Linking Socio- Economic Conditions with Blue and Green Spaces: A Case Study of South Dum Dum Municipality

Thesis submitted in partial fulfilment of the requirements for the award of the degree of

Masters of Planning
(Environmental Planning)

By

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Declaration

I **Laha Priyandri**, **Scholar No. 2015MEP005** hereby declare that the thesis entitled **"Linking Socio- Economic Conditions with Blue and Green Spaces: A Case Study of South Dum Dum Municipality"** submitted by me in partial fulfilment for the award of Master of Planning (Environmental Planning) in School of Planning and Architecture Bhopal, India, is a record of bonafide work carried out by me. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any degree or diploma.

Laha Priyandri

Certificate

This is to certify that the declaration of **Laha Priyandri** is true to the best of my knowledge and that the student has worked for one semester in preparing this thesis.

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Abstract

Our Urban blue and Green Space are at a constant pressure due to the densification of urban structures, unplanned growth, urban sprawl and spatial inequality within the urban and urban fringes. These are causes of degradation and pollution of these urban blue and green spaces. Spatial inequality exist in both the urban and rural areas. The unplanned development also result in inequitable distribution of environmental components resulting an environmentally inequitable in urban areas. This inequitable distribution of environmental components may have some relation with socio economic condition, race and ethnicity of urban residential areas but such studies have only been focused on developed countries and this linkage between socio economic condition and environmental components are missing in terms of Indian context. Kolkata Metropolitan Area (KMA) being one of the largest metropolitan region in India is facing environmental degradation. Increase in urban population and unplanned development is main reason behind the disappearing of the traditional water bodies which creates an ecological imbalance and increases water pollution. Not only the water bodies are but also the green cover of the KMA is also threatened, the tree cover has reduced at an alarming rate as the open spaces are constantly being converted to built-up areas. The rules and regulation as per Development control regulation (DCR) are not well described for which there is rapid conversion land, water bodies and deforestation of trees. So the study aims to identifying the linkages between socio- economic conditions and the environmental quality with respect to our blue and green spaces in an urban context. The study is based on identification of socio- economic micro areas (wards) based on the socio economic indicators as per different literature within the selected a municipality (South Dum Dum Municipality) in KMA. Then analyse the temporal change in land use, land cover and different environmental parameters. The environmental parameters selected are surface runoff, land surface temperature and diversity. Finally after mapping the land use land cover, calculating surface runoff by using rational method, diversity indexing using Shannon index. For identification of land surface temperature in a temporal scale satellite image satellite image interpretation have been applied. After the temporal results of all the land use land cover, surface runoff, diversity and land surface temperature has been derived it is then related with the socio economic condition of the micro areas. As the study was conducted on 4 wards and each ward belonging to a particular socio economic condition, the correlation between socio economic condition and rate of degradation in environmental quality was determined. Finally the result revealed that there has been a negative impact in study area but the impact with respect to degradation in environmental quality is more in terms of the low status area than in a medium or high status area. These results emphasizes that we need to critically revisit our development control regulation and formulated proper guidelines for future development of the cities.

सार

हमारे शहरी नीले और हरे रंग अंतरिक्ष शहरी संरचनाओं, अनियोजित विकास, शहरी फैलाव और शहरी और शहरी किनारे भीतर स्थानिक असमानता के densification की वजह से एक निरंतर दबाव में हैं। ये इन शहरी नीले और हरे रंग की रिक्त स्थान की गिरावट और प्रदूषण के कारण हैं। शहरी और ग्रामीण दोनों क्षेत्रों में स्थानिक असमानता मौजूद है। अनियोजित विकास से भी पर्यावरणीय घटकों का असमान वितरण होता है जिससे शहरी इलाकों में पर्यावरण की दृष्टि से असमानता होती है। पर्यावरणीय घटकों के इस असमान वितरण में शहरी आवासीय क्षेत्रों की सामाजिक आर्थिक स्थिति, जाति और जातीयता के साथ कुछ संबंध हो सकते हैं लेकिन ऐसे अध्ययन केवल विकसित देशों पर केंद्रित हैं और भारतीय आर्थिक संदर्भों के संदर्भ में सामाजिक आर्थिक स्थिति और पर्यावरणीय घटकों के बीच इस संबंध गायब हैं। कोलकाता मेट्रोपॉलिटन एरिया (केएमए) भारत के सबसे बड़े महानगरीय क्षेत्र में से एक है, पर्यावरणीय गिरावट का सामना कर रहा है शहरी आबादी और अनियोजित विकास में वृद्धि पारंपरिक जल निकायों के गायब होने का मुख्य कारण है जो पारिस्थितिक असंतुलन पैदा करता है और जल प्रदूषण को बढ़ाता है। केवल जल निकायों ही नहीं हैं लेकिन केएमए के हरे रंग के आवरण को भी खतरा है, पेड़ की आच्छादन खतरनाक दर से कम हो गई है क्योंकि खुली जगह लगातार बिल्ट-अप वाले क्षेत्रों में परिवर्तित हो रही है। विकास नियंत्रण नियमन (डीसीआर) के अनुसार नियम और नियमन का वर्णन नहीं किया गया है जिसके लिए तेजी से रूपांतरण भूमि, जल निकायों और पेड़ों की वनों की कटाई है। इसलिए अध्ययन का उद्देश्य शहरी संदर्भ में हमारे नीले और हरे रंग के स्थानों के संबंध में सामाजिक-आर्थिक स्थितियों और पर्यावरण की गुणवत्ता के बीच संबंधों को पहचानना है। यह अध्ययन केएमए में चयनित नगरपालिका (दक्षिण डम डम नगरपालिका) के भीतर विभिन्न साहित्य के अनुसार सामाजिक आर्थिक संकेतकों के आधार पर सामाजिक-आर्थिक सूक्ष्म क्षेत्रों (वार्ड) की पहचान पर आधारित है। फिर भूमि उपयोग, भूमि कवर और विभिन्न पर्यावरणीय मानकों में अस्थायी परिवर्तन का विश्लेषण करें। चयनित पर्यावरणीय मानकों में सतह के प्रवाह, भूमि सतह के तापमान और विविधताएं हैं। आखिरकार भूमि उपयोग भूमि के मानचित्रण के बाद, तर्कसंगत पद्धति का उपयोग करके सतह के प्रवाह की गणना, शैनन सूचकांक का उपयोग करके विविधता अनुक्रमण। एक अस्थायी पैमाने उपग्रह छवि उपग्रह छवि व्याख्या में भूमि की सतह के तापमान की पहचान के लिए लागू किया गया है। सभी भूमि उपयोग भूमि कवर, सतह के प्रवाह, विविधता और भूमि सतह के तापमान के अस्थायी परिणामों के बाद यह सूक्ष्म क्षेत्रों की सामाजिक आर्थिक स्थिति से संबंधित है। जैसा कि 4 वार्डों और एक विशेष सामाजिक आर्थिक स्थिति से संबंधित प्रत्येक वार्ड पर अध्ययन किया गया था, सामाजिक आर्थिक स्थिति और पर्यावरणीय गुणवत्ता में गिरावट की दर के बीच संबंध निर्धारित किया गया था। अंत में परिणाम से पता चला है कि अध्ययन क्षेत्र में नकारात्मक प्रभाव पड़ा है लेकिन पर्यावरणीय गुणवत्ता में गिरावट के संबंध में प्रभाव मध्यम या उच्च स्थिति क्षेत्र की तुलना में कम स्थिति क्षेत्र के संदर्भ में अधिक है। इन परिणामों पर जोर दिया गया है कि हमें शहरों के भविष्य के विकास के लिए हमारे विकास नियंत्रण विनियमन को गंभीर रूप से पुन: प्राप्त करने और उचित दिशानिर्देश तैयार करने की आवश्यकता है।

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List of Abbreviation

Full Form	Abbreviation
Atal Mission for Rejuvenation of Urban Transformation	AMRUT
Below Poverty Line	BPL
City Bio – diversity Index	CBI
City Level Program Action Plan	CLPAP
Development Control Regulation	DCR
East Kolkata Wetland	EKW
Government of West Bengal	GOWB
Housing Infrastructure Development Corporation	HIDCO
Indian Meteorological Department	IMD
Irrigation and Waterways Department	I&WD
Karnataka Town and Country Planning	KTCP
Kolkata Environmental Improvement Project	KEIP
Kolkata Metropolitan Area	KMA
Kolkata Metropolitan Development Authority	KMDA
Kolkata Municipal Corporation	KMC
Kolkata Solid Waste Management Improvement Project	KSWMIP
Land Surface Temperature	LST
Land use Development Control Plan	LUDCP
National Green Tribunal	NGT
Non- Governmental Organisation	NGO
Open Space Reservation	OSR
Pradhan Mantri Awas Yojana	PMAY
Social development unit	SDU
Solid Waste Management	SWM
South Dum Dum Municipality	SDDM
The United Nations University World Institute for Development Economics Research	UNU-WIDER
United Kingdom	UK
United Nation Habitat	UN habitat
United Nations Statistical Division	UNSD
United Nations Work Program	UNWP
United States America	USA
Urban and Regional Development Plan Formulation and Implementation	URDPFI
Urban Local Bodies	ULBs
World Health Organisation	WHO

Chapter 1. Introduction

1.1 Background

A fundamental component of an urban ecosystem are our green spaces within the urban area which help us to relax, facilitate physical activities, reduce pollution and moderate temperature. Some other benefits of our urban green spaces are that the help to improve our mental health and reduce health inequalities (World Health Organisation, n.d.). On the other hand urban blue spaces are public spaces which are valued for their economic, symbolic and are essential for sustainable urban development. In case of urban waterfronts forms an individual specie of urban space and its urban political ecology is important for sustainable development of the urban area. Both social and ecological dimensions are include in urban blue spaces like gathering, labour, recreation, economic exchange, fishing, cultural and traditional aspects and watersheds, primary productivity, species migration and environmental degradation respectively (Wessells, 2014). But in recent times the blue and green spaces are facing challenges due to the dense urban structures, increase in urban sprawl resulting in shrinkage of natural blue and green area mainly in urban fringe. These inappropriate uses leads to increase in pollution leading to degradation of these natural bodies. Further these challenges not only results in deterioration of the natural environment of urban area but also causing demographic challenges like urbanization and population growth. As a result of such challenges spatial inequality and unplanned peri urbanization is increasing. Spatial inequality is an increasing concern in both developed and developing nations as they reflect there is huge disparity between rural and urban areas and geographically some areas get more benefit than other. Even spatial inequality have resulted in unequal distribution of environmental parameters within urban environment. Spatial inequality not only includes disparity in development it also includes inequality in income, education, unemployment and indigenous and non-indigenous character of an area. Spatial in equality in not only visible in developing world it is also very common in developed countries. In countries like Australia spatial inequality is a growing issue where there is unequal distribution of basic services like public transport among the aboriginals while access to good or services is better in case of no-aboriginals. Considering environmental parameters

in many parts of United States America (USA) there is unequal distribution of urban trees with respect to race and ethnicity in urban areas. This inequality is very much visible in India with respect to urban and rural areas, but mainly this inequality is exist more in terms of access to basic services like drinking water, access to latrines etc.

According to United Nation Habitat (UN- habitat) we need public spaces to maintain the cities productivity, social cohesion and inclusion. Also there should be a symbiotic relation between the private and public spaces so that the city functions in an efficient, equable and sustainable manner and there by achieve goal number 10 – reduce inequality, 11 – sustainable cities and communities and 15 – life on land. As per the Urban and Regional Development Plan Formulation and Implementation guidelines (URDPFI) each city should have some allocated green spaces but in general the allocated green spaces per person as should be as per which gives us the norms for organised green for plain area. According to World Health Organisation (WHO) it suggest that there should be 9 sq meters of green spaces per capita within a city which is lacking in majority of the Indian cities. Even as per URDPFI the all water bodies are considered to be eco sensitive area which needs to be protected, but in most cases cities do not conserve and protect these water bodies.

Table 1: Organised green spaces for plain areas

Sl. No	Category	Population Served per Unit	Area Requirement (Ha)
1	Housing Area Park	5000	0.5
2	Neighbourhood Parks	15000	1
3	Community Parks	1 lakh	5
4	District Parks	5 lakh	25
5	Sub City Parks	10 lakh	100

Recently in Kolkata Metropolitan area (KMA) there has been rapid unplanned development which resulted in ecological imbalance, replacement of traditional water bodies into residential area and increase in pollution although development control regulation (DCR) strictly prohibits filling up of any surface water bodies. Even reports show that there has been huge loss in tree cover in the whole region and regulation for open green spaces are missing.

But in developed countries researchers are trying to relate such environmental conditions with socio- economic and demographic variables and also relate that

land use, land cover and other environmental parameters are very much influenced by the residential character of an area so these studies further highlights that such studies require further exploration which is completely missing in Indian context.

1.2 Aim

To analyse the linkages between the socio- economic conditions and environmental qualities (blue and green spaces) of an urban area.

1.3 Objective

To identify and analyse different socio- economic indicators and create clusters (micro area) of similar socio- economic condition in South Dum Dum Municipality (SDDM).

To analyse the land use, land cover and environmental performance within the identified micro area.

To find a relationship between the socio- economic condition, land use, land cover change and environmental performance within the identified micro area.

To prepare planning strategies and guidelines for blue and green spaces based on the outcome.

1.4 Scope of Study

Selected socio-economic and environmental indicators considered for this study.

1.5 Limitations

Due to time constrain micro study area are focused on few clusters (4 ward).

1.6 Methodology

The study process begins with understanding the background, current status of World and Indian cities and detail literature review of spatial inequality, environmental inequality, urban blue and green spaces and different guidelines. After preparing the aim, objective and base map to fulfil the 1st objective identification of socio- economic indicators are important. Base on different literature we select the indicators. As per the indicators we collect the relevant data and map each indicators ward wise and then analyse the indicators by ranking them according to the range and find the mean of all ranks of all the wards. After the mean ranking we identify the wards for further analysis. After final selection of wards 20m X 20m spatial matrix is created with help of geo - information system

(GIS). The spatial matrix will help to determine the land use land cover changes and calculation of environmental indicators. All environmental indicators are selected on basis of literature study. The land use, land cover and environmental analysis will help to fulfil the 2nd objective and for this analysis we use some techniques like the Shannon Index for diversity calculation, CN method / Rational Method / Analytical method of surface runoff calculation and satellite image interpretation for surface temperature identification. Next by interlinking socio-economic condition of the area with the land use land cover change and the environmental change we fulfil the 3rd objective. Base on the analysis we try to prepare strategies for the blue and green spaces and what should be the guideline for future development and what changes are required in development control regulation. The Figure 1: Detail Methodology shows the flow diagram of the methodology that has been adopted in the thesis.

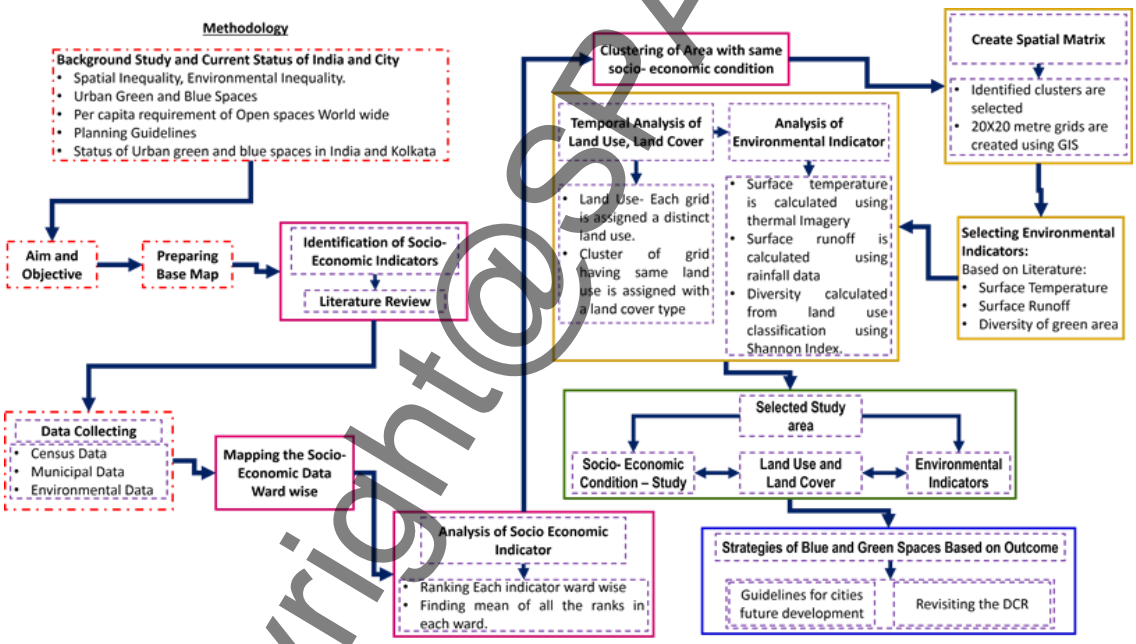

Figure 1: Detail Methodology

Chapter 2. Literature Review

2.1 Definition

2.1.1 Urban Green Spaces

"They are public and private open spaces mainly covered by vegetation which are directly and indirectly available to the users. They include both urban forest and green patches, green corridors etc." (Haq, 2011).

"An open spaces is any piece of land that is undeveloped as it has no buildings or other building structures and is accessible to the public which includes:

- Green Spaces: These are the lands that are partly or complete covered by grass, trees, shrubs and other types of vegetation. They include parks, community gardens and cemeteries.
- School yards
- Playgrounds
- Public seating areas
- Public plazas
- Vacant lots." (United States Environmental Protection Agency, n.d.)

"Public spaces are all places publicly owned or public use, accessible and enjoyable by all for free and without profit motive. They include streets, open spaces and public facilities." (UN Habitat III, 2015).

"Open Spaces in urban areas are seen as individual 'sites' such as parks or squares, and looked at from this point of view they can take a wide variety of forms. Even open spaces can be considered as a continuous matrix of all unbuilt land in urban areas which include public parks, private gardens, urban streets and city squares." (ln-institute, n.d.)

"Public open spaces is defined as the sum of the areas of the built up of cites which are devoted to streets and boulevard which includes sidewalks, walkways, bicycle lanes and also areas devoted to public parks, squares, recreational green areas, playgrounds and open areas allocated for public facilities." (UN Habitat, 2015)

2.1.1.1 *Urban Blue spaces*

"Urban blue spaces are defined as all surface waters within a city. They include spaces like ponds, lakes, rivers within an urban site." (Völker, et al., 2014)

"Blue Spaces are waterfronts parks, harbours, ports, marinas, rivers, open air streams, canals, lakes, ponds, and fountains which improve the quality of life and also moderate the urban heat island effect." (Simplicable Buisness Encyclopedia, n.d.)

"Blue spaces refers to all water areas that are visible and includes both man-made and natural water features." (Martin-Feeney, 2010)

2.1.1.2 *Spatial Inequality*

"Spatial inequality is defined as the uneven distribution of resources and there is a difference in the standard of living among the population just like some area have better access to clean drinking water and health services will some area dose not." (Spatial Inequality Geo, n.d.)

"Spatial inequality is a dimension of overall inequality which adds more significance when spatial and regional divisions align with political and ethnic tensions to undermine social and political stability." (Kunbur & Venables, 2005)

2.1.1.3 *Environmental Inequality*

"Environmental inequality or environmental racism is the uneven exposer to environmental risks and hazard and also when there is systematic exclusion of people from environmental decision making process." (The Society Page, 2013)

"When different social groups of people face the condition of uneven sharing of environmental opportunities then it is called environmental inequality." (LSX London Sustainable Exchange, n.d.)

"When the aspects of environment is distributed unevenly among different social groups then it is claimed to be environmental inequality. Social groups can be social classes, ethnicity, gender, age, location etc." (Environmental Agency, 2007).

2.1.2 Studies

2.1.2.1 *Urban Green and Blue Spaces*

Urban green spaces plays an important role in social, economic, cultural and environmental dimension and thereby help in sustainable development. It not only helps to improve the quality of life but also it helps to reduce pollution but also increase the property value because they increase the aesthetic characteristic and reduce energy consumption. By determining the quantity of green spaces, quality

of green spaces and the functionality of green spaces helps to evaluate the nature of green spaces. But high urbanization which is resulting in increase in population, lack of infrastructure, environmental degradation, this is also resulting in conversion of agricultural land and forest to land for urban use there by creating a big challenge to the green spaces (Haq, 2011). Now according to the UN Sustainable Development Goal – 11 we need to create cities that are sustainable and inclusive to all communities, so achieve by 2030 UN identifies that access to universal safety, inclusive and accessibility, green and public spaces particularly for children, old person, disables and women are important. When public spaces are designed poorly, privatized or inadequate it results in segregation. So to overcome such situation we need adequate planning and designing and there by generate equity. Green spaces acts as sustainable drains, temperature moderate, cooling corridors wind shelter and wildlife habitat. According to WHO 9 square meter of green spaces is required per person and all residential area to be within 15 minute walking distances (UN Habitat III, 2015). In case of urban blue spaces there impact in regulating temperature is much more than the urban green spaces and studies have found that it can cool to 2.5K (Kelvin) during the warmest months of in Northern Hemisphere while urban parks can cool on an average to 1K compared to non- green areas of city. (Völker, et al., 2014)

2.1.2.2 *Inequality*

Developing countries show very less signs of spatial inequality but in countries in Asia, Europe, Africa and Latin America the rapid economic growth is resulting in uneven regional and urban development. When spatial inequality is found in urban population results in social ills in society. So from this it is clear that social inequality across region is undesirable as it is destabilizing if there is divergence in economic welfare. (Kim, 2008). These disparities not only exist in urban area but we can also see disparity between a rural and urban area. As there very little understanding in spatial disparities the policy tends to create a vacuum in addressing this gap for this reason the World Institute for Development Economics Research of United Nation launched the project of “Spatial Disparities in Human Development.” From studies it has been identified that this heterogeneity is very high and in many countries it is rising. Like in Peru poverty is more in districts that are at an altitude above 3500 meters than the districts at sea level, in Indonesia the incidence of

poverty was 46.5% in West Kalimantan which is a rural province while only 10.7% in Yogyakarta. In this The United Nations University World Institute for Development Economics Research (UNU-WIDER) project the author identifies that natural geography and interaction between economic agent's results in such disparities as some regions get greater benefit geographically while others case some gets more economic benefit (Kunbur & Venables, 2005). The spatial inequality is also visible in India studies shows that in India caste segregation is a very predominant attribute where caste inequalities are higher in developed villages and small cites than bigger cites even there is residential segregation in the most populated cites not only by cast but also by access to basic services, goods and amenities (Sidhwani, 2015). In some of the studies highlight that this spatial inequality also causes environmental inequalities like in eastern part of India the man land ratio has increased from 1991 to 2001 but this situation is opposite in case of Kolkata city where environmental degradation is high (Lakshmana, 2013). On the other hand the social inequality in developed nations, mainly in USA and Canada is more towards racial where certain racial communities have more awareness towards environmental risk than others and studies in Canada revel that there are disadvantaged groups who are exposed to pollution disproportionately. In the area near the Great Lakes Basin in Canada there is a positive correlation between the toxic pollutant in air that are being released and the poverty rate as per their census subdivision (Canadian Environmental Law Association, n.d.). In the same way poverty level is negatively associated with distance of parks, percentage of green spaces both in urban and suburban context but positively in case of rural areas. Even the results are negative when it comes to the coverage and distance of parks and green space in case of Blacks and Hispanics in an urban rural spectrum (Wen, et al., 2013).

2.1.2.3 *Linking Socio- Economy with Environmental Quality*

Studies related environmental quality and their linkages with socio economic condition have been very less and most of them are showing linkages of developed countries and there environmental quality.

Case 1 – The political Ecology of Uneven Urban Green Spaces:

This article investigates how urban political economy, private and public property relation and the race and ethnicity socially modify or produce the urban forest cover in Milwaukee. In USA urban forest of Milwaukee there is an inequitable distribution of canopy cover and the urban trees positively affect the quality of life. There is direct relation between the race and ethnicity and the spatial unequable distribution of urban trees. The field of urban political ecology deals with the understanding of social formation of an urban environment and it demonstrates interdependences and intertwined power that leads social causes to produce uneven environment. In this city the forest department is mainly responsible in maintaining the city's public trees where the process have resulted in unequal distribution of trees. The method followed in this study is by linking remote sensing data that measures canopy cover with the urban social data. As per census the socio economic data was represented for 223 census tracts along with the urban forest canopy. The data for representing urban forest canopy was represented by dot method in GIS. The urban canopy is represented in percentage. Finally it was found that in Milwaukee households with medium income and non- Hispanic White have a positive correlation with canopy cover, however it is negatively correlated with housing rent ship and homes of Hispanic White (Heynen, et al., 2006).

Case 2: "City form and natural process" – indicators for ecological performance of urban areas and their application to Merseyside, United Kingdom (UK):

The study mainly quantifies the effect of urbanisation on 4 ecological performance indicator and they are surface temperature, hydrology, carbon storage and sequestration and biodiversity. The study highlights that as there is lack of green spaces the cities performance becomes poorer at local level. To predict the performance of these above mention indicator the author uses models like models that show the surface energy balance of an area in terms of surface temperature and it linearizes any non – liner equation to form a set of simulations equation, so basically it gives an energy balance equation. In case of hydrological assessment it uses the CN curve method where studies are made on small watersheds and precipitation data. The carbon storage and sequestration is calculated by using the formula which shows the relation between the trees diameter and the crown area of tree, it also use the ratio of broadleaved to conifer crown spread where

broadleaved is 75% and conifer is 25% and the calculating the fresh weight of the tree. Finally they calculate the bio diversity by measuring the heterogeneity by Shannon Weiner Index and lastly examine the connectivity of green space through inverse number linkage. The final results show that environmental performance indicators are greatly influenced by the contrasting wealth which demonstrates different degree of urbanization. Affluent areas have more grassland and tree covers than less affluent areas of Merseyside, UK (Whitford, et al., 2000).

Case 3: Modelling the environmental impact of urban land use and land cover change – a study in Merseyside, UK:

In highly industrialized countries the sprawl of low density settlements and urban development along transport corridors leads to high concern regarding landscape and environmental planning. Studies in United Kingdom show that 60% of the new housing development occurs on derelict land which are basically brown field sites, but this development may lead to loss of informal open spaces in the city. Many study demonstrates the importance of environmental parameters like surface temperature, surface runoff, carbon sequestration and biodiversity are affected by building density and amount of green spaces in urban areas. In this research the authors tries to find whether land use and land cover change in different residential areas with different socio- economic status influence the environmental indicators in that area. The environmental indicators used are surface temperature, surface runoff and biodiversity. In this study the author selects 11 sites in Merseyside and groups them as high and low status area as per the National Statistics Index of Multiple Deprivation which is a government measure in UK. Now the land use and land cover changes are analysed using the grid method and environmental indicators area measured by using thermal band of satellite imagery to identify the surface temperature, CN curve method to calculate the surface runoff and finally calculating total vegetative cover, Shannon index and multiplication of total vegetative cover and Shannon index to identify the importance of biodiversity. When such aspects are temporally analysed in Merseyside, UK it has been found that more affluent areas lose more greenspaces especially the tree cover while there is much higher value of runoff in low status area (Pauleit, et al., 2005).

These studies do highlight residential area with different socio economic status do have a significant impact on the environment which needs further study.

2.1.2.4 *Kolkata and its present Condition*

Kolkata Municipal Corporation (KMC) area and KMA is more than 300 years old and it's the oldest metropolis in Indian. As it is the oldest in India it is one of the largest in the World and it has the pioneer experience in urban planning in early 60s when Calcutta Metropolitan Planning Organisation was formed to carry out comprehensive planning for Kolkata Metropolis (Kolkata Metropolitan Developement Authority, 2005). As KMA is the third largest metropolitan area in country and the 13th most populous area in the world it faces a lot of environmental challenges. Kolkata is confronting with increase in urban pollution, traffic congestion, poverty, over population and even socio- economic problems. The metropolitan has grown from 144 Sq Km in 1970 to 633.2 Sq Km in 2010 which have resulted in conversion of marshy wetlands and agricultural areas. As the demand of urban space is increasing there has been large scale reclamation of all kinds of natural land which includes the East Kolkata Wetland (EKW) which a designated Ramsar Site and is home to different species of birds, fishes and trees and vegetation. As a result of such conversion there has been alteration in the natural drainage of the area and there by resulting in flooding, even Rajarhat New Town the new township that is being built for the last 15 years on the north- eastern side of the city has been reclaimed from the wetlands (WWF - India, 2011). Within Kolkata metropolitan area the loss of water bodies has been rapid and the water bodies are being converted to residential land and commercial land. Satellite image study show that the eastern side of Kolkata metropolitan region is losing the water bodies more rapidly than the western side, even many water bodies have been converted to agricultural lands as a result of which ecological imbalance, water scarcity, environmental pollution and change in weather condition have increased (Guha, 2016). The loss of water bodies in KMA is just one aspect, loss of urban trees within city is also affecting the metropolitan area. In recent years Kolkata has lost more than 5000 trees which have increased the carbon count to 5,500,000 Kg. per year. The removal of tress are usually unauthorised and for development projects. Less than 1% of the city is vacant and green and in North Kolkata the urban green has decreased to just 4.97% (Mondal, 2013). The urbanization have not only resulted in deterioration of environmental quality but also increased the demand and price of real estate properties in outskirts of the city and smaller towns

as a result of which new slums are being created in peri- urban areas and causing spatial inequality in the region. The demand and increase has created such a situation that even the middle income group (MIG) sector finds it difficult to afford a house with proper shelter. Land value has significantly increased in north-eastern part especially in Madhyamgram and Barasat and also in the southern side of Narendarpur and Baruipur areas (Sen, 2011).

2.1.2.5 *Socio – Economic parameter influencing environment*

"Environmental Indicator by United Nations Statistics Division"

The United Nations Statistical Division (UNSD) compiles and disseminates global statistical information, develops standards and norms for statistical analysis and activities thereby it helps in supporting nations and strengthening their statistical systems in the nation. According to UNSD they have developed a list of environmental indicators along with the Inter – governmental Working Group on Advancement of Environmental Statistics. This list provides list of environmental indicators and there related socio – economic indicators and was prepared on 6th – 10th February 1995 at Stockholm. This list was approved by the 28th session on 27th February to 3rd March 1995 at New York. The list is divided into 9 sub – division which has short term compilation directly from the national statistics or from international organisations or specialized agencies (United Nations Statistics Division, n.d.).

Table 2: List of environmental and related socioeconomic (UNSD)

Agenda 21 Issues(clusters)	FDES Information categories			
	A. Socioeconomic activities, events	**B. Impacts and effects**	**C. Responses to impacts**	**D. Inventories, stocks, background conditions**
ECONOMIC ISSUES	Real GDP per capita growth rate	EDP/EVA per capita	Environmental protection expenditure as % of GDP	Produced capital stock
	Production and consumption patterns	Capital accumulation (environmentally adjusted)	Environmental taxes and subsidies as % of government revenue	
	Investment share in GDP			
SOCIAL/ DEMOGRAPHIC ISSUES	Population growth rate	% of urban population exposed to concentrations of SO2, particulates, ozone, CO and Pb		Population living in absolute poverty
	Population density	Infant mortality rate		Adult literacy rate
	Urban/rural migration rate	Incidence of environmentally related diseases		Combined primary and secondary school enrollment ratio
	Calorie supply per capita			Life expectancy at birth
				Females per 100 males in secondary school
AIR/ CLIMATE	Emissions of CO2, SO2 and Nox	Ambient concentrations of CO, SO2, NOx O3 and TSP in urban areas	Expenditure on air pollution abatement	Weather and climate conditions
	Consumption of ozone depleting substances	Air quality index	Reduction in consumption of substances and emissions	
LAND/ SOIL	Land use change	Area affected by soil erosion	Protected area as % of total land area	Arable land per capita
	Livestock per km2 of arid and semiarid lands	Land affected by desertification		
	Use of fertilizers	Area affected by salinization and water logging		
	Use of agricultural pesticides			

Agenda 21 Issues(clusters)	FDES Information categories			
	A. Socioeconomic activities, events	**B. Impacts and effects**	**C. Responses to impacts**	**D. Inventories, stocks, background conditions**
WATER				
Fresh water resources	Industrial, agricultural and municipal discharges directly into freshwater bodies	Concentration of lead, cadmium, mercury and pesticides in fresh water bodies	Waste water treatment, total and by type of treatment (% of population served)	Groundwater reserves
	Annual withdrawals of ground and surface water	Concentration of fecal coliform in fresh water bodies	Access to safe drinking water (% of population served)	
	Domestic consumption of water per capita	Acidification of fresh water bodies		
	Industrial, agricultural water use per GDP	BOD and COD in fresh water bodies		
		Water quality index by fresh water bodies		
Marine water resources	Industrial, agricultural and municipal discharges directly into marine water bodies	Deviation in stock from maximum sustainable yield of marine species		
	Discharges of oil into coastal waters	Loading of N and P in coastal waters		
OTHER NATURAL RESOURCES				
Biological resources	Annual roundwood production	Deforestation rate	Reforestation rate	Forest inventory
	Fuelwood consumption per capita	Threatened, extinct species	Protected forest area as % of total land area	Ecosystems inventory
	Catches of marine species			Fauna and flora inventory
				Fish stocks
Mineral (incl. energy) resources	Annual energy consumption per capita	Depletion of mineral resources (% of proven reserves)		Proven mineral reserves
	Extraction of other mineral resources	Lifetime of proven reserves		Proven energy reserves
WASTE	Municipal waste disposal	Area of land contaminated by toxic waste	Expenditure on waste collection and treatment	Waste recycling
	Generation of hazardous waste			
	Imports and exports of hazardous wastes			
HUMAN SETTLEMENTS	Rate of growth of urban population	Area and population in marginal settlements	Expenditure on lowcost housing	Stock of shelter and infrastructure
	% of population in urban areas	Shelter index		
	Motor vehicles in use per 1000 habitants	% of population with sanitary services		
NATURAL DISASTERS	Frequency of natural disasters	Cost and number of injuries and fatalities related to natural disasters	Expenditure on disaster prevention and mitigation	Human settlements vulnerable to natural disasters

As per the Table 3 gives all the related socio – economic and the environmental indicated, but for this study only a few indicators are related to the study have been selected. The below Table 3: Selected Socio - economic indicators as per UNSD that are related to environment gives us only used in our study.

Table 3: Selected Socio - economic indicators as per UNSD that are related to environment

Literature	Indicators
United Nation Statistics Division, List of environmental and related socio- economic indicators.	Real GDP per capita growth
	Population living in absolute poverty
	Adult literacy rate
	Stock of shelter and infrastructure

"Social Indicators and Environmental dimensions by Tiril Vogt"

This report is based on survey of work on social indicators that have been developed by United Nations Work Program (UNWP). This study majorly aims to determine the environmental dimensions on social indicators. This study focus on showing the inter relationship of social and man – made environment in terms of sociology in environment concerns. The study provides us with a check list of social indicators with an environmental dimension there by providing us a quantitative expression of information on the interaction of elements and issues of common interest in a system. The indicators deal with "environmental indicators, role of sociology in environmental concerns, dimension of human ecosystem, natural environmental elements, social environmental elements, economic environmental elements, environmental hazards and environmental quality considerations." So by using these indicators will help us to compare elements within the system with respect to time and space (Vogt, 1984)

Table 4: Social Indicators and Environmental Dimension

Literature	Indicators
Social Indicators and Environmental Dimension, Tiril Vogt, Central Bureau of Statistics of Norway, 1984	Sex
	Age
	Urban
	Rural
	Geogrphical Area
	National or ethnic origin
	Size and type of family
	Size and type of Household
	Level of Education
	Type of Education
	Land Use
	Land Tenure
	Transportation
	Land Value
	Property Value
	Tax Base
	Income
	Labour Force
	Business and industry
	Municipal and Social Services related cost

As per dimension it shows the final list of indicators that has been selected for the study.

"Assessing the relationship between socio – economic conditions and urban environmental quality in Accra, Ghana"

As per the study it reflects that influence of socio – economic status on health inequalities has been known widely but the relationship between socio – economic conditions and the environmental conditions of neighbourhood is poor. So the study predicts the urban neighbourhood environmental quality. The indicators used in this study were economic activity, education attainment and occupation, place of work, marital status and ethnicity. These criteria are based on Ghana living Standard Survey framework. Through this they identify the different status group of urban areas (Fobil, et al., 2010).

Table 5: Socio-economic conditions as identified in the study

Literature	Indicators
Assessing the Relationship between Socio-economic conditions and Urban Environmental Quality in Accra, Ghana, Julius Fobil, 2010	Economic Activity Status
	Education attainment
	Occupation
	Place of Work
	Marital Status
	Ethnicity

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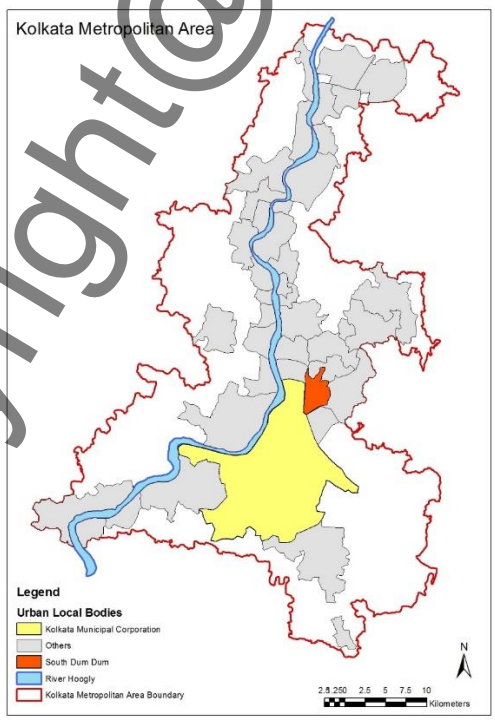
Chapter 3. South Dum Dum Municipality (Case Study Area)

3.1 Regional Context

Kolkata Metropolitan area is the largest metropolitan area in the eastern part of India and is second largest in India as per the perspective plan of 2025 of Kolkata Metropolitan Region (Kolkata Metropolitan Developement Authority, 2005). This metropolitan region consist of 37 municipalities and 4 municipal corporation. Out of the 4 municipal corporation KMC is the largest and then followed by Howrah Municipal Corporation, the other municipal corporation is Chandannagar Municipal Corporation followed by the newly formed Bidhannagar Municipal Corporation comprising of both Bidhannagar municipality and Rajarhat Gopal Nagar Municipality. My study area is South Dum Dum Municipality (SDDM) which lies just beside the KMC area and is separated by a railway line. Some of the new development project like the Belghoria express way and the Second Vivekananda bridge construction has direct impact on the municipality. The below Map 1 shows the position of the KMC in yellow while the small area in red is the location of SDDM the study area.



Map 1: Kolkata Metropolitan Area

3.1.1 South Dum Dum Municipality

South DumDum Municipality (SDDM) was established in year 1871 and is one of the oldest urban local bodies in West Bengal. The municipality has 35 wards and is about 17.39 sq km in area. The municipality falls in North 24 Parganas district and is one of the most important city for the people of this district. The municipality lies just adjacent to the KMC and from the gate way to the North 24 Parganas district. As it lies just beside the Kolkata Municipal corporation boundary the rate of urbanisation in this municipality is very high. Two major arterial road of KMA passes through this municipality and they are the Kazi Nazrul Islam Sarani or the VIP Road and the Jessore Road which is connecting the KMC with the Airport. Further North the Jessore Road is connecting the City of Jessore in Bangladesh. The other important road that borders the northern edge of the city is the newly formed the Belghoria Express way connecting Dakshineswar to Airport.

The municipality forms a strategically important part of KMA as it lies just adjacent to KMC area. Due to the presence of the Easter Railway on the south western side of the municipality and presence of Krishnapur canal on the southern side of the municipality has resulted in lot of transition over the years and for this reason there is hardly any difference in population and density composition of both KMC area and SDDM.

On the west the municipality is bordered by Baranagar municipality, on the north and North West lies Dum Dum Municipality and North Dum Dum municipality respectively. On the north east and south eastern side is bordered by the newly formed Bidhannagar Municipal Corporation comprising of both Rajarhat Gopal Nagar Municipality and Bidhannagar Municipality and on west lies Kolkata Municipal Corporation. (South Dum Dum Municipality, 2007) This is shown in Map 2.

Although the municipality cover an area of 17.39 sq km still it has seen a huge population growth in year 2001 of about 69% as some new area from the panchayat was added to the municipality in 1999. According to the draft development plan of the municipality around in 2001 22.45% pf the population resides in 144 slums which are located in different wards of the municipality. Even about 46,282 people lives under poverty line in 2001 as per the development plan. Now as per Table 6 it shows the population growth of the municipality from 1911

to 2001 as per census 2001 and the 2025 perspective plan of KMA area. (South Dum Dum Municipality, 2007)

Table 6: Population Growth till 2001

Year	Population	Decadal Growth (%)
1911	12,874	
1951	61,393	
1961	1,11,287	81.27
1971	1,74,342	56.66
1981	2,27,578	30
1991	2,31,204	1.59
2001	3,92,150	69.61
2011	4.33	
2021	5.32	
2025	5.73	

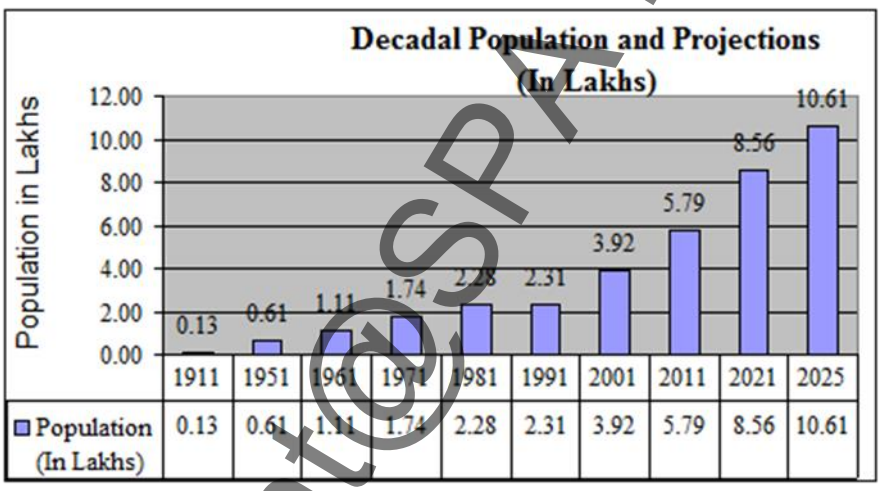


Figure 2: Decadal Population Projection in Lakhs

The Figure 2 shows the population that has been projected by the municipality till 2025. (South Dum Dum Municipality, 2007). The Map 2 shows the detail of SDDM. As urbanisation increases the number of environmental issues also increase in an area so as per the Draft development plan the municipality has identified some of the issues that needs to be catered in the development process of the municipality are as follows.

- Need regulatory control for insanitary water course and filling up of tanks.
- Existing wet land and lakes have been highly polluted.
- Large scale encroachment of open spaces.
- Increase in unauthorised construction.

- Even when we calculate 2 parameters of City Biodiversity Index we see that the study area has a low bio diversity.

