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ASSESSMENT OF BLUE-GREEN INFRASTRUCTURE INDEX; A CASE OF ODISHA

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ABSTRACT

The threat from climate hazards is rising rapidly, several global cities have altered their urban planning and design approaches to incorporate affordable nature-driven solutions as a counter to conventional infrastructure practices by harnessing blue elements (such as seas, rivers, lakes, ponds, wetlands and water utilities) alongside the green elements (such as trees, parks, gardens, playgrounds, open green spaces and forests). This paper explores the emerging concept of blue-green infrastructure, and analyses existing blue and green elements available in Odisha. It also identifies the existing highest and blue-green spaces and ranks the districts by generating Blue-Green Infrastructure Index level with the help of NDVI & GIS tool and clustering the most vulnerable districts to help Odisha respond to climate hazards for sustainable urban futures. And further highlights the need to recommend strategies for uplifting the BGI Index and maintain environmental sustainability.

Keywords: Blue Green Infrastructure, BGI Index, LANDSAT Images, NDVI, Supervised Classification, Identification Of Cluster, GIS.

I. INTRODUCTION

Blue-Green Infrastructure (BGI) is defined as an interconnected network of natural and designed landscape components, BLUE with GREEN. 'Blue' (urban hydrological functions) refers to water bodies like rivers, canals, ponds, wetlands and floodplains, and water treatment facilities, while 'Green' (vegetation systems) refers to trees, lawns, hedgerows, parks, fields, and forests. Blue-Green Infrastructure Index can be defined as the weighted average of Blue and Green proportion of respective districts of the whole state. Urban areas are heavily burdened with increasing rate of climate risks and threats to human comfort and environmental justice. Major global risks are projected to have a negative decadal consequence on countries through increase in temperature, environmental risks i.e., natural disaster, extreme weather and biodiversity loss, with climate action failure. In the attempts to address and provide solutions for these challenges, growing attention is being paid to the potential role of green (such as trees, parks, gardens, playgrounds, open spaces and forests) and blue (seas, rivers, lakes, wetlands, ponds and water utilities) spaces, i.e., through the concept of blue and green infrastructure. Odisha located in Eastern India, is the 8th largest state by area & the 11th largest by population. It is one of the warmest regions in India with an average daily high temperature of 32 degrees centigrade. It is yearlong warm or hot. For Odisha, which is always under the stress of different climate change risks such as cyclone, urban flood and heatwave has the potential to incorporate BGI in regional as well as local level. The aim is to climate-proofing in order to grow economy and building resilient development sectors. This mandates a policy and investment response addressing the linked aspects of sustainable development.

II. LITERATURE STUDY

BGI offers a feasible, affordable and valuable solution for the areas strangling with the challenges of climate change and helps in providing overall benefits which are greater than the sum of its individual components. AS per Sustainable Development Goals, for the requirement of mobilization of Sustainable Cities and Communities incorporation of BGI is being emphasized. It suggests combining Blue and Green elements together is an effective and valuable way of providing sustainable natural solution to urban and climatic challenges. Vegetation with waterbody will assist with air pollution removal, storm water management and heat island effect.

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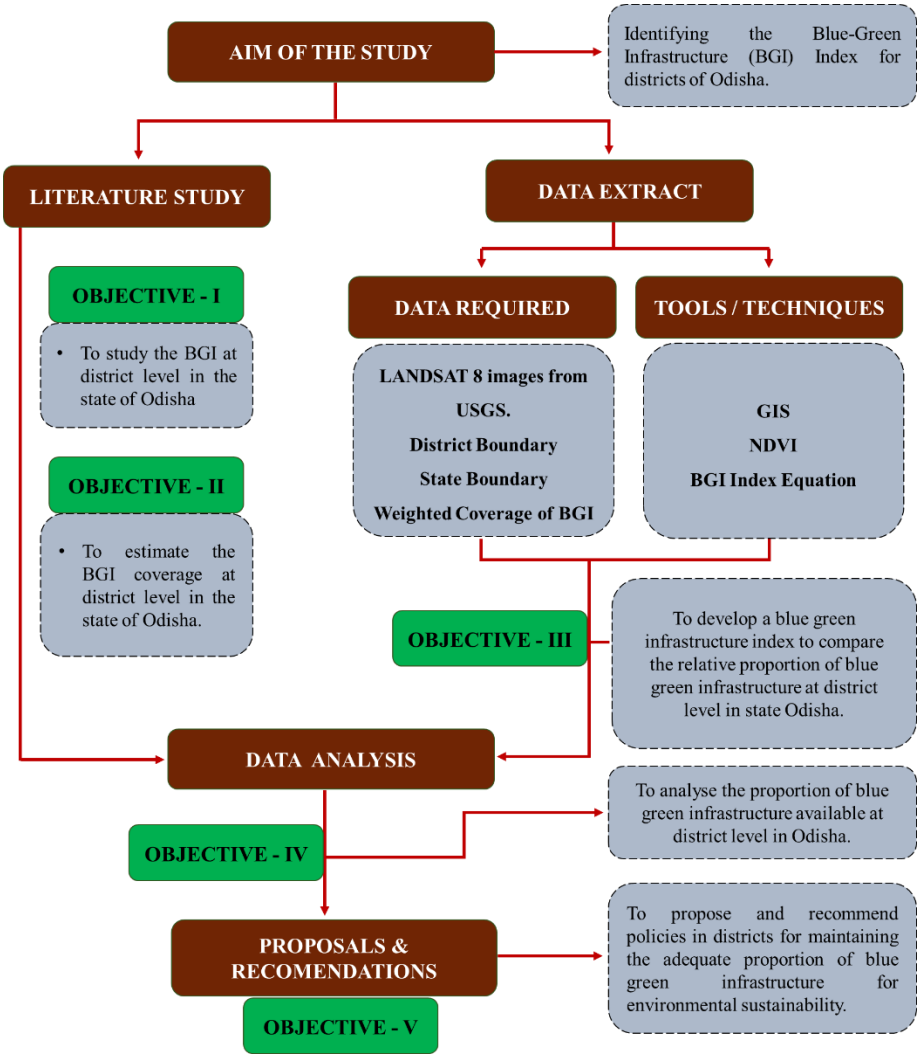
Each tree can absorb carbon at a rate of 21.6kg per year. Increased canopy cover would help in mitigating air pollution, with street trees reducing particulate matter concentration by 15 -20% and every 5% of tree canopy cover, the stormwater runoff is reduced by 2%. This highlights the concept in which the simplest ways such as planting trees can also have large impact on the environment. GI is based on the principle of sustainability and is sensitive to nature and the protection of its resource. Hence, by integrating these components of BGI projects together as a comprehensive system, would result in strengthening of urban ecosystems by employing natural processes in man-made environment.

