zone.
1.3	Surface cover was also the major factor for flooding or storm water.
1.4	No recycling programs was conducted for the awareness about storm water.
1.5	Rain water harvesting techniques have helped in reducing water scarcity in the lower areas.

S.NO	PRIORITY
2.1	Reducing Air Pollution from Industrial Sector.
2.2	Lack of Green Cover Belts in the primary corridors of the areas and in industrial sectorial zones
2.3	Polluting Companies should be fined; if they exceed the normal standards of the emissions.
2.4	Lack of Influence of Industrial authority management for providing help to the residing people in the industrial zone.

PRIORITY OF STORM WATER

S.NO	PRIORITY
3.1	No proper usage of green spaces present in the zone.
3.2	Plantations and ecofriendly techniques should be carried out to improve the healthy environment.
3.3	Increase the quality and quantity of green cover to provide better places of tranquility in the areas where it has high levels of poor air mental health.
3.4	Irregular differences in temperature was effecting the urban health in the city.

PRIORITY OF HEALTH

PRIORITY OF INDUSTRIAL POLLUTION

STORM WATER						
Zone	1.1	1.2	1.3	1.4	1.5	Total Score
1	0.7	0.8	0.66	0.4	0	2.56
2	0.81	0.61	0	0.52	0.35	2.29
3	0.52	0.67	0.78	0.61	0.39	3.08
4	0.63	0.81	0.75	0.56	0.49	3.26
5	0.52	0.52	0.23	0.42	0	1.69
6	0.36	0.22	0.3	0	0	1.18

INDUSTRIES					
Zone	2.1	2.2	2.3	2.4	Total Score
1	0.75	0.35	0.73	0.63	2.46
2	0.53	0.42	0.2	0	1.15
3	0.25	0.35	0.35	0	1.43
4	0.36	0.63	0.3	0	1.29
5	0.92	0.5	0.9	0.75	3.07
6	0.63	0.65	0.3	0.58	2.59

HEALTH					
Zone	3.1	3.2	3.3	3.4	Total Score
1	0.65	0.81	0.73	0.7	2.86
2	0.35	0.9	0.58	0.35	2.18
3	0.25	1	0.63	0.41	2.29
4	0.22	0.88	0.52	0.5	2.12
5	0	0.8	0.63	0.62	2.05
6	0.35	0.65	0.3	0.6	2.1

SCORING PATTERN

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SCORING PATTERN For Example. Priority 1.1 in zone 1 has a score of 0.7; it indicates that 70% of surveyed people conducted in zone 1 has given their preference to this priority. If the whole zone 1 area of the city was identified for targeting for Actions 1.1, 1.2 and 1.3, and two thirds of it have been identified for action 1.4. It was observed that zone 3 and 4 has the highest effect of storm water and it achieved the highest scoring rate on comparison with other zones; this can be due to topographical influence, lack of storm water drainage networks in the zone. The third priority map have shown that zone 1 was the prime consideration in terms of health; due to the presence of the hilly areas and industries in the northern direction of the zone; has made it to stand with the highest rating zone.

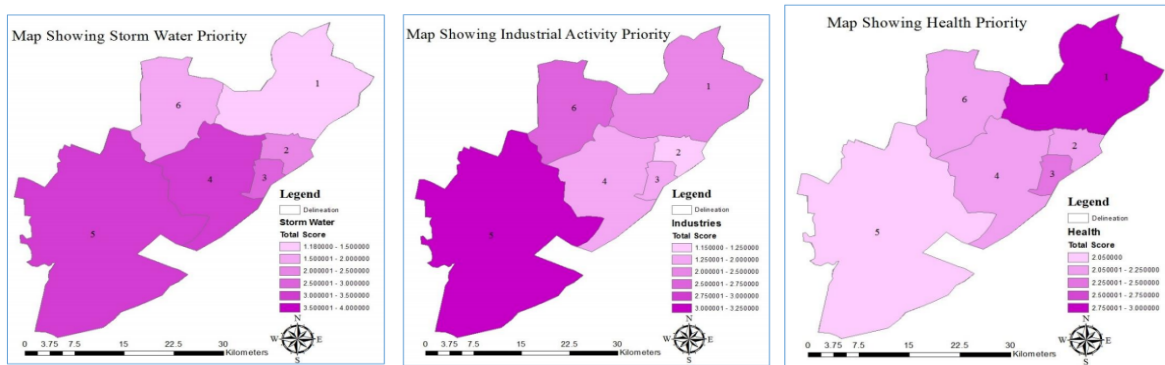
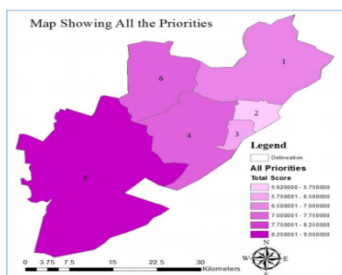


Figure 20 PRIORITY MAPS OF STORM WATER, INDUSTRIAL ACTIVITY & HEALTH

For obtaining the overall effect of three priorities; a combination of priority map was prepared to identify the critical affected areas by these effects. With the combination of scoring ratings assigned to the areas from all the zones; it was observed that zone 5 area has the highest scoring rate after combination of all the zone 1 area has the highest influence with rating of greater than 7.5. So the target of improving and developing can be taken through this priority maps. After finalising the priority maps; achievability and impact scorings were given to know the extent of delivering it in the real scenario. So, based on European strategy of Green infrastructure, which was adopted for the city of Liverpool city for preparing and developing the Green Infrastructure. For making the scoring rates of achievability and impact; certain formulas are developed and included.



$$\text{Achievability} = \frac{\text{Total Priority Score}}{\text{Individual Priority Score}} \times \text{Scale Factor}$$

$$\text{Impact} = \frac{\text{Achievability}}{\text{Each Set Priority Scoring Value}} \times \text{Assigned Priority Score}$$

LIVERPOOL GREEN STRATEGY

VII. OPPORTUNITIES & RESEARCH

Although the green infrastructure scenario is still bleak in the Indian context, a large number of infrastructure companies have responded to issues pertaining to environment degradation by adopting energy-efficient technologies. Many infrastructure projects are being completed using environment-friendly raw materials such as cement and a growing number of infrastructure companies are consulting environmentalists. To the coastal city; this could be just a beginning once after installing the GI solutions and after further observations of GI integration and evolution with the

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existing ecological conditions it can easily be implemented throughout the city and can achieve complete handling of storm water runoff with in the city and using its own resources without relying on foreign sources.

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