What is City Bio – diversity Index (CBI)? “It is a dynamic process for depicting the urban biodiversity status. Thereby helping the city to evaluate, plan improve and review the cities condition with respect to biodiversity. As cities uses generally of the natural resources from the surrounding ecosystems so it is vital for a city to keep its ecosystems and biological diversity to function properly and be healthy. Thus to assess this CBI is a useful tool which has already been adopted Greater Hyderabad City.” (Ministry of Urban Development, 2014)

Calculation:

Proportion of Natural Area= (Total Area of Natural Area) / (Area of City) X100

= (0.833/15.6)x100 = 5.34%

Range:

0 point: < 1%

1 point: 1%-6%

2 point: 7%-13%

3 point: 14%-20%

4 point: >20%

Regulation of Quality of Water= (Total Permeable Area) / (total Terrestrial Area of the City)

= (0.825/15.6 = 0.0529

Range:

1 point: < 0.307

2 point: 0.307-0.4785

3 point: 0.4785-0.65

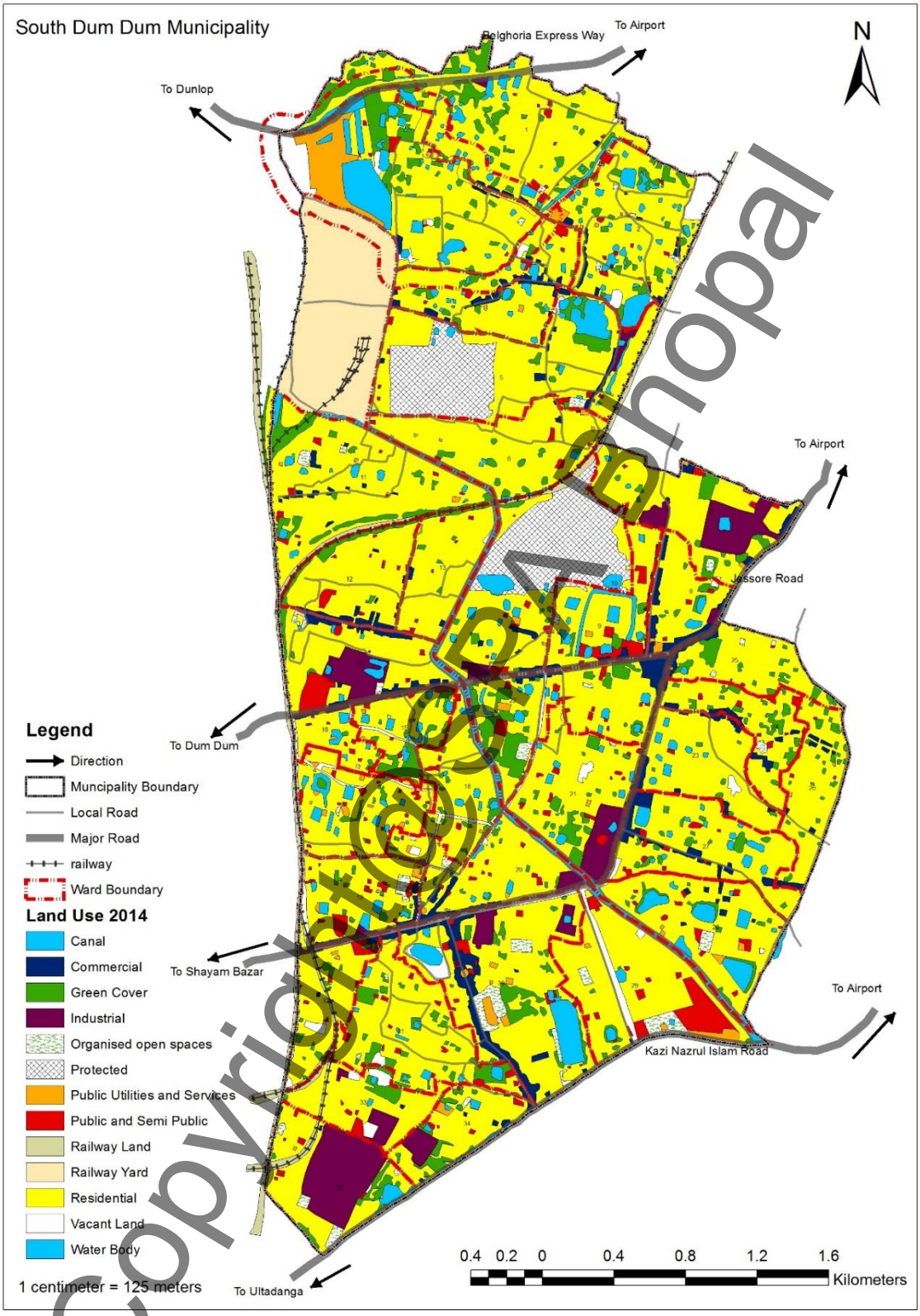
4 point: >0.65

Thus for sustainable development the URDPFI guidelines emphasizes on developing of green belts and natural environment which is required to reduce the effects of urban heat island effect and storm water system.

3.1.2 Data Collection

The main data that is required for the analysis are majorly for the analysis of socio-economic condition of the area and for the calculation of surface run off. Other

analysis is based on image interpretation. The 1st set of data required is mainly census data like working population, non- working population and other working population, literacy level, number of main workers, household condition, number of familiars falling below poverty level and the housing demand of the area. These data are the basic data are required to analyse the social condition of the area, here all data are ward level data as we need to select wards which are the micro study area. Now for the economic analysis data that have been used are property tax rate per square feet, property circle rate per square feet, property market rate per square feet, land value of the municipality in lakhs per Katha. These data are mostly available in zone wise from which we can easily identify the wards in each zone and analyse the data at ward level. For the next set of analysis we need areal imagery for which we are basically following the GOOGLE EARTH PRO image, thermal imagery these data set will be used for the land use and land cover analysis and surface temperature analysis. The last analysis requires detail for surface runoff calculation. So for that we need rainfall data of the calculation of rainfall intensity but in general as per Indian condition the rainfall intensity is generally taken as 12mm/hr to 20mm/hr based on actual recodes (CPHEEO, 2013). The other general data required are list of parks and water bodies.



Map 2: Map of Study Area

Chapter 4. Socio Economic study of the Municipality

The first step of the research is to identify the socio – economic status of the case study area that is SDDM. Socio – economic status determination is purely a ward level study, where it is required consider that although the socio – economic status is homogeneous throughout the ward although in reality this is not true as the socio economic condition are not evenly distributed throughout the ward.

So socio – economic status determination is according objective 1 which says "to identify and analyse different socio- economic indicators and create clusters (micro area) of similar socio- economic condition in South Dum Dum Municipality."

The socio – economic parameter that have considered are the ones that might have some kind of influence on surrounding environment, for this reason a detail literature study has been conducted which highlights different socio – economic parameters that influence our surrounding environment. Depending upon the data availably the different indicators were selected from literatures related to Socio – Economic parameter influencing environment and then proceeded with the study further.

Indicators like working population, literacy level, number of BPL household and housing demand under PMAY and the economic indicators selected are average property tax paid, municipal property market rate and land value which was collected during secondary data collection have a close resemblance with the indicators in indicators in Table 3, Table 4 and Table 5 studying. The final list of indicators used for the research with reference to the indicators used in different literature have been represented in Table 7

Table 7: Corresponding indicators of the highlighted indicator.

Highlighted Indicators	Used Indicators For Analysis
Size and type of family	number of BPL household and housing demand under PMAY
Level of Education	literacy level
Land Value	land value
Property Value	municipal property market rate
Tax Base	average property tax paid
Labour Force	working population
Population living in absolute poverty	number of BPL household
Adult literacy rate	literacy level
Stock of shelter and infrastructure	housing demand under PMAY

These socio economic indicators will be used for further analysis to understand the spatial variation in the socio economic pattern in the municipality

4.1.1 Ranking of Socio – Economic parameter

The indicators in

Table 7 area mainly Census of India 2011 data and data as obtained from the municipality and are ward level data. The number of working population and literacy level is represented as percentage of total population of the wards. In the same way the number of below poverty line (BPL) household and housing demand under Pradhan Mantri Awas Yojana (PMAY) are represented as percentage of total number of household in each ward. All social indicators are divided into a three ranges base on the available values of each ward. Now these ranges have been ranked in three ranking category where 1 is for low or least acceptable range, 2 is for medium or moderately acceptable value and 3 is for high or an acceptable value. In some cases it has been seen that a lower range has been ranked with the highest rank that is just because a higher percentage is not acceptable and if the percentage range is low it means it more preferred than the higher one. In case of economic parameters we do divide all values of each ward into 3 range but it is not represented in from of percentage as they are monetary values. In the same way the economic parameter has been ranked. The economic parameters used in this are average property tax paid per household in rupees in the year 2011, municipal property market rate in rupees per square feet and land value in lakhs per katha (1 katha = 720 square feet). Finally after ranking the parameters have been mapped as an attribute of the wards.

Example of Rank (Social parameter)

Table 8: Ranking range and Ranks of percentage of Working Population

Social			
Indicators	**Range**	**Rank**	**Remarks**
Percentage Working Population	34%-36%	1	Low Working population
	37%-39%	2	Medium Working population
	40%-41%	3	High Working population

Table 9: Ranking range and Ranks of literacy rate

Social			
Indicators	**Range**	**Rank**	**Remarks**
Literacy Level	<= 80%	1	Low literacy level
	81%-86%	2	Medium literacy level
	>=87%	3	High literacy level

Table 10: Ranking range and Ranks of Percentage No of BPL Household

Social			
Indicators	**Range**	**Rank**	**Remarks**
Percentage No of BPL Household	10% - 11%	1	High no of BPL HH
	3%-6%	2	Medium Level of BPL HH
	0%-2%	3	Low Level of BPL HH

Table 11: Ranking range and Ranks of Percentage Housing Demand under PMAY

Social			
Indicators	**Range**	**Rank**	**Remarks**
Percentage Housing Demand under PMAY	>=10%	1	High demand for Housing
	5%-9%	2	Medium demand for Housing
	<= 4%	3	Low demand for Housing

Table 9 9, Table 10 and Table 11 the range of each parameter and the allocated rank of each value is given. But in some case the like in Table 10 and Table 11 then range which having a lower value has been given a higher rank as we see in both cases the a ward having low number of BPL families and low housing demand shows that there is less poverty which is more acceptable in the process of development. Although they have a low value they get a higher rank and same in case of higher value range and lower rank for Table 10 and Table 11.

Example of Rank (Economic Indicators)

Table 12: Ranking range and Ranks of Average property tax paid per household in Rs in year 2011

Economic			
Indicators	**Range**	**Rank**	**Remarks**
Average property tax paid per household in Rs in year 2011	< 500 /-	1	Low tax paid
	500-999/-	2	Medium Tax paid
	>1000/-	3	High tax paid

Table 13: Ranking range and Ranks of Municipality property (market) rate in Rs / sq ft.

Economic			
Indicators	**Range**	**Rank**	**Remarks**
Municipality property (market) rate in Rs / sq ft	< 3000 /-	1	Low property value
	3000-3999	2	Medium property value
	> 4000 /-	3	High property value

Table 14: Ranking range and Ranks of Land Value in Lakh per Katha

Economic			
Indicators	**Range**	**Rank**	**Remarks**
Land Value in Lakh per Katha (1 Katha = 720 Sq. Ft)	>20 lakh	1	Low land value
	20-30 lakh	2	Medium Land value
	>30 lakh	3	High Land value

From the above Table 12, Table 13 and Table 14 it is clear that there are no opposite ranking in case of economic parameters. Finally after ranking each ward with respect to social and economic parameter the average social and economic rank of each ward was calculated and then the average of both final social and economic rank was considered. This final average ranking helped to select the different wards for the study and are represented in the Table 15 and Table 16. The Wards and the Ranks in bold and underlined are the final micro study area of the research.

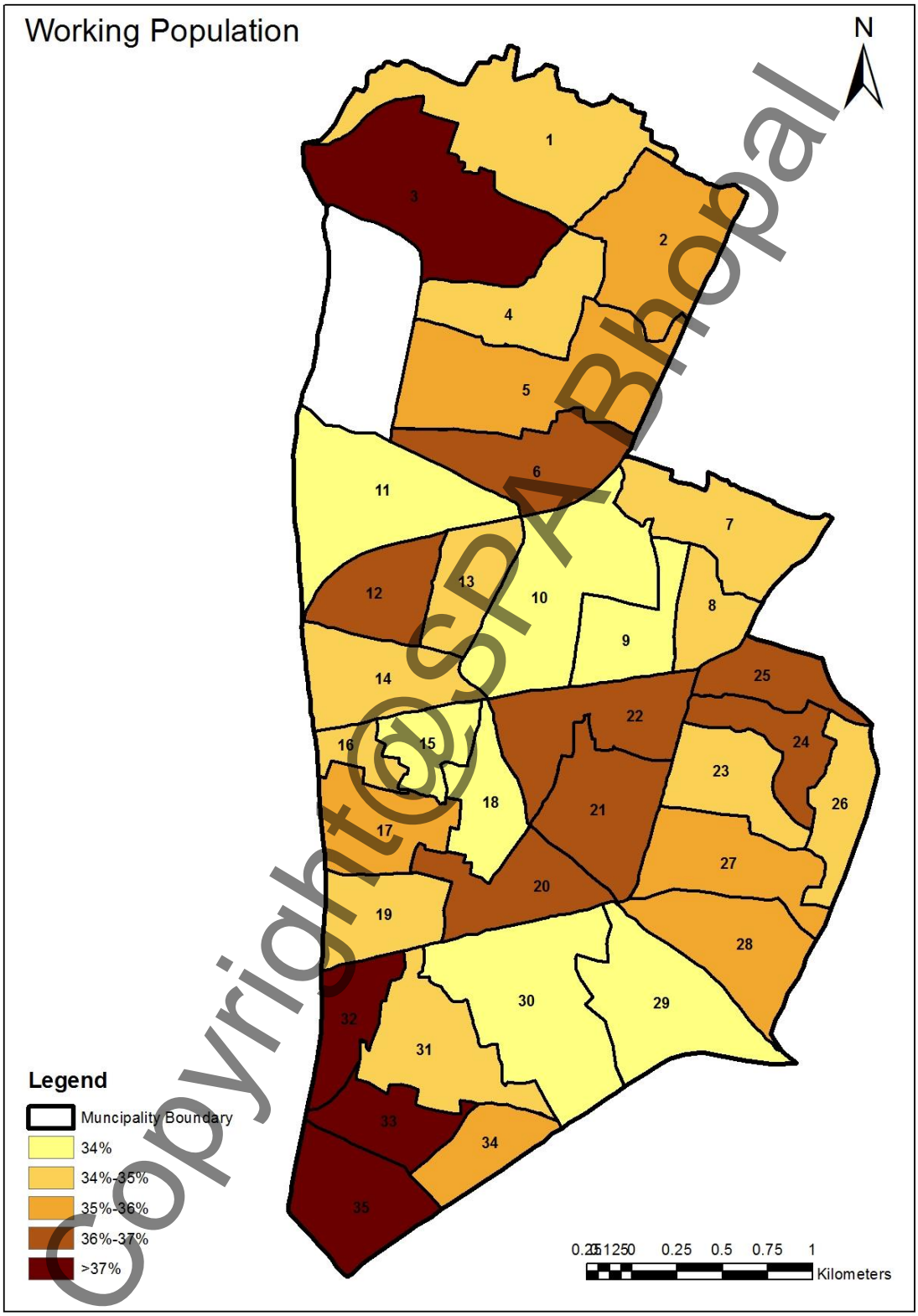
Table 15: Average rank of 1st 18 wards

Ward No	Average Rank		
	Social	Economic	Socio- Economic
1	2.25	1.00	1.63
2	2.00	1.00	1.50
3	**1.00**	**1.00**	**1.00**
4	2.50	2.00	2.25
5	1.75	2.33	2.04
6	1.75	2.00	1.88
7	1.75	2.67	2.21
8	2.50	2.33	2.42
9	2.25	2.33	2.29
10	2.50	2.33	2.42
11	2.00	1.67	1.83
12	2.25	1.67	1.96
13	2.50	1.67	2.08
14	2.50	2.33	2.42
15	2.50	2.00	2.25
16	2.00	2.00	2.00
17	2.25	2.00	2.13
18	**2.75**	**2.00**	**2.38**

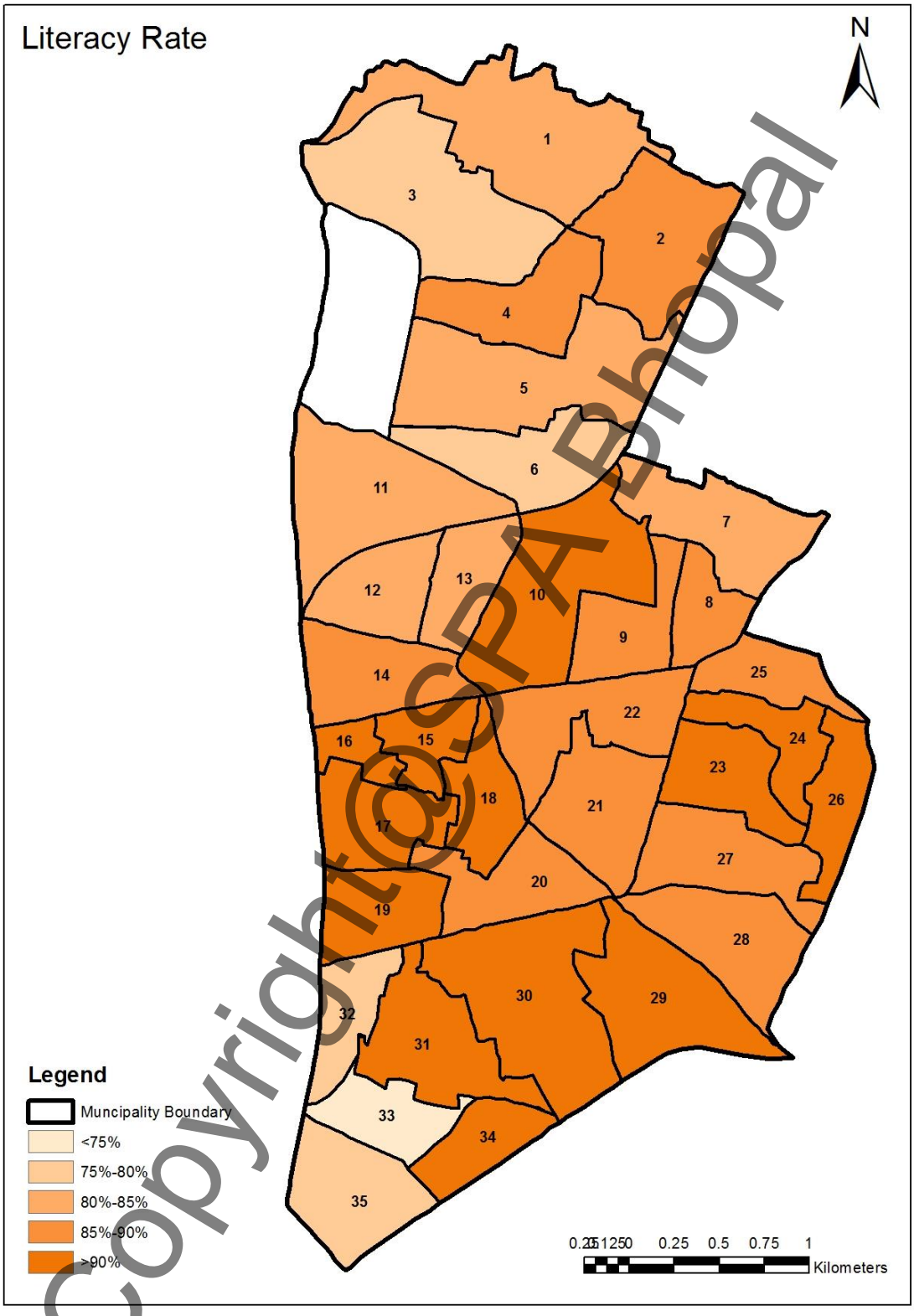
Table 16: Average rank of last 17 wards

Ward No	Average Rank		
	Social	Economic	Socio- Economic
19	2.25	2.67	2.46
20	2.50	2.67	2.58
21	2.50	2.67	2.58
22	2.50	2.67	2.58
23	2.75	2.67	2.71
24	2.75	2.67	2.71
25	2.00	2.67	2.33
26	2.50	2.67	2.58
27	2.50	2.67	2.58
28	2.25	3.00	2.63
29	2.50	3.00	2.75
30	2.50	3.00	2.75
31	2.75	2.67	2.71
32	1.75	2.33	2.04
33	**1.25**	**3.00**	**2.13**
34	**2.75**	**3.00**	**2.88**
35	1.75	2.67	2.21

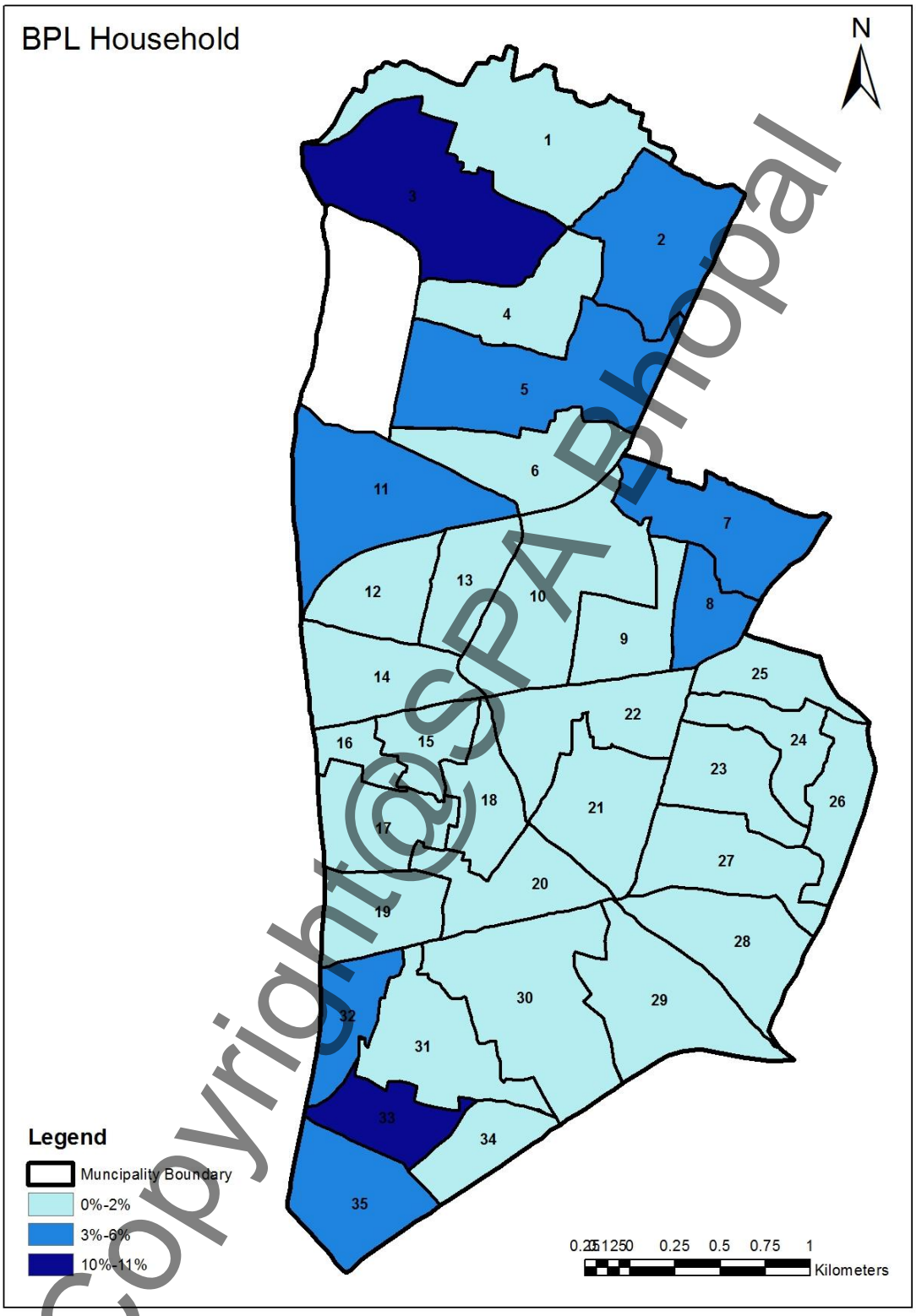
Social parameters and its spatial distribution.



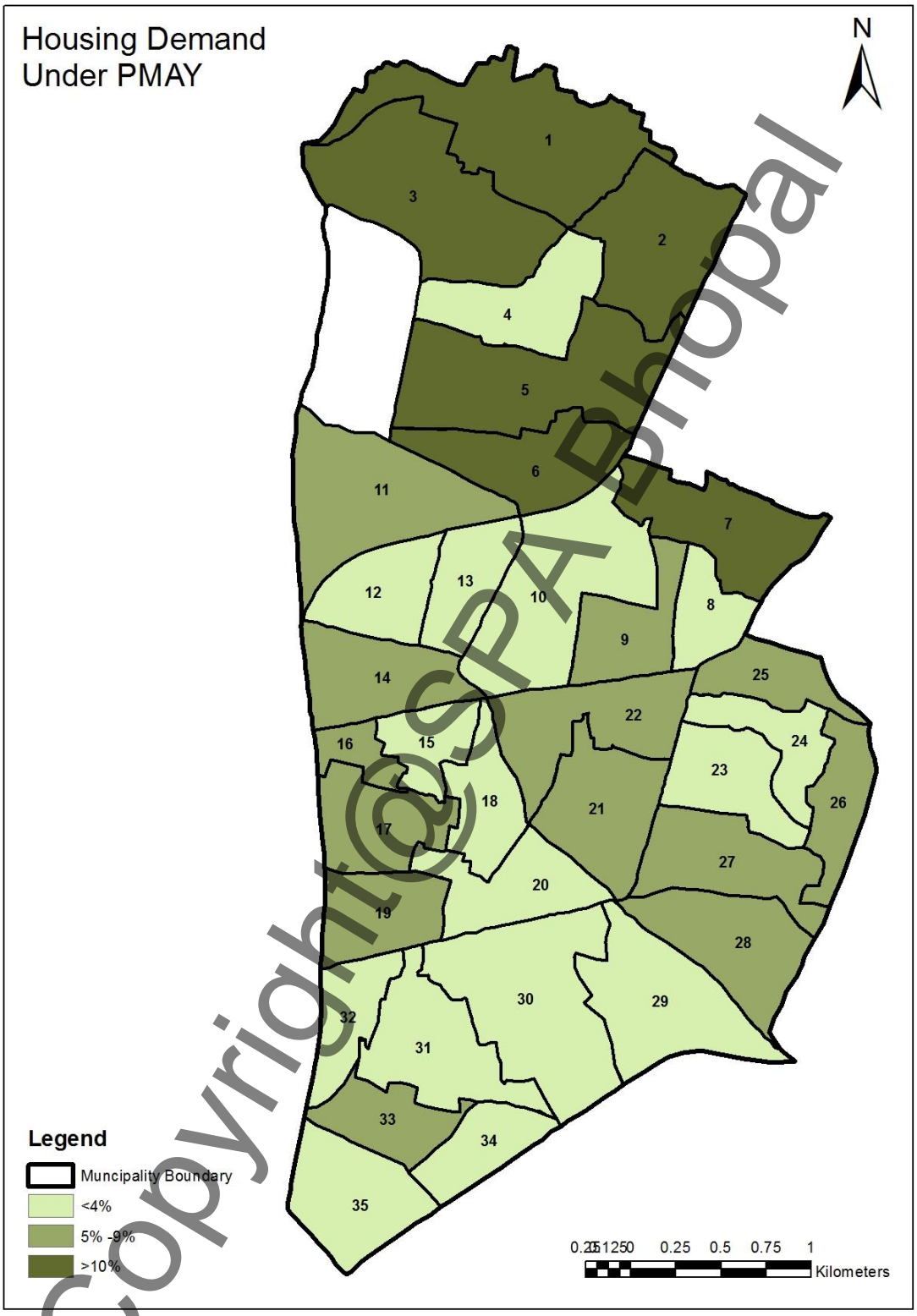
Map 3: Working Population



Map 4: Literacy Rate



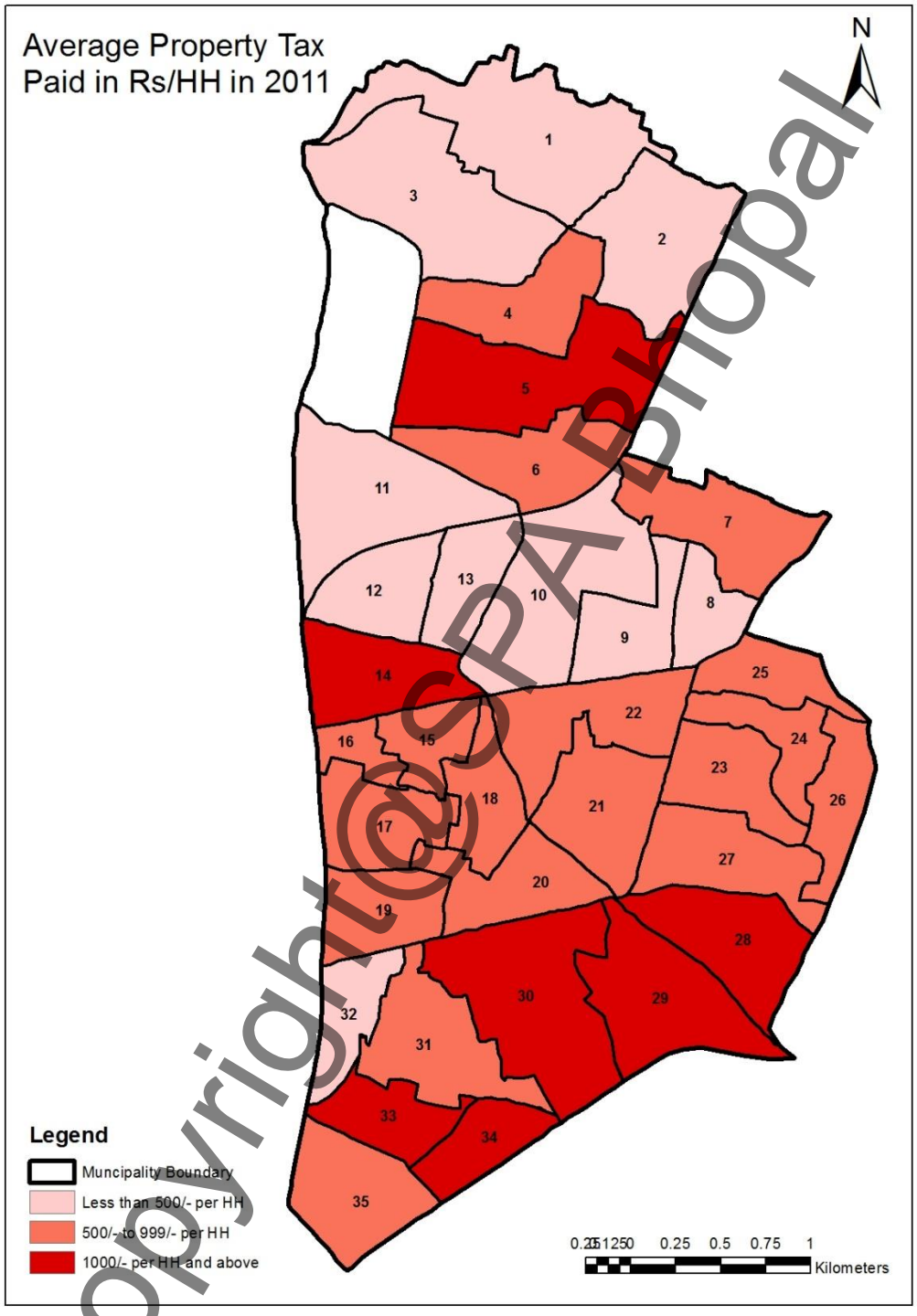
Map 5: Number of BPL household



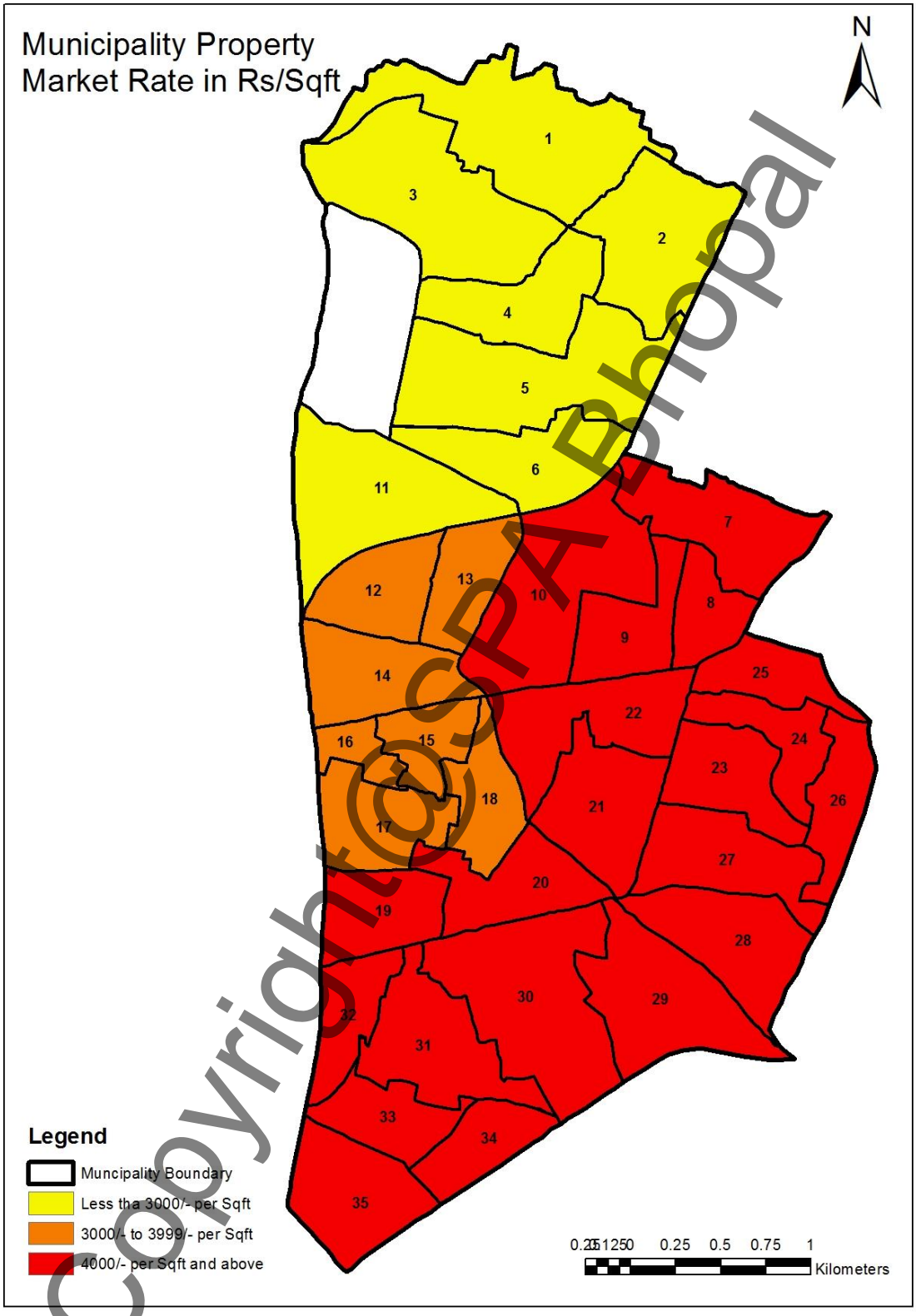
Map 6: Housing Demand under PMAY

The Map 3, Map 4, Map 5 and Map 6 shows the spatial distribution of social parameter in the whole municipality as per the range that have been defined in Table 8, Table 9, Table 10 and Table 11.

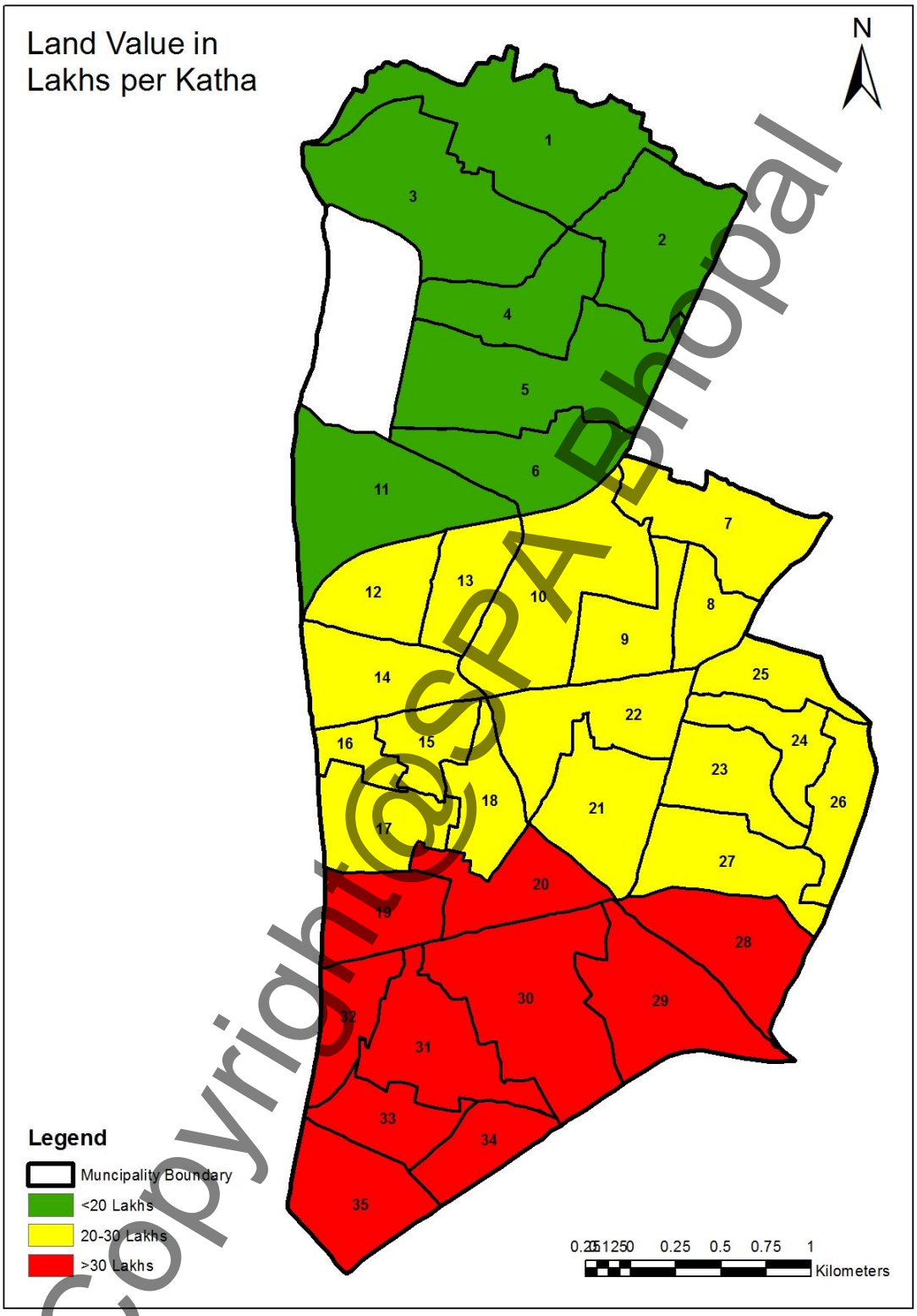
Economic indicators and their spatial variation



Map 7: Average property tax paid per household in Rs in year 2011

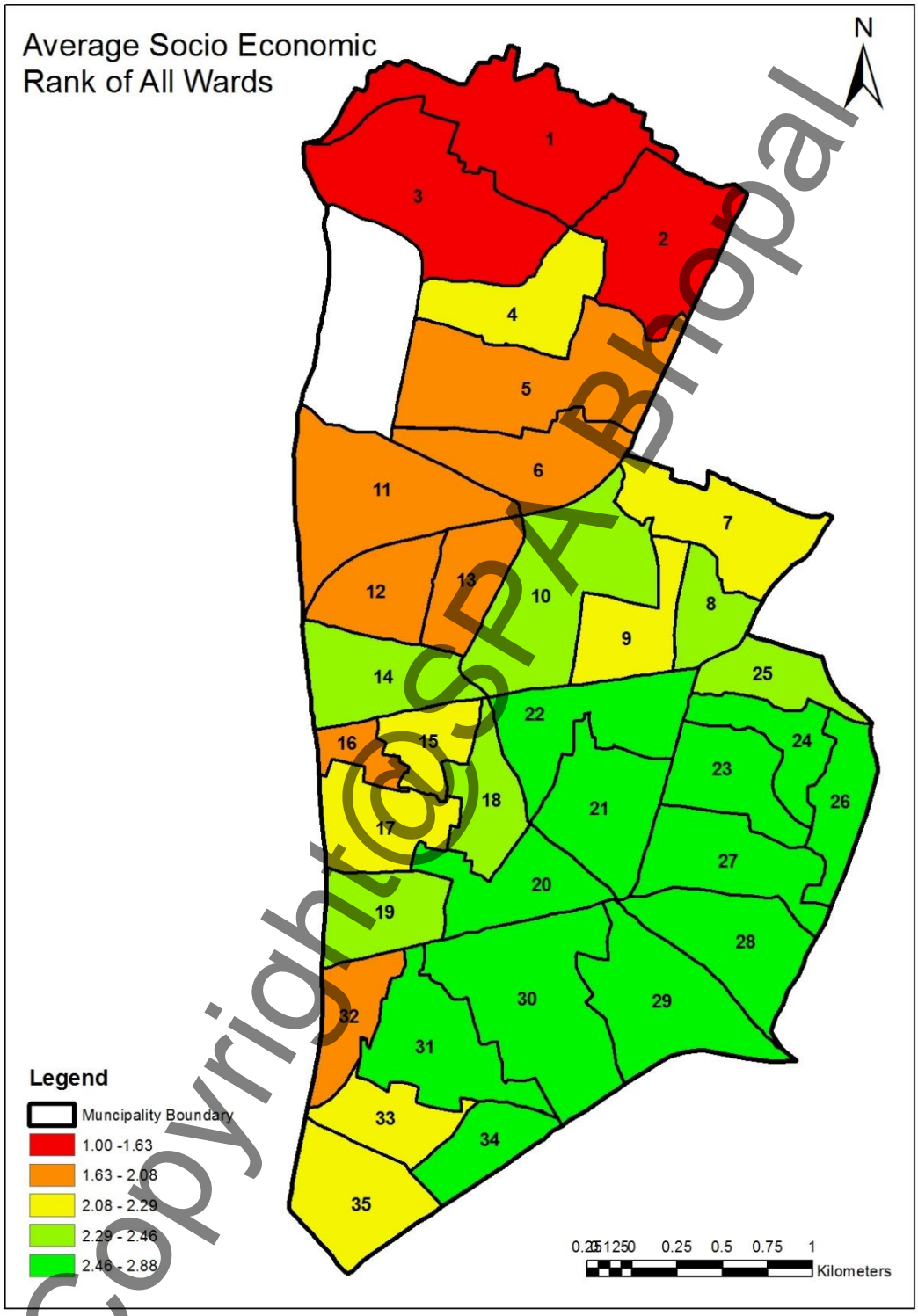


Map 8: Municipality property (market) rate in Rs / sq ft.

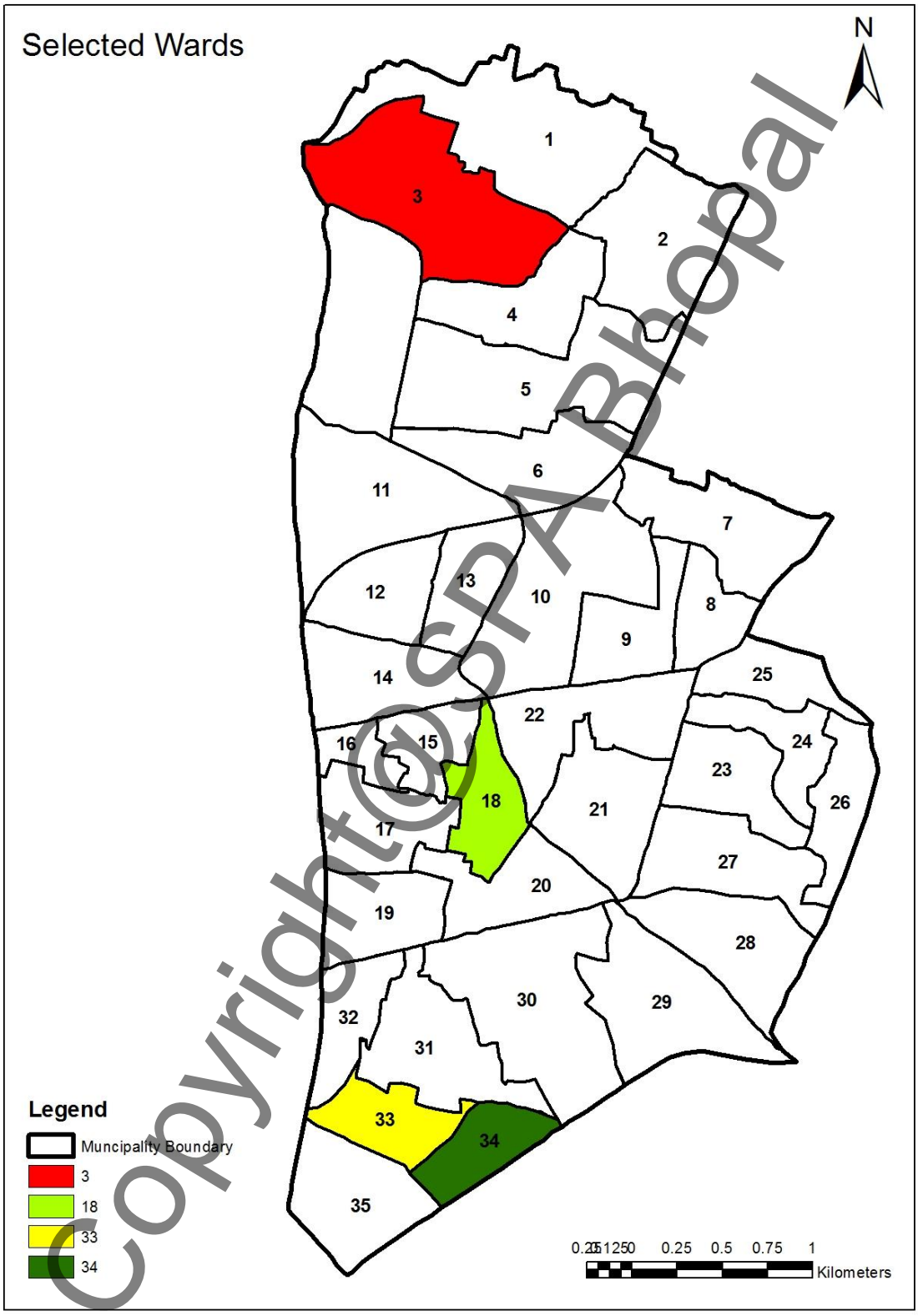


Map 9: Land Value in Lakh per Katha

The Map 7, Map 8 and Map 9 shows the spatial distribution of economic parameters of the municipality especially the land value and property rate zones in the municipality. The average ranking of both social and economic indicators for all wards in the municipality.