Figure 1: Blue and Green Infrastructure

Thus, BGI is regarded as a nature-friendly means which is cost-effective and simultaneously provide environmental, social and economic benefits and help build resilience of managing climate change. Some examples include green roofs, retention & detention ponds, re-naturalized & de-culverted rivers, swales & rain gardens.

III. METHODOLOGY



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The first phase of this research involves identifying the existing BGI in various districts and estimating the BGI coverage at district level of Odisha by integrating the LANDSAT 8 images from USGS.

The second phase involves in developing a blue and green index to compare the relative proportions of BGI at district level with the help of NDVI & GIS tool and analyzing the proportions of BGI of the whole state on the basis of districts by generating BGI Index through average weightage blue-green coverage available formula.

The final phase involves in identification of the vulnerable cluster and recommending suitable policies and strategies for maintaining the adequate proportion of blue and green infrastructure for environmental sustainability.

IV. DATA COLLECTION AND ANALYSIS

The Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images which consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9 is derived from Arc GIS Software. By integrating LANDSAT 8 Band 4 and LANDSAT 8 Band 5 Green coverage map is generated throughg Arc GIS. Similarly, by integrating LANDSAT 8 Band 4, LANDSAT 8 Band 5 and LANDSAT 8 Band 6 Blue coverage map is generated in Arc GIS.

LANDSAT 8 Band 4 is representing Red Color

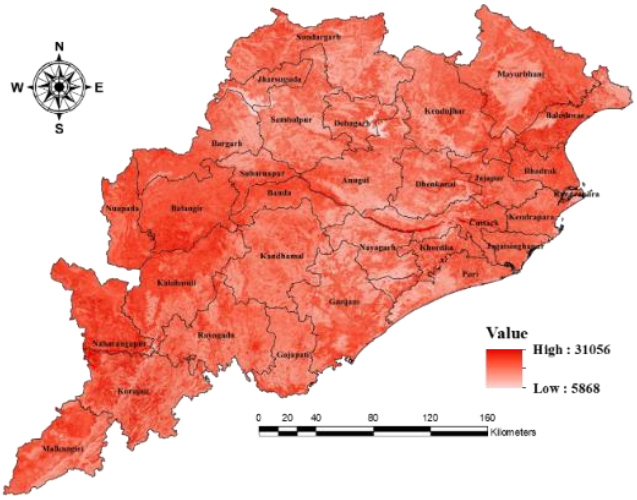

Figure 2: Satellite Imagery of LANDSAT 8 band 4

LANDSAT 8 Band 5 is representing Red Color

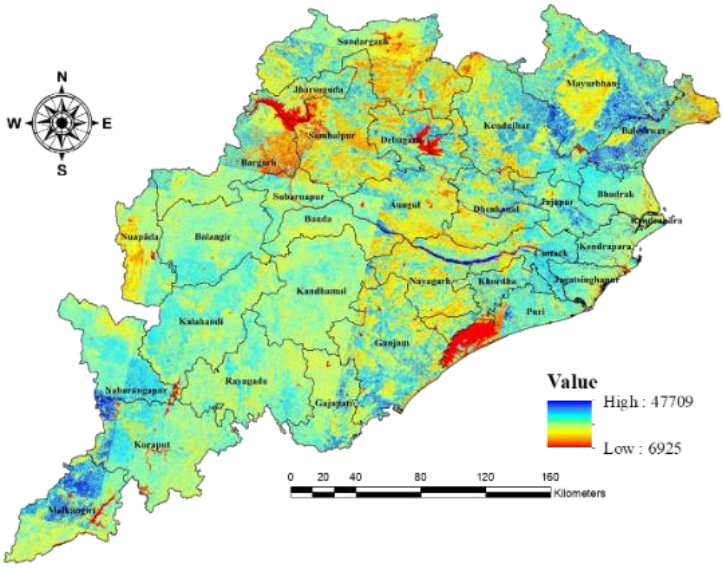

Figure 3: Satellite Imagery of LANDSAT 8 band 5

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LANDSAT 8 Band 6 is representing Red Color

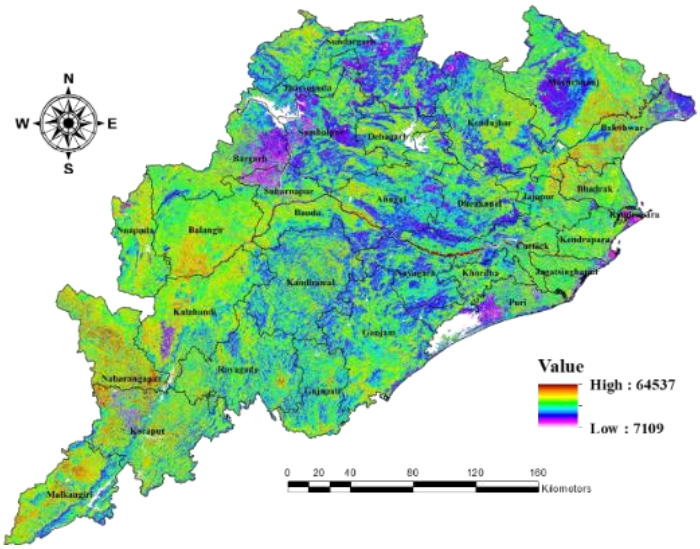

Figure 4: Satellite Imagery of LANDSAT 8 band 6

Major Green Coverage of Odisha is held by Sanctuaries, National parks and forests (i.e., Balukhand-Konark Wildlife Sanctuary, Nandankanan Wildlife Sanctuary, Debgarh Wildlife Sanctuary, Sunabeda Wildlife Sanctuary, Hadagarh Wildlife Sanctuary, Kotagarh Wildlife Sanctuary, Ushakothi (Badrama) Wildlife Sanctuary, Chilka Wildlife Sanctuary, Gahirmatha Marine Sanctuary Nalban Bird Santury, Satkosia Tiger Reserve, Simlipal National Park, Bhitarkanika National Park, Chandaka).

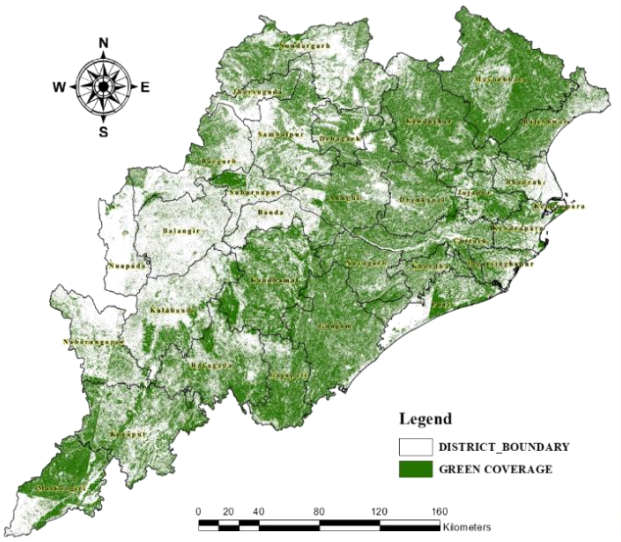

Figure 2: Green Coverage Map

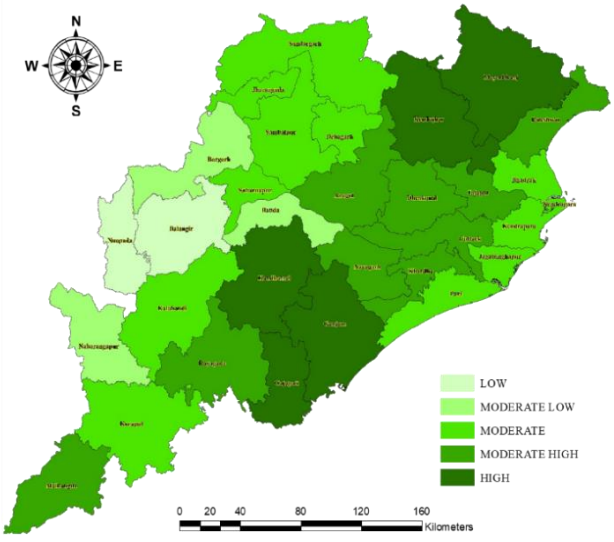

Figure 6: Ranking of Green coverage

The India State of Forest Report (ISFR) 2021 released by the Forest Survey of India (FSI) said Odisha's Forest cover has increased to 52,155.95 sq km in 2021, from 51,619 sq km in 2019. In Odisha, very dense constitutes forest 7,212.8 sq km and moderately dense forest is 20,994 sq km. The remaining 23,948.2 sq km forest area is designated as open forest.

32,686 sq km forest is categorized under-recorded forest area, while remaining 19,470 sq km forest cover is recorded forest area of the state. The existing forest cover of 52,155.95 sq km is 33.50 per cent of the state's total geographical area. Besides, around 4,923.7 sq km area in Odisha is covered with scrub which accounts for 3.16 per cent of the state's total geographical area.

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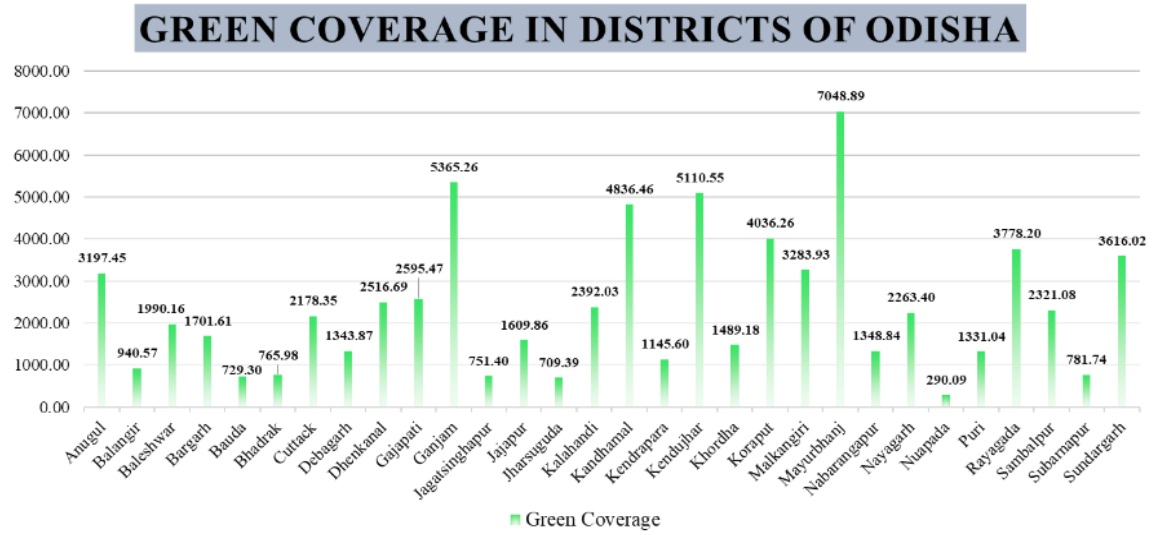

Figure 7: Green Cover in different districts of Odisha

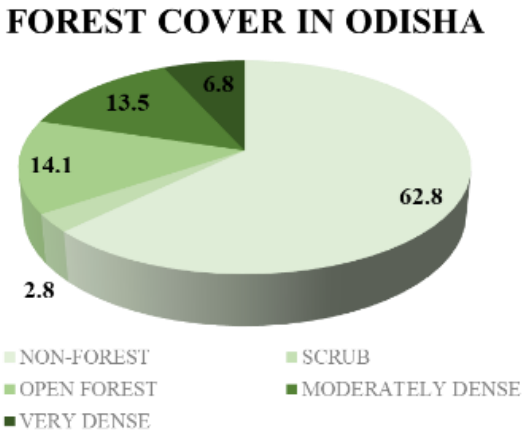

Figure 8: Forest Cover in Odisha

The green coverage is highest in the district of Mayurbhanj with 7048.89 sqkm and lowest is in the district of Nuapada with 290.09 sqkm of green coverage of Odisha.

Major Blue Coverage of Odisha is held by Rivers and Lakes (i.e., Bahuda, Baitarani, Bramhani, Burhabalanga, Indiravati, Kolab, Mahanadi, Nagavali, Rushikulya, Chilika, Subarnarekha, Vanshadhara river)