Map 10: The average rank map of the wards



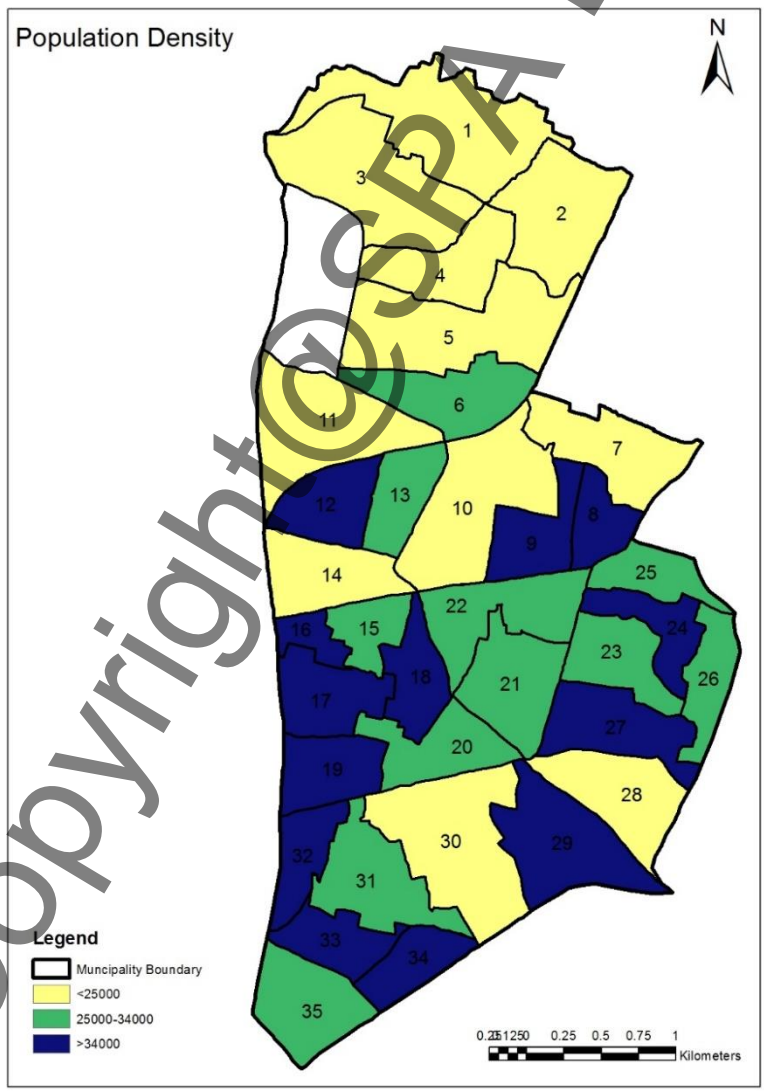
Map 11: The Four selected ward map for further stud

Map 10 and Map 11 shows us the final ranks of all wards and the four selected wards for further study respectively.

Table 17: Selected wards and there socio- economic character

Ward No	3	18	33	34
Social	Low	High	Low	High
Economic	Low	Low	High	High

The last Table 17 shows the characteristic of social and economic parameters of the final four selected wards. Although population density have not been considered in the analysis still to understand the variation in population of the municipality the population density map has been plotted as in Map 12. The density of each selected ward has been shown in Table 18.



Map 12: Population Density Census 2011

Table 18: The final status and density of selected wards

Parameters	Wards			
	3	18	33	34
Average Density	28454.5	28454.5	28454.5	28454.5
Density	18246.2	37014.3	61354.3	45914.6
Density Range	Low	High	High	High
Social	Low	High	Low	High
Economic	Low	Low	High	High

According to this it shows that ward 3 has a low density with respect to the average density of the whole municipality but other wards have a high density when compared to the average density of the municipality

Chapter 5. Land use and Land Cover change and its relation with Socio Economic condition

As we have selected 4 wards whit different socio – economic characteristics now the further analysis related to land use and land cover change will be studied. This analysis mainly follows the grid analysis of the each four wards on a temporal manner. This study is a part of our objective 2 where the objective states “to analyse the land use, land cover and environmental performance within the identified micro area.”

Land use is basically the various ways in which human beings use the land and mange it and its resources. Over the time period there has been a changeable relation between human and the land. The growing population results in construction of structures for shelter on land, defences, alteration of land cover for food, power, transport etc. (Environment Literacy, n.d.).

So we can say that land use is a “fictional dimension of land for different human purpose or activities (The Organisation for Economic Co-operation and Development (OECD), n.d.).”

While land cover is the physical and the biological materials that are found on the surface of land like the existing vegetation, water bodies and built environment. Land use change results in conversion of these land cover characters over the time period (Environment Literacy, n.d.).

As earlier stated that there has been very little study regarding the socio – economic condition of an area and its related environmental condition, so as per objective 3 we need “to find a relationship between the socio- economic condition, land use, land cover change and environmental performance within the identified micro area.”

The study sites are ward level but ward are not entirely homogeneous with respect to socio economic condition but we assume that the socio economic condition for the selected wards are sufficient to represent the condition for the full wards (Pauleit, et al., 2005). The socio economic condition as achieved from the previous

Chapter 4 will help us to compare different land use, land cover and other environmental parameters within the micro study areas.

5.1 Land Use and Land Cover determination

The land use is studied in a temporal pattern that is it studied in relation to time. The land use is mapped using the grid system. As per this the wards are divided into grid of 20 metres by 20 metres grid. Each grid gets one identified land use based on the areal image that has been used. So for this study I use Google Earth Pro image which gives clear aerial view of the place with an aerial resolution of less than one kilometre. The grid represents exact 20 m X 20 m cell on earth surface. Now if one grid has more than one land use as per the image then the dominant land use is identified and marked. Now if there are more than one land use then whatever comes in mid-point of the grid is marked as the land use for that cell. By doing this there is less than 1% chance of error as the land use that we assign have more size than the size of the cells (Sekliziotis, 1980). The same technique is applied for determination of land cover in the 4 wards. The basic land use categories considered are Built up, Kuccha Road, Asphalt/ Concrete road, Water Bodies, Playgrounds, Tree, Marshy land, Open land, Land fill, Railway line, Factory. Now as per the land use category marshy land are those land which have small patches of water bodies and the size of these water bodies varies also the area has tall grasses growing along with herb like plants. Even the land fill area is not a sanitary landfill area it is just the “Municipal Solid Waste” dumping ground. Open land are mostly vacant lands and plots while railway land consist of both railway line and the area falling under the railway yard within the municipality.

5.2 Land use Change

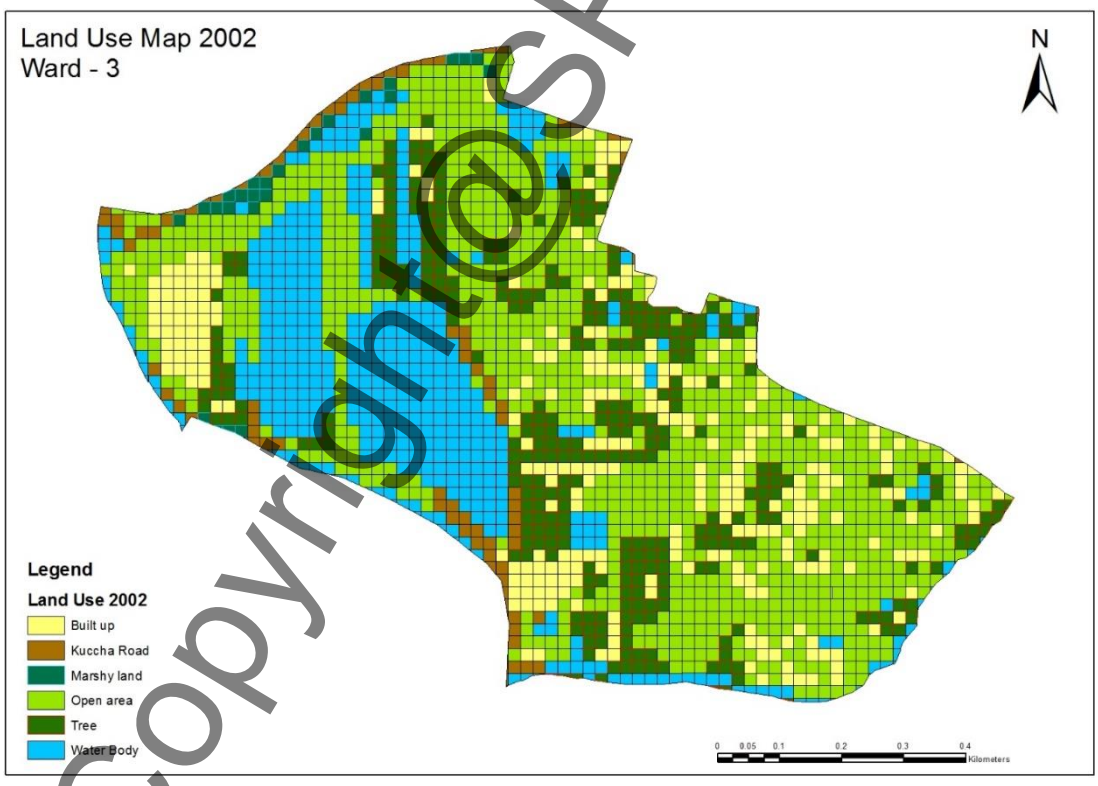
To identify the land use change temporal image of 2002, 2005, 2010, 2015 and 2017 are use. The selected four wars has been divided in to 20 X 20 meter grids and as per the above mentioned process the land use of each selected years have been marked. The selection of the years are based on consultation with the local and municipal authorities, local people and based on visual survey. The analysis is an Arc GIS based analysis where we use the Gird Index Feature in Cartography tool and geo reference each aerial image of the wards to identify the land use. The Grid Index Feature tools helps to create the 20 X 20 grids and each cell becomes

one unique feature, while land use is inserted in the attribute table. Each gird has an area of 400 sq meter and the grids surrounding the boundary of the wards are clipped in the Geoprocessing menu and there area is determined calculating the area of the field. The clipping of boundary grids is necessary just to maintain the exact administrative area of the selected wards. Finally area of all the assigned land use is calculated through simple summation of each land use category in excel sheet. This process is repeated for all the selected years and the area of each land use category has been determined.

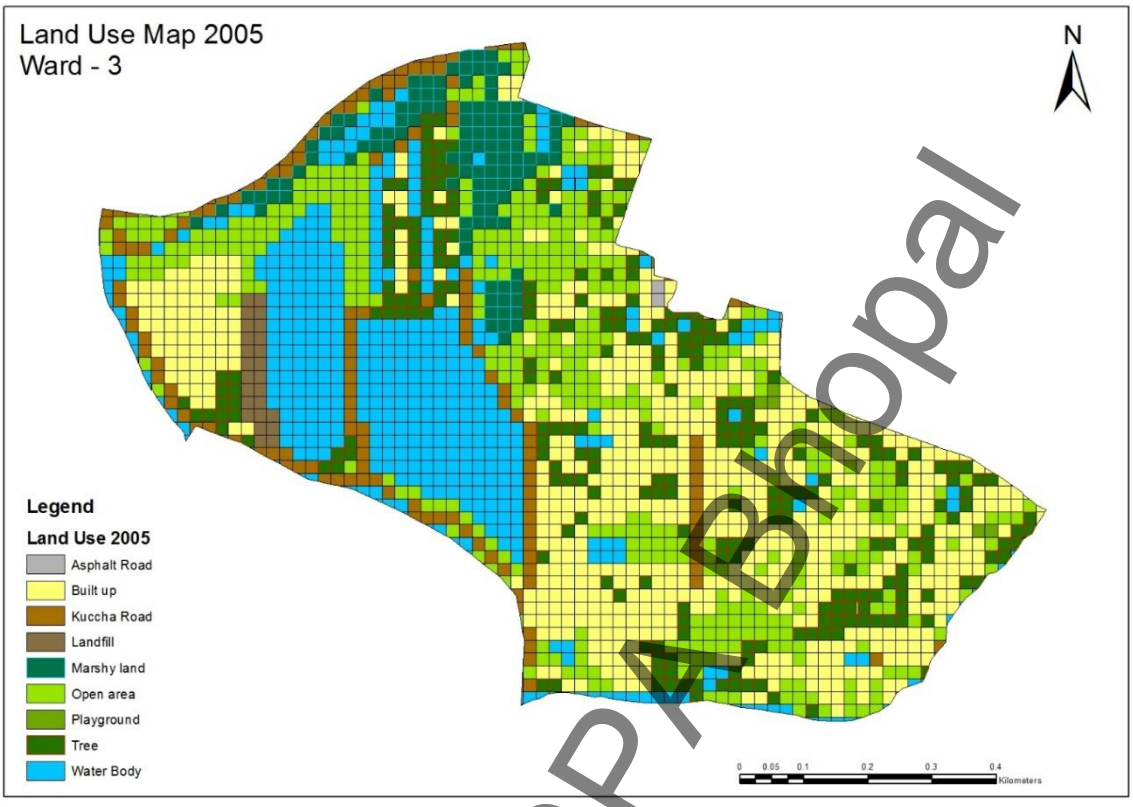
5.2.1 Land Use Change of Selected 4 Wards

5.2.1.1 *Land Use of Ward 3 –*

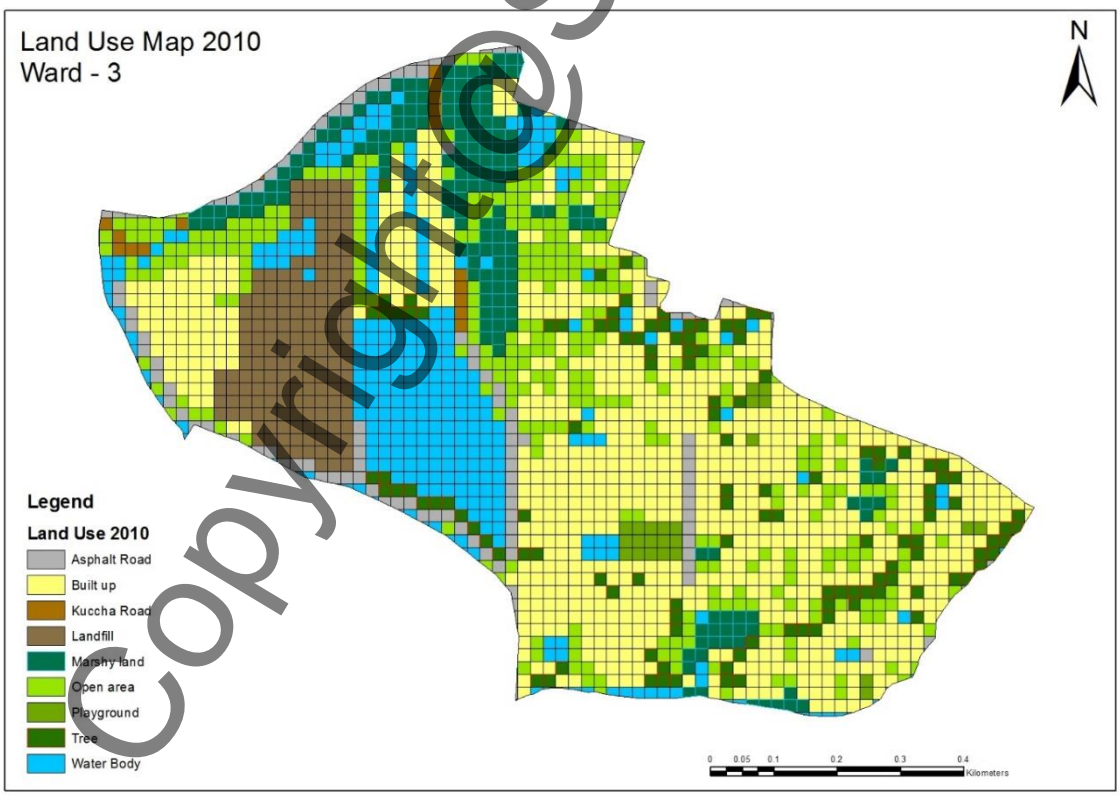
Ward 3 is a low social and low economically developed area as per the socio – economic ranking. As we see the temporal changes there has been huge change in this ward inter of land use change. The below maps will give details of this change.



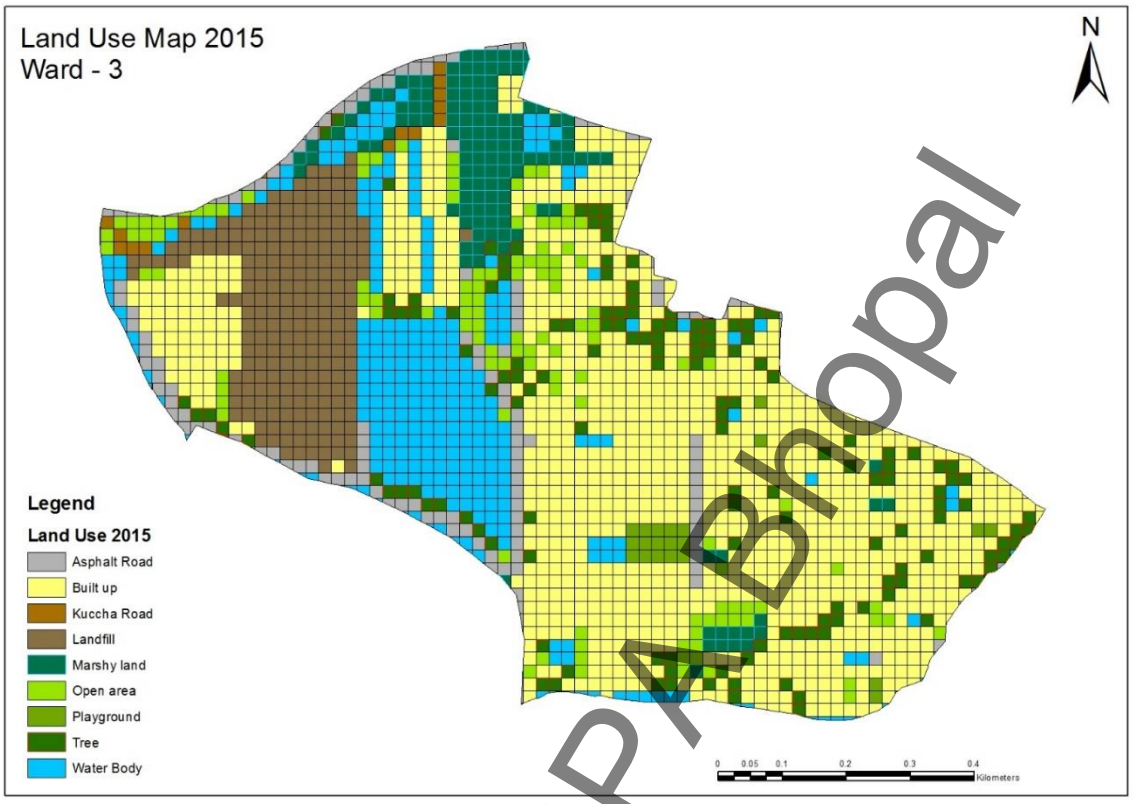
Map 13: Land use 2002 ward 3



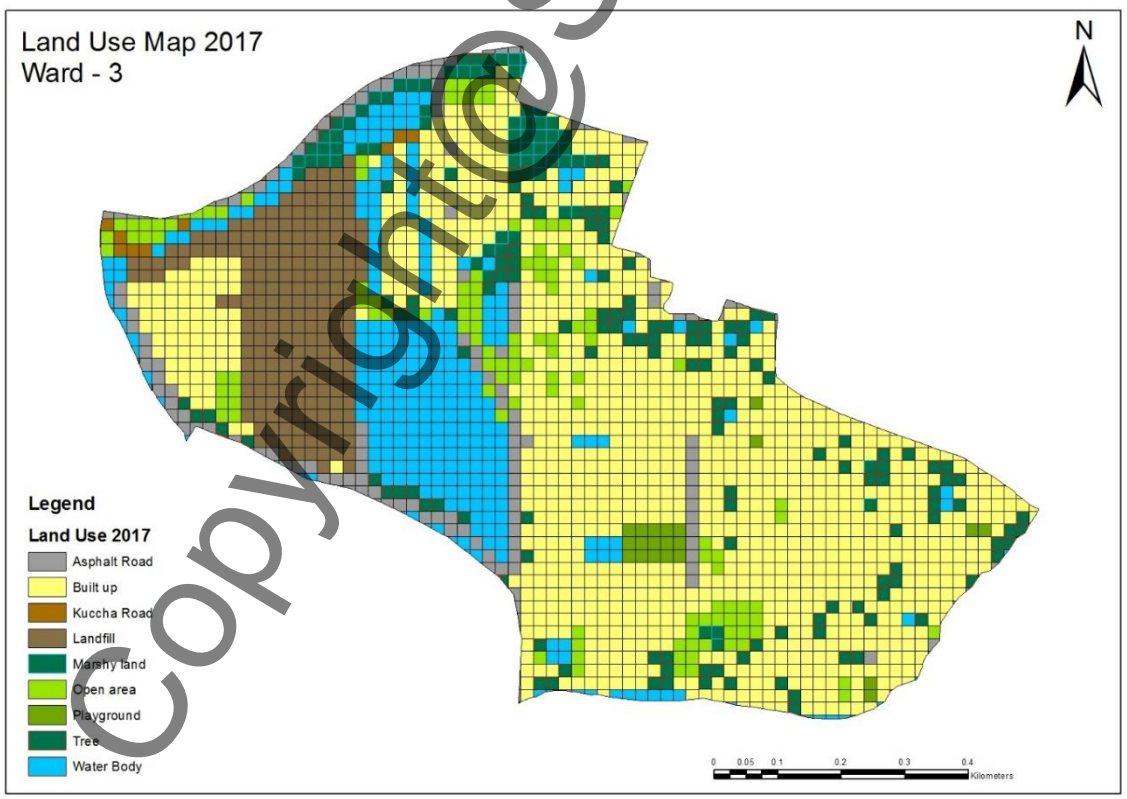
Map 14: Land use 2005 ward 3



Map 15: Land use 2010 ward 3



Map 16: Land use 2015 ward 3



Map 17: Land use 2017 ward 3

As per the Map 13, Map 14, Map 15, Map 16 and Map 17 it is very clear that there has been huge change in land use within the ward. Also after 2002 it is clearly visible that a huge water body is being completely converted into a land fill site of municipal solid waste. Another major change that have been notices is that the conversion of marshy land in the northern part of the ward into built up in recent years that is from 2015 to 2017. This conversion is due to the construction of low cost housing for the people affected by removal of encroachment along the canal where new Metro Rail overhead line being constructed. So for this reason changes in marshy land is visible from 2005 to 2017.

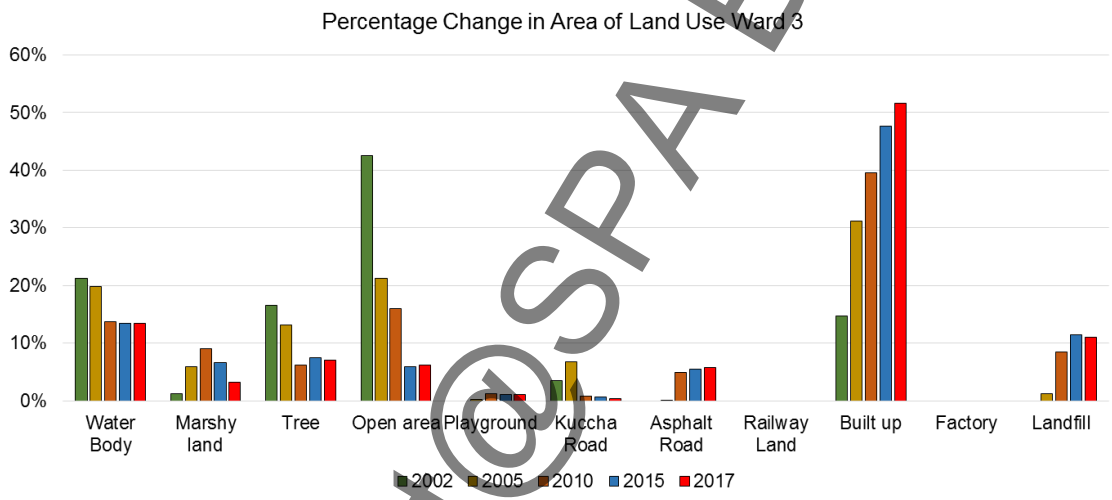
Table 19: Land Use area in different years of Ward 3

Land Use	**Area in Sq Km**				
	2002	**2005**	**2010**	**2015**	**2017**
Water Body	0.167	0.157	0.108	0.106	0.106
Marshy land	0.010	0.047	0.072	0.053	0.025
Tree	0.131	0.104	0.049	0.059	0.055
Open area	0.335	0.168	0.126	0.047	0.049
Playground	0.000	0.002	0.010	0.008	0.008
Kuccha Road	0.028	0.053	0.006	0.006	0.004
Asphalt Road	0.000	0.001	0.039	0.043	0.046
Railway Land	0.000	0.000	0.000	0.000	0.000
Built up	0.116	0.246	0.311	0.375	0.407
Factory	0.000	0.000	0.000	0.000	0.000
Landfill	0.000	0.010	0.067	0.090	0.087
Total	**0.787**	**0.787**	**0.787**	**0.787**	**0.787**

Table 20: % area of each land use in different year's ward 3

Land Use	**Percentage Area in Sq Km**				
	2002	**2005**	**2010**	**2015**	**2017**
Water Body	21%	20%	14%	13%	13%
Marshy land	1%	6%	9%	7%	3%
Tree	17%	13%	6%	8%	7%
Open area	43%	21%	16%	6%	6%
Playground	0%	0%	1%	1%	1%
Kuccha Road	4%	7%	1%	1%	0%
Asphalt Road	0%	0%	5%	5%	6%
Railway Land	0%	0%	0%	0%	0%
Built up	15%	31%	40%	48%	52%
Factory	0%	0%	0%	0%	0%
Landfill	0%	1%	9%	11%	11%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

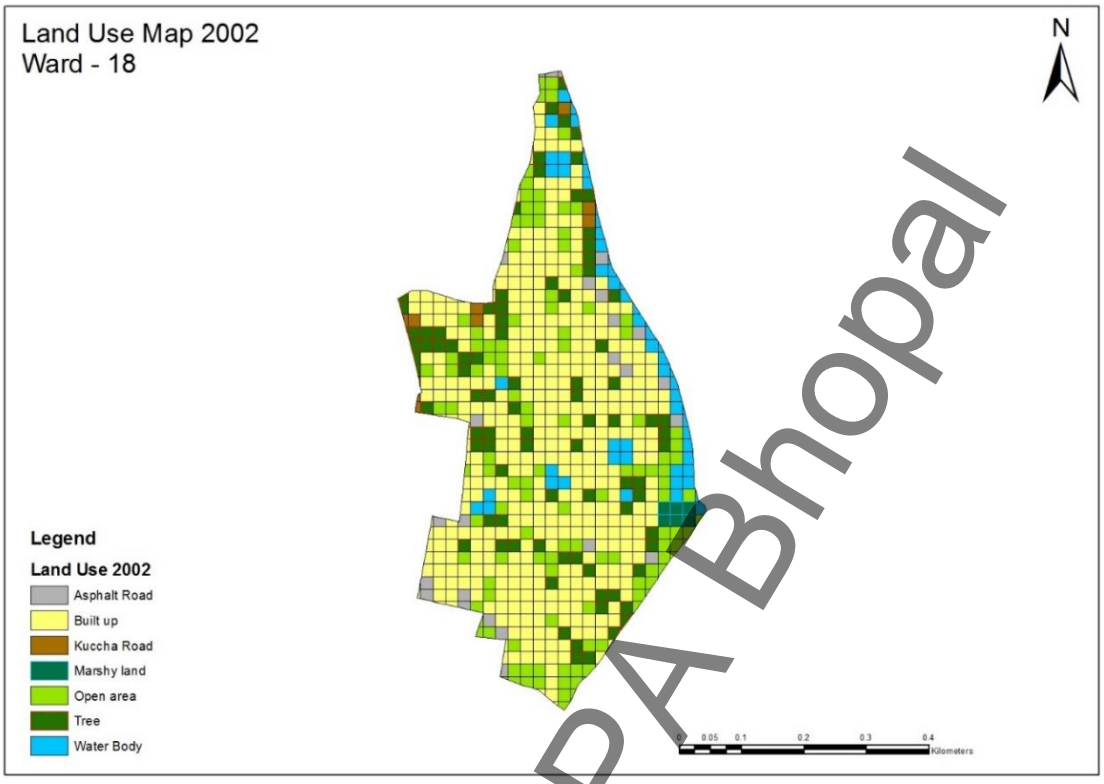
The Table 19 and Table 20 gives the detail values and percentage area of land use in year 2002, 2005, 2010, 2015 and 2017 of ward 3. From the area and the value it is very clear that the built up has increased tremendously from 15% at 2002 to 52% at 2017 while the available open spaces within the wards have decreased from 43% at 2002 to just 6% at 2017. Same is the case of water bodies where the decrease is from 21% at 2002 to 13% at 2017. The tree canopy cover is has also decreased from 17% to 7% in between 2002 to 2017. But a major change that is reflected is that the land fill site which did not exist in 2002 started to increase gradually and covered 11% of the land in 2017 of the ward. The Graph 1 shows the change in land use of the selected years.



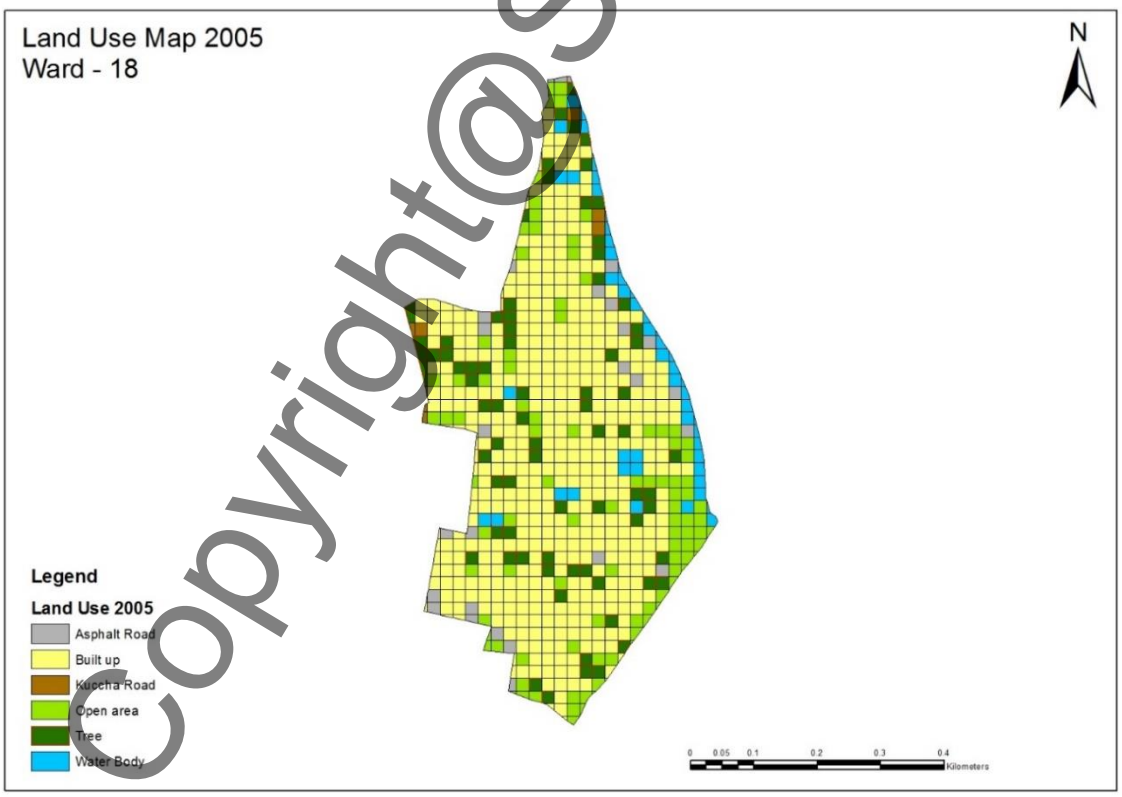
Graph 1: Change in land use of Ward 3

5.2.1.2 *Land Use of Ward 18 –*

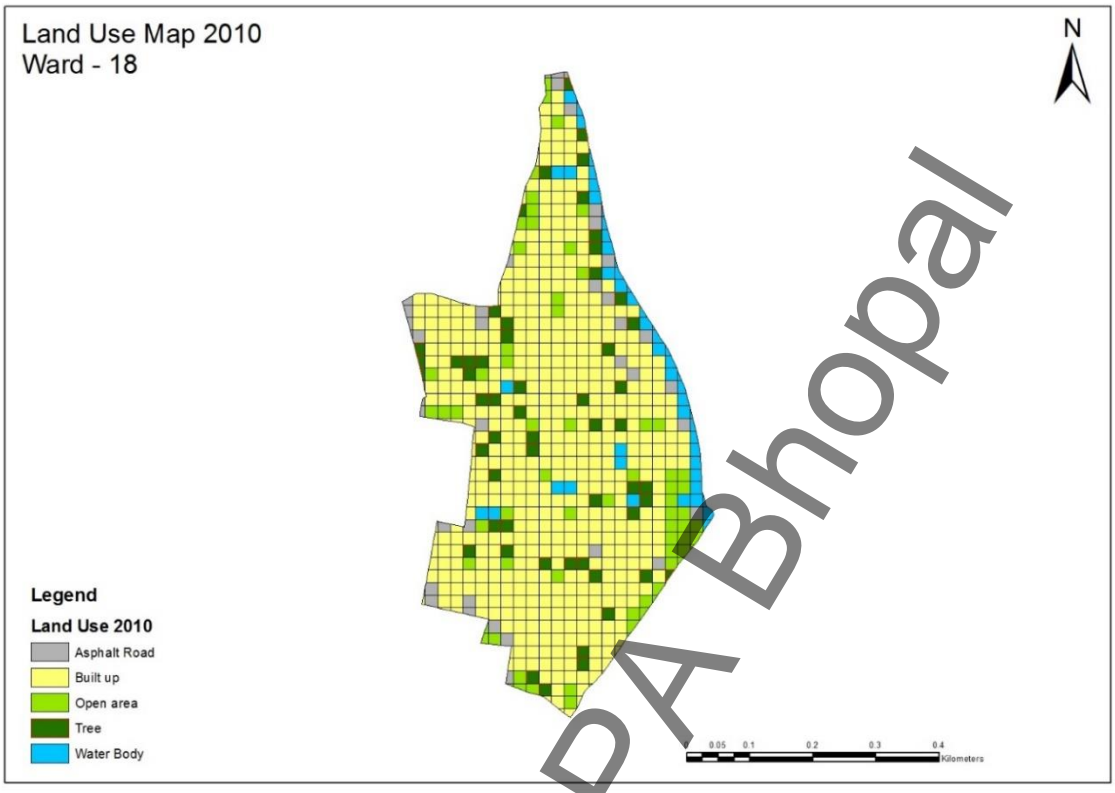
Ward 18 fall into the medium status category with socially high rank while economically low rank. This ward covers a total area of 2.5 sq km approx. but has seen quite significant amount of land use changes. This ward do not have any railway land or land fill sites so the area within land use category remains zero. While land uses like marshy land and Kuccha road do exist bit at later stage these land uses are no longer there and becomes zero.



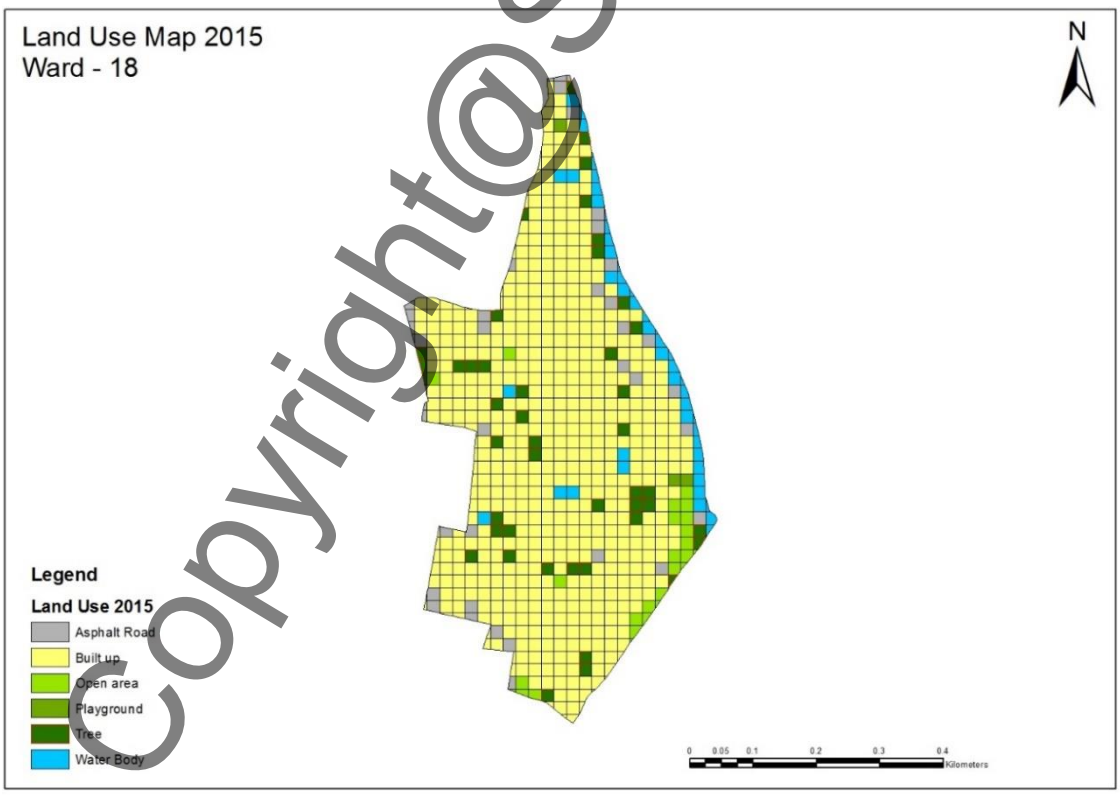
Map 18: Land use 2002 ward 18



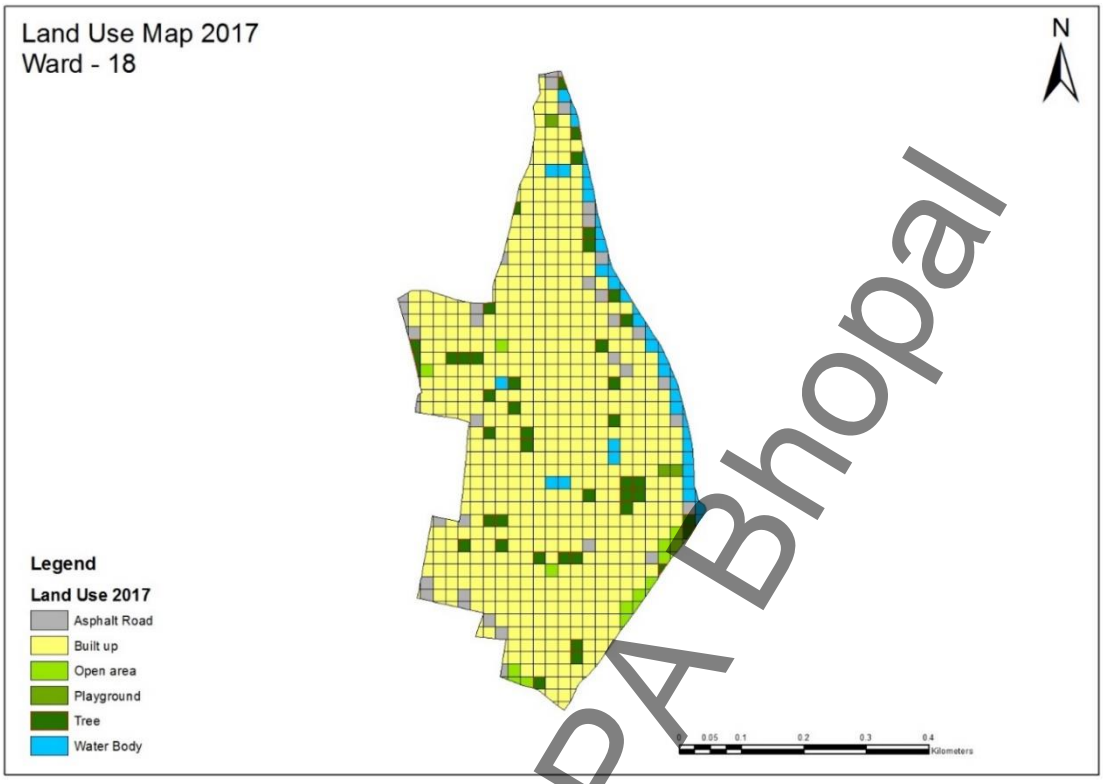
Map 19: Land use 2005 ward 18



Map 20: Land use 2010 ward 18



Map 21: Land use 2015 ward 18



Map 22: Land use 2017 ward 18

The land use Map 18, Map 19, Map 20, Map 21, Map 22 shows the transition of land use from 2002 to 2017.