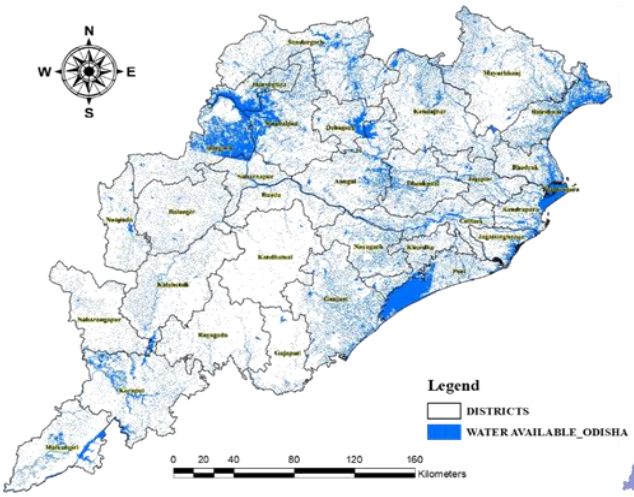

Figure 9: Blue Coverage Map

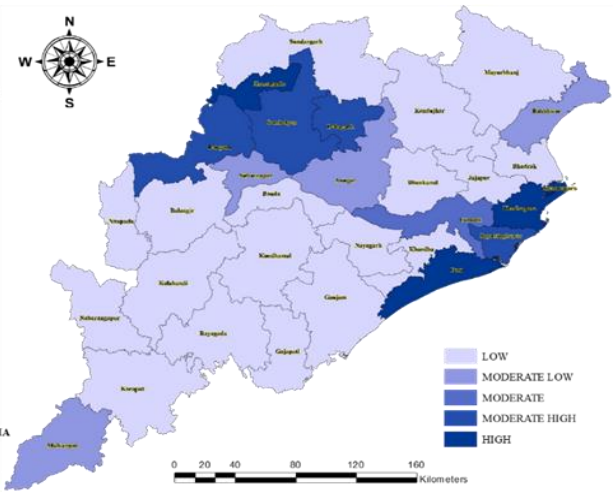

Figure 10: Ranking of Green Coverage

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Odisha has been going through water scarcity and groundwater depletion. The groundwater extraction has increased to 42% from 30%. There is a huge increase in annual groundwater extraction but also there is a reduction in annual groundwater recharge. Central Ground Water Board (CGWB) has clearly indicated that the groundwater of 24 out of 30 districts in Odisha is depleting, the groundwater aquifers in many regions of Odisha have already gone dry.

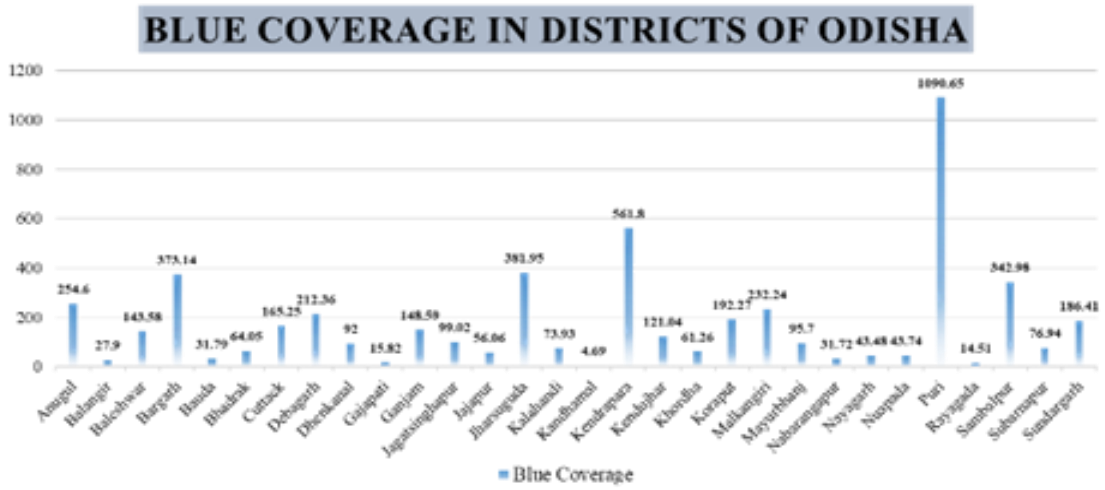

Figure 11: Blue Cover in different districts of Odisha

Puri district has the Highest blue cover whereas Kandhamal has the Lowest blue cover in Odisha. But also, the fresh water available is very much contaminated in puri and this must be addressed in the near future.

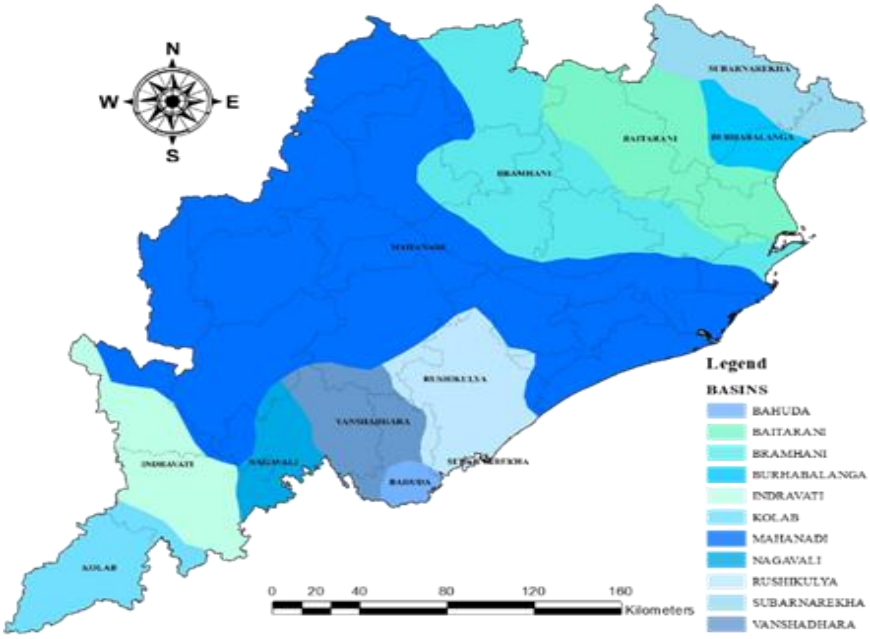

Figure 12: River Basin Map

The western and central part of the state are covered by shale-sandstone sequences. The sandstones generally are fine to coarse grained and white to grey in colour. The aquifer systems which are shallow as well as at deeper depths are mainly formed by sandstones. The shale form generally phreatic aquifers with limited potential. The average weathered zone in the state extends up to 12 to 15m and top most weathered part to an average depth of 5 – 6m.

V. RESULTS

BGI INDEX can be defined as the weighted average of blue and green proportion of respective districts of the whole state. It is derived as:

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$$\frac{w_1x_1 + w_2x_2}{w_1 + w_2}$$

Where,

W1 is Weightage of Water available

W2 is Weightage of Green coverage available

X1 is Actual Water on site

X2 is Actual Green coverage on site

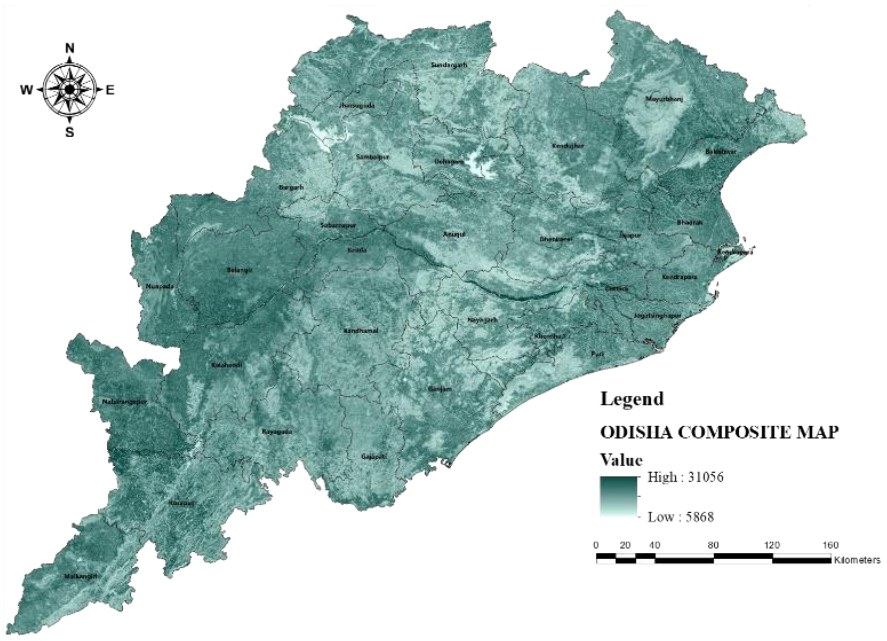

Figure 13: Composite Map

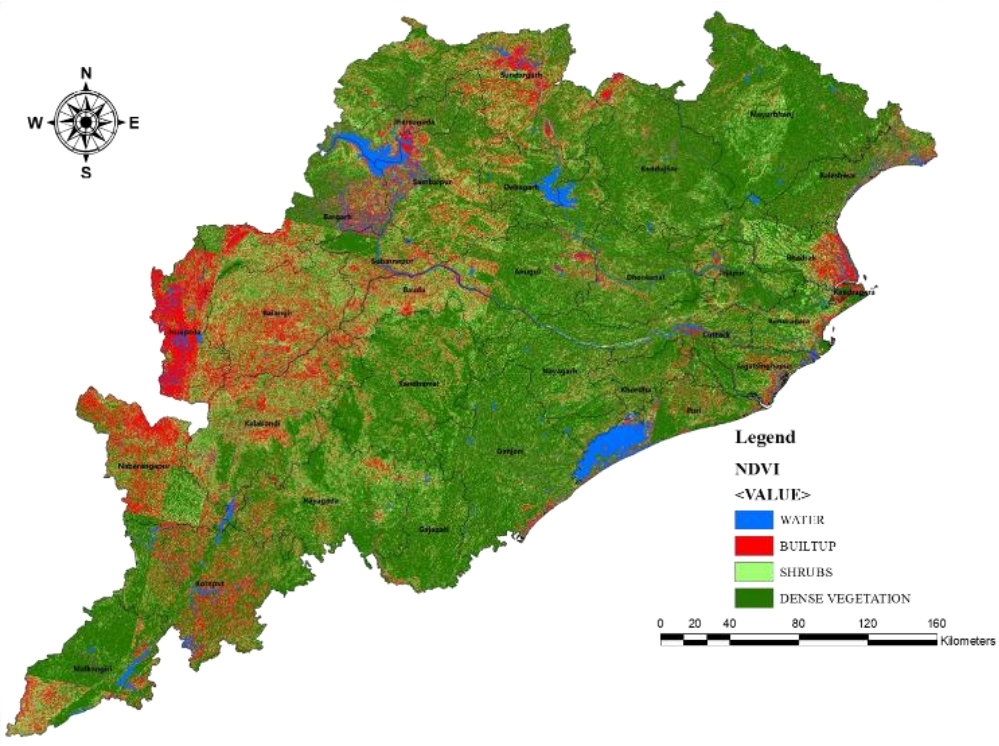

Figure 14: NDVI Map

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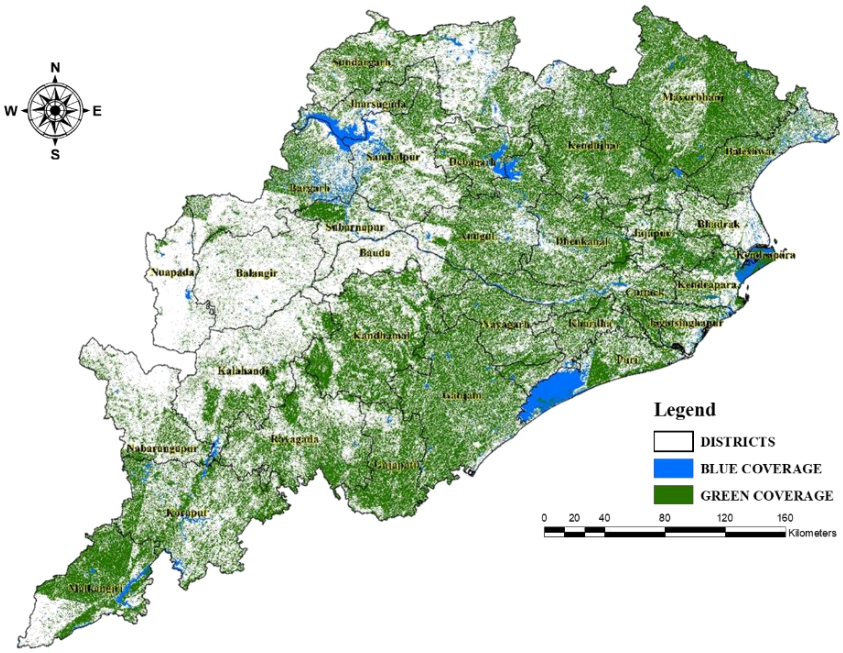

Figure 15: Blue-Green Coverage Index Map

Figure 13 represents the composite features superimposed one upon the other to assess BGI Index.

Figure 14 represents the NDVI index to assess the green vegetation.

MAP 15 represents the BGI Index of each District in the state.

From the composite map NDVI map is derived through GIS tool. The LANDSAT 8 imagery with the NDVI map in GIS generates Blue-Green index combining both the green and blue elements together.

Puri district with an area of 3520.56 sqkm holds green coverage of 1331.04 sqkm and blue coverage of 1090.65 sqkm. BGI Index of Puri district is 0.34 and is highest among all other districts.