Table 21: Land Use area in different years of Ward 18

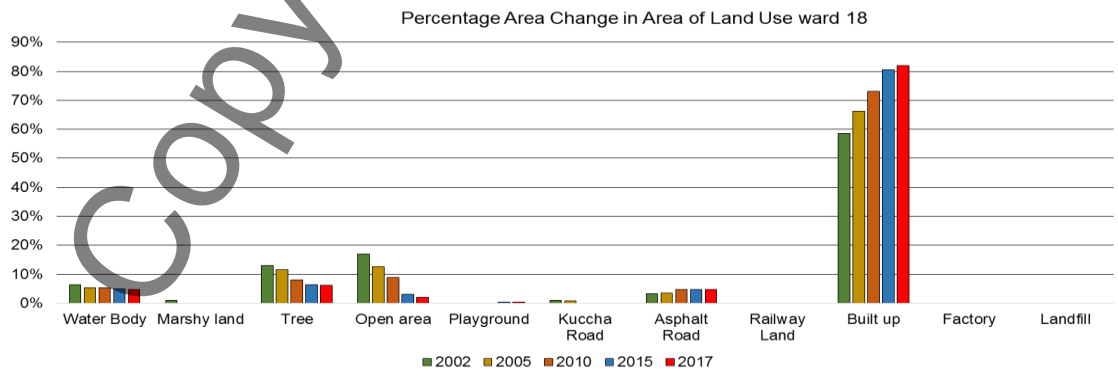
	Area in Sq Km				
Land Use	**2002**	**2005**	**2010**	**2015**	**2017**
Water Body	0.0165	0.0141	0.0138	0.0126	0.0122
Marshy land	0.0024	0.0000	0.0000	0.0000	0.0000
Tree	0.0336	0.0297	0.0207	0.0166	0.0158
Open area	0.0437	0.0328	0.0231	0.0078	0.0054
Playground	0.0000	0.0000	0.0000	0.0012	0.0012
Kuccha Road	0.0027	0.0020	0.0000	0.0000	0.0000
Asphalt Road	0.0083	0.0091	0.0123	0.0123	0.0123
Railway Land	0.0000	0.0000	0.0000	0.0000	0.0000
Built up	0.1520	0.1716	0.1893	0.2088	0.2124
Factory	0.0000	0.0000	0.0000	0.0000	0.0000
Landfill	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.2592**	**0.2592**	**0.2592**	**0.2592**	**0.2592**

Table 22: % area of each land use in different year's ward 18

Land Use	Percentage Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	6%	5%	5%	5%	5%
Marshy land	1%	0%	0%	0%	0%
Tree	13%	11%	8%	6%	6%
Open area	17%	13%	9%	3%	2%
Playground	0%	0%	0%	0%	0%
Kuccha Road	1%	1%	0%	0%	0%
Asphalt Road	3%	3%	5%	5%	5%
Railway Land	0%	0%	0%	0%	0%
Built up	59%	66%	73%	81%	82%
Factory	0%	0%	0%	0%	0%
Landfill	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Now as per Table 21 and

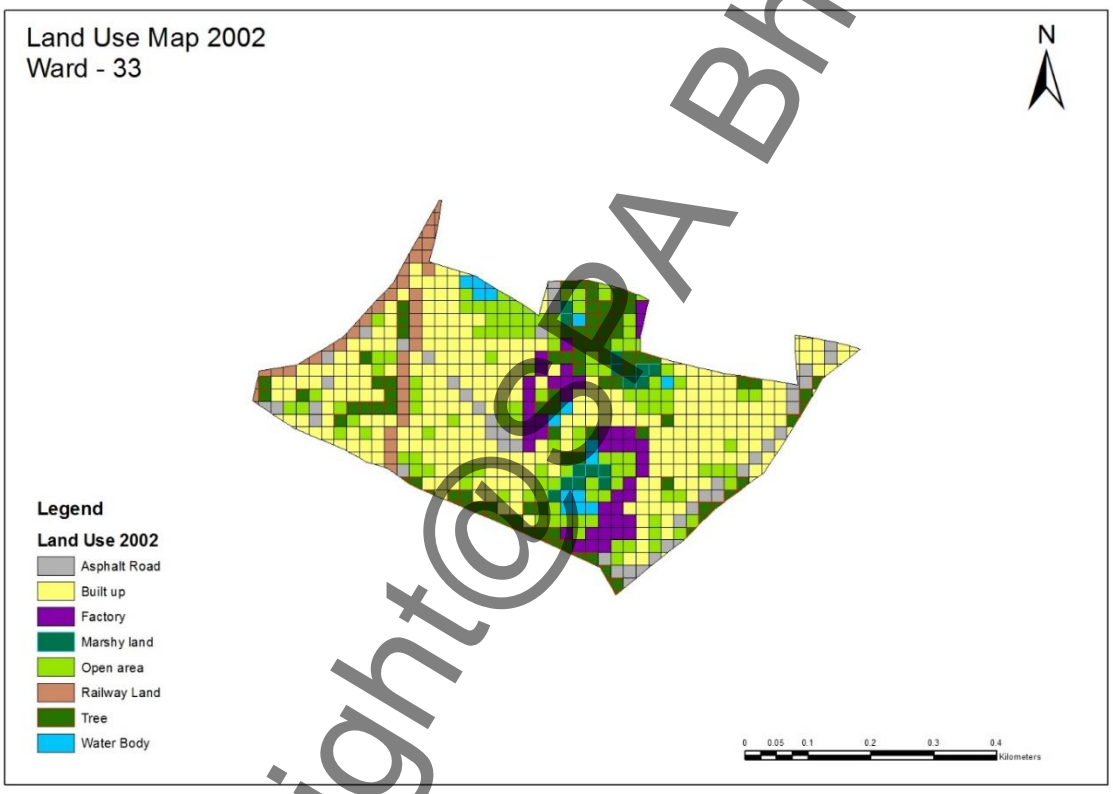
Table 22 show the distribution and percentage of different land use in the selected years. From the tables it is clear that the percentage area under water bodies have not changed a lot with just 1% change from 2002 to 2017 and the area under asphalt road has increased from 3% to 5% from 2002 to 2017 due to the conversion of kuccha road to asphalt roads. But some of the major changes that have taken place is in the change of tree cover, open area and built up land. Tree canopy have decreased from 13% to 6% by 2017, open area decreased from 17% to just 2% in 2017, but increase in built up area is from 59% in 2002 to 82% in 2017. The other important observation is that the amount of playground provided in this ward is so less that it is almost equal to zero present of the total ward area. The below Graph 2 graphically represents the change in land use of Ward 18.



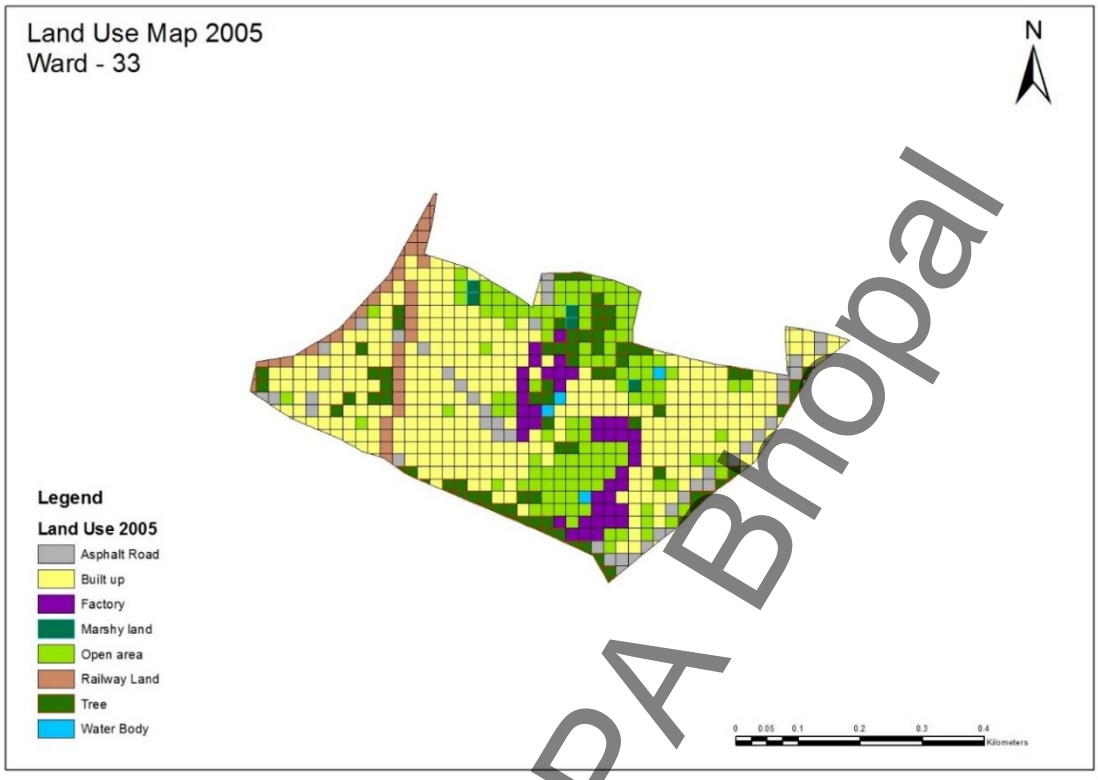
Graph 2: Change in land use of Ward 18

5.2.1.3 *Land Use of Ward 33 –*

Ward 33 is also a medium status ward with a socially low rank and economically high rank. As per visual survey this ward has a lot of slum area but due to the proximity to high status area and accessibility to major road the land value and tax rates are high in this wards. The slums are mainly along the two railway line that is which passes through this ward and so this ward has a rail way land as one of the land use but the area under this land use have not changed from 2002 to 2017 which indicates this railway area has not been encroached by the local people.

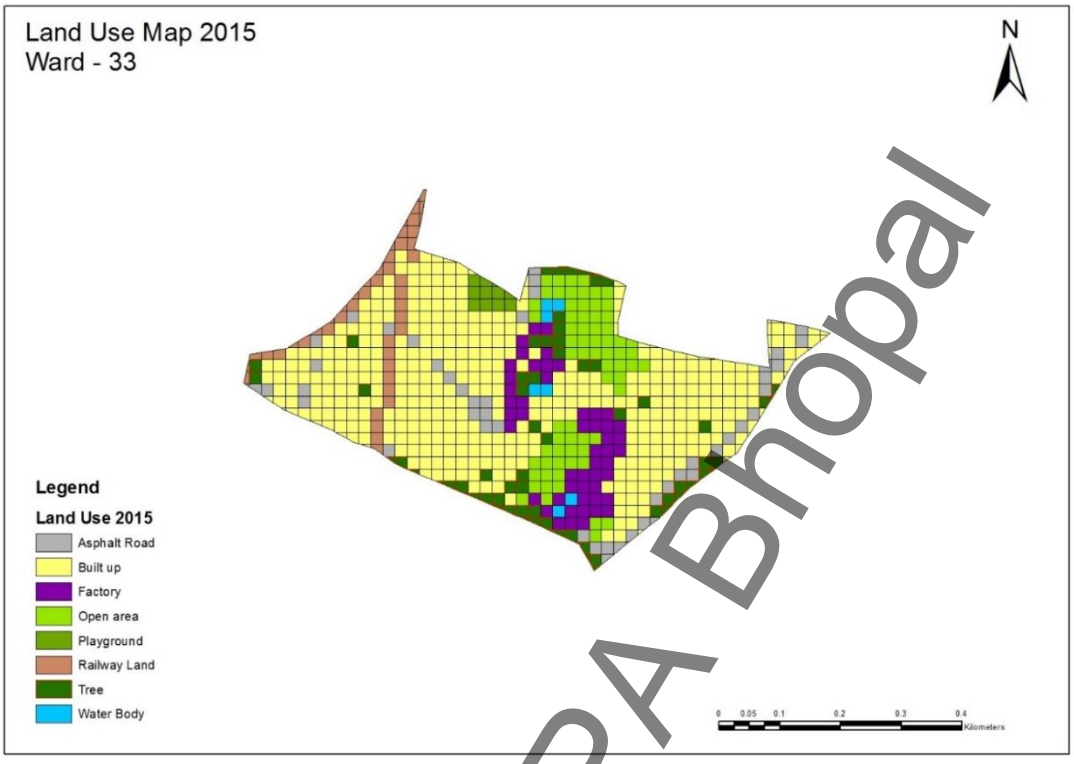


Map 23: Land use 2002 ward 33

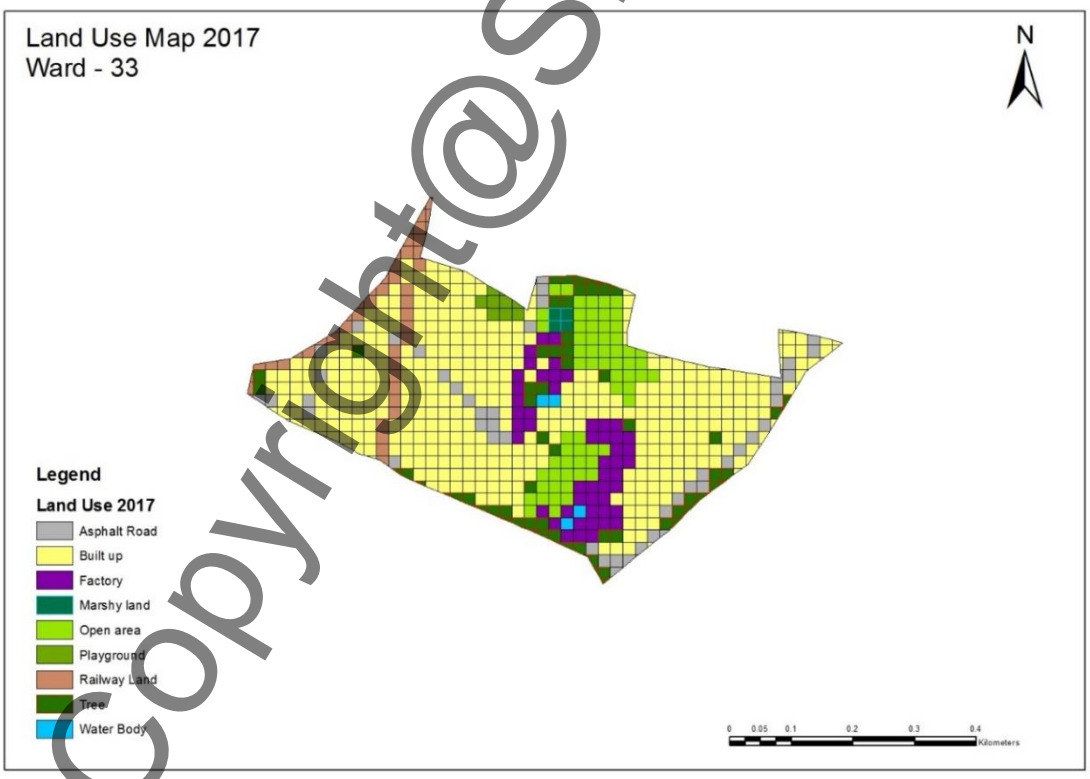


Map 24: Land use 2005 ward 33

Map 25: Land use 2010 ward 33



Map 26: Land use 2015 ward 33



Map 27: Land use 2017 ward 33

The land use Map 23, Map 24, Map 25, Map 26, Map 27 show the land use in selected years for the study. It is visible that this ward has railway area and also

factory area but do not have any land fill area. The factories that are present in this ward are not in working condition and are mainly closed condition. These factors are now mainly used as storage warehouse purpose only and these factors have huge amount of open spaces surrounding them. But even these open areas within the factory premises are being converted to built-up land use.

Table 23: Land Use area in different years of Ward 33

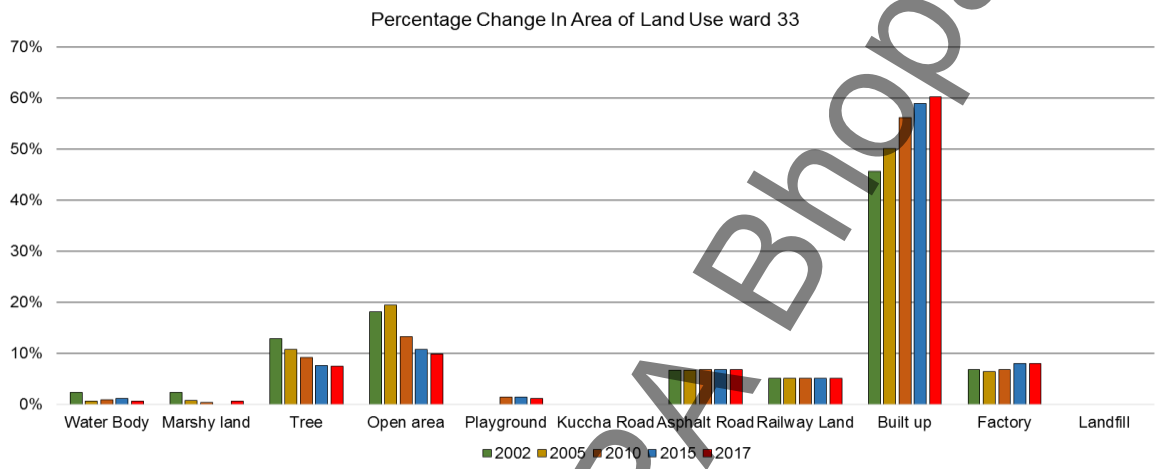
Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.006	0.002	0.002	0.003	0.002
Marshy land	0.006	0.002	0.001	0.000	0.002
Tree	0.032	0.027	0.023	0.019	0.019
Open area	0.046	0.049	0.034	0.027	0.025
Playground	0.000	0.000	0.004	0.004	0.003
Kuccha Road	0.000	0.000	0.000	0.000	0.000
Asphalt Road	0.017	0.017	0.017	0.017	0.017
Railway Land	0.013	0.013	0.013	0.013	0.013
Built up	0.116	0.127	0.142	0.149	0.152
Factory	0.017	0.016	0.017	0.020	0.020
Landfill	0.000	0.000	0.000	0.000	0.000
Total	**0.253**	**0.253**	**0.253**	**0.253**	**0.253**

Table 24: % area of each land use in different year's ward 33

Land Use	Percentage Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	2%	1%	1%	1%	1%
Marshy land	2%	1%	0%	0%	1%
Tree	13%	11%	9%	8%	8%
Open area	18%	19%	13%	11%	10%
Playground	0%	0%	1%	1%	1%
Kuccha Road	0%	0%	0%	0%	0%
Asphalt Road	7%	7%	7%	7%	7%
Railway Land	5%	5%	5%	5%	5%
Built up	46%	50%	56%	59%	60%
Factory	7%	6%	7%	8%	8%
Landfill	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

The above Table 23 and Table 24 clearly gives the detail land area and % of land covered in each category of land use. As per the two tables we can see that the area under the land use asphalt road and railway land is quite constant but built up has increased from 46% to 60% from 2002 to 2017. The decrease in open spaces

and tree canopy cover is there but not as much as the other two wards. Also the amount of water body have decreased from 2% to 1% which means that the area already had less number of water bodies and there has been further decrease in the number of water bodies in this ward. The below Graph 3 gives the graphical change in land use of the area.

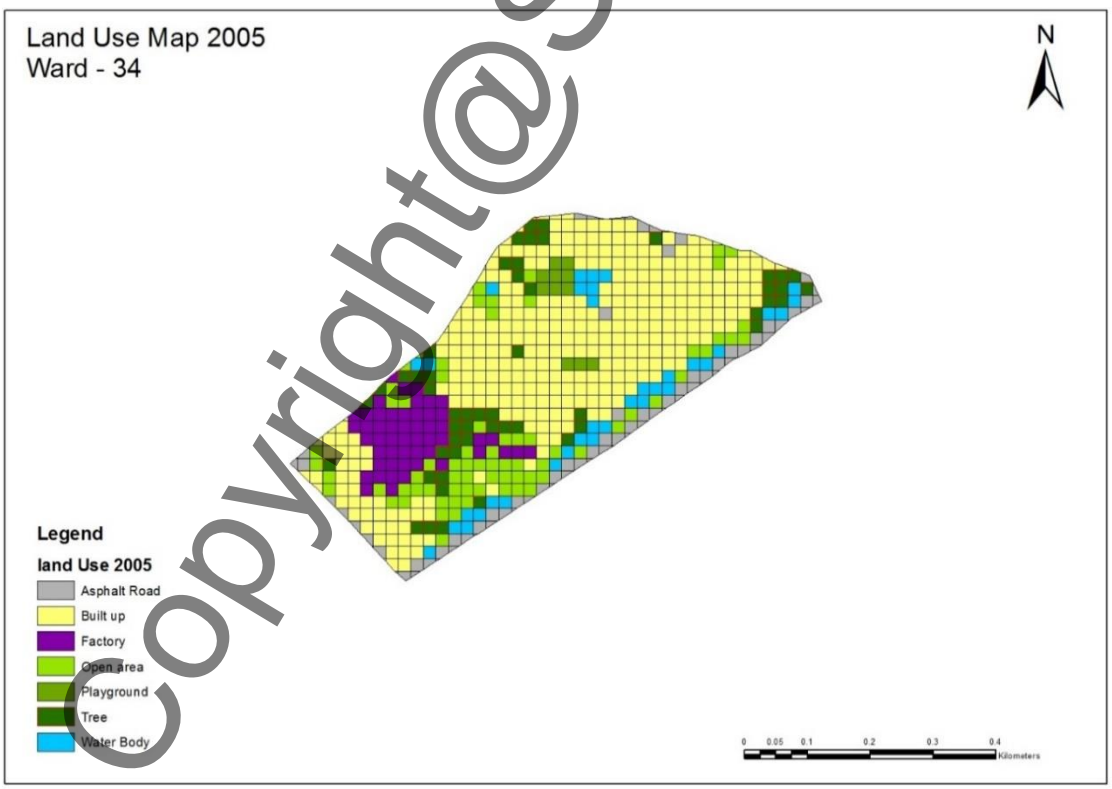


Graph 3: Change in land use of Ward 33

5.2.1.4 *Land Use of Ward 34 –*

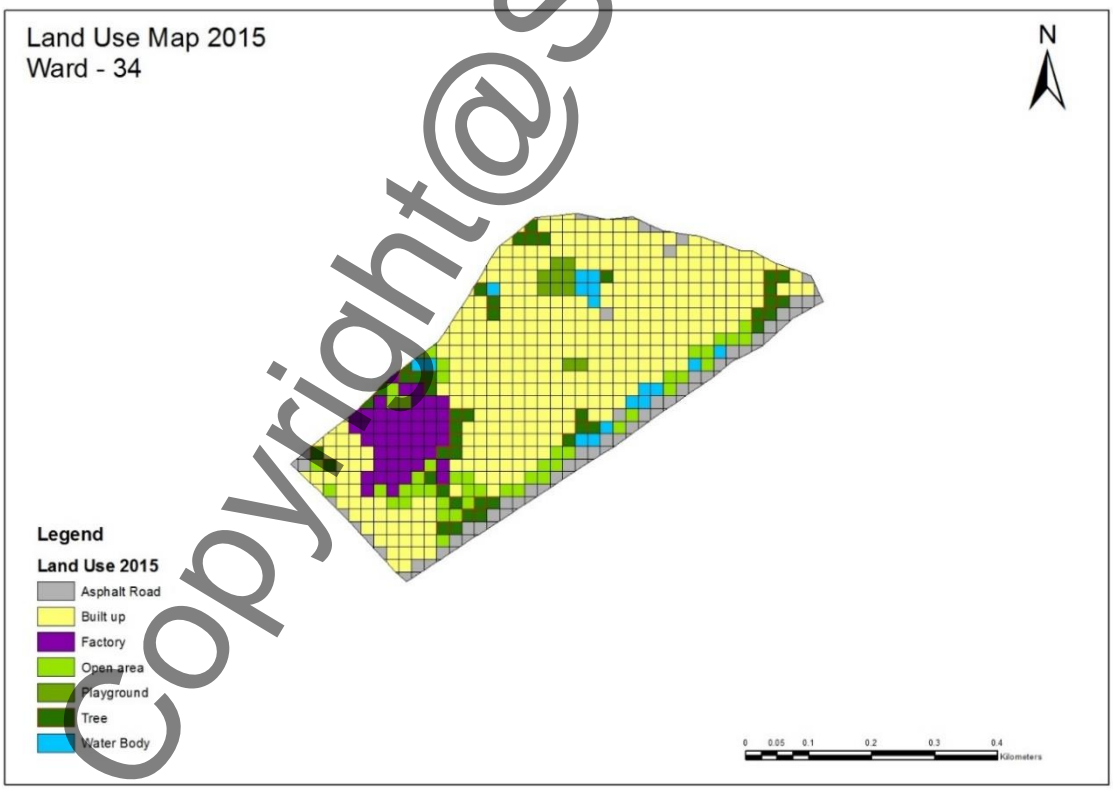
Ward 34 belongs to the high status group where both the social and economic ranking is high. This ward has well access to all major road and areas within the municipality and also there are no slums present in this ward. Even the housing typology is mostly apartment type. The land value and market property rate in this ward is highest in the municipality and pays the highest amount of tax per household in the municipality. So this ward forms the high status ward within the municipality and selected study area.

Map 28: Land use 2002 ward 34

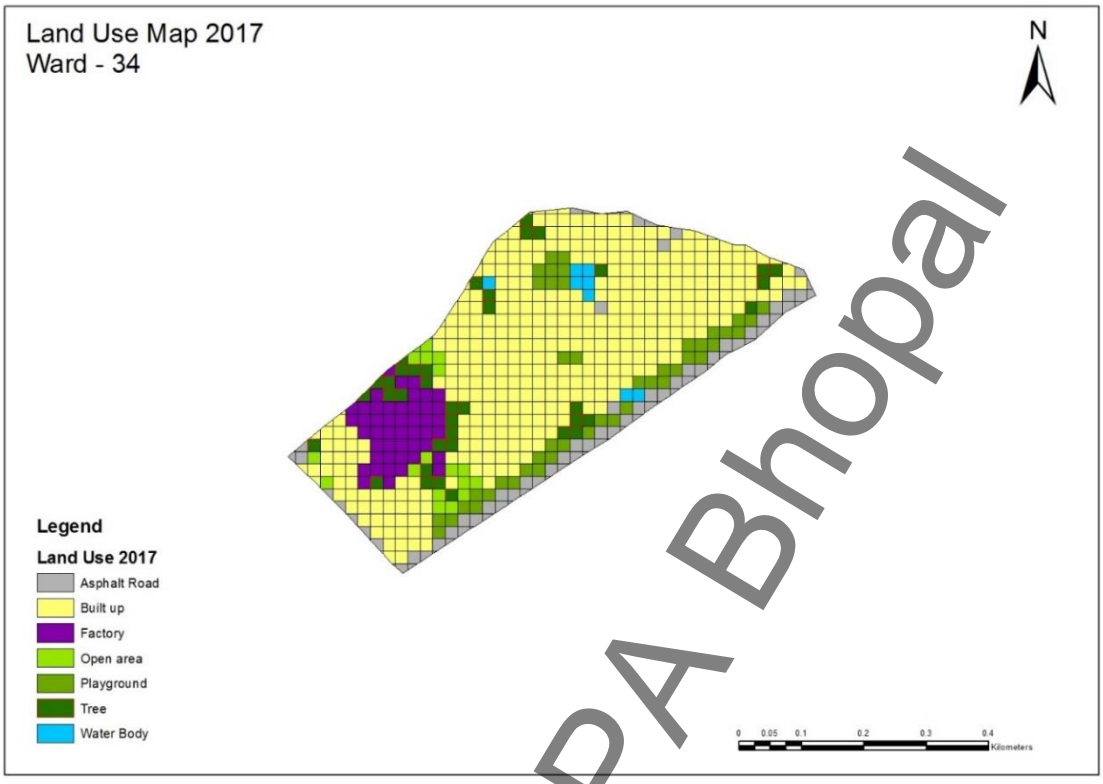


Map 29: Land use 2005 ward 34

Map 30: Land use 2010 ward 34



Map 31: Land use 2015 ward 34



Map 32: Land use 2017 ward 34

The land use Map 28, Map 29, Map 30, Map 31, Map 32 gives the clear picture of the land use pattern of the ward. We can see that a large portion of the land is allocated to factory but as these factories are in closed condition they land parcels from them are getting concerted to built-up area mainly residential areas. Also it is very much visible that in between 2015 to 2017 some of the major water bodies which from a part of the canal system along the side of major road is complete converted to playground.

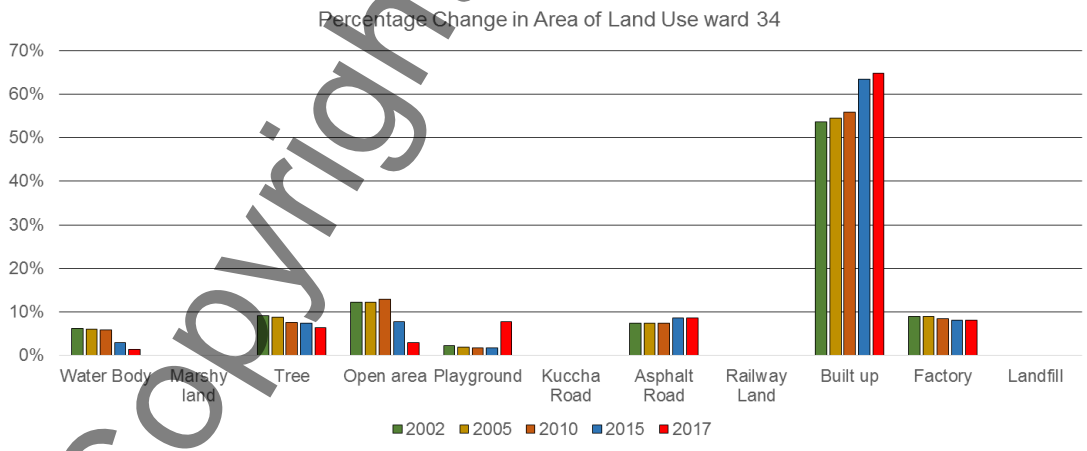
Table 25: Land Use area in different years of Ward 34

Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.014	0.014	0.014	0.007	0.003
Marshy land	0.000	0.000	0.000	0.000	0.000
Tree	0.021	0.020	0.017	0.017	0.015
Open area	0.028	0.028	0.030	0.018	0.007
Playground	0.005	0.004	0.004	0.004	0.018
Kuccha Road	0.000	0.000	0.000	0.000	0.000
Asphalt Road	0.017	0.017	0.017	0.020	0.020
Railway Land	0.000	0.000	0.000	0.000	0.000
Built up	0.124	0.126	0.129	0.146	0.149
Factory	0.021	0.021	0.019	0.019	0.019
Landfill	0.000	0.000	0.000	0.000	0.000
Total	**0.230**	**0.230**	**0.230**	**0.230**	**0.230**

Table 26: % area of each land use in different year's ward 34

Land Use	Percentage Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	6%	6%	6%	3%	1%
Marshy land	0%	0%	0%	0%	0%
Tree	9%	9%	8%	7%	6%
Open area	12%	12%	13%	8%	3%
Playground	2%	2%	2%	2%	8%
Kuccha Road	0%	0%	0%	0%	0%
Asphalt Road	7%	7%	7%	9%	9%
Railway Land	0%	0%	0%	0%	0%
Built up	54%	55%	56%	63%	65%
Factory	9%	9%	8%	8%	8%
Landfill	0%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

The above Table 25 and Table 26 shows the land use area and % of area of the land use. The two table shows that there has been decrease of water bodies from 6% to 1% from 2002 to 2017 mainly because of conversion of canal to playground area. While loss in open area is from 12% to 3% which do not include the play grounds. Also built up has increased from 54% to 65% as the factory area has been converted to built-up land use. Some of the other increase are increase in playground which was just 2% in 2002 and in 2017 it became 8% and also increase in asphalt road as open land converted to service lane in this ward. The land use change Graph 4 below show the variation of land use over the years.



Graph 4: Change in land use of Ward 34

5.2.2 Land Cover Change

Just like the previous analysis the land cover analysis also follows the same methodology or process as the grid system where we divide the selected wards into 20 metre X 20 metre grids. Even the temporal aerial image of Google Earth Pro has been used and the years are same as land use years. So for this analysis we use identify the land cover instead of the land use and the dominant land cover is identified and marked using Arc GIS software. The basic land cover category that have been used are Asphalt, Built, Shrub, Rough, Trees, Water, Others, Bare ground and Turf Grass.

Table 27: Land Cover and their related Land Use

Asphalt	**Built**		**Shrubs**	
Asphalt Road	Factory	Built up	Opens Spaces	Trees
Rough Grass	**Trees**	**Water**	**Others**	
Marshy Land	Trees	Water Bodies	Landfill	Railway Land
Bare Ground and Turf Grass				
Kaccha Road	Open spaces		Play Grounds	

The Table 27 shows the grouping of land use under different land cover. As per the table we see that entire open area has not been considered under “Bare ground and Turf grass”, this is because the land is not completely bare and do have some small hedges and shrub like plant so those areas that are clearly visible under aerial image have been marked as Shrubs. Even in case of trees especially in private gardens of local residents it is visible that shrubs has been planted along with trees so those area have been marked as shrub land cover. The reason behind considering Kuccha road as bare ground as they are not permanent and are just dirt track made by compacting mud. For the purpose of analysing the amount of vegetative cover space we calculate all area under bare soil and turf grass, rough grass, shrub and tree which gives us the total green space of the area and for calculating the amount of built environment present in the micro study areas we calculate the sum of all built and asphalt land cover. Now as we see that built land cover is the combination of all area under built- up and factory areas. Finally we

determine the ratio of built environment verses the total green space in each selected wards and in a temporal manner.

5.2.2.1 *Land Cover Calculation*

Sample Calculation (Built Environment by Total green space ratio)

Considering the area of Ward 3 in year 2002

Land cover area:

Bare soil and Turf grass – 0.42 Sq Km (a)

Rough Grass – 0.01 Sq Km (b)

Shrub – 0.06 Sq Km (c)

Tree – 1.14 (d)

Total Green Space (A) = (a) + (b) + (c) + (d) => 0.42 + 0.01 + 0.06 + 0.14 = 1.64 Sq Km

Built – 0.15 Sq Km (B)

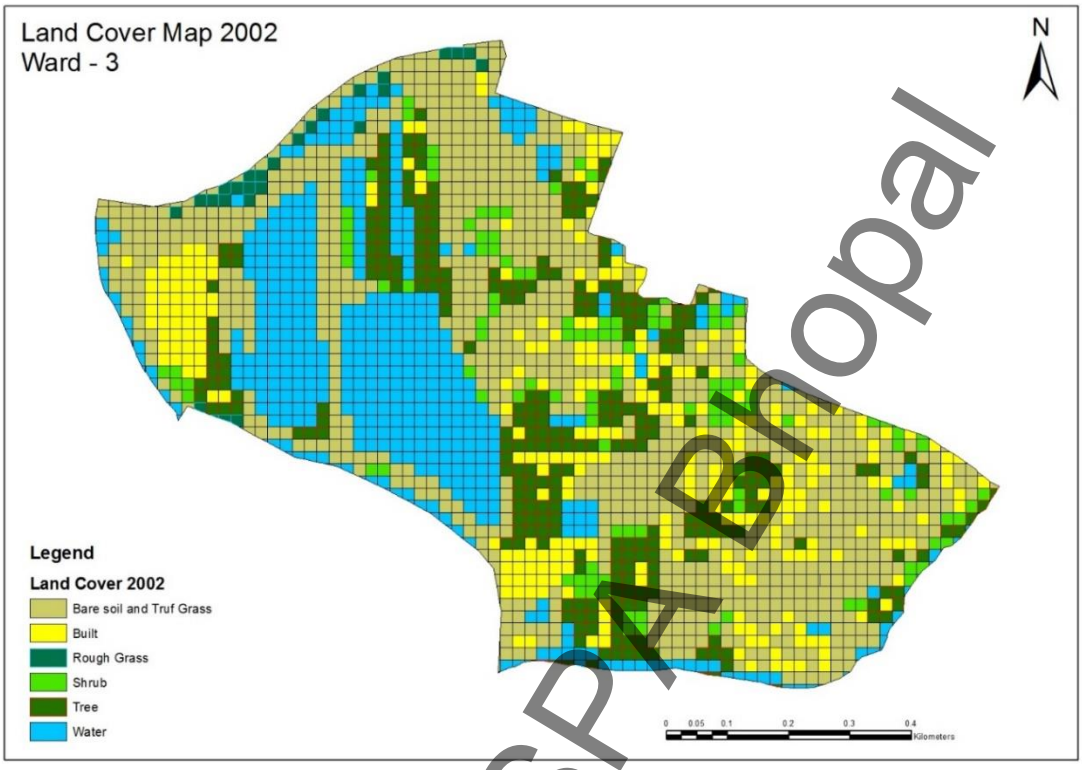
Asphalt – 0 Sq Km (C)

Built Environment (D) = (B) + (C) => 0.15 + 0 = 0.15

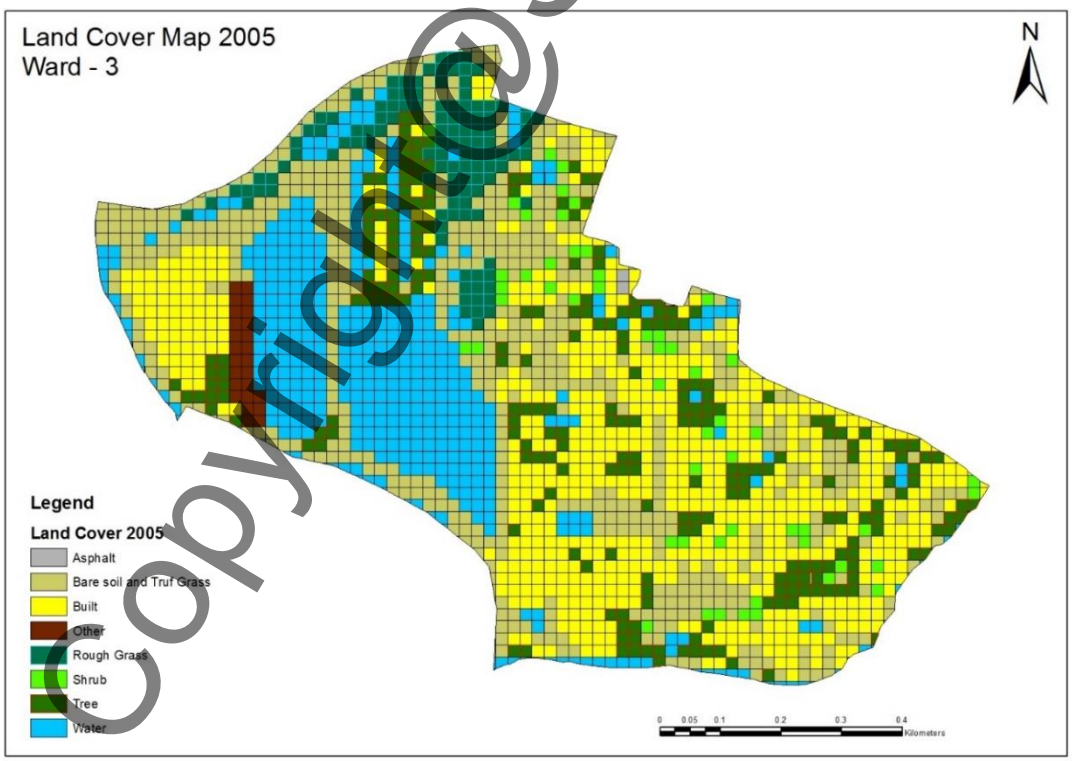
Ratio of Built Environment (D) by Total Green Space (A) => (D) / (A) = 1.64/0.15 = 0.09.

This calculation is repeated for all the selected years and the selected micro study area and finally we find the variation in ratio of the built environment to the total green space in each wards.

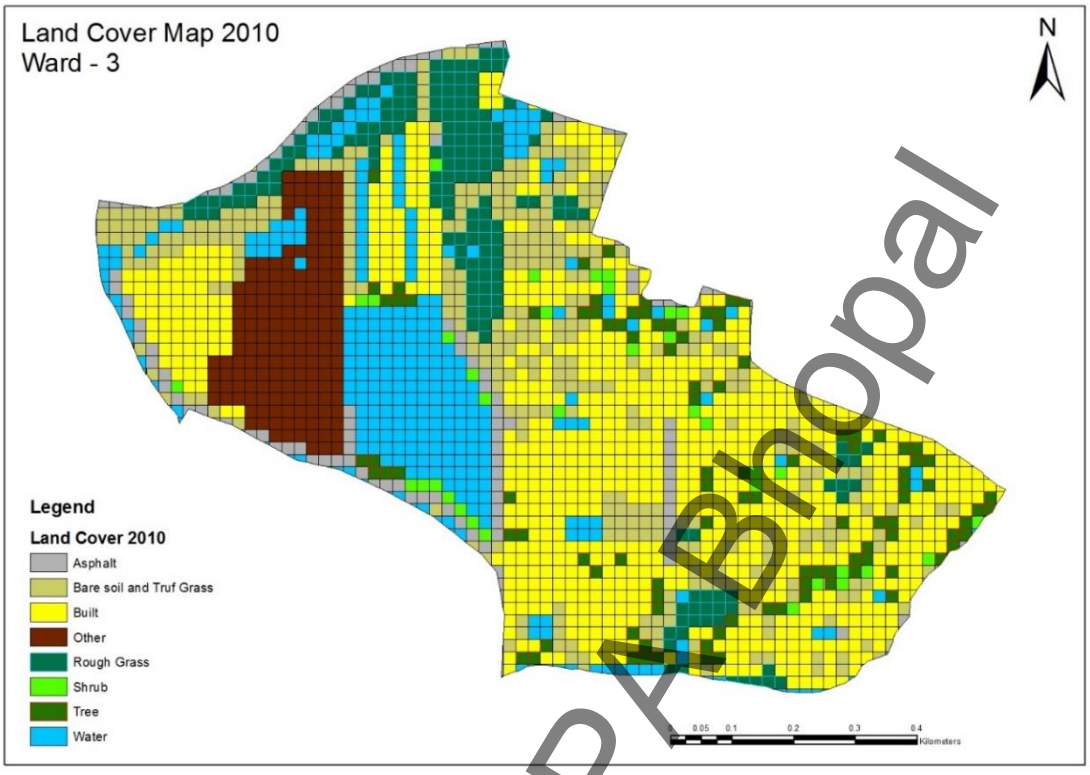
5.2.2.2 *Land Cover of Ward 3 –*



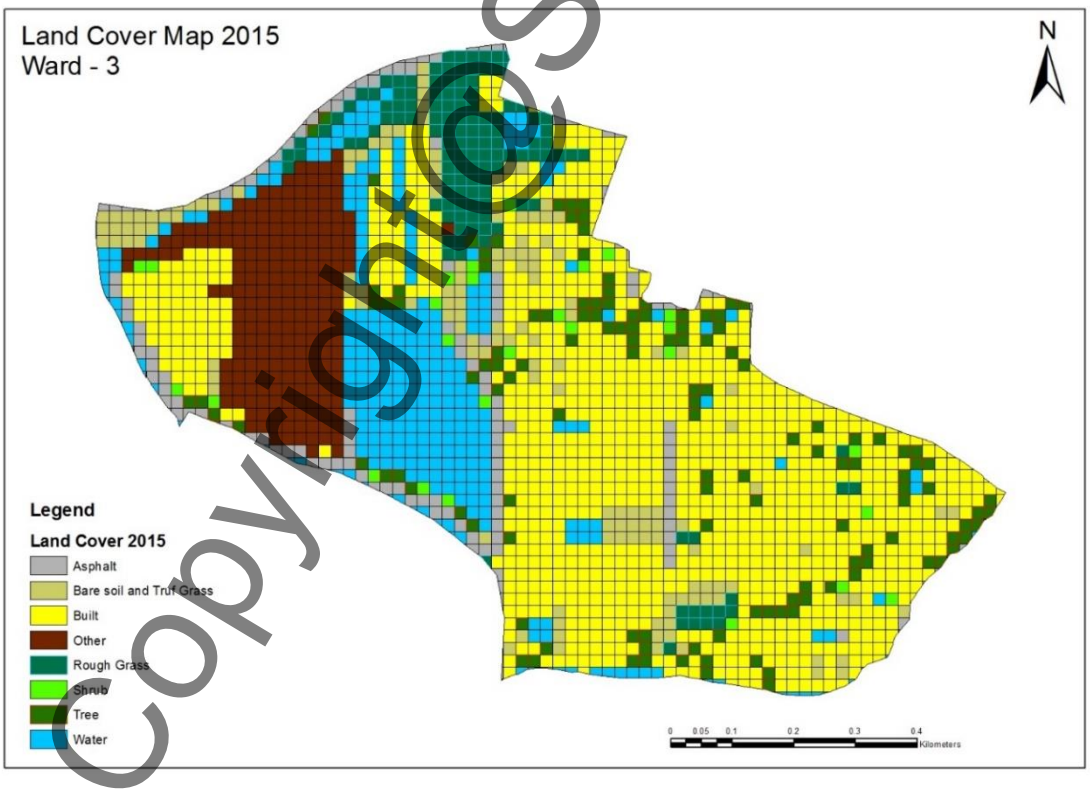
Map 33: Land Cover 2002 ward 3



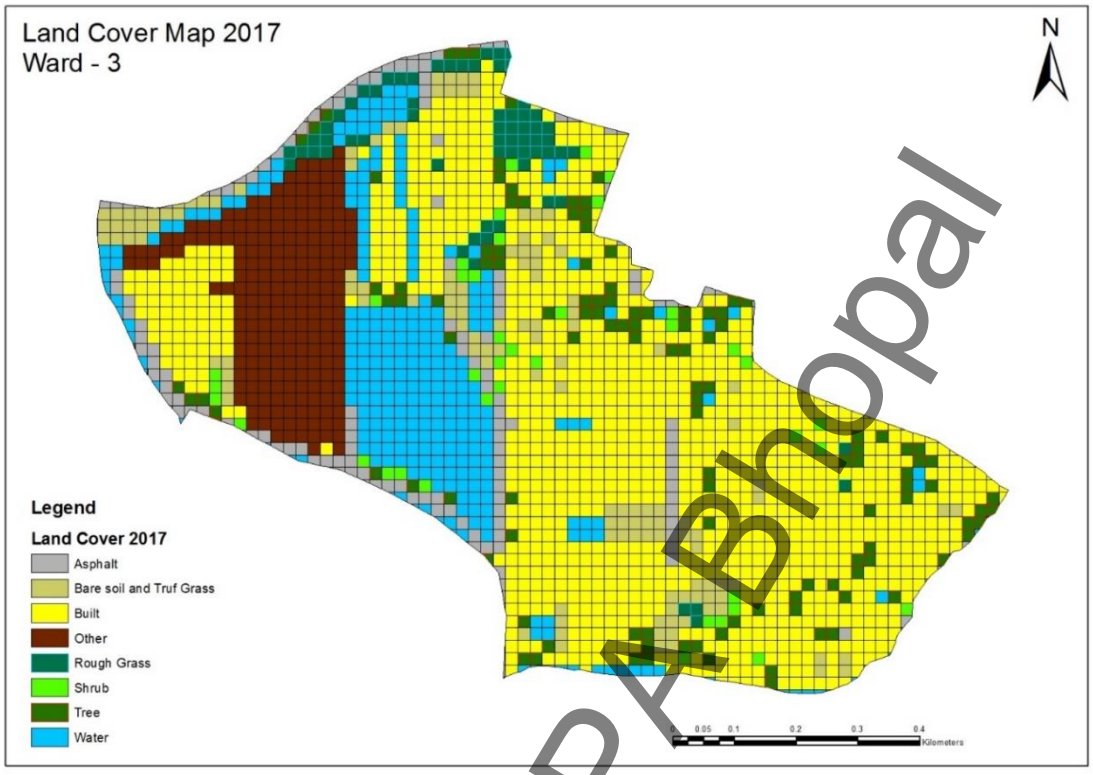
Map 34: Land Cover 2005 ward 3



Map 35: Land Cover 2010 ward 3



Map 36: Land Cover 2015 ward 3



Map 37: Land Cover 2017 ward 3

From the above Map 33, Map 34, Map 35, Map 36 and Map 37 we determine the area of the different land cover category and then as per the Sample Calculation we calculate the ratio of built environment to the total green space.