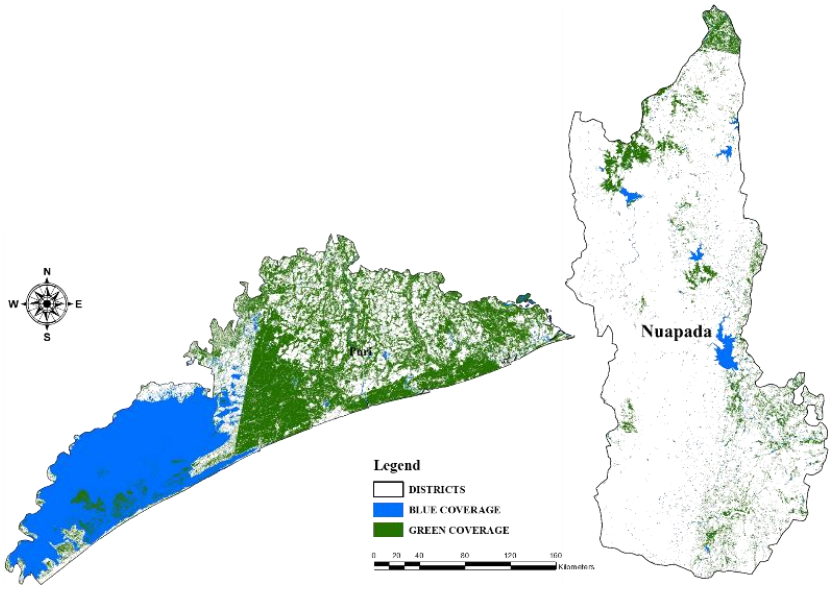

Figure 16: Puri and Nuapada BGI Coverage Index

Major Blue-Green Cover in Puri is Balukhand Wildlife Sanctuary & Chilika. Where, Nuapada district with an area of 3870.32 sqkm holds green coverage of 290.09 sqkm and blue coverage of 43.74 sqkm. BGI Index of Nuapada district is 0.04 and is the lowest among all other districts.

Figure 16 represents the highest and lowest BGI Index districts i.e., Puri & Nuapada.

Figure 17 represents the Ranking of each District in the state as per the BGI Index.

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Odisha's decision to open more mines to harbor resources and growth of economy is set to affect the green cover in the state further which has been already warned by environmentalists.

The state has witnessed an impact full loss of forest land over the years due to mining and industrial projects. It has already lost a large chunk of forest cover following the diversion of forest land.

About 44,351 hectares of forest land have been already diverted at the end of 2014 under the Forest (Conservation) Act, 1980, for different projects. The government must enquire with the mine lease holders to extract minerals in the incomplete mines rather than going in for new areas. Mining in fresh areas means cutting of existing trees and contamination of blue resources.

Almost 20,265 hectares of forest land have been diverted for 164 mining projects in Odisha followed by irrigation projects (about 9,712 hectares) which is being set up by cutting trees. Industries account for 4,265 hectares which are polluting the environment. Odisha has agreed to reopen 29 mines and proposes to open several others.

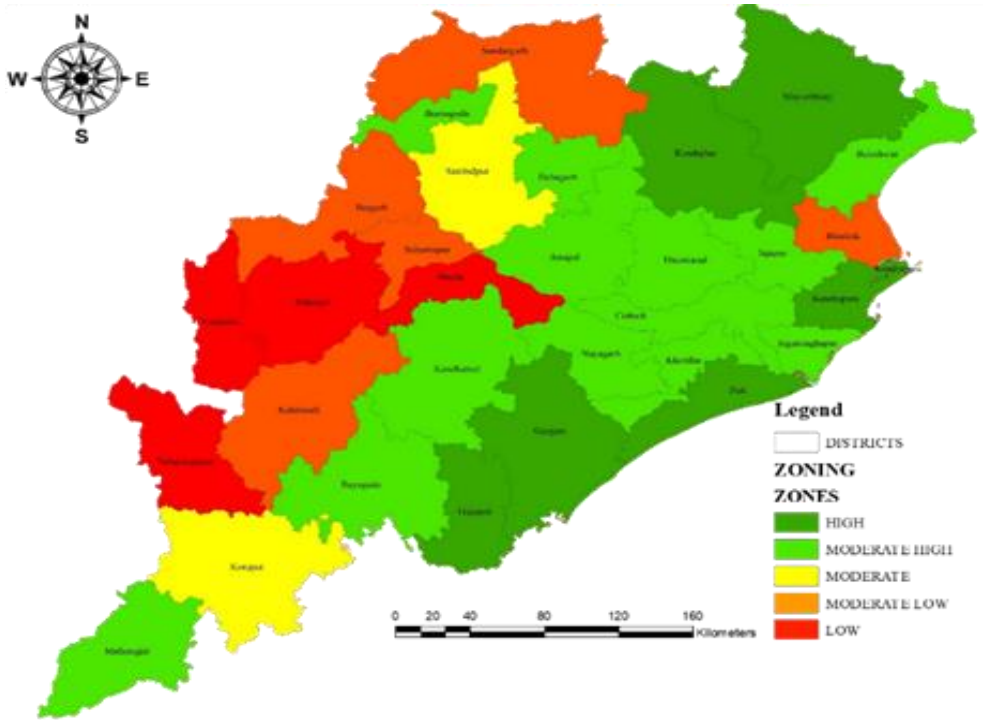

Figure 17: Ranking of different districts as per BGI Index

The government, however has emphasized that it had taken up compensatory afforestation against forest land diverted for non-forestry activities.

The total requirement for compensatory afforestation against forest land diversion for various projects has been pegged at 56,831 hectares to achieve a stable coverage of green and blue infrastructure.

Table 1: BGI Coverage Index

RANK NO.	DISTRICTs	AREA (sqkm)	GRREN COVERAGE (sqkm)	PROPORTION (X_1)	BLUE COVERAGE (sqkm)	PROPORTION (X_2)	BGI INDEX =	ZONE
1	Puri	3520.56	1331.04	0.378	1090.65	0.310	0.337107278	**HIGH**
2	Kendrapara	2501.68	1145.60	0.458	561.8	0.225	0.317914202	
3	Mayurbhanj	10523.9	7048.89	0.670	95.7	0.009	0.27337542	

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		0					2	
4	Ganjam	8404.43	5365.26	0.638	148.59	0.018	0.26596207	
5	Gajapati	4075.85	2595.47	0.637	15.82	0.004	0.257045671	
6	Kendujhar	8366.09	5110.55	0.611	121.04	0.014	0.253026539	
7	Malkangiri	5828.04	3283.93	0.563	232.24	0.040	0.249297191	
8	Cuttack	3964.86	2178.35	0.549	165.25	0.042	0.24477293	
9	Jharsuguda	2123.48	709.39	0.334	381.95	0.180	0.241548816	
10	Kandhamal	8078.98	4836.46	0.599	4.69	0.001	0.239807352	
11	Nayagarh	3913.14	2263.40	0.578	43.48	0.011	0.238030431	
12	Baleshwar	3736.87	1990.16	0.533	143.58	0.038	0.236083139	
13	Dhenkanal	4502.32	2516.69	0.559	92	0.020	0.235850673	**MODERATE HIGH**
14	Debagarh	2822.63	1343.87	0.476	212.36	0.075	0.23558256	
15	Jajapur	2922.05	1609.86	0.551	56.06	0.019	0.231885012	
16	Khordha	2769.36	1489.18	0.538	61.26	0.022	0.228365687	
17	Anugul	6395.17	3197.45	0.500	254.6	0.040	0.223878458	
18	Jagatsinghapur	1682.57	751.40	0.447	99.02	0.059	0.213942742	
19	Rayagada	7388.79	3778.20	0.511	14.51	0.002	0.20571509	
20	Koraput	8582.67	4036.26	0.470	192.27	0.022	0.201553223	**MODERATE**
21	Sambalpur	6758.04	2321.08	0.343	342.98	0.051	0.167832626	
22	Sundargarh	9763.50	3616.02	0.370	186.41	0.019	0.159599816	
23	Bargarh	5809.88	1701.61	0.293	373.14	0.064	0.155687691	**MODERATE LOW**
24	Subarnapur	2364.81	781.74	0.331	76.94	0.033	0.151749697	
25	Bhadrak	2471.74	765.98	0.310	64.05	0.026	0.13950621	

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26	Kalahandi	7918.98	2392.03	0.302	73.93	0.009	0.126426787	
27	Nabarangapur	5306.57	1348.84	0.254	31.72	0.006	0.105259405	**LOW**
28	Bauda	3129.91	729.30	0.233	31.79	0.010	0.099297795	
29	Balangir	6580.36	940.57	0.143	27.9	0.004	0.059718538	
30	Nuapada	3870.32	290.09	0.075	43.74	0.011	0.036761715	

VI. RECOMMENDATIONS

Clustering districts on the basis of BGI index:

The districts which have very low Blue Green Infrastructure Index in the whole state have been clustered together to form a vulnerable zone which would help in implementation of government interventions. This cluster comprised of seven districts of lower BGI index (i.e. Bolangir, Bargarh, Bauda, Kalahandi, Nabarangpur, Nuapada and Subarnapur).

Total GREEN COVERAGE of this CLUSTER is 8184.18 sqkm and total BLUE COVERAGE of this CLUSTER is 659.15 sqkm.

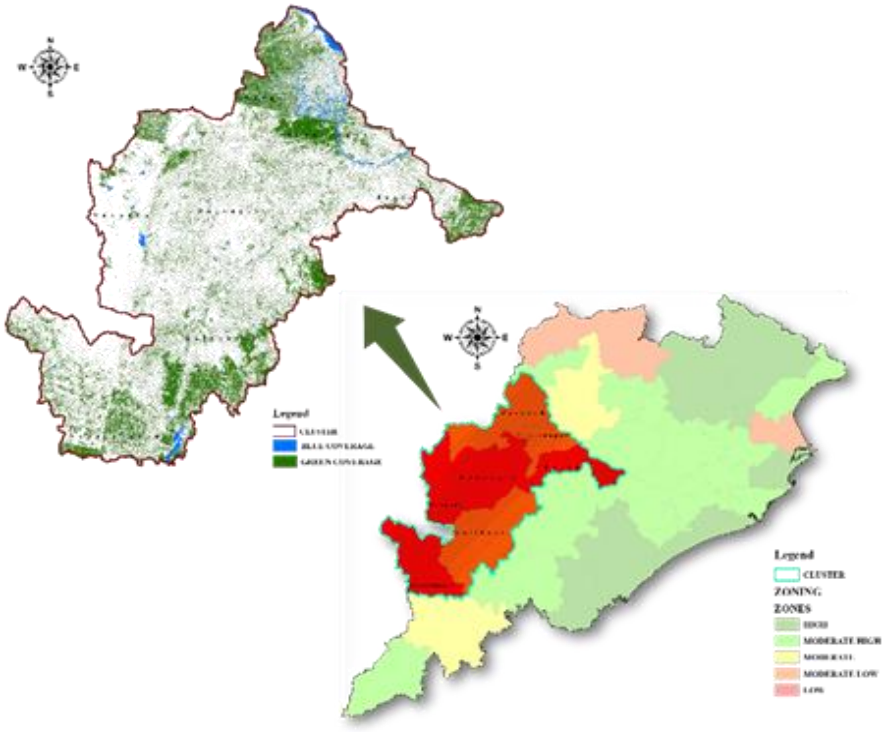

Figure 18: Clusterification of Blue Green Index Map

Total area of this CLUSTER is 34980.8 sqkm. Where the GREEN COVERAGE is held by 23.39% and BLUE COVERAGE is held by 1.9% of total area.

According to WHO and Different development bodies the green coverage should vary from 28% to 33% for an area.

Integration of BGI:

Generally, the drains (blue areas) are managed by different agencies in different regions and due to their poor condition and encroachment, the land around (green areas) is also been affected.

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The development authorities should integrate them and remove all sources of pollution by checking the outfall of untreated wastewater as well as removal of existing pollutants.

A mix of mechanized and natural systems should be adopted, and dumping of solid wastes in any of those sites should be strictly prohibited by local bodies, through the imposition of penalties. The land around the drains, carrying stormwater, could act as buffer. A network of connected green spaces should be developed in the form of green mobility circuits of pedestrian and cycling paths to serve functional as well as recreational strips.

BGI in Neighborhood Scale:

Inclusion of Blue and Green Infrastructure in Neighborhood level involves the incorporation of natural and affordable solutions in the infrastructures such as Green roofs, Green walls, Rain gardens, Pocket Parks, Permeable pavements, Runoff water seepage drains along the road, hedgerows, planting trees inside and outside residences, etc.

These solutions helps to maintain the water levels, lowers the heat, regulates air quality, urban flood management, carbon sequestration, etc in the neighborhood.

BGI urban ecosystem services as a whole plays a particularly significant role in offsetting the impacts of climate change at the neighborhood level.