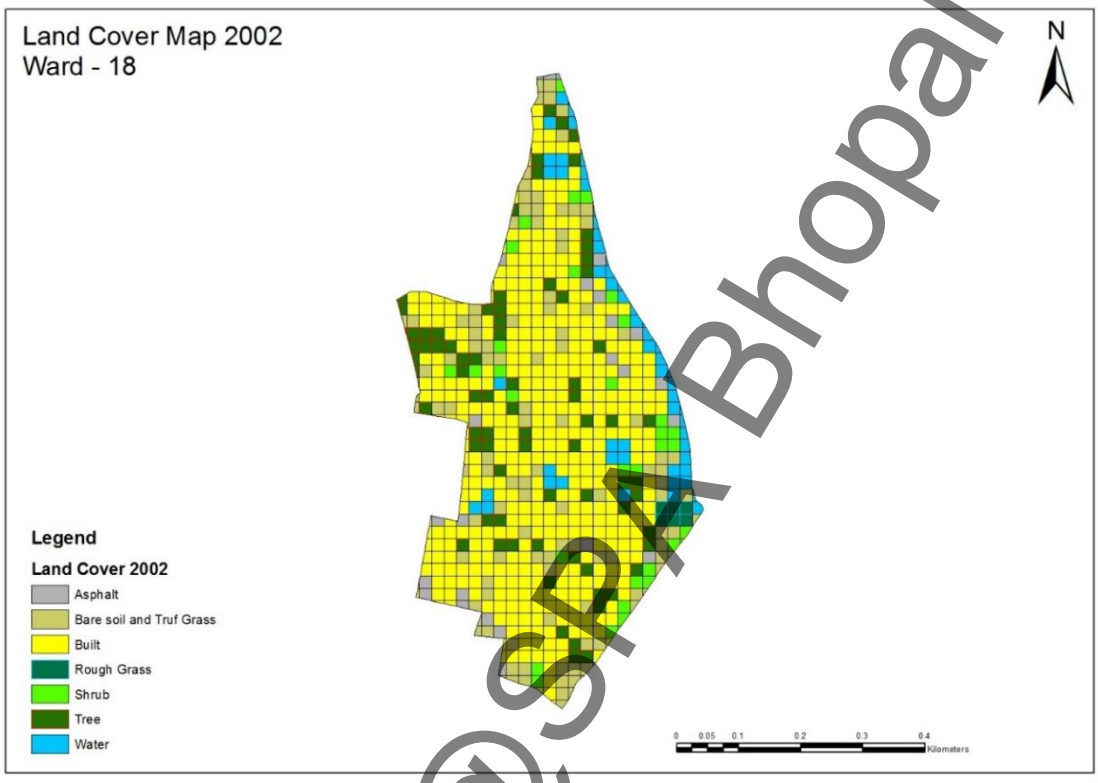
Table 28: Result of Built environment to Total Green Space

Types of Spaces	Percentage Area-(Ward 3)				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.42	0.27	0.17	0.07	0.07
Rough Grass	0.01	0.06	0.09	0.07	0.03
Shrub	0.06	0.03	0.02	0.01	0.02
Tree	0.15	0.12	0.05	0.07	0.06
Total Green Space (A)	**0.64**	**0.47**	**0.33**	**0.22**	**0.18**
Built (B)	0.15	0.31	0.40	0.48	0.52
Asphalt (C)	0.00	0.00	0.05	0.05	0.06
Built Environment (D= B+C)	**0.15**	**0.31**	**0.44**	**0.53**	**0.57**
Built Environment/ Total Green Space (E= D/A)	***0.23***	***0.66***	***1.33***	***2.42***	***3.19***

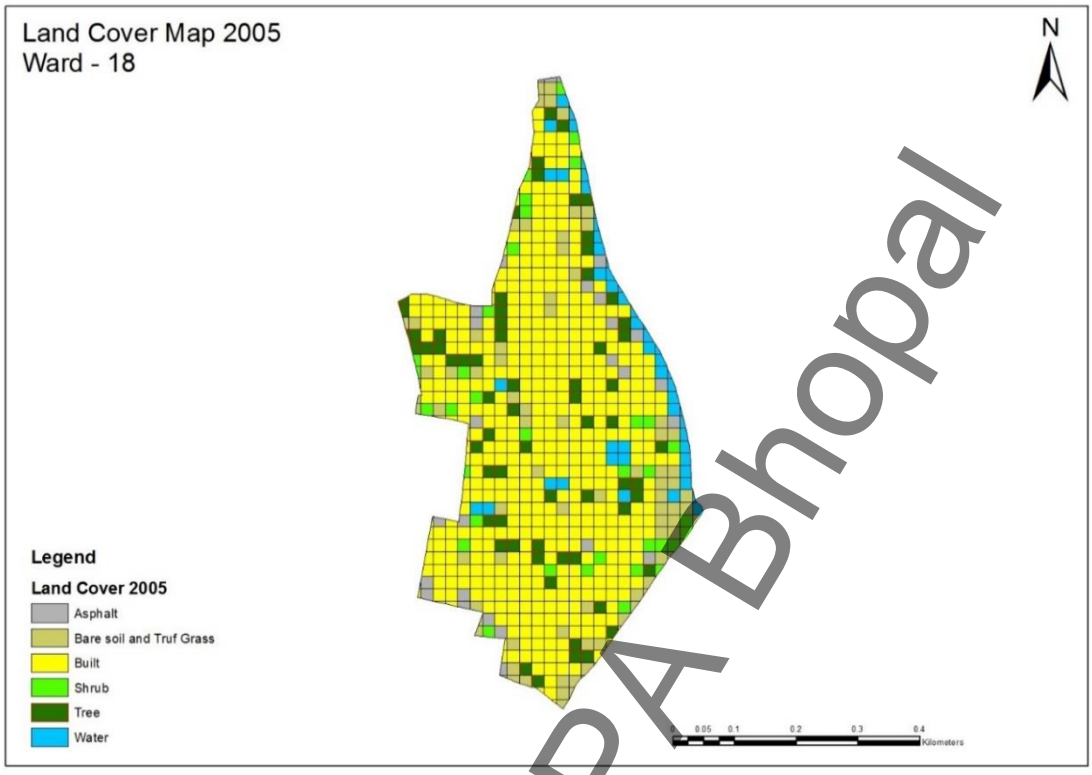
The Table 28 shows the area under each land cover, the summation of the total green space and the built environment and the ratio of built environment to total green space. From the table it is clear that the value of the ratio is increasing as

the area under is built environment is dominating over total green area in a temporal pattern.

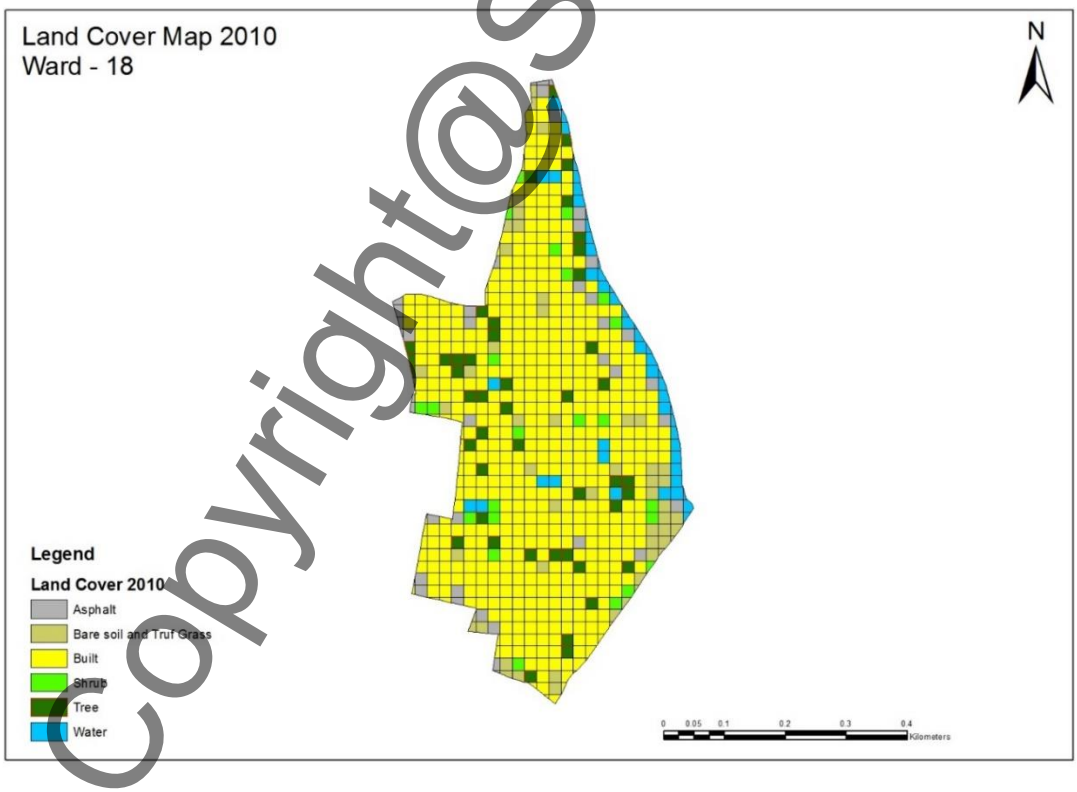
5.2.2.3 *Land Cover of Ward 18 –*



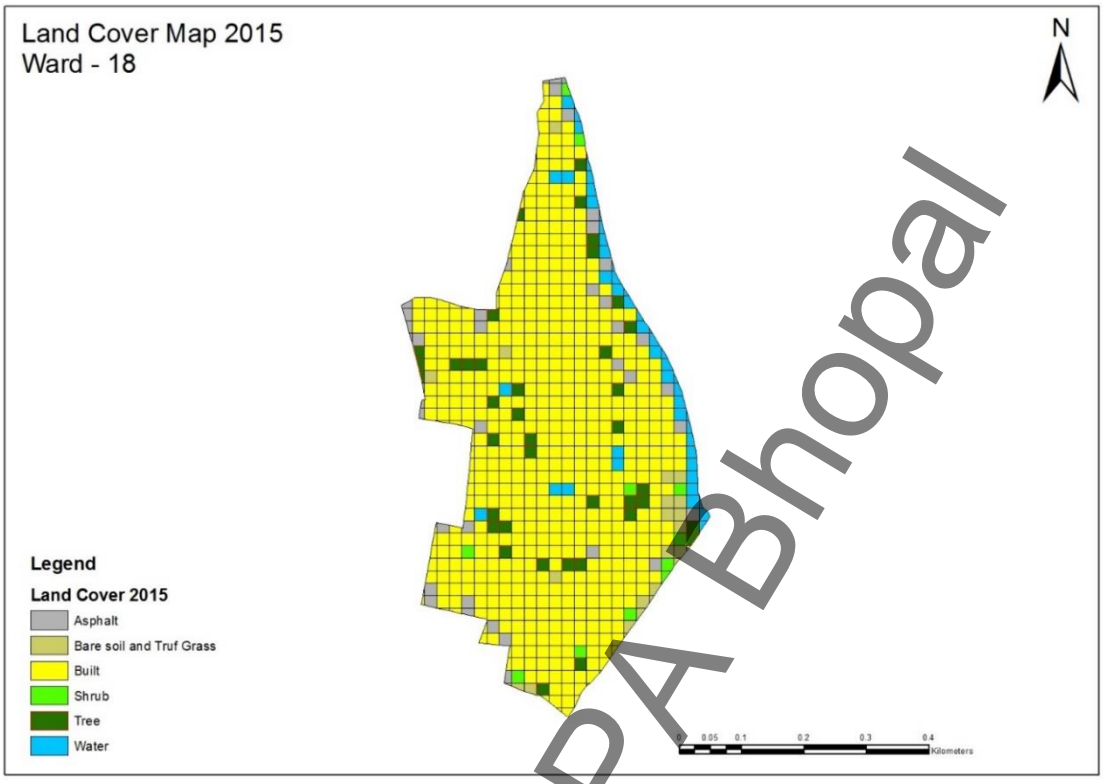
Map 38: Land Cover 2002 ward 18



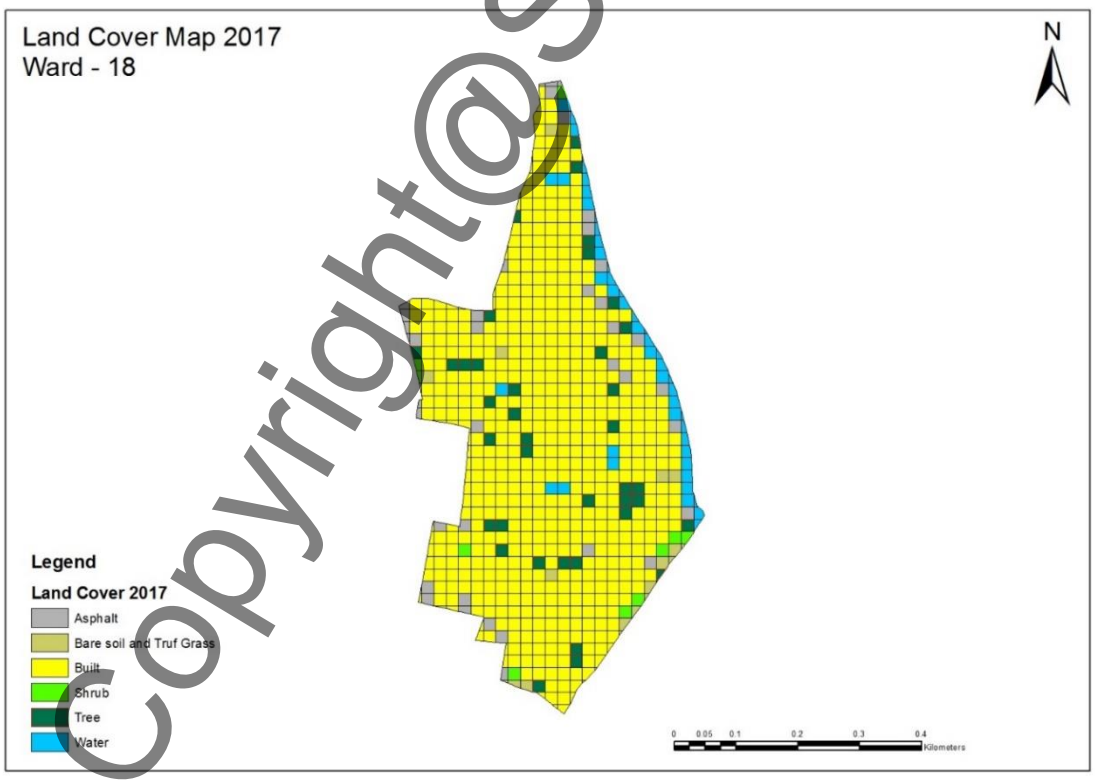
Map 39: Land Cover 2005 ward 18



Map 40: Land Cover 2010 ward 18



Map 41: Land Cover 2015 ward 18



Map 42: Land Cover 2017 ward 18

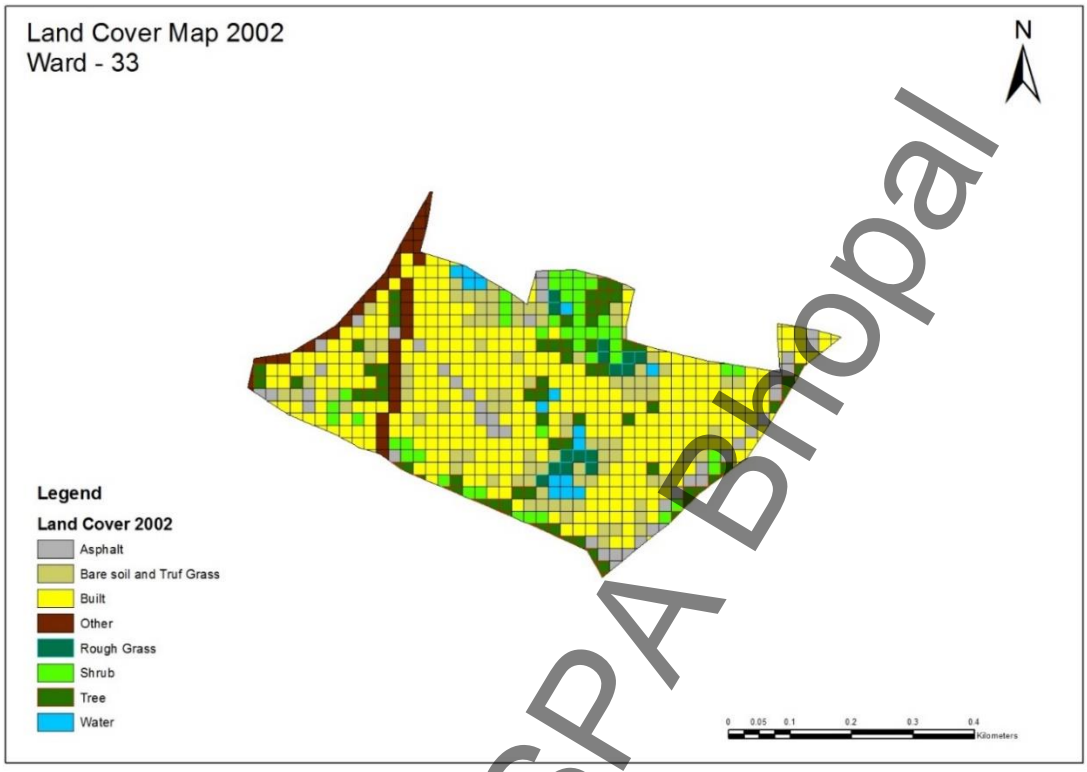
The Map 38, Map 39, Map 40, Map 41 and Map 42 spatial represents the temporal change of land cover in ward 18 and from these map determine the temporal change in area of the land cover and calculate the total green space and built environment and then calculate the ratio of the built environment verses the total green spaces.

Table 29: Result of Built environment to Total Green Space

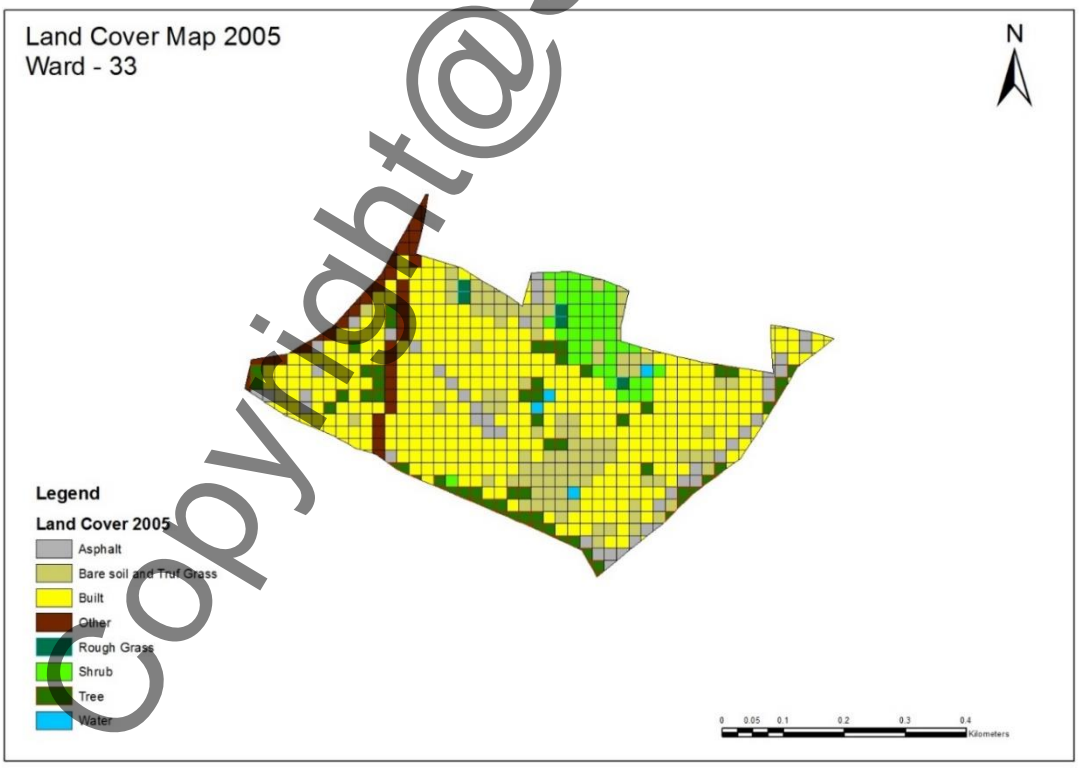
Types of Spaces	Percentage Area- Ward 18				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.149	0.112	0.069	0.027	0.018
Rough Grass	0.009	0.000	0.000	0.000	0.000
Shrub	0.047	0.048	0.033	0.015	0.012
Tree	0.112	0.096	0.068	0.057	0.056
Total Green Space (A)	**0.318**	**0.256**	**0.169**	**0.099**	**0.086**
Built (B)	0.586	0.658	0.730	0.806	0.819
Asphalt (C)	0.032	0.035	0.047	0.047	0.047
Built Environment (D= B+C)	**0.618**	**0.693**	**0.778**	**0.853**	**0.867**
Built Environment/ Total Green Space (E= D/A)	***1.945***	***2.704***	***4.595***	***8.640***	***10.036***

From the Table 29 it is clear that from 2002 the amount of built environment is more than the amount of total green space available in the ward. But in recent years this value of the ratio has increased indicating increase in more amount of built cover.

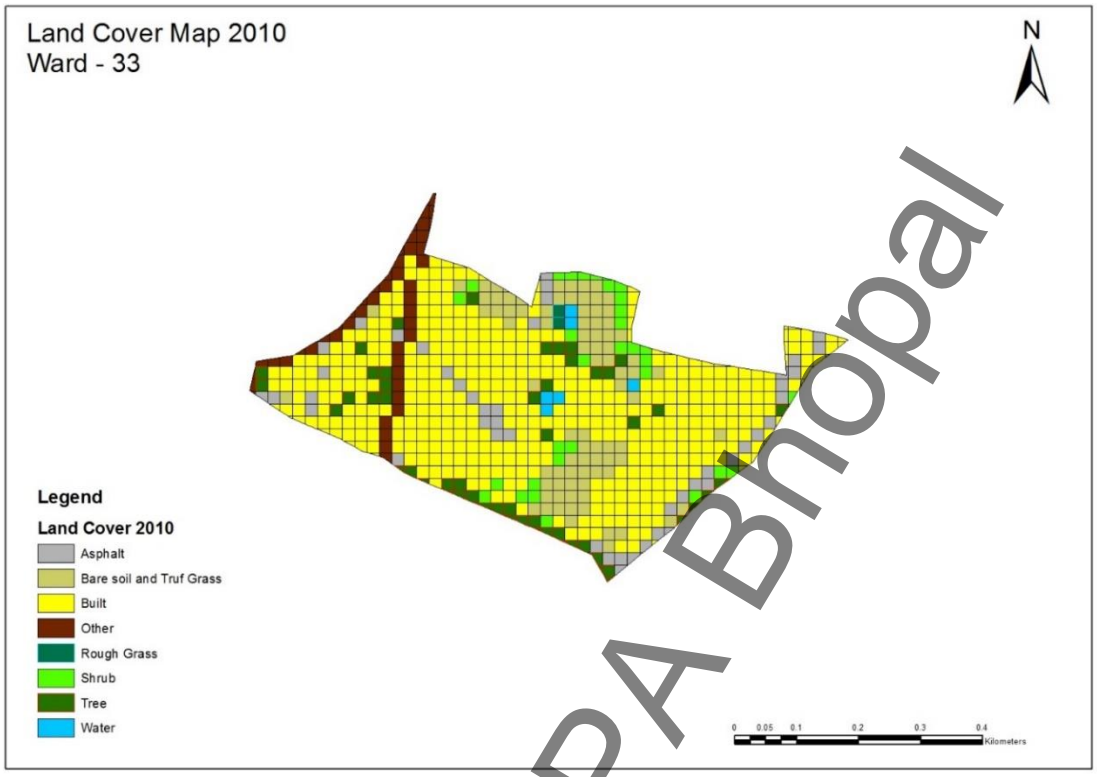
5.2.2.4 *Land Cover of Ward 33 –*



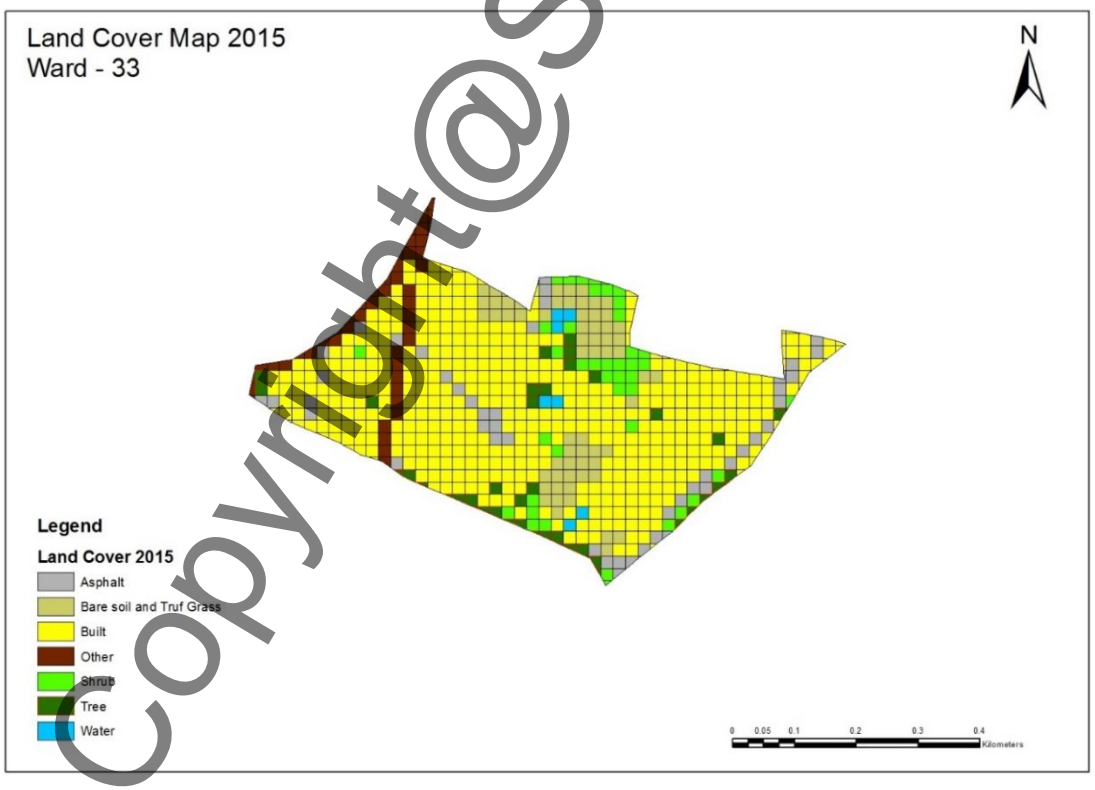
Map 43: Land Cover 2002 ward 33



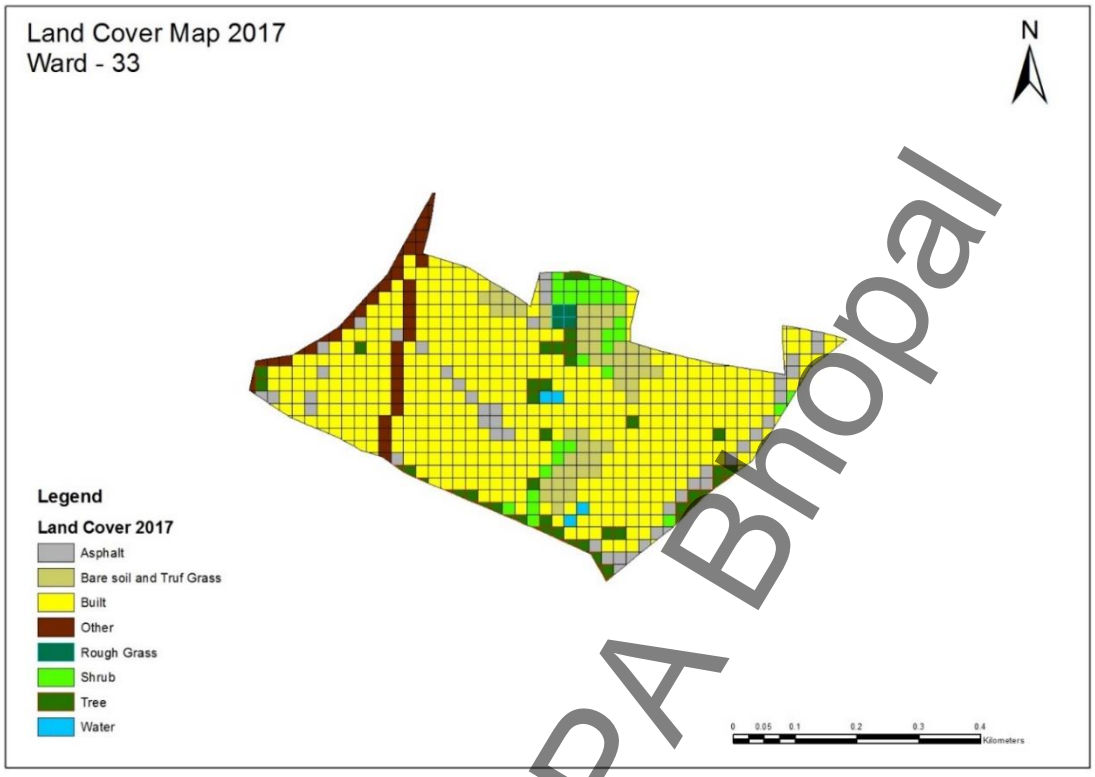
Map 44: Land Cover 2005 ward 33



Map 45: Land Cover 2010 ward 33



Map 46: Land Cover 2015 ward 33



Map 47: Land Cover 2017 ward 33

After representing the land cover in Map 43, Map 44, Map 45, Map 46 and Map 47 as per the previous way we calculate the area of each land cover, total green space, built environment and the ratio of built environment to total green spaces for the ward in temporal manner.

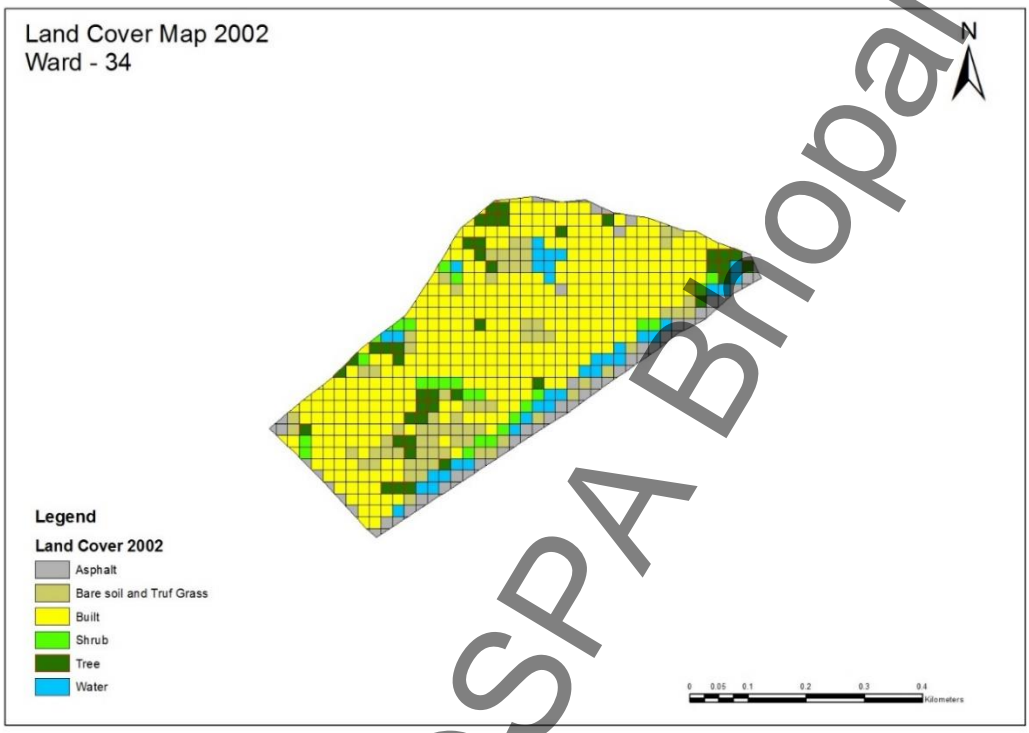
Table 30: Result of Built environment to Total Green Space

Types of Spaces	Percentage Area - Ward 33				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.15	0.15	0.13	0.10	0.08
Rough Grass	0.02	0.01	0.00	0.00	0.01
Shrub	0.07	0.07	0.04	0.06	0.05
Tree	0.09	0.08	0.06	0.04	0.05
Total Green Space (A)	**0.33**	**0.31**	**0.24**	**0.20**	**0.19**
Built (B)	0.52	0.57	0.63	0.67	0.68
Asphalt (C)	0.07	0.07	0.07	0.07	0.07
Built Environment (D= B+C)	**0.59**	**0.63**	**0.70**	**0.74**	**0.75**
Built Environment/ Total Green Space (E= D/A)	***1.77***	***2.04***	***2.89***	***3.71***	***3.93***

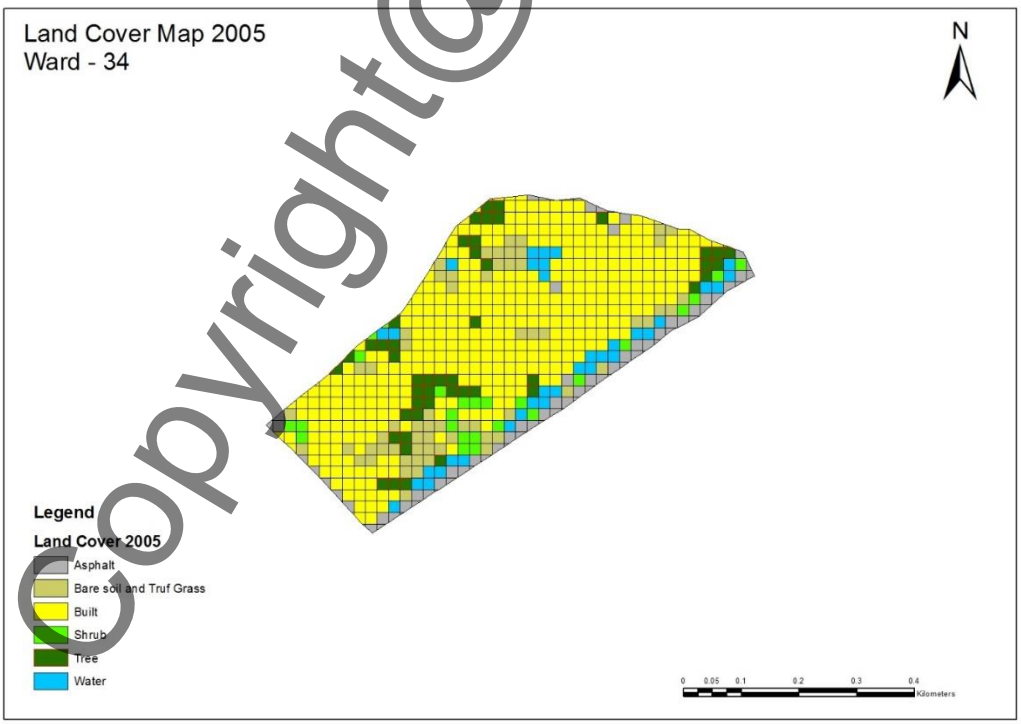
The Table 30 gives the final result of built environment verses the total green space for ward 33. Even in this case it is seen that in 2002 the built environment is more

that the total green space as a result of which the ratio is high and further increase results in more increase in value of the ratio.

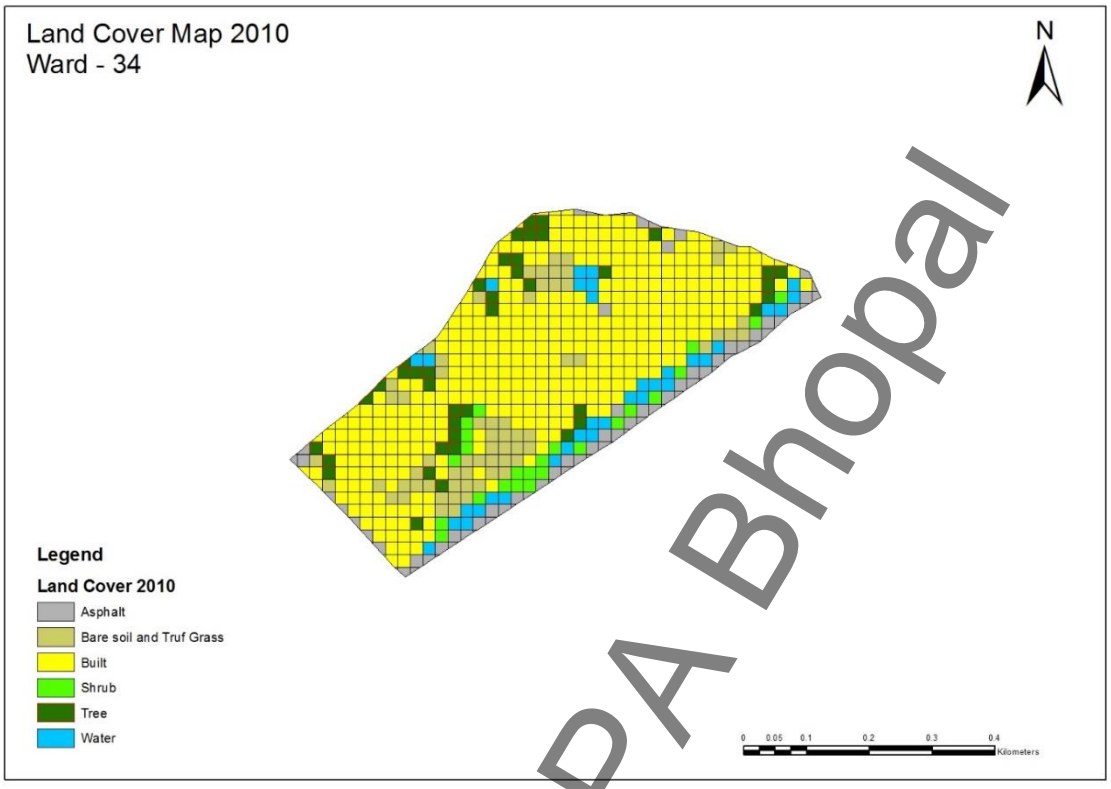
5.2.2.5 *Land Cover of Ward 34 –*



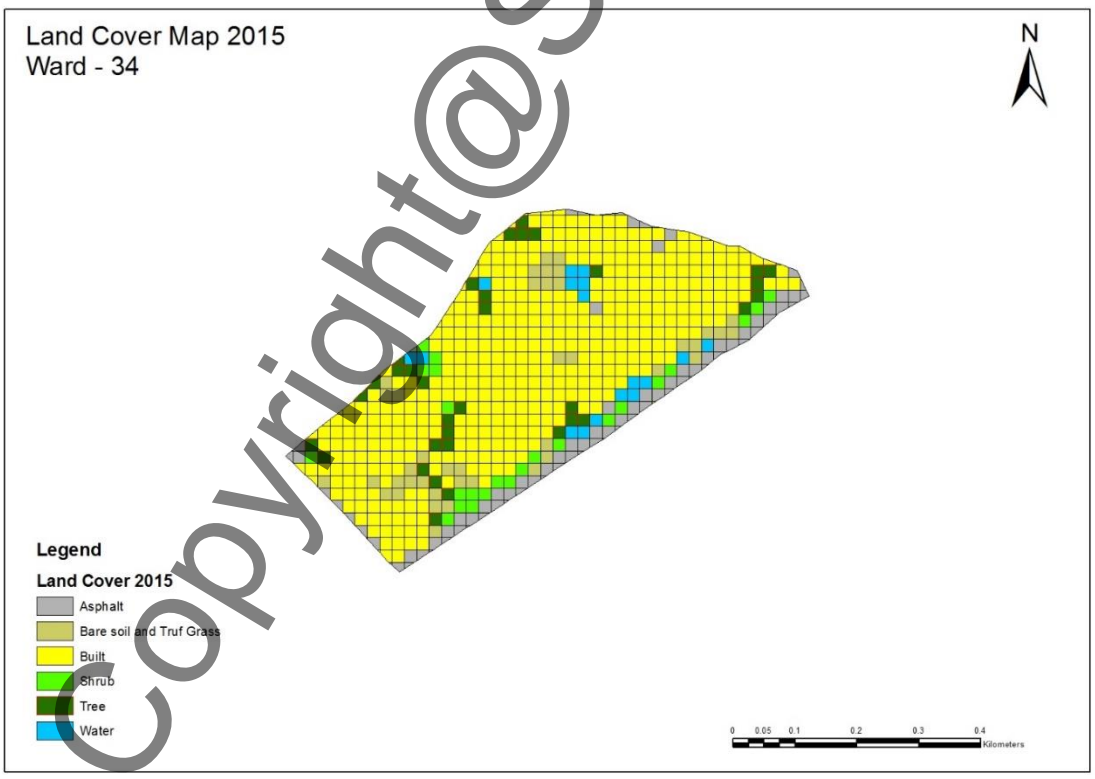
Map 48: Land Cover 2002 ward 34



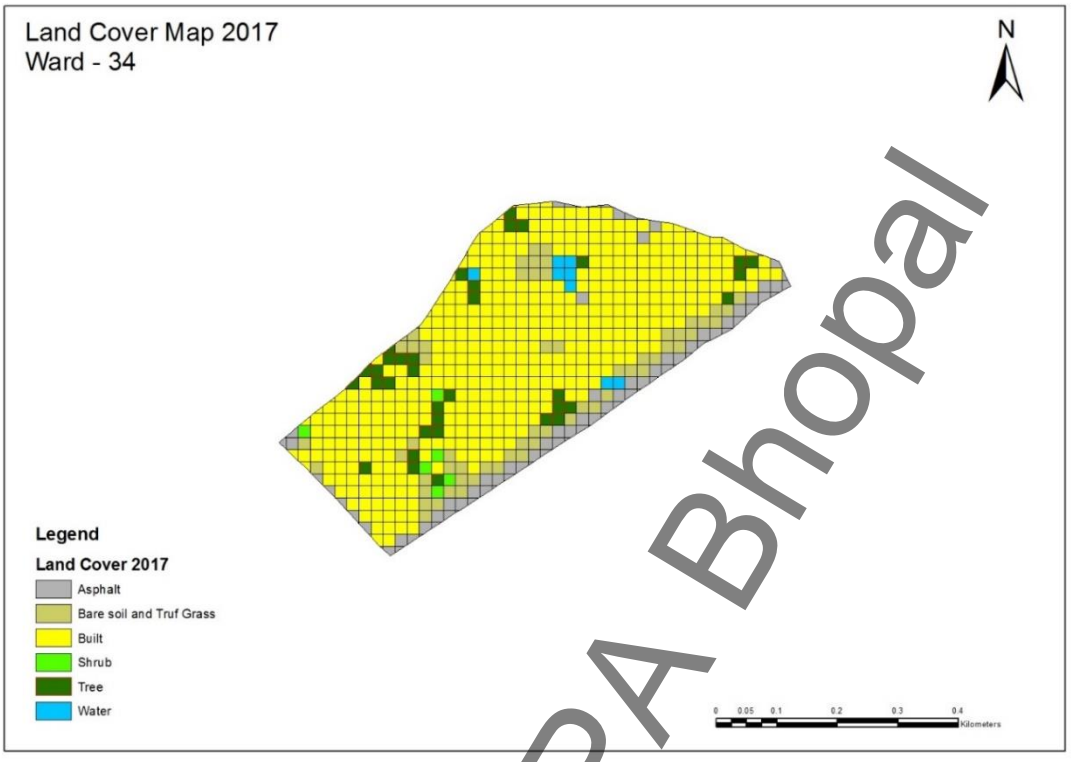
Map 49: Land Cover 2005 ward 34



Map 50: Land Cover 2010 ward 34



Map 51: Land Cover 2015 ward 34



Map 52: Land Cover 2017 ward 34

So the land cover of ward 34 is spatially represented in Map 48, Map 49, Map 51 and Map 52 from which we calculate the land cover category area, total green space, built environment and the ratio between built environment to total; green space in the similar process.

Table 31: Result of Built environment to Total Green Space

Types of Spaces	Percentage Area- ward 34				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.12	0.11	0.11	0.07	0.10
Rough Grass	0.00	0.00	0.00	0.00	0.00
Shrub	0.04	0.04	0.04	0.04	0.01
Tree	0.07	0.08	0.07	0.06	0.06
Total Green Space (A)	**0.24**	**0.23**	**0.22**	**0.17**	**0.17**
Built (B)	0.63	0.63	0.64	0.71	0.73
Asphalt (C)	0.07	0.07	0.07	0.09	0.09
Built Environment (D= B+C)	**0.70**	**0.71**	**0.72**	**0.80**	**0.81**
Built Environment/ Total Green Space (E= D/A)	***2.96***	***3.09***	***3.22***	***4.73***	***4.76***

Therefore the Table 31 represent the final result of the built environment to total green space ratio which shows that the built environment is more in area than the total green space. The complete land cover analysis shows that in all the four wards

over the time the built environment have increased and the total green spaces are reducing. So amount of green space per built land is very low and decreasing at an alarming rate.