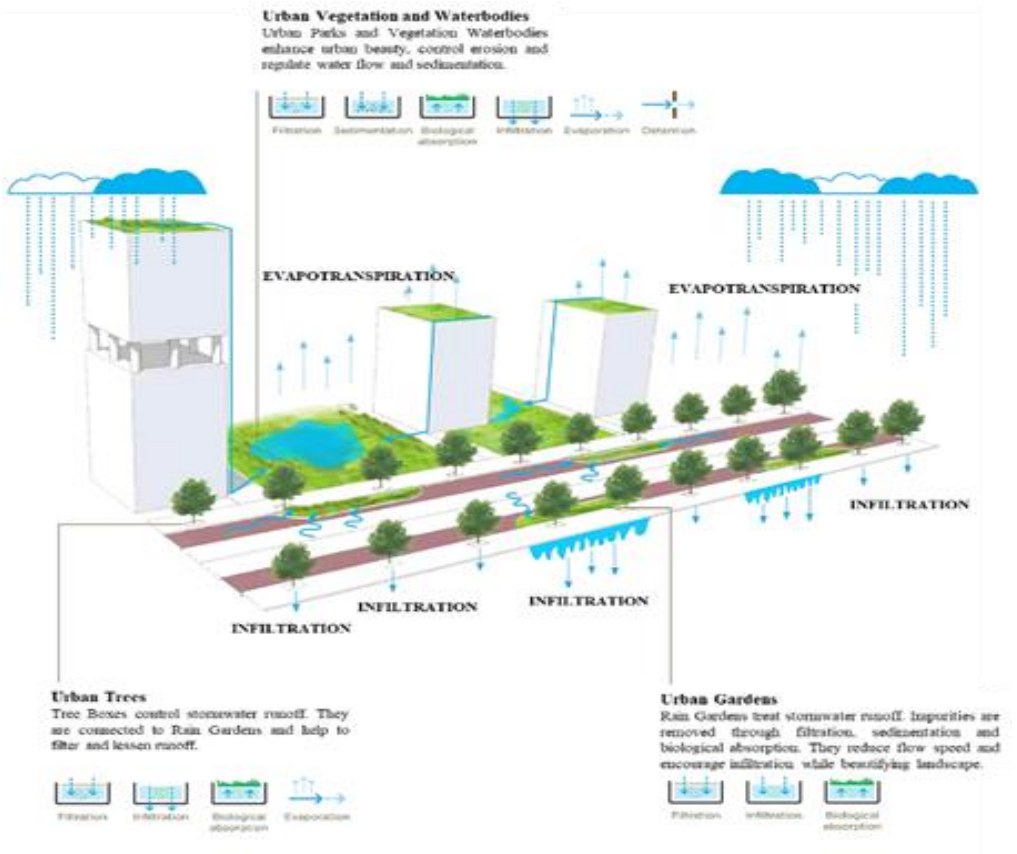

Figure 19: Inclusion of BGI at neighborhood level

Government, Developers, transport providers, as well as local community and transport authorities, have a role in delivering sustainable development i.e., urban development integrating BGI which will be key for successful adaptation to future change.

Integration of BGI at the local level ensures the application of the effective nature-based solutions at the grass root level.

BGI in Regional Scale:

Inclusion of Blue and Green Infrastructure in Regional scale involves majorly the development authority or municipalities interventions in terms of large-scale structural measures and incorporation of the BGI in Mater plans to ensure successful adaptation in future.

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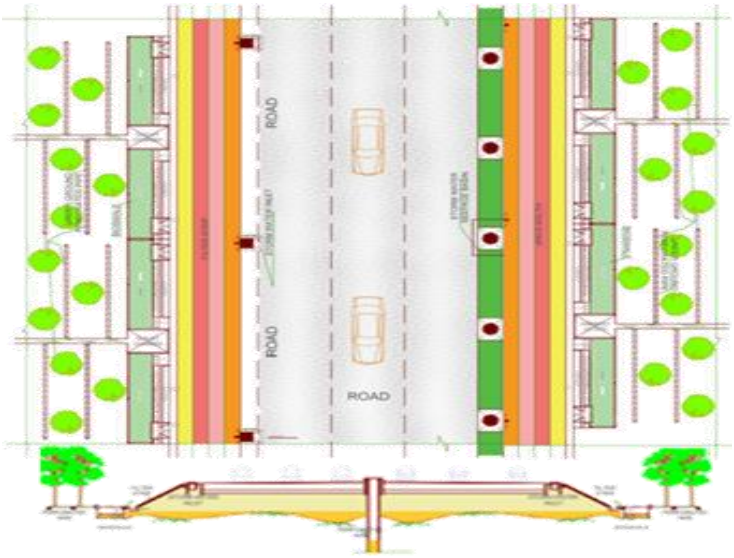

Figure 20: Street trees

Structural measures that can be integrated in cities and regions are; Green Highways, Rain water harvesting, Storm water management, Bioswales, Bioretention basins, Street trees, etc.

Figure 21: Green Highway concept

Implementation Strategy:

Formation of a special committee or department under the forest and water department to monitor the existing blue and green spaces with its maintenance. It must ensure the integration of BGI in the whole state from the grass root level. It must impose rules and regulation for the inclusion of BGI in local level and must penalize those who are degrading and disobeying. They should conduct monthly Awareness campaigns and training programs with NGOs.

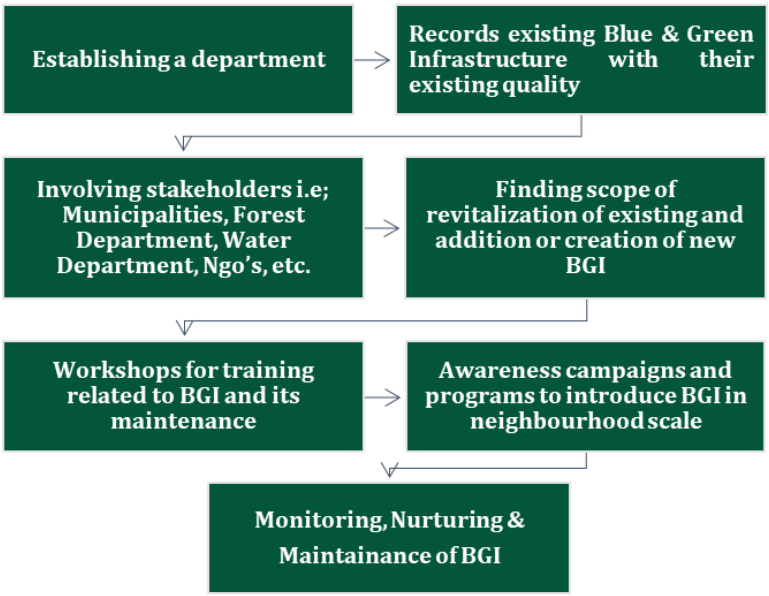

Figure 22: Department formation for BGI regulation

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VII. CONCLUSION

This research has derived the outcome that integration of BGI would mitigate the actions of climate change to some degree. NDVI tool demonstrates that there is a degree of correlation between the blue and green spaces. The study therefore provides unique empirical evidence that integration of both blue and green elements specifically targeted at leisure, recreation, play, residential, commercial, institutional and in multi-purpose BGI spaces could improve sustainability. Built BGI spaces, can be created through human interference through government interventions. Hence, the identified vulnerable cluster should be given emphasize for imposing rules and regulation in conservation, creation and maintenance of Blue-green spaces.

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