5.3 Relation between Land use, Land Cover and the Socio – Economic Condition

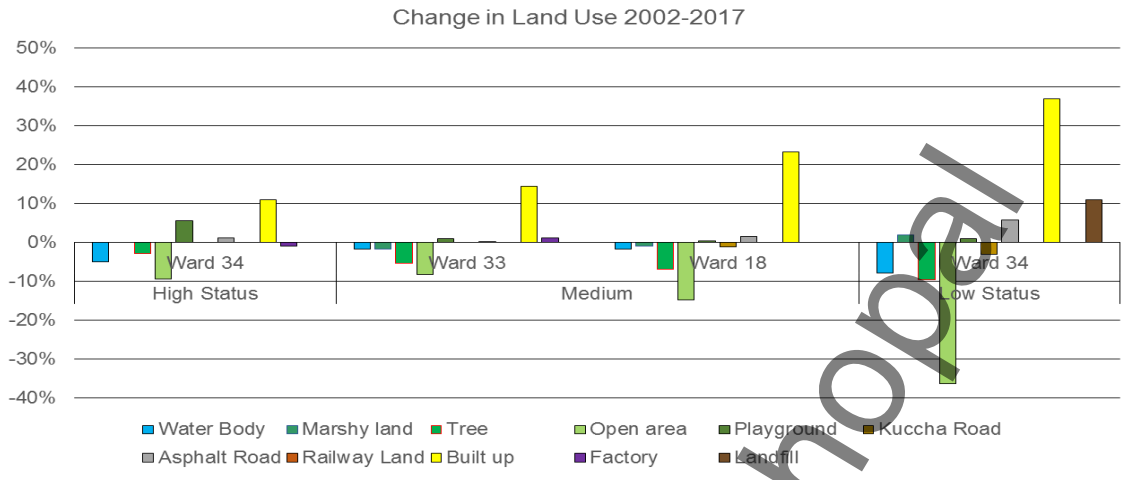
In many cases it has been found that there is a relation between the socio economic condition of the area and the land use and cover change in those area. As earlier described in the background of the study that we need to identify the relation between the social and economic condition and the surrounding land use, land cover and environmental relation.

5.3.1 Land Use and Socio – Economic Relation

For better understanding we plot the difference land use from 2002 to 2017on the y-axis according and the socio economic class on x-axis and then understand the relation between the two.

Table 32: Difference in land use of 4 Wards

Land Use	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Water Body	6%	1%	-5%	2%	1%	-2%	6%	5%	-2%	21%	13%	-8%
Marshy land	0%	0%	0%	2%	1%	-2%	1%	0%	-1%	1%	3%	2%
Tree	9%	6%	-3%	13%	8%	-5%	13%	6%	-7%	17%	7%	-10%
Open area	12%	3%	-9%	18%	10%	-8%	17%	2%	-15%	43%	6%	-36%
Playground	2%	8%	6%	0%	1%	1%	0%	0%	0%	0%	1%	1%
Kuccha Road	0%	0%	0%	0%	0%	0%	1%	0%	-1%	4%	0%	-3%
Asphalt Road	7%	9%	1%	7%	7%	0%	3%	5%	2%	0%	6%	6%
Railway Land	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%
Built up	54%	65%	11%	46%	60%	15%	59%	82%	23%	15%	52%	37%
Factory	9%	8%	-1%	7%	8%	1%	0%	0%	0%	0%	0%	0%
Landfill	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	11%



Graph 5: Relation between Socio economic condition and Land use

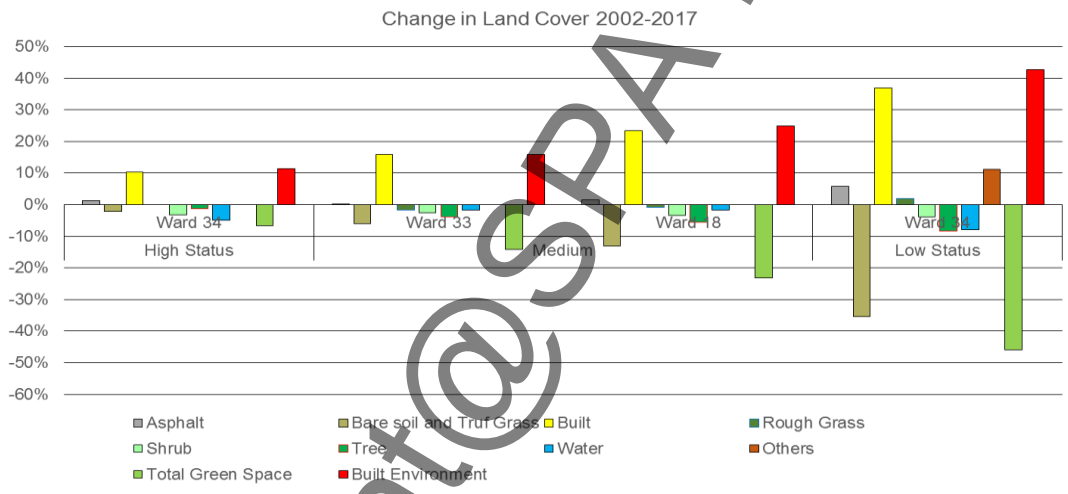
From this Table 32 and Graph 5 we see that major changes have taken place in low status area where there has been maximum increase in built up land use and maximum decrease in open spaces while the least increase have taken place in high stats are. Also as the increase in playground area in high status area than the low status area indicate that the high status are being developed into more liveable area than the low status area. Even maximum decrease in water bodies took place in low status area than the high status or the middle status area. In case of medium status the change in most land use are almost same except in Ward 18 where the increase in built up is more than ward 33 and decrease in open area is also more in ward 18 than ward 33. So we can conclude from this that in our case the major changes in land use is taking place in a low status condition than in a high status.

5.3.2 Land Cover and Socio – Economic Relation

Just as we identified the relation between land use and socio economic condition in the same way we identify the relation between the between the land cover and socio economic conditions of the wards. So we plot the difference in land cover on y – axis and the socio economic condition on x – axis.

Table 33: Difference in land cover of 4 Wards

Land Cover	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Asphalt	7%	9%	1%	7%	7%	0%	3%	5%	2%	0%	6%	6%
Bare soil and Truf Grass	12%	10%	-2%	15%	8%	-6%	15%	2%	-13%	42%	7%	-36%
Built	63%	73%	10%	52%	68%	16%	59%	82%	23%	15%	52%	37%
Rough Grass	0%	0%	0%	2%	1%	-2%	1%	0%	-1%	1%	3%	2%
Shrub	4%	1%	-3%	7%	5%	-3%	5%	1%	-3%	6%	2%	-4%
Tree	7%	6%	-1%	9%	5%	-4%	11%	6%	-6%	15%	6%	-8%
Water	6%	1%	-5%	2%	1%	-2%	6%	5%	-2%	21%	13%	-8%
Others	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	11%	11%
Total Green Space	23%	17%	-6%	33%	19%	-15%	32%	9%	-23%	64%	18%	-46%
Built Environment	70%	82%	11%	59%	75%	16%	62%	87%	25%	15%	58%	43%



Graph 6: Relation between Socio economic condition and Land Cover

As per the Graph 6 and the Wards the maximum decrease in total green space has occurred in low status with lowest decrease in high status area. Even the decrease in total green space in ward 18 is higher than the ward 33. In the same way the increase in built environment is most in case of the low status area where as the increase in built environment is least in high status area. So from this relation also it is clear that the major changes have taken place in low status area than the high status area.

So from this it is very much clear that in Indian context also there is some kind of interrelationship between the socio – economic condition and the surrounding land use and land cover of the area.

Chapter 6. Environmental Quality change and relation to Socio Economic condition

Environmental quality is the state of environmental conditions in environmental media which are expressed in terms of indicators, indices and related to environmental quality standards (The Organisation for Economic Co-operation and Development (OECD), n.d.). In this study we consider three environmental parameters and they are Diversity of the area, Surface Runoff and the Surface temperature. These three indicators are analysed on a temporal scale to understand the change in environmental quality over the years. The years selected are same as the years of land use and land cover. The changes in environmental quality are mainly due to the changes in land use and land cover changes. These changes can lead to negative impact and so it is important for use to understand what kind of changes in environmental quality are taking place with respect to the socio economic condition of the study areas.

6.1 Diversity of the Area

The diversity of the study area major deals with the biodiversity of the area. It has been seen that the biodiversity in and urban area is affected by different factors like the total amount of green space present, site factors like soil type, history of the area and also the way they are managed. Even the spatial; distribution of the total green spaces affect the biodiversity in urban areas (Pauleit, et al., 2005).

The analysis of diversity in the study area deals with three calculation the 1st one is the amount of total green space available which we can get from the land cover analysis. The 2nd one is the calculation of Shannon Index and the 3rd calculation is the multiplication of the total green space with the Shannon Index to get the importance of the index.

Now we calculate diversity index mainly to measure species diversity in community in mathematical terms. So they give us the information about the composition of species in the community than the richness of the spices (The Institute for Environmental Modeling, n.d.).

The total green space is obtained from the land cover analysis but detail calculation is require for Shannon Index.

6.1.1 Shannon Index

Shannon Index characterizes the species diversity within the community. It gives the abundance and evenness of the species that are present within the community. Shannon index can easily be used to identify the richness in land cover of an area. As per this more the land cover classes more is the richness of the study area. No change in land scape or land cover cause fragmentation in landscape which further causes a threat to the biodiversity of the area (Dupras, et al., 2016).

Formula –

H= $-\sum_{i=1}^{5} pi \log_2 pi$

H – Shannon diversity index

Pi – are the proportion area of land cover types

So by using this Shannon Index we will calculate the heterogeneity of the green cover in our area.

6.1.1.1 *Sample Calculation (Shannon Index)*

Pi for study area

P1 – proportion area of bare ground and turf grass

P2 – proportion of rough grass

P3 – proportion of shrub

P4 – proportion of trees

P5 – proportion of built environment.

Calculating H for Ward 3 for year 2002

Total Area under –

Bear Soil and Turf Grass – 3.32 Sq Km

Rough Grass – 0.10 Sq Km

Shrub – 0.47 Sq Km

Tree – 1.14 Sq Km

Built Environment – 1.16 Sq km

Total area – 6.20 Sq km

Proportion (Pi)

Bear Soil and Turf Grass – (3.32 /6.20) = 0.54

Rough Grass – (0.10/6.20) = 0.02

Shrub – (0.47/6.20) = 0.08

Tree – (1.14/0.18) = 0.18

Built Environment – (1.16/6.20) = 0.19

Sum of Pi = (0.54+0.02+0.08+.018+0.19) = 1

Ln (pi)

Bear Soil and Turf Grass – ln (0.54) = -0.62

Rough Grass – ln (0.02) = -4.13

Shrub – ln (0.08) = -2.58

Tree – ln (0.18) = -16.9

Built Environment – ln (0.19) = -1.67

Pi * ln (Pi)

Bear Soil and Turf Grass – (0.54) * -0.62 = -0.33

Rough Grass – (0.02) * -4.13 = -0.07

Shrub – (0.08) * -2.58 = -0.20

Tree – (0.18) * -16.9 = -0.31

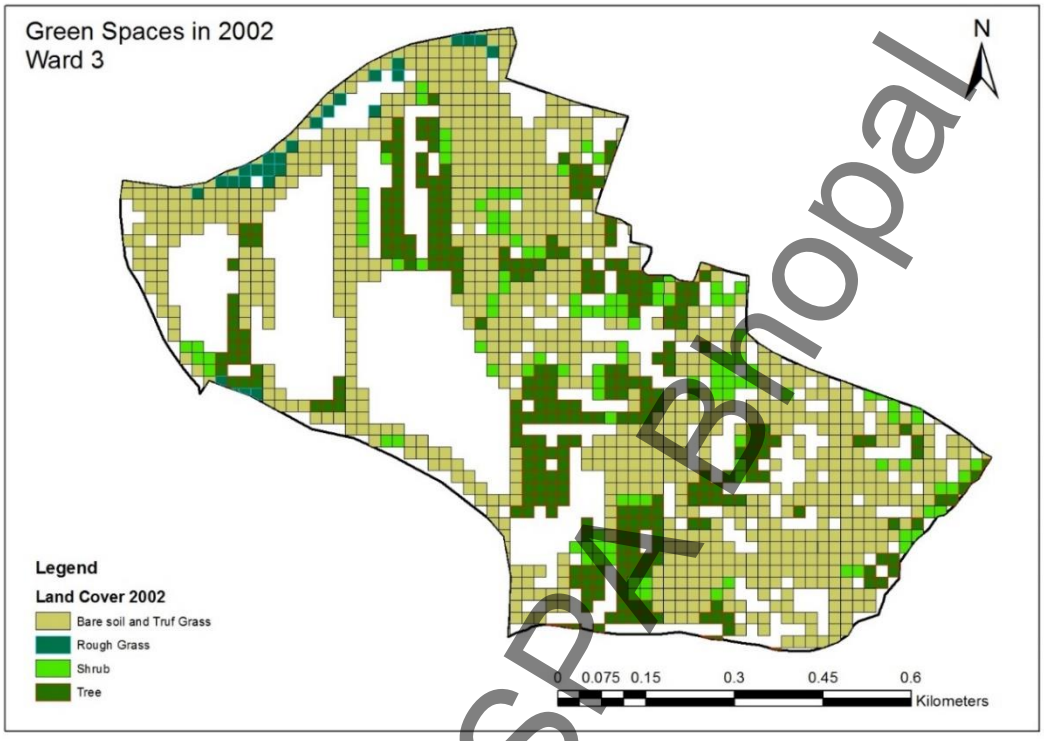
Built Environment – (0.19) * -1.67 = -0.31

Total of Pi * ln (Pi) = H = - (-0.33 + -0.07 + -0.20 + -0.31 +-0.31) = 1.22 (The value of H is represented in positive manner)

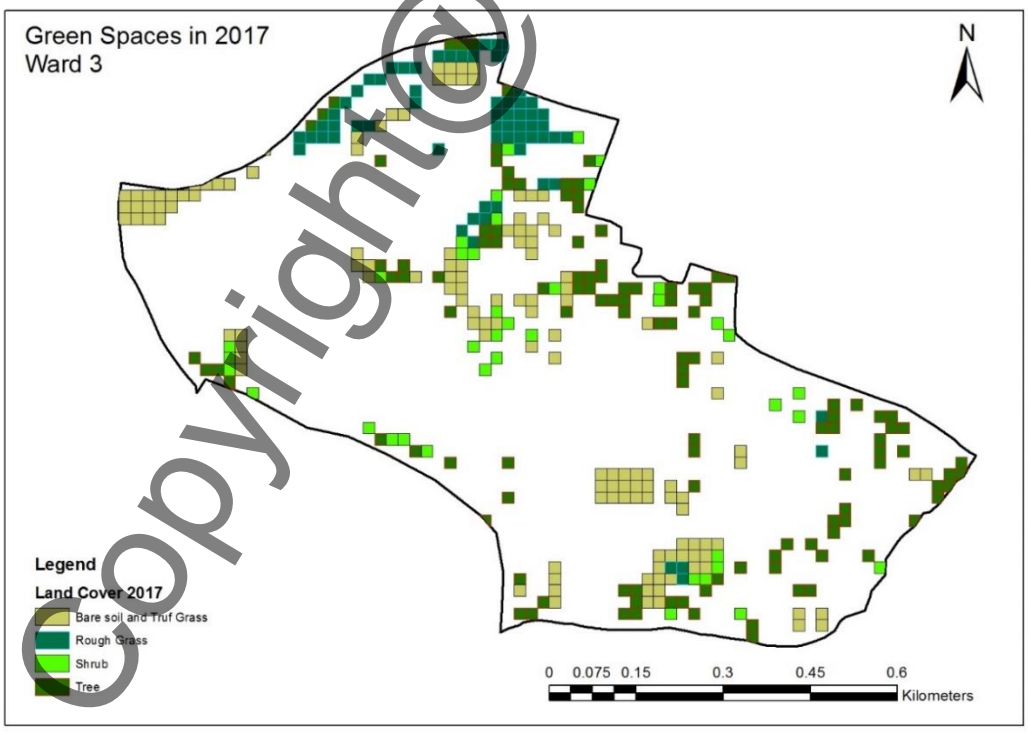
Evenness – (H / ln (5)) = (1.22 / ln (5)) = 0.76

So we get heterogeneity for year 2002 ward 3 as 1.22 and Evenness of 0.76

6.1.1.2 *Total Green Cover, Shannon Index and Total green cover multiplied by Shannon Index Ward 3*



Map 53: Green Cover 2002 ward 3



Map 54: Green Cover 2017 ward 3

Table 34: Difference Total Green Cover area of Ward 3

Types of Green Spaces	Percentage Area Ward 3		Difference
	2002	2017	
Bare soil and Turf Grass	0.42	0.07	-0.36
Rough Grass	0.01	0.03	0.02
Shrub	0.06	0.02	-0.04
Tree	0.15	0.06	-0.08
Total Green Space	**0.64**	**0.18**	**-0.46**

The Map 53 and Map 54 shows the spatial change in only green cover and from which Table 34 is derived, which give the total area of green cover in ward 3. This

Table 34 will further be used to calculate the Shannon Index in the study area as per the Sample Calculation (Shannon Index) for each year to understand the temporal change in the heterogeneity and evenness of ward 3.

Table 35: Shannon Index and Difference Ward 3

Shannon Index value – Ward 3		
Year	H	Evenness
2002	1.22	0.76
2005	1.33	0.83
2010	1.17	0.73
2015	0.98	0.61
2017	0.86	0.53
Difference (2017-2002)	**0.36**	

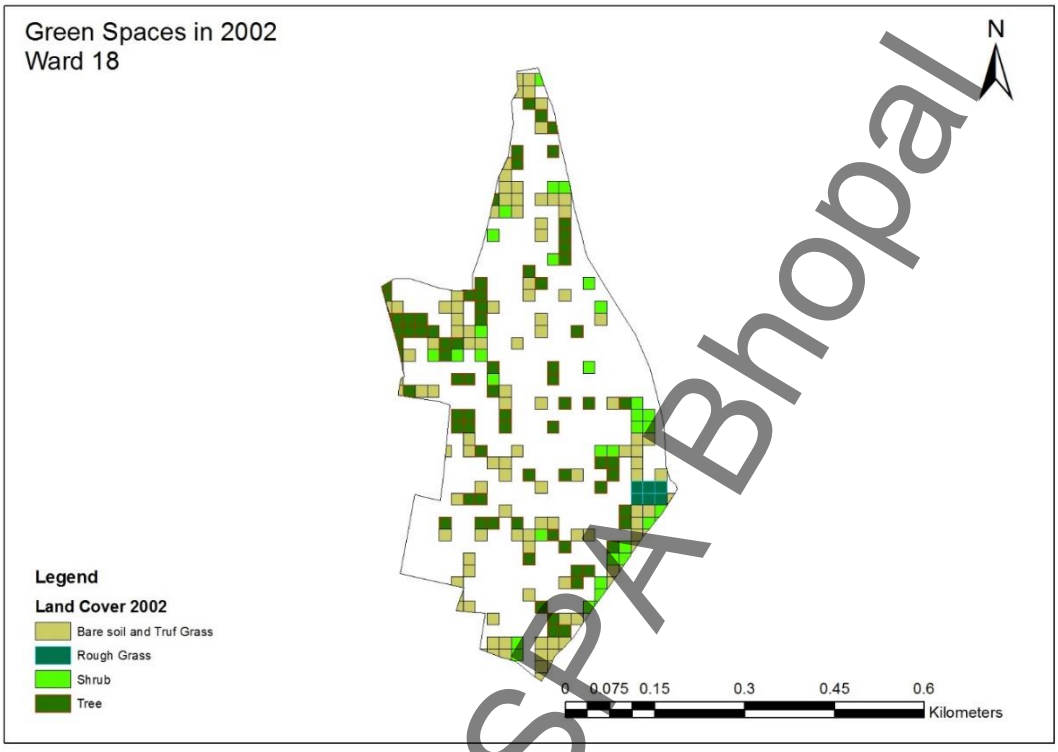
So the Table 35 shows the Shannon index calculation from which we can say that the heterogeneity in species are decreasing over the years.

*Table 36: Total Vegetative Area * Shannon Index ward 3*

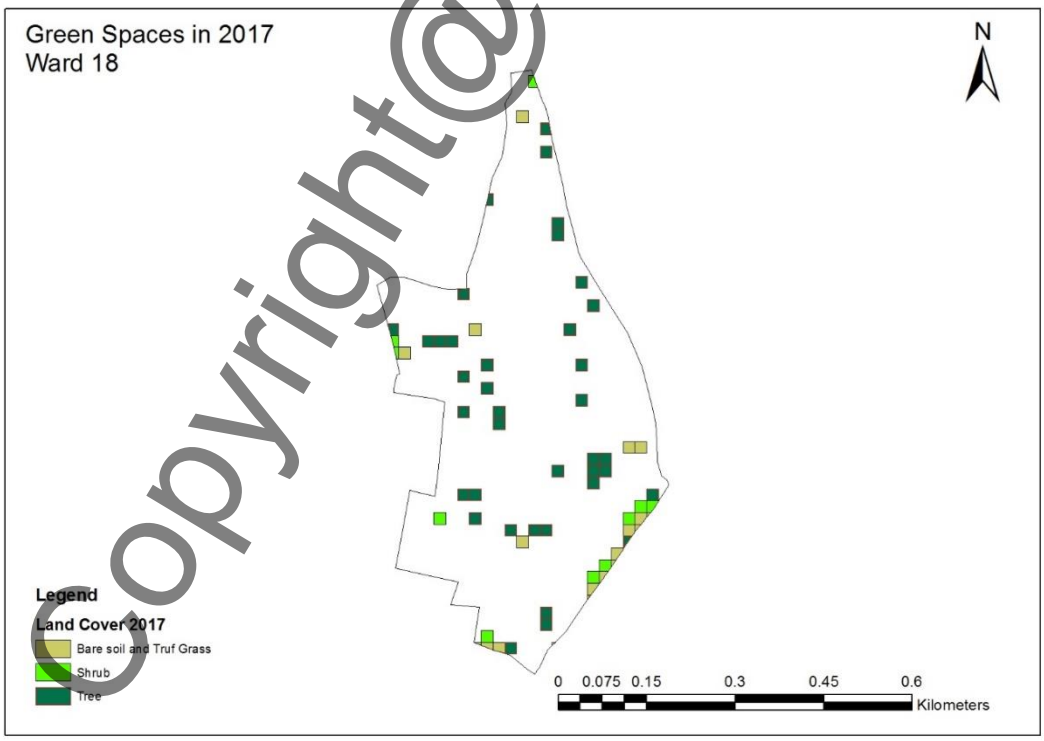
Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.50	1.22	0.62
2005	0.37	1.33	0.50
2010	0.26	1.17	0.31
2015	0.17	0.98	0.17
2017	0.14	0.86	0.12
Difference (2017-2002)			**-0.49**

The final Table 36 shows the multiplied value of total green cover and Shannon Index to represent the importance.

6.1.1.3 *Total Green Cover, Shannon Index and Total green cover multiplied by Shannon Index Ward 18*



Map 55: Green Cover 2002 ward 18



Map 56: Green Cover 2017 ward 18

Table 37: Difference Total Green Cover area of Ward 18

Types of Green Spaces	Percentage Area Ward 18		Difference
	2002	2017	
Bare soil and Truf Grass	0.149	0.018	-0.13
Rough Grass	0.009	0.000	-0.01
Shrub	0.047	0.012	-0.03
Tree	0.112	0.056	-0.06
Total Green Spaces	**0.318**	**0.086**	**-0.23**

To represent the green cover area spatially we produce the Map 55 and Map 56 from which the total green cover area of all land cover is calculated and proportion of the land cover types are determined for further Shannon Index calculation. Also the difference in green cover from 2002 to 2017 is determined as per Table 37.

Table 38: Shannon Index and Difference Ward 18

Shannon Index value – Ward 18		
Year	H	Evenness
2002	1.02	0.63
2005	0.86	0.54
2010	0.66	0.41
2015	0.42	0.26
2017	0.38	0.24
Difference (2017-2002)	**0.63**	

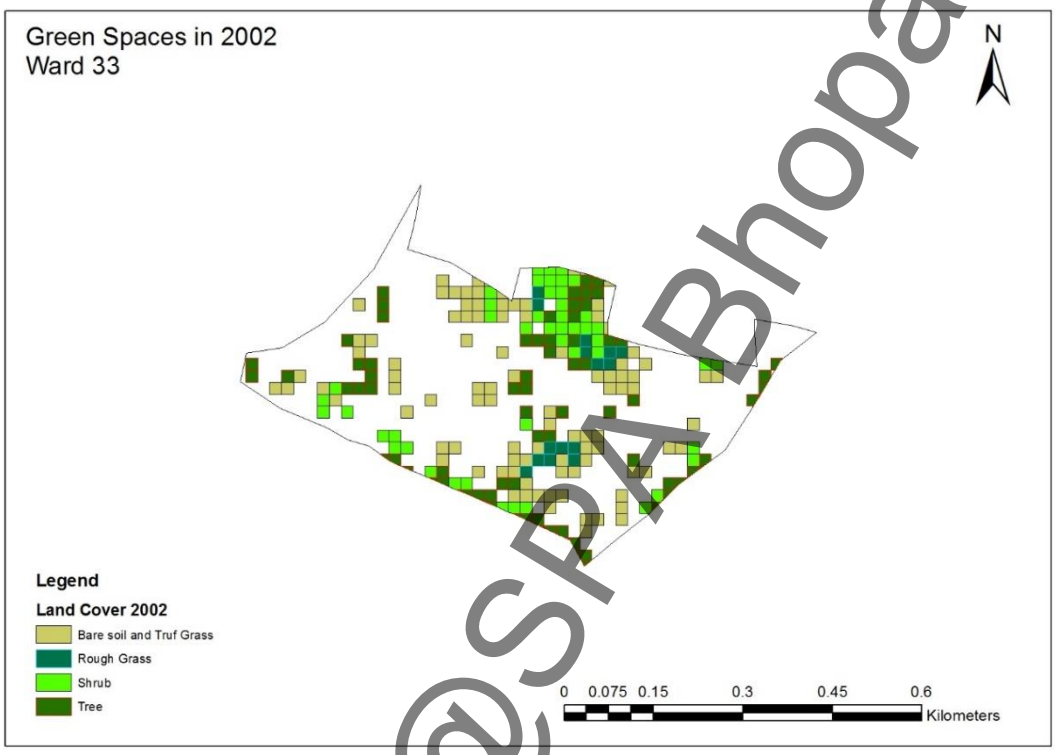
This Table 38 represent the temporal change in Shannon index of ward 18 where there is also decrease in heterogeneity and increase in evenness of land cover diversity of ward 18.

*Table 39: Total Vegetative Area * Shannon Index ward 18*

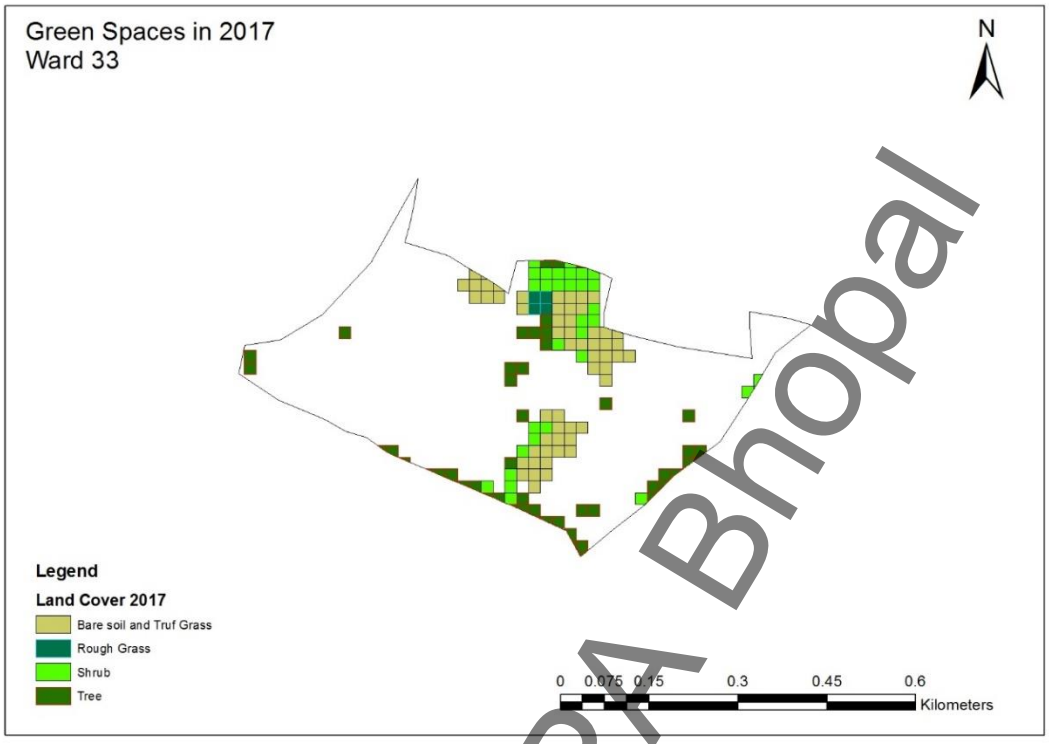
Total Vegetative Area * Shanno Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.08	1.02	0.08
2005	0.07	0.86	0.06
2010	0.04	0.66	0.03
2015	0.03	0.42	0.01
2017	0.02	0.38	0.01
Difference (2017-2002)			**-0.08**

The final Table 39 shows the multiplied value of total green cover and Shannon Index to represent the importance.

6.1.1.4 *Total Green Cover, Shannon Index and Total green cover multiplied by Shannon Index Ward 33*



Map 57: Green Cover 2002 ward 33



Map 58: Green Cover 2017 ward 33

Table 40: Difference Total Green Cover area of Ward 33

Types of Green Spaces	Percentage Area Ward 33		Difference
	2002	2017	
Bare soil and Truf Grass	0.15	0.08	-0.06
Rough Grass	0.02	0.01	-0.02
Shrub	0.07	0.05	-0.03
Tree	0.09	0.05	-0.04
Total Green Space	**0.33**	**0.19**	**-0.14**

The above Map 57 and Map 58 gives the change in total green space which shows that the amount of green space lost is high and in 2017 the green spaces have been concentrated in few location only. From the land cover analysis we get the area of the types of green space and from that we calculate the Shannon index as per the Sample Calculation (Shannon Index). Now Table 40 we get to see the difference in green cover from 2002 to 2017.

Shannon Index value – Ward 33		
Year	**H**	**Evenness**
2002	1.10	0.68
2005	1.00	0.62
2010	0.84	0.52
2015	0.73	0.46
2017	0.74	0.46
Difference (2017-2002)	**0.36**	

Table 41: Shannon Index and Difference Ward 33

This Table 41 represent the temporal change in Shannon index of ward 33 where there is also decrease in heterogeneity and increase in evenness of land cover diversity of ward 33.

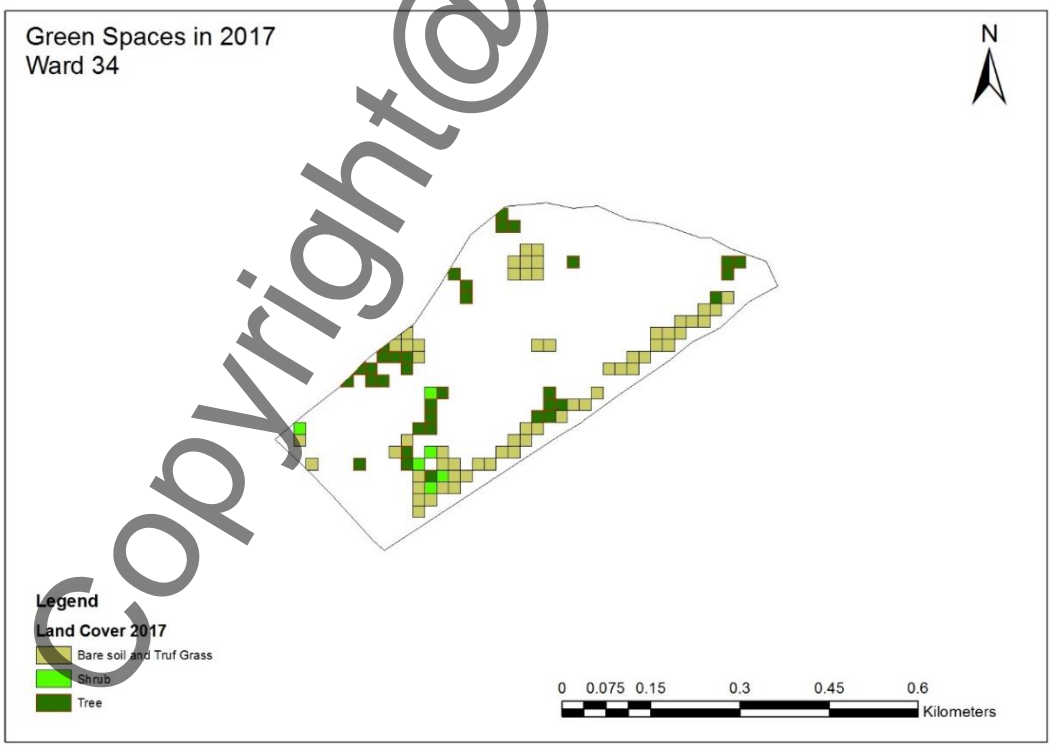
*Table 42: Total Vegetative Area * Shannon Index ward 33*

Total Vegetative Area * Shannon Index			
Year	**Total Vegetative Area**	**Shannon Index**	**TVA * SI**
2002	0.08	1.10	0.09
2005	0.08	1.00	0.08
2010	0.06	0.84	0.05
2015	0.05	0.73	0.04
2017	0.05	0.74	0.04
Difference (2017-2002)			**-0.06**

The final Table 42 shows the multiplied value of total green cover and Shannon Index to represent the importance.

6.1.1.5 *Total Green Cover, Shannon Index and Total green cover multiplied by Shannon Index Ward 34*

Map 59: Green Cover 2002 ward 34



Map 60: Green Cover 2017 ward 34

Table 43: Difference Total Green Cover area of Ward 34

Types of Green Spaces	Percentage Area Ward 34		Difference
	2002	2017	
Bare soil and Truf Grass	0.12	0.10	-0.02
Rough Grass	0.00	0.00	0.00
Shrub	0.04	0.01	-0.03
Tree	0.07	0.06	-0.01
Total Green Space	**0.24**	**0.17**	**-0.07**

The spatial distribution of the green cover is represented in Map 59 and Map 60 where it is seen there has been decrease in green cover but the green cover is distributed rather than concentrated in one area. The Table 43 shows the difference in green cover from year 2002 to 2017.

Table 44: Shannon Index and Difference Ward 34

Shannon Index value – Ward 34		
Year	H	Evenness
2002	0.82	0.51
2005	0.81	0.50
2010	0.79	0.49
2015	0.63	0.39
2017	0.61	0.38
Difference (2017-2002)	**0.21**	

This Table 44 represent the temporal change in Shannon index of ward 34 where there is also decrease in heterogeneity and increase in evenness of land cover diversity of ward 34.

*Table 45: Total Vegetative Area * Shannon Index ward 34*

Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.05	0.82	0.04
2005	0.05	0.81	0.04
2010	0.05	0.79	0.04
2015	0.04	0.63	0.02
2017	0.04	0.61	0.02
Difference (2017-2002)			**-0.02**

The final Table 45 shows the multiplied value of total green cover and Shannon Index to represent the importance.

6.2 Surface Runoff

Surface runoff is defined as the water from the rain, snow melt and other sources of precipitation that flows over the surface of land and is a part of our water cycle (Science Daily, n.d.).

The surface runoff in a particular area depends upon the intensity, duration of precipitation and the characteristic of the tributary areas. In general runoff in urban areas are greatly affected by the removal of vegetation, increase in impervious surface as a result of which there is decrease in infiltration. This further results in increase in the urban flood if not the storm water drains are designed properly (Pauleit, et al., 2005).

Surface runoff calculation can be based on many different models one of them is CN curve number method for which we require data like the soil type of the area, micro water shed, runoff coefficient and CN number for each type of soil.

The other method is the Rational Method for which we require the intensity of rainfall in that particular area, Area of the drainage district and the runoff coefficient which is dimension less (CPHEEO, 2013).

For this analysis the rational method of calculating the surface runoff was found to be suitable as per data availability. According to CPHEEO manual on sewage and sewage treatment system part A for any Indian condition rainfall intensity is generally adopted between 12 mm/hr to 20 mm/hr depending on the actual condition (CPHEEO, 2013). So for the case of city like Kolkata and its surrounding area the average annual rainfall is higher than the average annual rainfall of India so we take the rainfall intensity on higher side of the range as given by CPHEEO.

6.2.1 Rainfall intensity for Kolkata

According to Indian Meteorological department we can consider the rainfall for the calculation of surface runoff within a 50 Km radius from the meteorological station. In Kolkata and adjoin municipalities there are two meteorological station one at Alipur and other at the Neitaji Subhas Chandra International Airport. Both of them fall under 50 Km radius of study area so we can consider rainfall for both the station. According to the Rainwater harvesting and Conservation manual by Central Public Works Department they have provided the average annual rainfall in millimetre form year 1951 to 1980 for 69 cities including Kolkata (Central Public

Works Department, 2002). Now this annual average rainfall is plotted for all 69 cities and the rainfall are divided in 9 equal ranges. Each range is allocated one intensity depending upon the rainfall that is if the city fall in the lowest range of average rainfall it is allocated with rainfall intensity of 12 mm/hr. This is because for calculating intensity of rainfall in a particular area we require hourly rainfall frequency data which is not available. So after allocating the intensity based on average rainfall we see Kolkata fall in the range which has 19 mm/hr rainfall intensity. So for our surface runoff calculation we consider the rainfall intensity as 19 mm/hr.

6.2.2 Rational Method of Surface Runoff

Rational method is considered to be the simplest method to determine the surface runoff. Application of rational method is best when the area is small. The rational method formula is the product of runoff producing potential of the water shed, the average intensity of rainfall for a particular length of time and the area of the drainage basin (Thompson, 2006). The basic formula is

$Q = C_u * C * i * A$

Q = Runoff

C_u = unit of conversion coefficient

C = runoff coefficient (dimension less)

i = rainfall intensity

A = area of drainage.

As per CPHEEO recommends the use of rational method for the design of Storm Water Drainage system.

Runoff Coefficient is dimension less and indicates the amount of runoff generated by the watershed for an average intensity of precipitation for a storm (Thompson, 2006).

Rainfall Intensity is basically the function of geographical location and design exceedance frequency or the return interval (Thompson, 2006). So using this formula we calculate the temporal change surface runoff for our all four micro study area. In case of area the land cover area of different land cover type has been considered as the area of drainage for calculation.

6.2.2.1 *Sample Calculation (Surface Runoff)*

Formula

$Q = C_u * C * i * A$

Q = Surface Runoff

C_u = 0.278 for calculating runoff in m^3/sec

C = Runoff Coefficient (considered average of all land Use and Land Cover types)

A = Area of the land use or land Cover

Runoff coefficient

Table 46: Runoff Coefficients for different Land Use

Land Use	Coef Type	Max Coef	Min Coef	Avg Coef	Reference
Water Body	Water Bodies	1.00	1.00	1.00	
Marshy land	large flood plain storage or large number of ponds or marshes	0.04	0.06	0.05	(HIGHWAY DESIGN MANUAL, 2001)
Tree	Wood Land	0.05	0.25	0.15	(Poullain, 2012)
Open area	Grass land	0.70	0.70	0.70	(Water Resource Division, 2011)
Playground	Playground	0.20	0.35	0.28	(Central Public Works Department, 2002)
Kuccha Road	Drives and Walk	0.75	0.85	0.80	(Goldman, et al., 1986)
Asphalt Road	Asphalt	0.72	0.95	0.84	(Central Public Works Department, 2002)
Railway Land	Railroad	0.20	0.40	0.30	(Goldman, et al., 1986)
Built up	Multiunit attached	0.60	0.75	0.68	(Central Public Works Department, 2002)
Built up	Multiunit detached	0.40	0.60	0.50	(Central Public Works Department, 2002)
Factory	Light Industry	0.50	0.80	0.65	(Goldman, et al., 1986)
Landfill	Unimproved	0.10	0.30	0.20	(Central Public Works Department, 2002)

Table 47: Runoff Coefficients of Different Land Cover

Land Cover	Coef - Type (Depending on Land Use)	Avg Coef (C)
Asphalt	Asphalt	0.84
Bare soil and Truf Grass	Grass land, Playgrounds, Drives Walk Ways	0.59
Built	Multiunit attached / Detached, Light Industry	0.66
Rough Grass	large flood plain storage or large number of ponds or marshes	0.05
Shrub	Wood Land	0.15
Tree	Wood Land	0.15
Water	Water Bodies	1.00
Others	Unimproved, Railroad	0.25

Calculating Runoff for Asphalt Land Cover Type ward 3

Avg Coefficient C = 0.835 (Table 47)

Average Rainfall intensity = 19 mm/hr

Area under Asphalt Land Cover = 0.0456 Sq Km

$Q = 0.278*C*i*A$ (m^3/sec)

$Q = 0.278*0.835*19*0.456 = 0.2011$ m^3/sec

In the same way calculate the runoff for all the land cover and the summation of all the runoff of each land cover category will give the total runoff generated for that particular ward

.

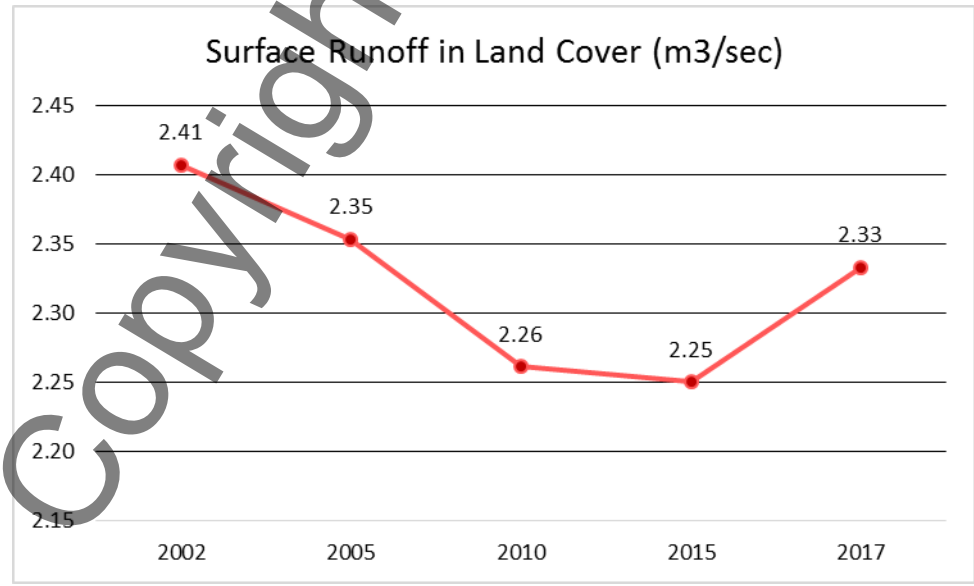
6.2.3 Surface Runoff Ward 3

Table 48: Temporal Surface Runoff Land Cover Ward 3

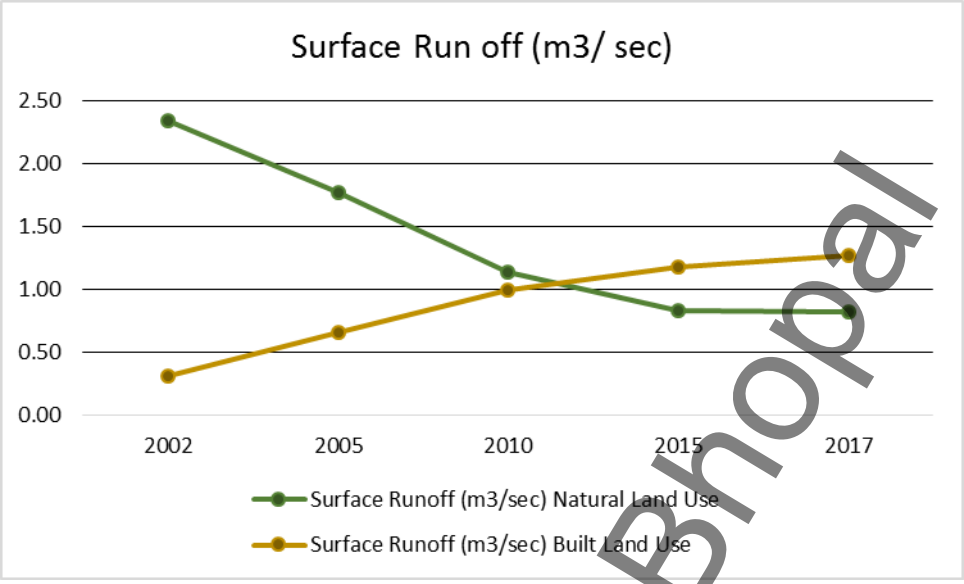
Year	Surface Runoff in Land Cover (m3/sec)
2002	2.41
2005	2.35
2010	2.26
2015	2.25
2017	2.33
Difference (2002- 2017)	**-0.07**

Table 49: Temporal Surface Runoff of Natural and Built Land Use Ward 3

Year	Surface Runoff (m3/sec)	
	Natural Land Use	Built Land Use
2002	2.35	0.31
2005	1.77	0.65
2010	1.13	0.99
2015	0.83	1.18
2017	0.82	1.28
Difference (2002- 2017)	**-1.53**	**0.97**



Graph 7: Surface Runoff Land Cover Ward 3



Graph 8: Natural Vs Built Land Use Runoff ward 3

As per the Table 48, Table 49, Graph 7 and Graph 8 it is very clear the surface runoff in the ward is decreased till 2015 but again started to increase after 2017. But when Surface runoff for natural and Built up land use is considered the runoff in built up area is increasing while the surface runoff in natural land use is decreasing. Natural land use only considered the green spaces.

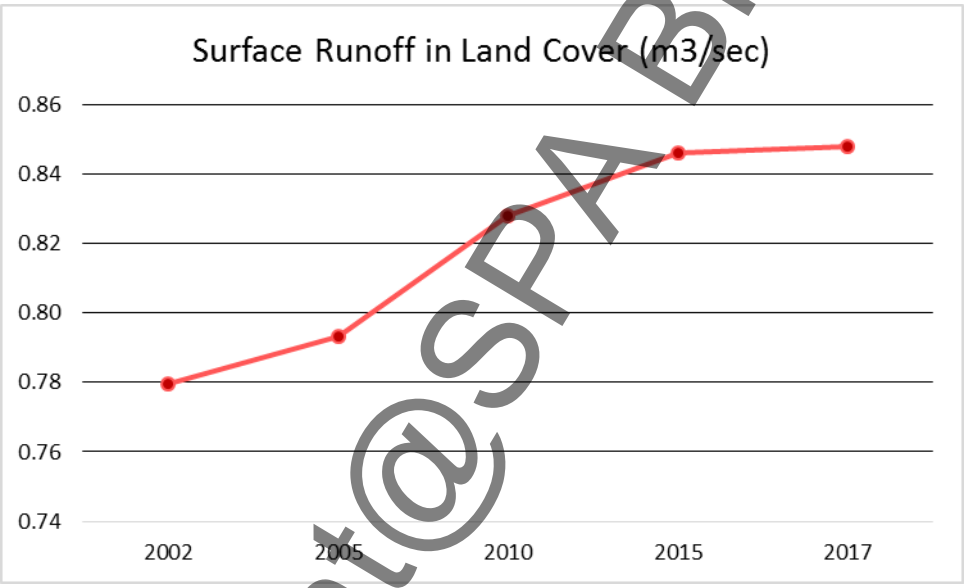
6.2.4 Surface Runoff Ward 18

Table 50: Temporal Surface Runoff Land Cover Ward 18

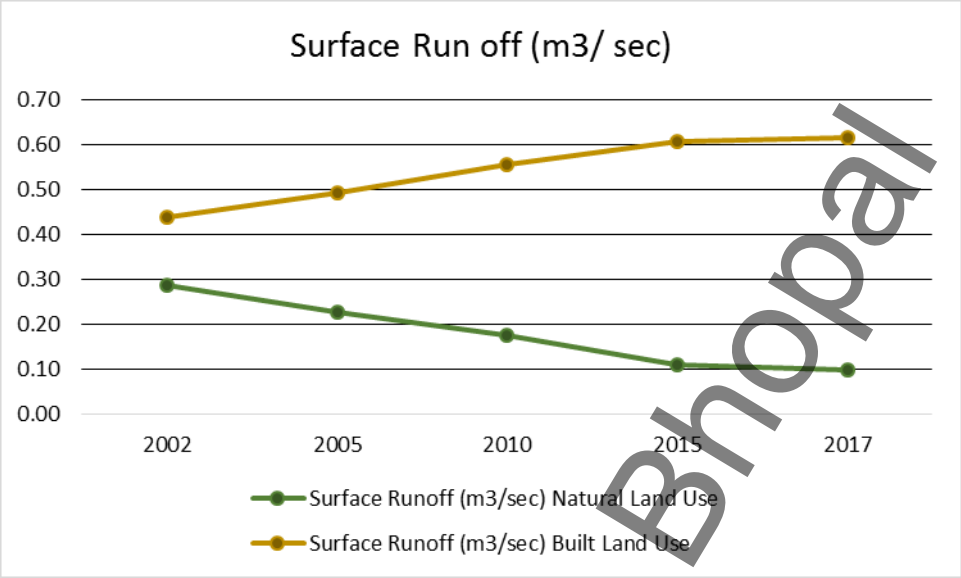
Year	Surface Runoff in Land Cover (m3/sec)
2002	0.78
2005	0.79
2010	0.83
2015	0.85
2017	0.85
Difference (2002- 2017)	**0.07**

Table 51: Temporal Surface Runoff of Natural and Built Land Use Ward 18

Year	Surface Runoff (m3/sec)	
	Natural Land Use	Built Land Use
2002	0.29	0.44
2005	0.23	0.49
2010	0.17	0.55
2015	0.11	0.61
2017	0.10	0.62
Difference (2002- 2017)	**-0.19**	**0.18**



Graph 9: Surface Runoff Land Cover Ward 18:



Graph 10: Natural Vs Built Land Use Runoff ward 18

The Table 50, Table 51, Graph 9 and Graph 10 clearly shows that from 2002 the surface runoff have increased and the runoff in natural areas in less compared to the runoff in built area.

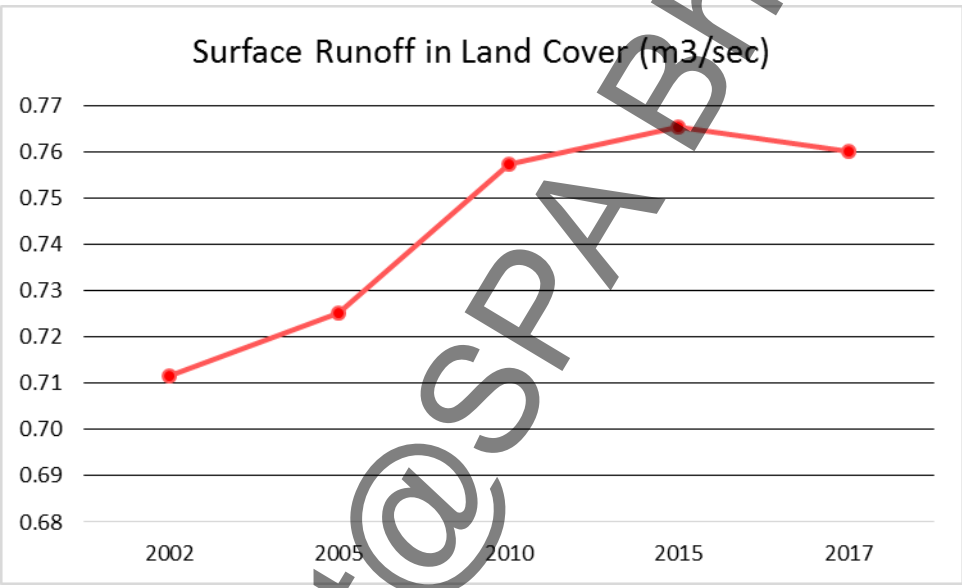
6.2.4.1 *Surface Runoff Ward 33*

Table 52: Temporal Surface Runoff Land Cover Ward 33

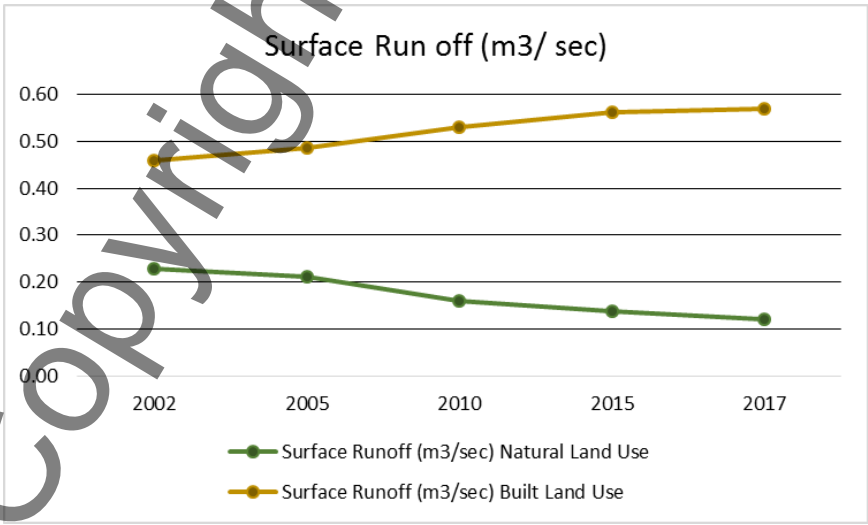
Year	Surface Runoff in Land Cover (m3/sec)
2002	0.71
2005	0.73
2010	0.76
2015	0.77
2017	0.76
Difference (2002- 2017)	**0.05**

Table 53: Temporal Surface Runoff of Natural and Built Land Use Ward 33

Year	Surface Runoff (m3/sec)	
	Natural Land Use	Built Land Use
2002	0.23	0.46
2005	0.21	0.49
2010	0.16	0.53
2015	0.14	0.56
2017	0.12	0.57
Difference (2002- 2017)	**-0.11**	**0.11**



Graph 11: Surface Runoff Land Cover Ward 33



Graph 12: Natural Vs Built Land Use Runoff ward 33

Now as we can see from the Graph 11, Graph 12, Table 52 and Table 53 that the surface runoff here also over the years have increased and the runoff generated by natural vegetative cover is less compared to the built up land use.

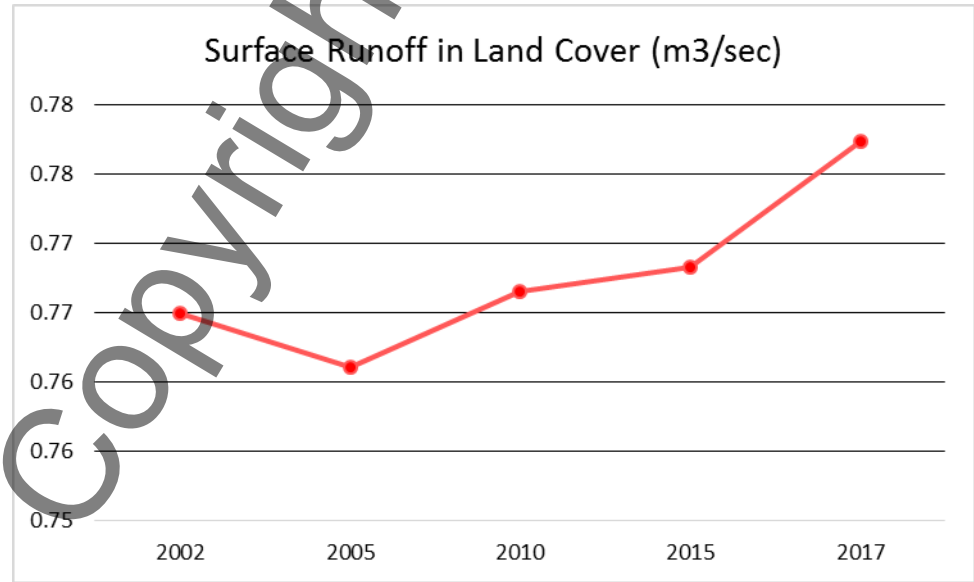
6.2.5 Surface Runoff Ward 34

Table 54: Temporal Surface Runoff Land Cover Ward 34

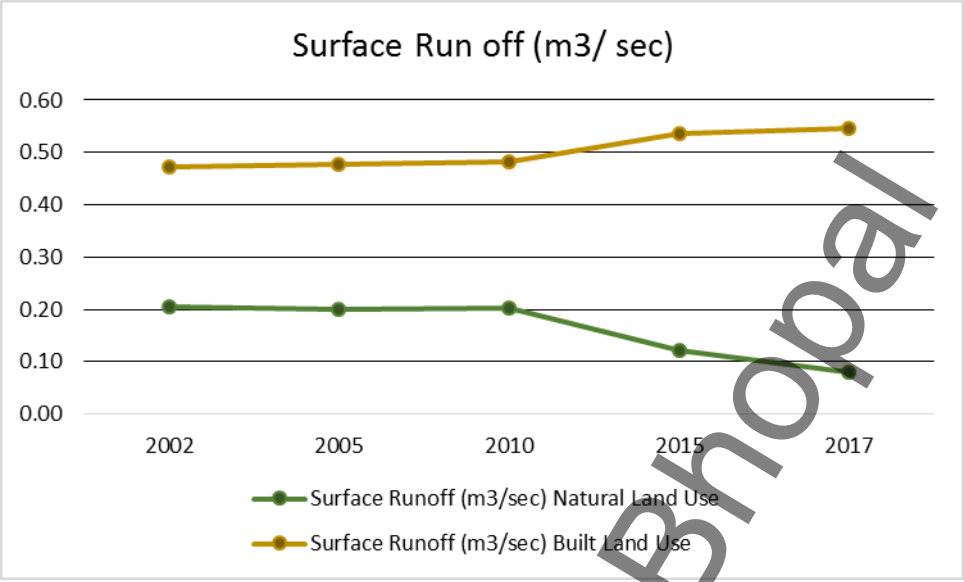
Year	Surface Runoff in Land Cover (m3/sec)
2002	0.76
2005	0.76
2010	0.77
2015	0.77
2017	0.78
Difference (2002- 2017)	**0.01**

Table 55: Temporal Surface Runoff of Natural and Built Land Use Ward 34

Year	Surface Runoff (m3/sec)	
	Natural Land Use	Built Land Use
2002	0.20	0.47
2005	0.20	0.48
2010	0.20	0.48
2015	0.12	0.54
2017	0.08	0.55
Difference (2002- 2017)	**-0.12**	**0.07**



Graph 13: Surface Runoff Land Cover Ward 34



Graph 14: Natural Vs Built Land Use Runoff ward 34

So it is very clear from Table 54, Table 55, Graph 13 and Graph 14 that the surface runoff over the years have almost remained same with only a slight increase in case of built land use and slight decrease in case of natural land use. But overall there has been increase in surface runoff but in less amount if compared with ward 18 and 33.

We consider only green areas under natural area because water bodies are itself considered to have 100% runoff for which its runoff coefficient is considered as 1. But it do not imply that we need to remove all water body to increase the runoff in natural area. In Overall runoff quantity water bodies have been consider and from the analysis it is clear that in major cases the runoff is increasing.

6.3 Land Surface Temperature

Land surface temperature (LST) is defined as the “radiative skin temperature of the ground.” Major factors that affect the land surface temperature are the albedo, vegetative cover and moisture within the soil (Copernicus Global Land Service, n.d.). Also land surface temperature gives us the feeling of how hot the surface of the earth is if we touch in any particular location. Generally land surface temperature is measured using satellite image where we interpret the thermal band of the image. So accordingly the surface is considered to be whatever the satellite can see through the atmosphere to the ground as per the satellite (NASA Earth Observatory, n.d.).

LST forms one of the major parameter in environmental analysis of urban areas and are mainly focused on the land use and land cover changes of the area. Even in some respect the land surface temperature may vary from place to place depending on the bio – physical and demographic variable of the cities. The bio – physical elements generally deal with the urban vegetative cover, built up area, urban street geometry etc. Also it may vary on basis of population distribution, intensity of human activity etc. (Xiao, et al., 2008).

As the surface temperature over the urban area increase than the surface temperature in surrounding country side the urban heat island effect starts to build. This causes a negative impact on human comfort level. Thereby changing the local climatic condition over the urban areas. As urban area comprises of different socio – economic status group of people there may be some relation between the surface temperature and socio – economic condition of the area.

For this study we have used Landsat satellite imagery and interpreted the thermal band of each Landsat image and identified the Land surface temperature of all the four micro study area.

6.3.1 Land Surface Temperature Interpretation

Land surface temperature is determined using Landsat images of the selected study years. Landsat program is the longest and continuous space based recode of earth surface. The Landsat satellite provides information for professionals, academicians and others information to manage the land and environment (NASA Landsat Science, n.d.). The Landsat satellite was first launched in 1972 and till date 8 satellites have been launched. Satellite Landsat 1 to 6 are not active and each satellite have been launched in different years with an upgradation from the former one. So the images has been use do not belong to only one satellite it belongs mainly three satellite the Landsat 5 , Landsat 7 and Landsat 8.

6.3.1.1 *Year and Landsat Image:*

- 2002 – Landsat 7 (No strip error)
- 2005 – Landsat 5 (No strip error)
- 2010 – Landsat 5 (No strip error)
- 2015 – Landsat 8 (No strip error)

- 2017 – Landsat 8 (No strip error)

For determining the land surface temperature of the study area, need to follow few steps in Arc GIS software. The steps are as follows:

Bands Required for Study

Landsat 7 – Band 2, Band 3 (Red), Band 4 (infrared), Band 5, Band 6_1 (thermal) and Band 6_2 (thermal).

Landsat 5 – Band 2 (Red), Band 3 (infrared), Band 4, Band 5 and Band 6 (thermal)

Landsat 8 - Band 2, Band 3 (Red), Band 4 (infrared), Band 5, Band 10 (thermal) and Band 11 (thermal).

Step 1 Extraction of satellite image of study area:

1. Landsat image consist of different bands and the image is spread over a very large region. In this case the Landsat image of all the year belongs to WRS path 138 and WRS Row 44 which gives the major Southern part of West Bengal.
2. The images of each band is opened in Arc GIS and the boundary of the study area is placed.
3. After this we open the Extraction in Arc GIS tool box within Spatial Analyst tools.
4. From Extract tool we select Extract by Mask option.
5. Extract by Mask – Input Raster will be required bands and Feature Mask Data will be the Study area boundary.
6. Select the location for saving the output raster.
7. Each band is select one at a time and exacted one by one.

Step 2 NDVI of study area

NDVI – It is Normalized Difference Vegetation Index (NDVI) which shows the greenness or photosynthetic activity of plants. It is one of the most common vegetative index to represent vegetation (Landscape Tool Box, n.d.).

1. Open band 2, 3, 4 and 5 in Arc GIS.
2. All band should be in ascending order.
3. Now open Image Analysis window from the windows dropdown menu.
4. In image analysis window we will see all the 4 band in ascending order.

5. Select all the 4 band by clicking shift and selecting the bands in image analysis.
6. We will see an option called Composite Band as per the given symbol ( ). Click the Composite Band option and a composite band layer will be formed.
7. As the composite band is formed it is not a permanent layer so to make it permanent right click the composite band in Table of Content window and through Data option Export the Data as a TIF file in the required location with the required name.
8. Now the saved composite band that we have saved appears on the image analysis window. Click on this saved composite band and the NDVI option in the image Analysis window as per the symbol ( ).
9. Now before clicking the NDVI option we need to check the Bands to be used for NDVI. So for that in the top left corner of Image Analysis window we have the Image Analysis option where we put the Red band and the infrared band numbers.
10. For Landsat 7 and 8 Red band is 3 and infrared Band is 4 and for Landsat 5 Red band is 2 and infrared is 3 (in my case only).
11. Now click NDVI and the NDVI temporary layer is generated which needs to be saved by right clicking the NDVI layer and from data option Export the Data as a TIF file in the required location with the required name.

Step 3 Conversion to Radiance

1. Open the Thermal Band in Arc GIS.
2. Open Raster Calculator in Map Algebra within Spatial Analyst Tool from Arc Tool Box
3. Put the formula as given in below:

Formula

Lλ = ((LMAXλ - LMINλ) / (QCALMAX-QCALMIN)) * (QCAL-QCALMIN) +LMINλ

Where

Lλ = Spectral Radiance at the sensor's aperture in watts/ (meter squared * ster * μm)

Grescale = Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm)/DN

Brescale = Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * μm)

QCAL = the quantized calibrated pixel value in DN

LMINλ = the spectral radiance that is scaled to QCALMIN in watts/ (meter squared * ster * μm)

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/ (meter squared * ster * μm)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

= 1 for LPGS products

= 1 for NLAPS products processed after 4/4/2004

= 0 for NLAPS products processed before 4/5/2004

QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN = 255

4. Open the MTL.txt file as given in the Landsat image file in Word pad.

Now we will get all the values of the variables there

Where

LMAXλ = RADIANCE_MAXIMUM_BAND_6_VCID_1

LMINλ = RADIANCE_MINIMUM_BAND_6_VCID_1

QCALMAX = QUANTIZE_CAL_MAX_BAND_6_VCID_1

QCALMIN = QUANTIZE_CAL_MIN_BAND_6_VCID_1

QCAL = BAND_6_1 (The band itself)

Put the values in Raster calculator for each thermal band at a time and generate the output raster.

5. Finally the output raster is our Radiance of the study area.

Step 4 Conversion to Satellite Temperature

1. Open Raster Calculator.
2. Use formula as:

Formula:

$$T = \frac{K2}{\ln(\frac{K1}{L\lambda}+1)-272.15}$$ (°C)

Where

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2

K1 = Calibration constant 1

Lλ = Spectral radiance in watts/ (meter squared * ster * μm) (the new radiance band created in previous step)

Table 56: ETM+ and TM Thermal Band Calibration Constants

ETM+ and TM Thermal Band Calibration Constants		
	Constant 1- K1 watts/(meter squared * ster * μm)	**Constant 2 - K2 Kelvin**
Landsat 7	666.09	1282.71
Landsat 5	607.76	1260.56

For Landsat 8 the constant values are given in the MTL.txt file.

Step 5 Proportion of Vegetation

1. Open Raster Calculator and Put formula as Below

Formula:

PV = (NDVI – NDVI min / NDVI max – NDVI min)

NDVI = the NDVI layer created in step 1

NDVI max = Maximum value of NDVI in NDVI layer

NDVI min = Minimum value of NDVI in NDVI layer

2. Generate the raster layer

Step 6 Emissivity

1. Open Raster Calculator and apply formula as

Formula

e= 0.004Pv + 0.986

P v = Proportion of vegetation layer created in previous step.

2. Generate the raster layer

Step 7 Land Surface temperature

1. Open raster calculator and apply formula as below

Formula

LST = BT / 1 + W * (BT / P) * ln (e)

BT = Satellite temperature band created in step 4

W = Wavelength of the emitted Radiance (it is the thermal bands only)

P = h * c/s = 14380 (constant)

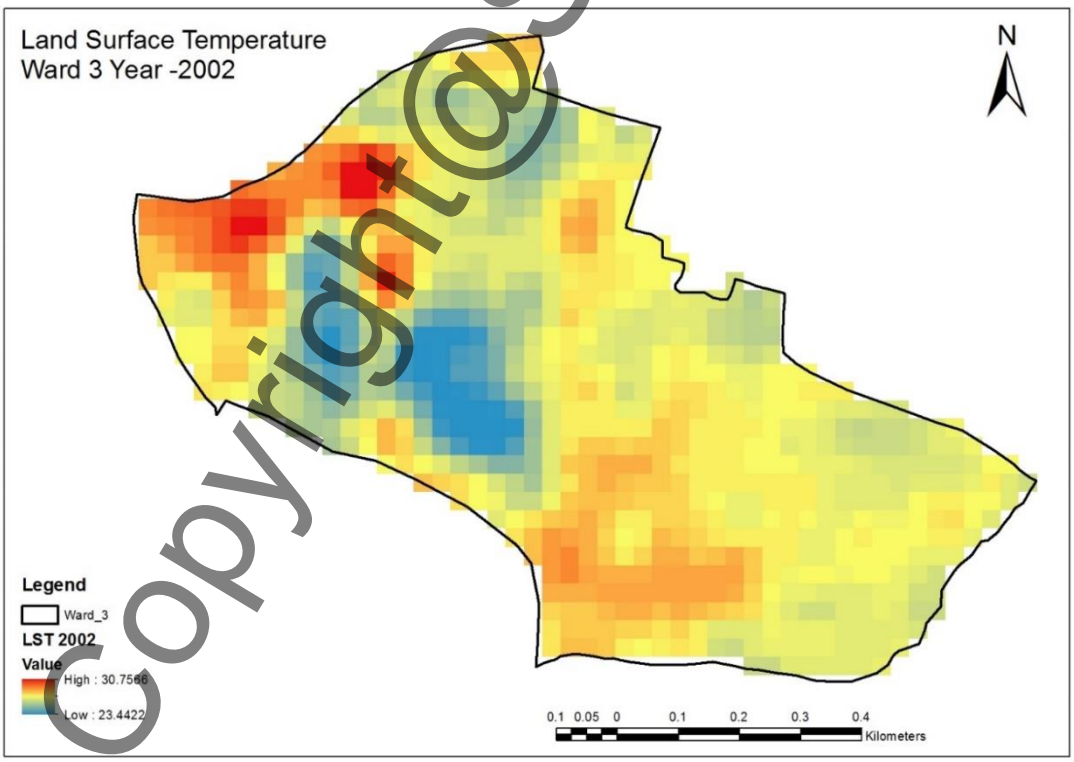
C = Velocity of light

e= emissivity (layer created in step 6) (Semi-Automatic Classification Manual, n.d.)

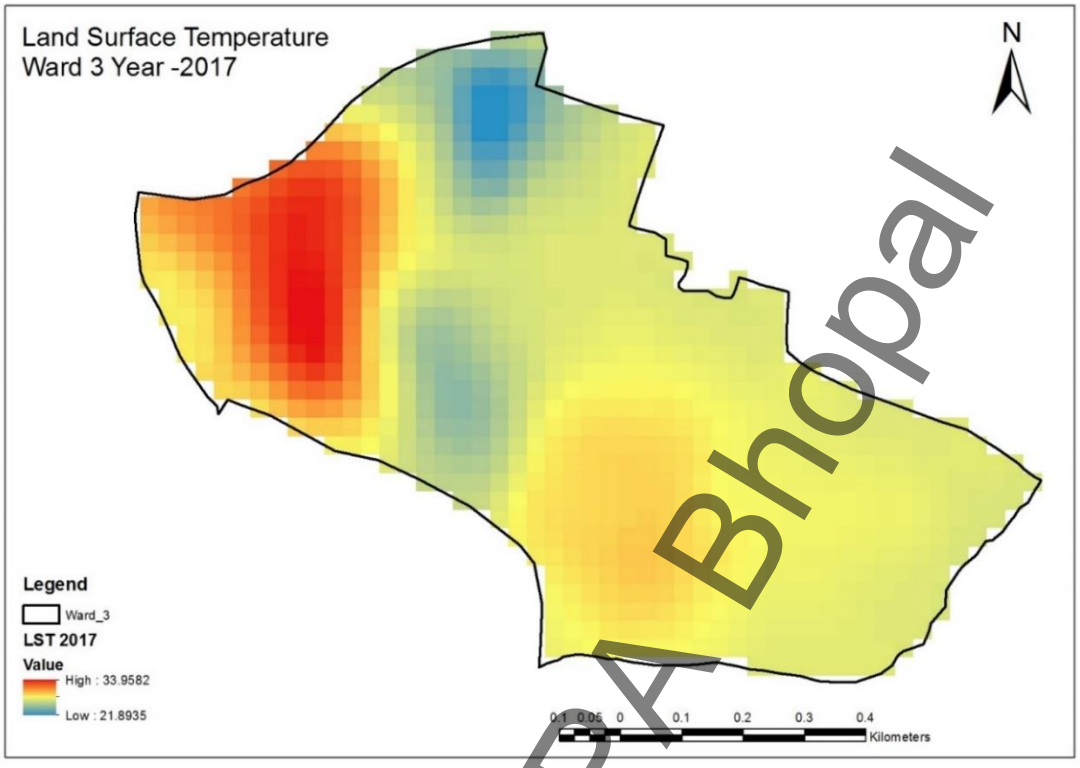
2. Save the LST layer in required area and create it for all the thermal bands.
3. If anyone Landsat image have more than two thermal band get the mean LST of both the band by using Cell statistics tool after generating the LST.

This detail steps have been followed to generate the Land surface temperature of all the study areas.

6.3.1.2 *Land Surface Temperature of Ward 3*



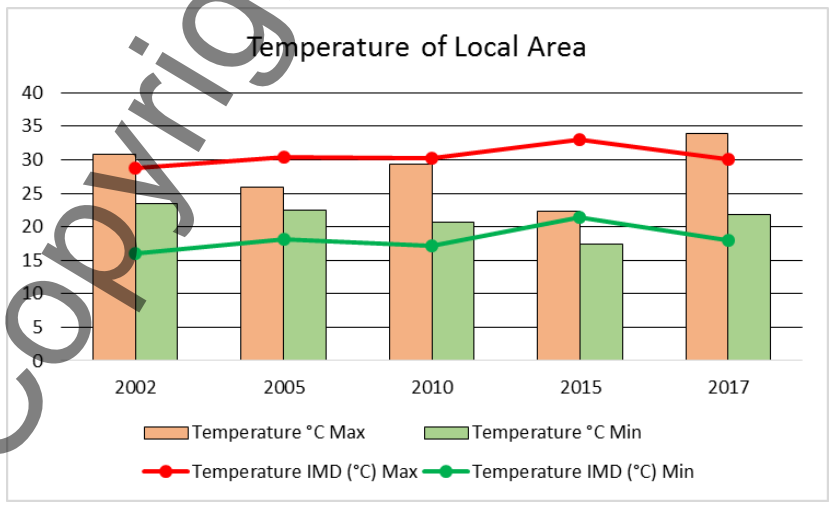
Map 61: LST ward 3 2002



Map 62: LST ward 3 2017

Table 57: LST Vs IMD temperature ward 3

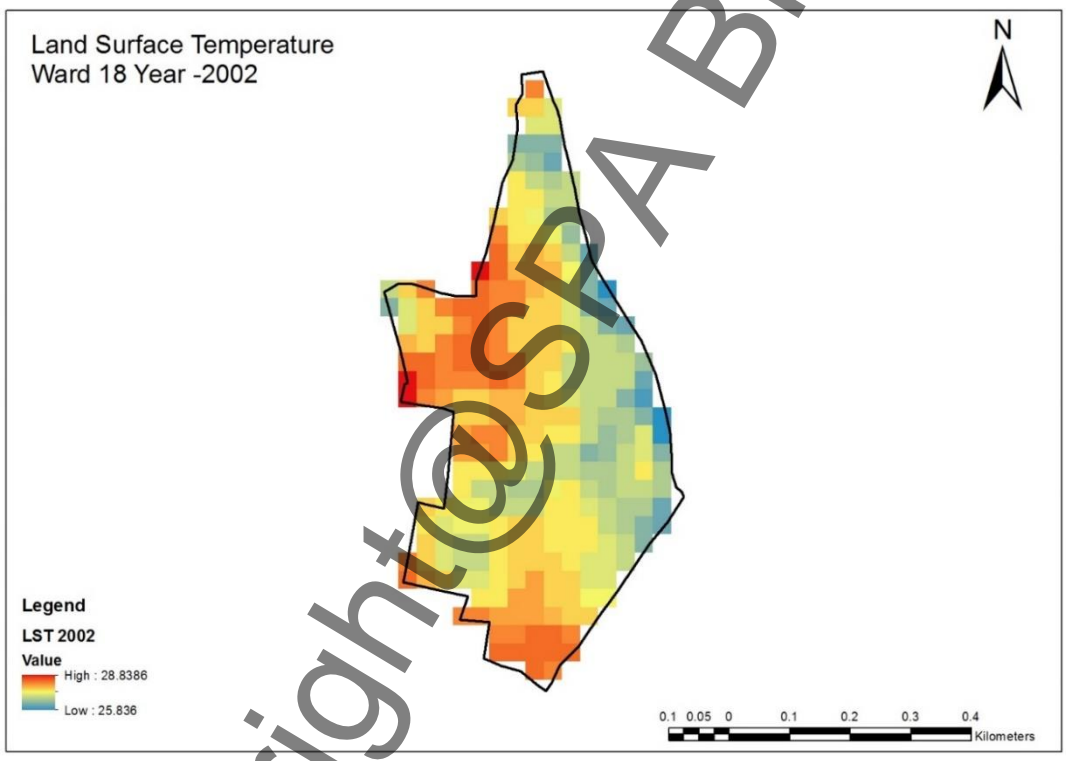
Year	LST Temperature °C		Temperature IMD (°C)	
	Max	Min	Max	Min
2002	30.75	23.44	28.7	16
2005	25.97	22.49	30.4	18.2
2010	29.34	20.72	30.2	17.2
2015	22.24	17.41	33	21.4
2017	33.95	21.89	30	18
Differnece	3.2	-1.55		



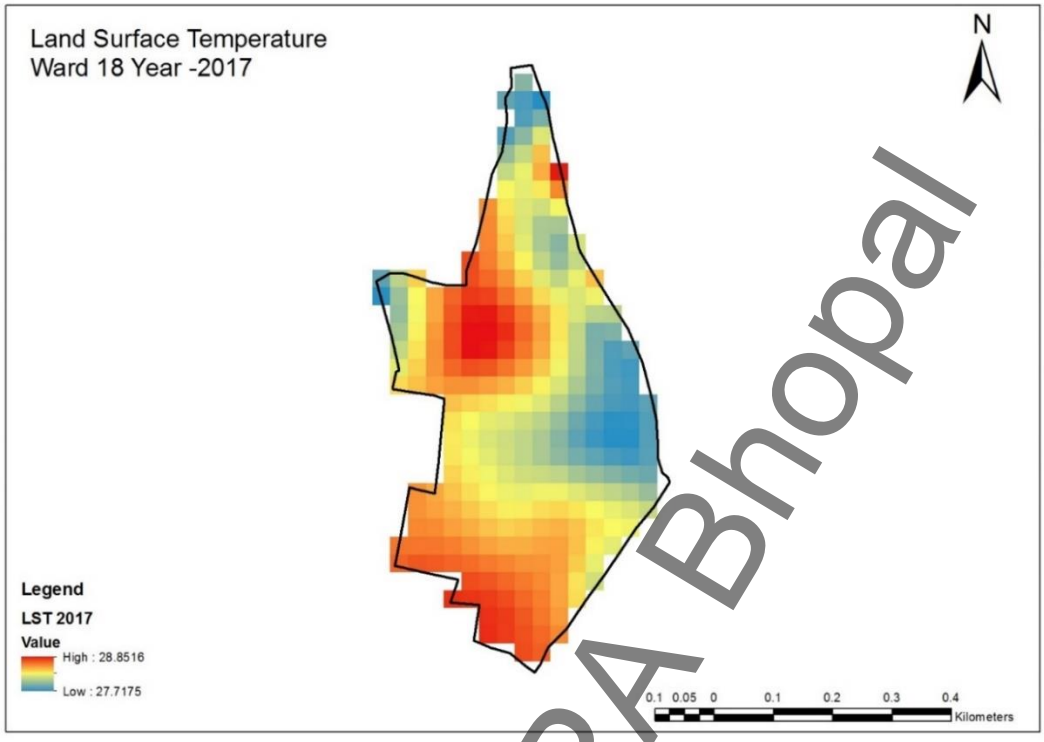
Graph 15: LST Vs IMD temperature graph ward 3

From the above Map 61, Map 62, Table 57and Graph 15we can see that over the years due to increase in built up the temperature have increase in the ward but the maximum temperature concentration is in the landfill area. The area near the water bodies are much cooler than the other area. But in overall the maximum temperature have increased and the minimum temperature have decrease thereby creating a larger difference in maximum and minimum temperature of the area. Also in 2017 the Land surface temperature for that month is more than the Atmospheric temperature as given by Indian Meteorological Department.

6.3.1.3 *Land Surface Temperature of Ward 18*



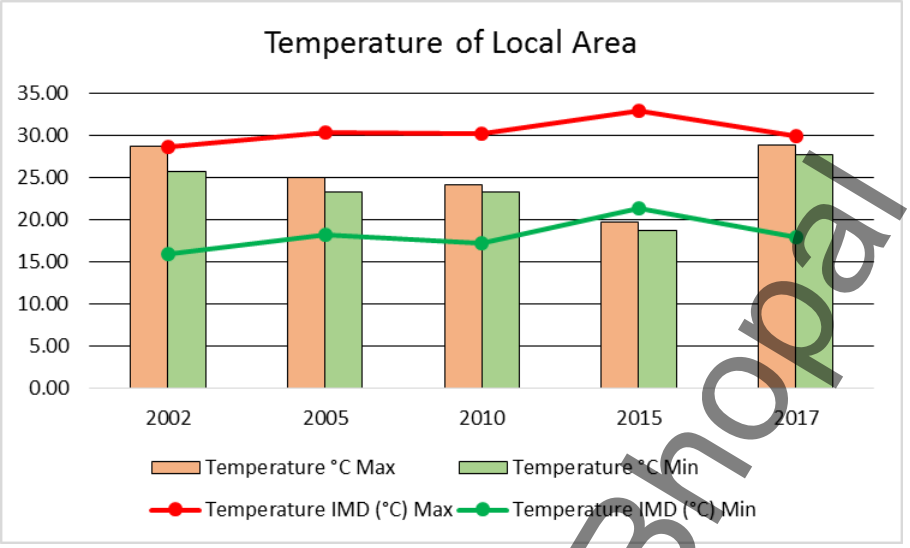
Map 63: LST ward 18 2002



Map 64: LST ward 18 2017

Table 58: LST Vs IMD temperature ward 18

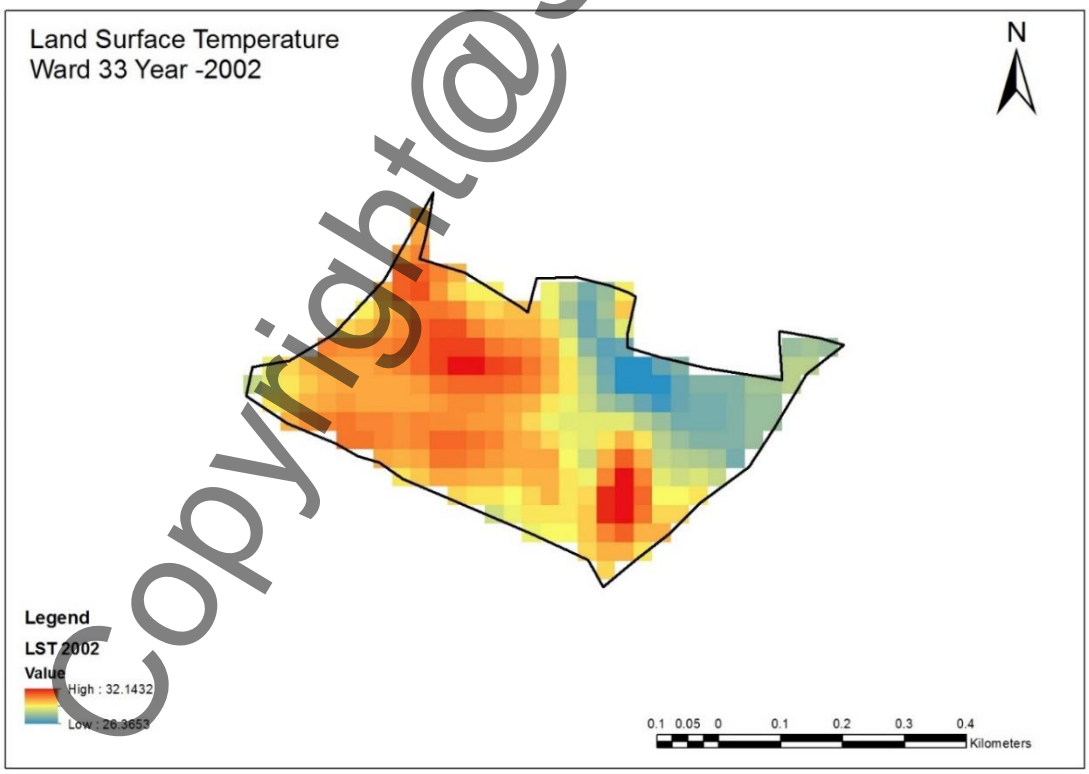
Year	LST Temperature °C		Temperature IMD (°C)	
	Max	Min	Max	Min
2002	28.83	25.83	28.7	16
2005	25.11	23.37	30.4	18.2
2010	24.24	23.37	30.2	17.2
2015	19.69	18.8	33	21.4
2017	28.85	27.71	30	18
Differnece	0.02	1.88		



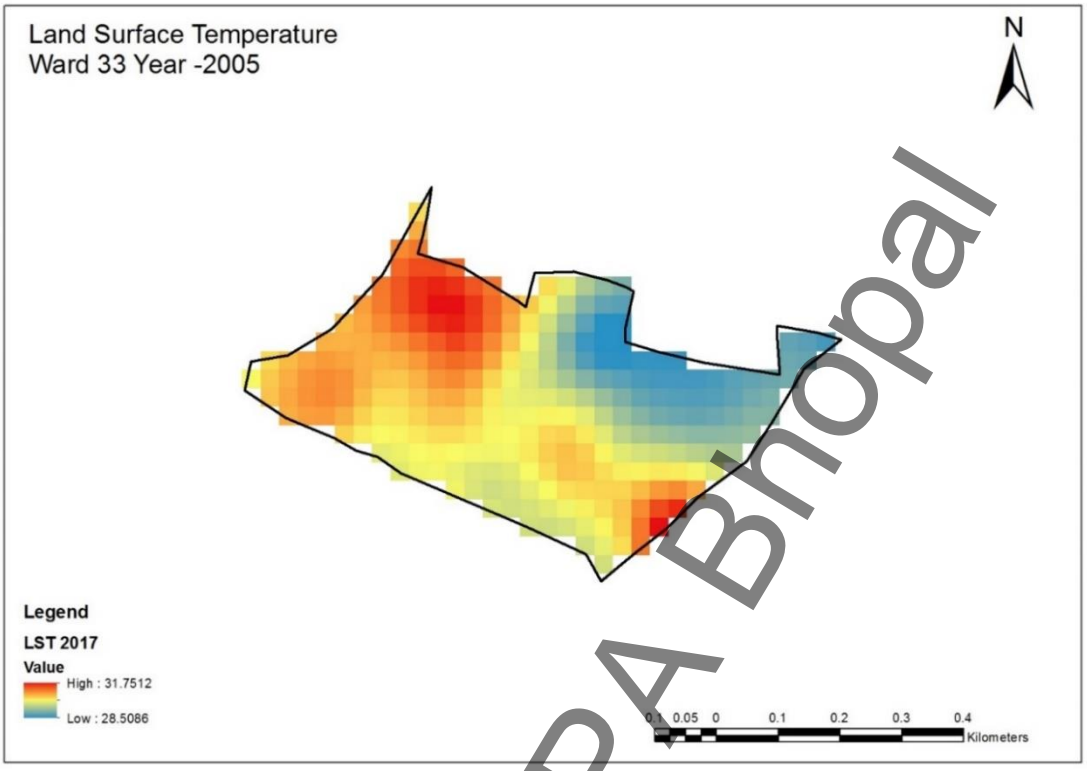
Graph 16: LST Vs IMD temperature graph ward 18

So from the above Graph 16, Map 63, Map 64 and Table 58 we can see that there has been increase in minimum land surface temperature of the ward thereby decreasing the range between the maximum and minimum temperature which is a characteristic of the urban heat island effect.

6.3.1.4 *Land Surface Temperature of Ward 33*



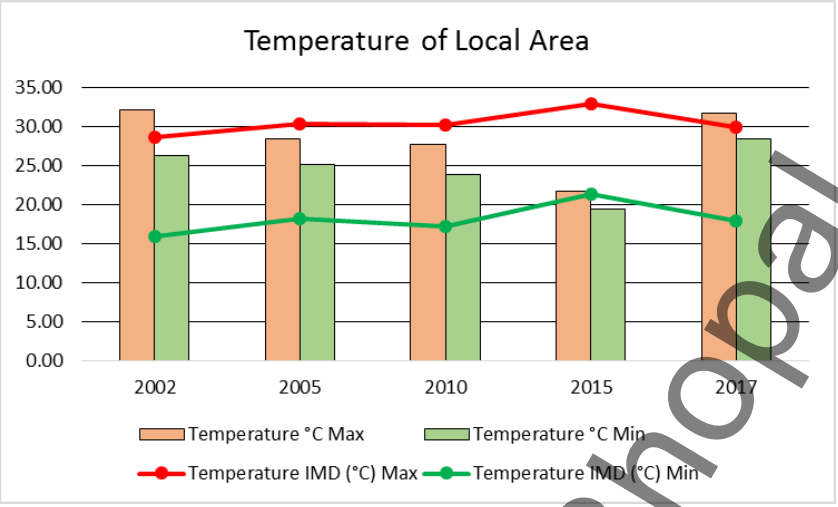
Map 65: LST ward 33 2002



Map 66: LST ward 33 2017

Table 59: LST Vs IMD temperature ward 33

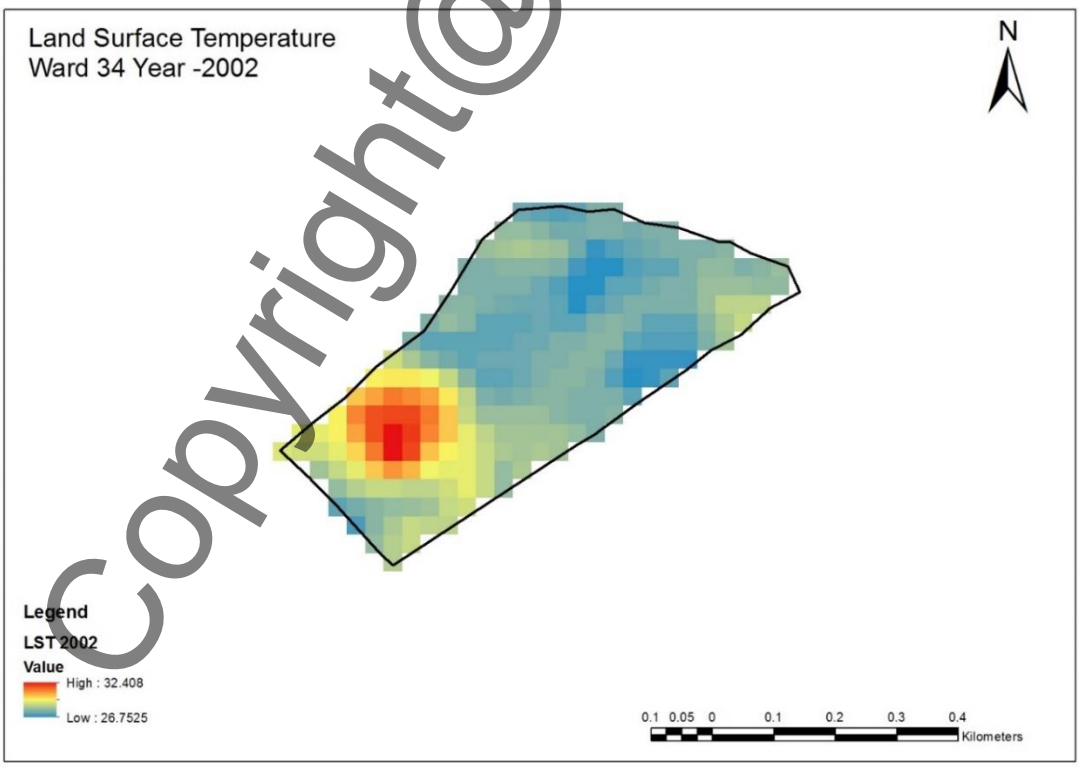
Year	LST Temperature °C		Temperature IMD (°C)	
	Max	Min	Max	Min
2002	32.14	26.36	28.7	16
2005	28.51	25.11	30.4	18.2
2010	27.67	23.81	30.2	17.2
2015	21.79	19.39	33	21.4
2017	31.75	28.5	30	18
Differnece	-0.39	2.14		



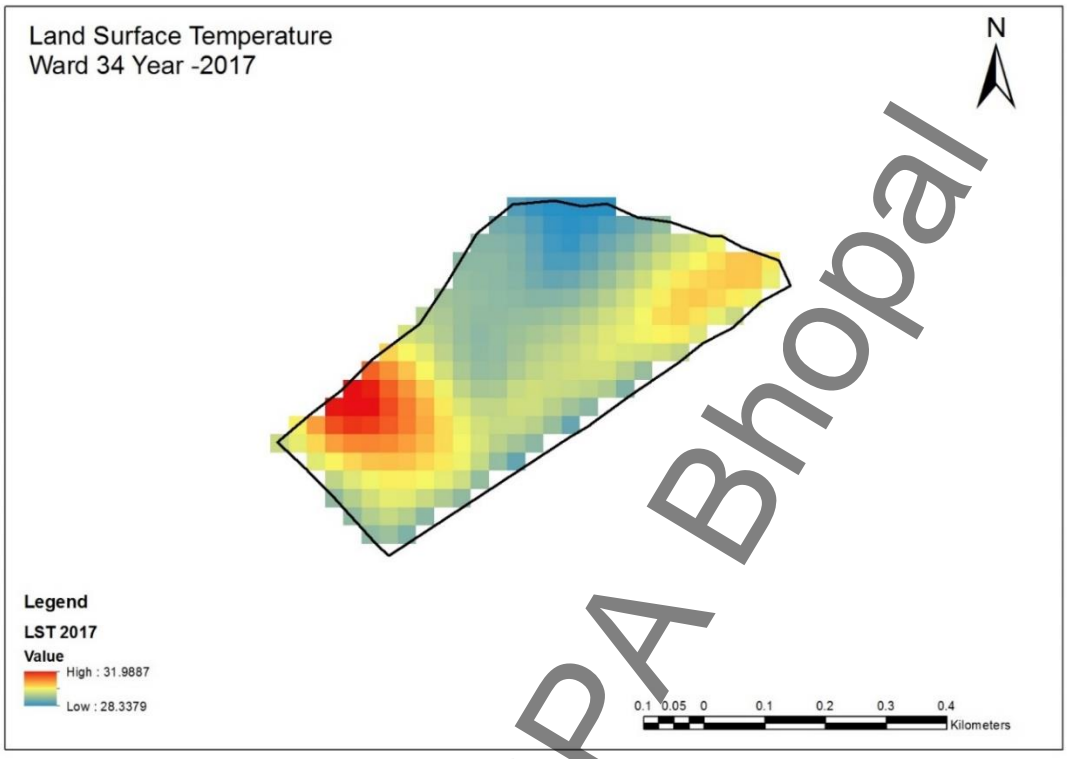
Graph 17: LST Vs IMD temperature graph ward 33

Even in this case the above Table 59, Map 65, Map 66 and Graph 17 we can see that there has been increase in minimum land surface temperature of the ward thereby decreasing the range between the maximum and minimum temperature which is a characteristic of the urban heat island effect. Also in this case the Land surface temperature of 2017 for that month is more than the Atmospheric temperature as given by Indian Meteorological Department.

6.3.1.5 *Land Surface Temperature of Ward 34*



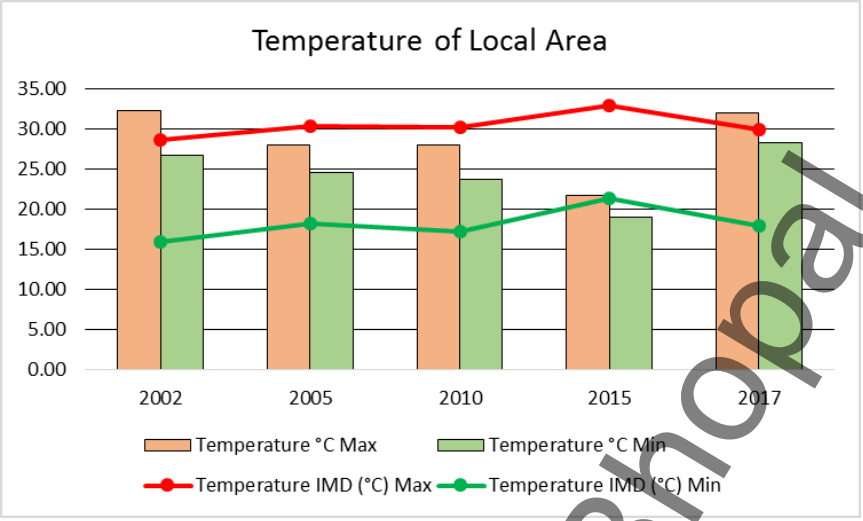
Map 67: LST ward 34 2002



Map 68: LST ward 34 2017

Table 60: LST Vs IMD temperature ward 34

Year	LST Temperature °C		Temperature IMD (°C)	
	Max	Min	Max	Min
2002	32.4	26.72	28.7	16
2005	28.09	24.68	30.4	18.2
2010	28.09	23.81	30.2	17.2
2015	21.81	19.08	33	21.4
2017	31.98	28.33	30	18
Differnece	-0.42	1.61		



Graph 18: LST Vs IMD temperature graph ward 34

In this ward we can see that the temperature has increased from 2002 to 2017 both in terms of maximum and minimum temperature which is depicted in Graph 18, Map 68, Table 59 and Table 60. We can also see from Map 68: LST ward 34 2017 where the new playground has been created the temperature have increased which was much cooler when there was a water body. So conversion of water bodies to playground with bare soil and grass is not a correct option to improve the environment.

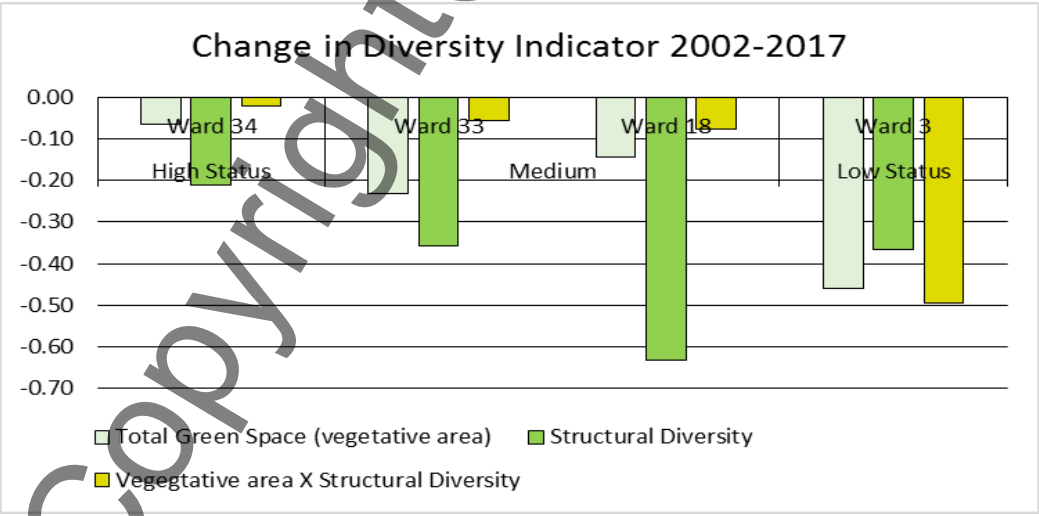
6.4 Relation between environment and socio economic condition

6.4.1 Diversity and socio economic condition

As we have earlier said that the biodiversity of an urban area do get affected by the amount and size of green space and its spatial distribution, but where there is a relation between socio economic justified. So when we examine all 3 index of diversity that is total green space, structural diversity and product of structural diversity and the total vegetative area we find that a low status area has maximum decrease in total green cover and least decrease in high status area. If we verify the structural diversity id dose not depict any significant effect on it, rather it depicts that all areas are losing its diversity. But the scenario changes as we multiply the structural diversity with the total green space which clearly shows that low status areas has a greatest decline than any other area.

Table 61: Differences in Diversity in different socio- economic conditions

Bio-diversity Indicators	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Total Green Space (vegetative area)	0.24	0.17	-0.07	0.33	0.19	-0.14	0.32	0.09	-0.23	0.64	0.18	-0.46
Structural Diversity	0.82	0.61	-0.21	1.10	0.74	-0.36	1.02	0.38	-0.63	1.22	0.86	-0.36
Vegetative area X Structural Diversity	0.04	0.02	-0.02	0.09	0.04	-0.06	0.08	0.01	-0.08	0.62	0.12	-0.49



Graph 19: Difference in diversity index in different socio economic condition

As per the Table 61 and Graph 19 show that by plotting the difference of diversity index on y – axis and socio economic status on x – axis it gives a clear picture that

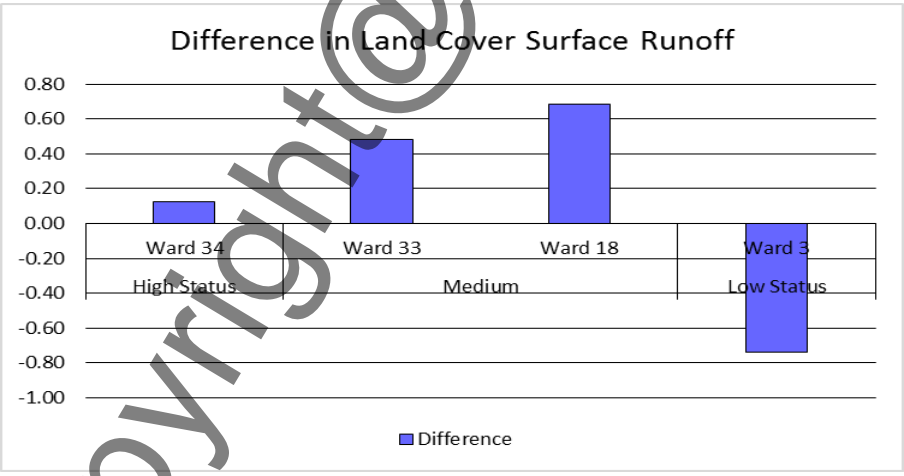
the major difference has occurred in low and the medium status areas have lost their heterogeneity more than the high status area. So we can say that low and medium status areas were more diverse in terms of species richness than high status areas and due to fragmentation they have lost their richness. The least difference is in high status. So in overall perspective the low status area is being affected more than any other status area.

6.4.2 Surface Runoff and Socio – Economic condition

As we can see from that the socio – economic condition do have an interrelation between environmental condition in that same we need to understand the relation between socio – economic condition and surface runoff. As runoff is greatly influenced by the amount of built up space in an area so from the land use and land cover analysis it is expected that if built up increases the surface runoff will increase.

Table 62: Land Cover and Socio - economic Condition

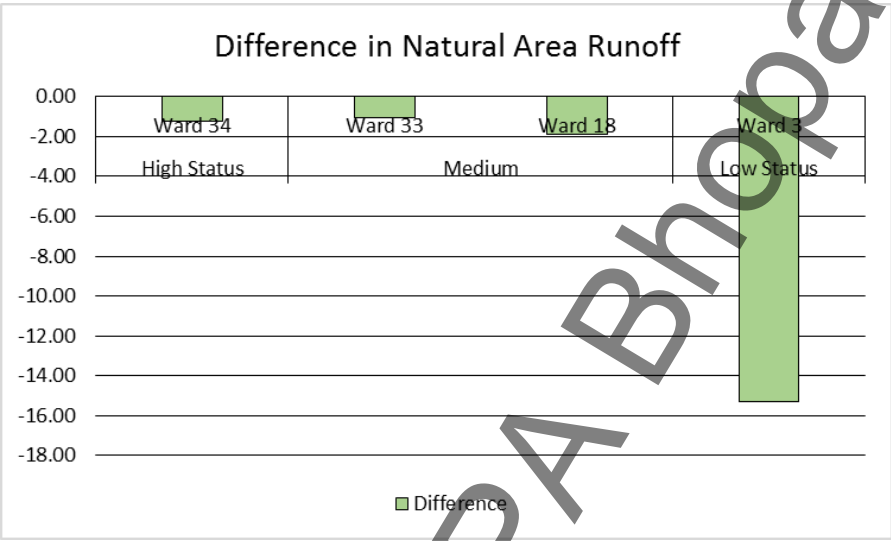
Land Cover				
Surface Runoff (m3/sec)	**High Status**	**Medium**		**Low Status**
	Ward 34	**Ward 33**	**Ward 18**	**Ward 3**
Difference	0.12	0.48	0.68	-0.74



Graph 20: Land Cover and Socio-economic status

Table 63: Natural Land Use and Socio - economic Condition

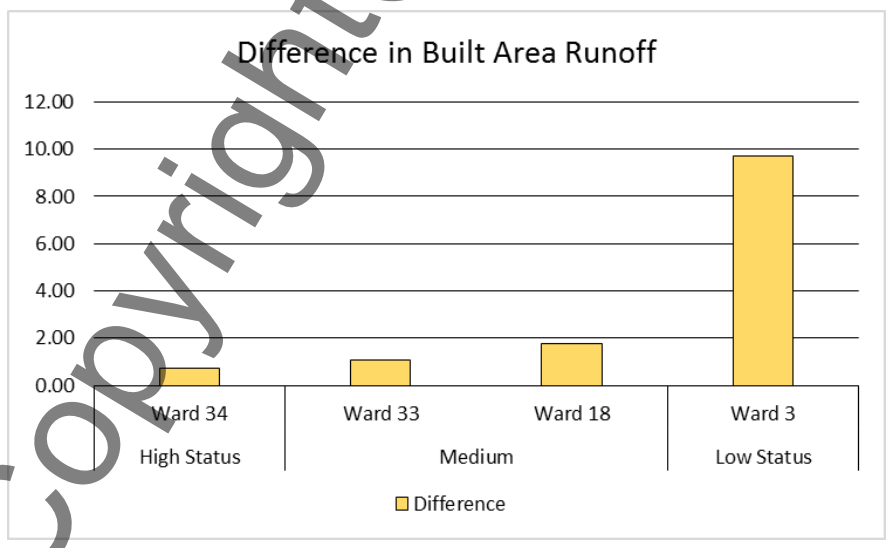
Natural Area				
Surface Runoff (m3/sec)	**High Status**	**Medium**		**Low Status**
	Ward 34	**Ward 33**	**Ward 18**	**Ward 3**
Difference	-1.25	-1.09	-1.89	-15.28



Graph 21: Natural Land Use and Socio - economic status

Table 64: Built Land Use and Socio - economic Condition

Built Area				
Surface Runoff (m3/sec)	**High Status**	**Medium**		**Low Status**
	Ward 34	**Ward 33**	**Ward 18**	**Ward 3**
Difference	0.73	1.10	1.77	9.69



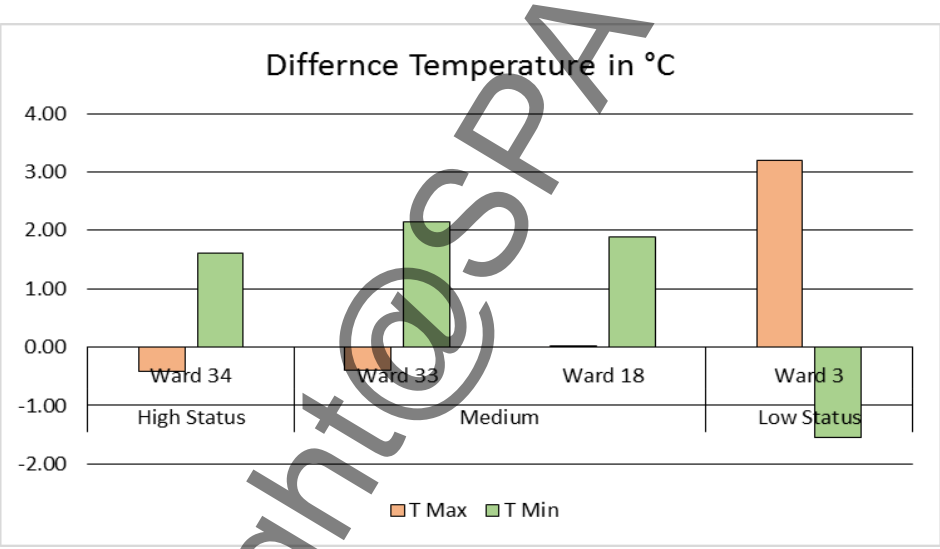
Graph 22: Built Land Use and Socio - economic status

Form the Graph 20, Graph 21, Graph 22, Table 62,

Table 63 and Table 64 shows that the surface runoff difference have been plotted on y – axis and socio –economic status on x – axis and finally we infer that the major increase in built up runoff and major decrease in natural runoff is in low status with least in high status and moderate in medium status. But a good sign is that the overall runoff generation has decreased in low status areas while the overall runoff in other area have increase. This may due to the consideration of multi detached housing group for runoff calculation in low status areas.

6.4.3 Land Surface Temperature and Socio – Economic condition

So the land surface temperature analysis shows that there is different situation in different wards so to understand the relation between land surface temperature and the socio – economic condition we plot the difference of the temperatures in y axis and socio economic status in x axis.



Graph 23: LST and Socio economic condition

Table 65: Temperature differences and Socio economic condition

Difference in Temperature °C	High Status	Medium		Low Status
	Ward 34	Ward 33	Ward 18	Ward 3
T Max	-0.42	-0.39	0.02	3.20
T Min	1.61	2.14	1.88	-1.55

From the Graph 23 and Table 65 we can see that the in high status and medium status the maximum temperature have decreased from 2002 to 2017 while the minimum temperature in the local area have increase there by decreasing the gap

between the maximum and minimum temperature. But this is not in case of low status where there is increase in maximum temperature and decrease in minimum temperature which increase the difference in minimum and maximum temperature range. So in this case the high and medium status are showing characteristic of UHI than the low status area.

Therefor concluding from the analysis are:

Low Status

- ✓ Increase in Built up and Asphalt road area.
- ✓ Conversion of large water bodies to landfill sites.
- ✓ Reduction in Tree canopy of the area.
- ✓ Decrease in bare soil and tough grass area.
- ✓ Decrease in shrub type land cover also.
- ✓ Huge decrease in total green spaces.
- ✓ Highest decrease in value of vegetative area and Shannon index.
- ✓ Highest decrease in surface runoff in natural area and maximum increase in runoff in built up area. Overall there is decrease in runoff.
- ✓ Maximum increase maximum temperature and decrease in minimum temperature over the years.

Medium Status

- ✓ Increase in built up is more in case of high social and low economic area.
- ✓ Decrease in tree cover and bare soil and turf grass is more in high social and low economic area.
- ✓ Decrease in total green space is more in high social and low economic than the low social and high economic area.
- ✓ Both areas have seen a large increase in surface runoff.
- ✓ But in case temperature both area are facing increase in minimum temperature which is a characteristic of UHI.

High Status

- ✓ From all other areas there has been least increase in built up area.
- ✓ There has been increase in playground by converting few water bodies.
- ✓ As tree cover area is very less there has been decrease in tree cover but it is least with respect to other areas.
- ✓ Not much decrease in bio- diversity indicator of the area.
- ✓ The minimum land surface temperature have increase in the area which indicates UHI characteristic.

- ✓ Also from map it is visible that conversion water bodies to playgrounds have increase the amount of bare soil in that place and therefore there is an increase in land surface temperature.

So from all the analysis it is clear there is rapid degradation of environmental quality in low status area that the other areas. In case of high status area environmental components are low so rate of degradation is least. Therefore the recommendations are purely based on the analysis and have been suggested for the Low status ward only that is Ward No. 3.

Chapter 7. Recommendation and Suggestions

The approach that was adopted to analysis the land use, land cover and the environmental quality give us helped us to identify and establish a relation between the socio – economic condition and its environmental condition in all aspects. The analysis showed that there is decline in environmental quality in all perspective but the rate at which the environment is declining is varying as per the socio – economic condition. Based on pervious discussion and analysis we find that the rate of declination of environmental quality is more with respect to low status areas than the medium and high status areas. Not only this we can also say that to upgrade the environmental quality in status area by increasing parks and playground we are actually degrading the environmental quality which is not acceptable. So to as per our objective three we need "to prepare planning strategies and guidelines for blue and green spaces based on the outcome."

7.1 The issues that Municipality is facing:

- Only few areas have been identified as Parks and Public Open Spaces in all the 4 study areas under municipality.
- There are open grounds that can be declared as Parks and Public open spaces within the municipality but has a threat of being encroached or converted to built-up area.
- As per DCR no ponds, water bodies and no canal shall be filled but yes narrowing of water channels are taking place for construction of residential buildings and also construction of metro bridge over the canal. As a result of this the natural flow of the channels are hindered and bottle neck situation is creating more urban flooding.
- Sick and closed industrial land are converting to Real estate development zones.
- There is no provision for conservation of and marinating trees cover and reducing deforestation as a part of DCR.

7.2 Hierarchy of Parks as per DCR

According to DCR the parks and public open spaces are classified as:

1. Small Park and public open spaces with an area up to 1500 sq metres.

2. Medium parks and public open spaces from 1500 sq metre to 7000 sq metres.
3. Large parks and public open spaces above 7000 sq metres.

So accordingly the number of parks available in each of the 4 study area are:

Ward 3:

1. Small Park 1 in number as per municipal recodes
2. Medium Park no medium parks are there as per municipal recodes.
3. Large Park no large parks are present as per municipal recodes.

Ward 18:

1. Has only 1 small park under municipal recodes and no other parks are there.

Ward 33

1. Small park is only 1 as per municipal recodes
2. No medium park is there
3. Has one large park under municipal recodes.

Ward 34:

1. One small park is there as per municipal recodes.
2. One medium park is there as per municipal recodes.
3. Even one large park is there under municipal recodes.

So from this it is clear that the High status area that is ward 34 has all the hierarchy of parks while the low status and medium status lacks this hierarchy of parks and public open spaces.

7.3 Rules as per present Land use and Development control Plan

The present Land use and development control plan include all areas lying on the east bank of Hooghly River which is a part of the Kolkata Metropolitan Area and includes all municipalities except area under Kolkata Municipal Corporation, Bidhannagar, Kalyani and parts of the Raipur – Sonarpur Municipality.

According to this DCR the authorities have identified different “No Development Zones” which are:

- Parks and Public Open spaces if recorded in Municipality.
- Parks and Playground within Railway Colonies, Defence area.

- Cremation, Burial and last rites performing grounds.
- Plots and premises being used as Industries even if identified sick, closed etc.
- No pond, water bodies or wetland and no canals shall be filled.

7.4 Need to focus on:

- Prevention and conservation of water bodies
- Increase vegetative cover
- Prevention, conservation and proper upgradation and management of the open spaces.

So now if we think to achieve sustainable development we need to take environment and the landscape based on our socio – economic condition of area. This does not mean that if the area is socio – economically low area we do not need to consider its environment and landscape as everyone has the right to enjoy a good and health environment.

As per our constitution article 21 “No person shall be deprived of his life or personal liberty except according to the procedure of established by law.” (The Constitution of India, 1949). So environment is a part of life and everyone has equal right on it.

7.5 New Regulations that can be incorporated in DCR

As we see that the present DCR lacks many rules that should be incorporated for the preservation, maintenances, protection of both open spaces and water bodies and also the plantation of trees at the neighbourhood level. Majority of the metropolitan zones in India do have these regulation to protect their natural spaces within the city. As per our URDPFI guidelines we should incorporate open spaces and vegetation that will act as a heat sink of the local area. It suggests in planting deciduous trees so that they can cut the intense and glazing heat, cut off hot breeze and provide shade (Ministry of Urban Development, 2014).

7.5.1 Some of the existing Rules in different Development Control Regulation of other cities and Metropolitan areas

7.5.1.1 *Tamil Nadu Government*

Open Space Reservation (OSR):

This has been incorporated in various Master plans of different cities in Tamil Nadu like Erode, Vellore, Tiruvallur, Coimbatore, Madurai, Gummudipoondi, Kanchipuram, Salem, Chengalpattu, Tiruppur and Tiruchirappalli local planning areas (Government Of Tamil Nadu, 2010) and also the Chennai Metropolitan area. The main purpose of this is to reserve open spaces for community where plot size exceeds 3000 sq metres. This has been made under the umbrella act of Town and Country planning Act, 1971 by the Government of Tamil Nadu.

So they mainly focus on reserving lands for recreational purpose as parks, play grounds for the communities

Table 66: Community and recreational open spaces (Government Of Tamil Nadu, 2010)

Community and recreational open spaces	
Extent of layout	**Reservation**
For the first 2500 square metres	Nil
More than 2500 square metres	10% of the area shall be reserved and this space shall be maintained as communal and recreational open space to the satisfaction of the authority such as parks, play grounds, community play space etc. and this should be handed over to the local body and a minimum of 1% shall be reserved for local shops apart from this in major layout more than 10 acres of site 4 to 5% of area shall be reserved for public purpose such as community buildings viz., educational, commercial, community facilities in accordance with the norms given below (GOVERNMENT OF TAMIL NADU, 2010)

Table 67: OSR (Government Of Tamil Nadu, 2010)

Extent of Site	Up to 2500 sq m site	Above 2500sq m site
Reservation	Nil	10% of area with min dimension of 10m

Generally as per these Table 66 and Table 67 are marked as one place only and to get exemption equivalent land must be valued by the Registration Department and then the market value of the land must be paid by the developers or the owners. In case the area is more than 10,000 sq metres then 10% area must be allocated for OSR. Even before approval of layout one has to pay the OSR charges (Nair, 2016).

7.5.1.2 *Draft Development Plan 2034 Greater Mumbai:*

In this draft development plan they provide a separate regulation for providing recreational open spaces which will be an integral part of the developed site and will be open to sky and will be used for recreation but it will not be a terrace kind of structure (Municipal Corporation of Greater Mumbai, 2016).

In residential and commercial zones amenities and facilities should be developed in such a way that if development area is within 4000 sq m to 10000 sq m then only 5% of the plot will be used as Public open space but if this area exceeds 10000 sq m then 10% area will be for public amenity space where 50% area will be meant only for public open space balance 50% area will be for education, health, social and other amenities (Municipal Corporation of Greater Mumbai, 2016).

Also this DCR provides the provision for the plantation of trees at the rate of 5 trees per 100 sq m in recreational spaces and 1 tree per 80 sq m if the plots are subdivided (Municipal Corporation of Greater Mumbai, 2016).

7.5.1.3 *DCR of Bangalore:*

In the Bangalore DCR focuses on the conservation and preservation of natural environment which include the water bodies, forest, drains, parks, playgrounds and also burial grounds and crematoria. Some of the permissible land use that they have allowed in these areas are sports ground, stadiums, playgrounds, gardens and under special circumstances the authority can allow open air theatres, sports clubs, milk booth libraries etc.

Even no obstruction can created by constructing roads, pathways, culverts bridges the water courses, runoffs and the channels.

All water bodies within the city should have a 30 m buffer zone which will be a no development zone. The drain have a buffer of 50, 25 and 15 m on either side which is measured from the centre of the drain. All these rules have been developed under the KTCP Act, 1961 and Sec 32 of BDA Act, 1976.

In case of tree plantation there must be 1 tree for a site more than 2400 sq Ft and 2 trees for site around 4000 sq Ft.

For Residential development it says that 10% of area should be reserved for parks and Open spaces and this open space needs to relinquished to the authorities at free of cost for maintenance (Bangalore Development Authority, 2007).

Table 68: Major regulation for development (Bangalore Development Authority, 2007)

Water Bodies	No Development Zone	Need to have 30m buffer
Residential Development	10% for Park and Open Space	Relinquished to the authority free of cost
Tree Plantation	1 tree for site more than 2400 sq ft.	2 tree for site 4000 sq ft.

7.5.1.4 *Revised Master plan for the Core area of Hyderabad metropolitan Development Authority:*

The major focus of open space zoning in this revised master plan is the natural conservation of green buffers and water bodies.

They even have zoning of water bodies which include all the existing water bodies in city, rivers, streams, lakes tanks and kuntas. In this Water body zoned area no construction is permitted and have to provide a minimum 30 meter buffer on all side of the water body.

Now they have included a tax exemption system within their revised master plan where they allow the private plot and land owner if they create, develop and maintain open spaces where the site is 1000 sq m and above in built up area for recreational purpose then there will be exemption of 25% of property tax. If this is in case of a registered society the 50% of the tax will be exempted (Hyderabad Metropolitan Development Authority, n.d.).

Table 69: Regulation as per HMDA revised Master Plan (Hyderabad Metropolitan Development Authority, n.d.)

Water Bodies	No Development Zone	Need 30m buffer
Property tax Exemption	Private land owners with 1000 sq m and above – 25%, Register Society – 50%	Develop or maintain open spaces
Tree Plantation	1 tree for site more than 2400 sq ft.	2 tree for site 4000 sq ft.

Now for application of the above proposal Ward 3 is best as it rate of degradation is more and in terms of socio – economic condition it is low in both cases. So for detailing the proposal Ward 3 has been selected and different approaches have been identified.

7.6 Rejuvenation of Green Spaces

As per consultation with the municipal authorities the rejuvenation of Green Spaces within the municipality is taking place under Atal Mission for Rejuvenation of Urban

Transformation (AMRUT) guidelines. But the Guidelines as given by AMRUT only focuses on few basic things and other things are missing.

7.6.1.1 *The Steps involved in Rejuvenating a Green Space under AMRUT mission:*

Step 1 Asses Service Level Gap:

The Service level gaps are asses based on the following:

1. Policies and Plans and Scheme Documents.
2. Discussion with citizens and officials.
3. Physical Assessment of Park under current situation.
4. Service level Status (Per person open space as per URDPFI)
5. Physical resources
6. Family facility including child friendly play equipment.
7. Availability of general services and facilities.
8. Aesthetics and other.

The main focus is to understand the requirements, physical condition and current status of park.

Step 2 bridging the gap

1. Bridge the gap by listing all initiatives taken under any program, project and development plan.
2. 1 park to be developed for the children, youth and elderly people.

This will help to bring out the gap of open space in terms of allocation, having citizen friendly feature and also issues related to the maintenances.

Step 3 Examine Alternative and Estimate Cost

1. Identify the alternative option to complete the project
2. Identify the quick win parks where development can be for children, youth and elderly

It basically finds the alternative of the project.

Step 4 Citizens Engagement

1. Consultation with citizens
2. Get feedback and Suggestion and alternatives.
3. Understand priorities to meet the gap.

It focuses mainly on public participation in development of the parks.

Step 5 Prioritize Projects

1. Based on funds
2. Based on different programs and schemes.

Step 6 Conditionality

1. Based on availability of land, environment, social obligation and clearances.

Step 7 Resilience

1. Talks about environmentally sustainable, safety and Security.
2. Type of material to be used for construction mainly to make it children friendly and safe.

Step 8 Financial plan

1. Based on investment
2. Based on capital cost and operation and maintenances
3. Financial plan for the complete life cycle.

Now according to this there can be some extra condition incorporated in few of the steps to make it a better park and public open spaces for all. (AMRUT, n.d.)

7.6.1.2 *Incorporating the following in different steps for AMRUT*

Step 1 Asses service level gap

1. Consider Socio – Economic Condition for Assessment.
2. Consider Area of ward and population of the ward
3. Include surrounding Environmental Indicators and quality for Assessment of current status of parks so that the things that are lacking can be included while rejuvenating the park.

Step 2 Bridging the Gap

1. If we are focusing in developing parks for children we should also focus on developing parks that have more biodiversity and help in restoring biodiversity by attracting birds, growing trees that provide shade and also cool the surrounding area instead of having just the grassy parks and play grounds.

Step 5 Prioritize project

1. We should not only prioritizes development of parks on basis of funds, programs and schemes but also depending on the surrounding environmental conditions of the ward or neighbourhood.

Step 7 Resilience

1. There should be detail out steps to achieve environmental sustainability.
2. Also sustainability should be in terms of environment, social and economy. So we should develop our parks in such a way that they should uplift social conditions of area, generate economy for the local people by engaging them is small activities and also improve the surrounding environmental condition of the neighbourhood.

7.7 New Development Control Rules

7.7.1 Conservation and prevention of water bodies

As we see in many of the development control regulation the development authority have incorporated a buffer for the preservation of these water bodies and the buffer areas are no development zones. In the same way the new development control regulation for Land use Development Control plan (LUDCP) with respect to east bank of River Hooghly should have the same buffer system but according to the rate of urbanization and the land availability for buffering.

According to Municipal there are only few water bodies have been identified and registered in their records. This is also one of the reason that have resulted in decrease in water bodies over the years. As the water bodies are ranging from different sizes they should also be registered according to a hierarchical classification and also provide a buffer zone. This will result in appropriately identify all the water bodies and understand its importance and also it will help to protect these bodies as our water bodies will have at least some level of buffer zone which will act as a no development zone.

So the hierarchy of water bodies are:

Table 70: Water Bodies Hierarchy and Buffer

Hierarchy of Water Bodies (Area)		
Type	**Area Range (Sq Mtr)**	**Buffer (Mtr)**
Large pond / Lake	Above 10000 Sq Mtr	10 Mtr
Medium Pond	2500 - 10000 Sq Mtr	6 Mtr
Small Pond	Below 2500 Sq Mtr	3 Mtr

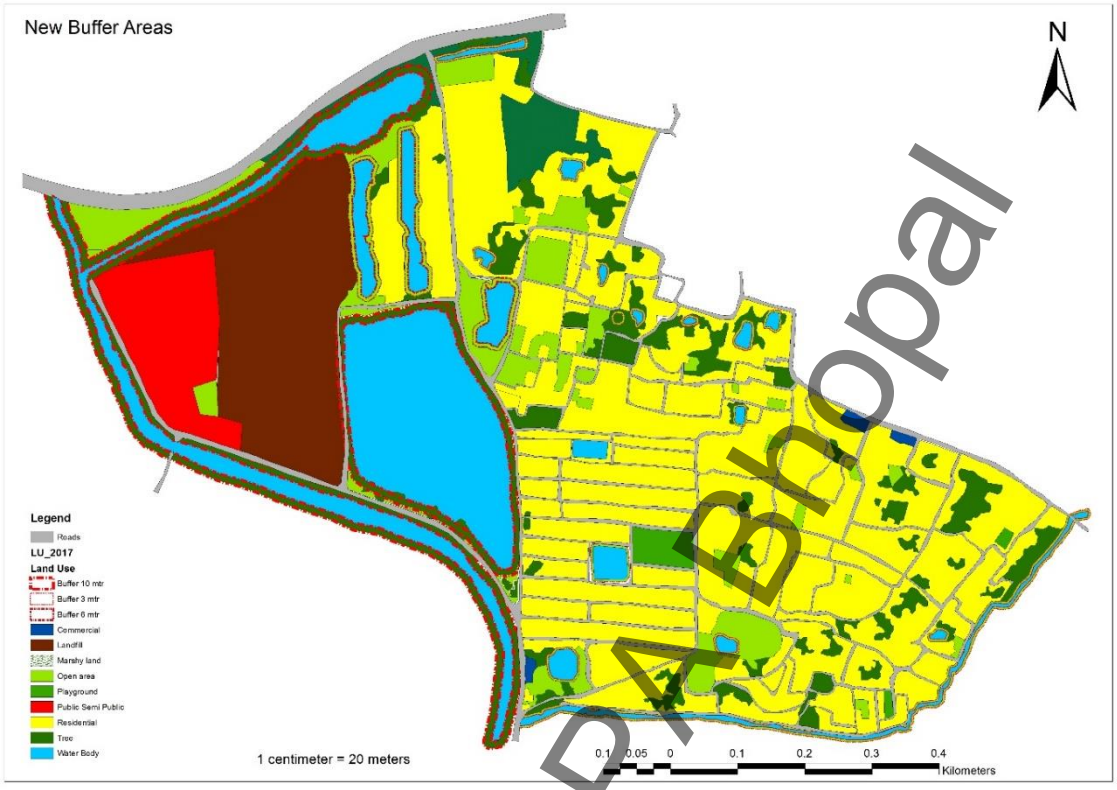
As the study area has lot of canals which are used as storm water discharge networks and sewage network in whole of KMA these canals need to be protected as in many cases these canal banks have been encroached by slum or built up has come up which have restricted the flow of water in the canals. Therefore it is necessary that the canals also have a buffer.

The buffer for the canals are also based on the width of the canal and accordingly the buffer length has been suggested. But in case where there is the already built up then the buffer will not be applicable as the removal of the built form is not possible. So the buffers for the canals are as per the

Table 71: Canal size and Buffers

Buffer for Canals (Width)		
Type	**Width of Canal (Mtrs)**	**Buffer (Mtr)**
Wide Canal	Above 20 Mtrs	10 Mtr
Medium Wide Canal	10 - 20 Mtrs	6 Mtr
Narrow Canal	Below 10 Mtrs	3 Mtr

Now according to the Kolkata Environmental Improvement Project (KEIP) they have already proposed that the canals as a green belt area with a 10 meters width buffer and a minimum of 3 metres buffer for the purpose of maintenances. But this green belt is only applicable in Kolkata Municipal Corporation (KMC) area (Kolkata Municipal Corporation, 2013). Although study area is just outside the KMC boundaries this model will be applicable and help to connect the proposed green belt within KMC area as the same canals flows through both the study and KMC areas. Thereby creating a larger green belt and such can be replicable within other municipalities a under KMDA and form a network of green belt for the whole KMA. The Map 69: Spatial location of the buffer zones of all water bodies highlights all the water bodies and their buffers depending upon the area and width of each water body.



Map 69: Spatial location of the buffer zones of all water bodies

According to this same KEIP canal resettlement plan this canal green belt will be a source of income generation mainly for the people living along the edge of the canal. According to this the Government have encourage the growth and plantation of mainly fruits and vegetables from which in come can be generated are in Table 70 and Table 71 can easily be applied in ward 3 as they have many small water bodies and also both type of canal with wide more than 20 m to width less than 10 metres.

7.7.2 Increase the Vegetative cover through Tax exemption and Tree plantation.

As already mentioned before many of the DCR of different metropolitan have implemented tree plantation as a part of their development control regulation. Even some development authorities are promoting private owners and registered societies to maintain open spaces. Such initiatives can be incorporated as a guideline in the LUDCP and help the local communities to maintain the natural vegetative cover in the area.

As in Ward 3 has mainly detached housing and while surveying it was identified that many house do have home gardens. So the houses which have home gardens

can be considered as the part of tax exemption. Even as per the amendment of Kolkata Municipal Corporation act of 1980 have incorporated the clause "exemption from the payment of a portion of property tax which will not exceed ninety percent of the actual gross amount of the property tax on pond, tank or water bodies in nature, either whole or a part thereof such that the actual pond, tank or water body is kept and preserved by the owner in a good manner so that the ecological balance of the locality is maintained." But such water bodies can't be a water body which is used as a swimming pool (Government of West Bengal, Kolkata Gazette, 2014).

So if such tax exemption can be incorporated in KMC area these can also be incorporated as a LUDCP guidelines for other municipalities within KMDA area.

Therefore the Tax exemption can be for both private gardens and for water bodies as per Table 72.

Table 72: Tax exemption on natural areas (Government of West Bengal, Kolkata Gazette, 2014), (Common Floor, 2014), (BANGALORE DEVELOPMENT AUTHORITY, 2007)

Tax exemption Criteria				
Type	**Plot Size**	**Considered amount of Blue / Green Space**	**Tax Exemption**	**Remarks**
Housing	**In Mtr**	**in %**	**in %**	**Consideration**
Residential - Single Detached Housing	Below 1000 Sq Mtr	10%	Upto 90%	1. Only applicable for the portion of Garden Space or Water Body. 2. Depending on the maintenances of the natural area and the authorities inspection.
Residential - Private Owner	1000 - 5000 Sq Mtr	25%	Upto 50%	1. Only applicable for the portion of Garden Space or Water Body. 2. Depending on the maintenances of the natural area and the authorities inspection.
Residential - Registered Society	Above 5000 Sq Mtr	50%	Upto 50%	1. Only applicable for the portion of Garden Space or Water Body. 2. Depending on the maintenances of the natural area and the authorities inspection.
Residential Develpoment	Above 5000 Sq Mtr	Not less than 10% of area under Parks and Open Spaces	100%	1. If relinquesed to the Authorities at Free of cost for maintenances for the area under open spaces and parks.

The other way is through plantation of trees. In many cases it is visible that there is huge deforestation of trees in name of development. In case of residential development manly in cases of construction of high rise apartment, gated communities and residential societies there is complete removal of tree cover but this tree cover that has been removed is not replaced by the required amount of tress and are also not maintained.

Table 73: Tree Plantation Rate (MUNICIPAL ADMINISTRATION & URBAN DEVELOPMENT DEPARTMENT, 2016)

Tree Cover		
Building and Construction	**Rate of Tree Cover**	**Type of Trees**
Less than 20000 Sq Mtr	Minimum 1 tree for every 80 Sq Mtr	Native Spceies only
	> 100 Sq Mtr trees need to be planted within the set back of the plot.	
	If the trees are cut during Construction of the Building then plantation should be at a ration of 1:3 (1 tree cut then 3 tree needs to be planted)	
20000 - 50000 Sq Mtr	Minimum 1 tree for every 80 Sq Mtr	Native Spceies only
	> 100 Sq Mtr trees need to be planted within the set back of the plot.	
	If the trees are cut during Construction of the Building then plantation should be at a ration of 1:3 (1 tree cut then 3 tree needs to be planted)	
50000 and Above	Minimum 1 tree for every 80 Sq Mtr	Native Spceies only
	> 100 Sq Mtr trees need to be planted within the set back of the plot.	
	If the trees are cut during Construction of the Building then plantation should be at a ration of 1:3 (1 tree cut then 3 tree needs to be planted)	
Note: 1. No falling of trees in front of house is to be allowed. 2. Avenue Greening should take place and preferably plant native trees.		

Thereby as per the Table 73 it is seen that any development requires tree plantation as a mandatory part of the regulation and try to achieve the targets of "National Mission for a Green India."

7.7.3 Identify new areas for development of parks and play grounds

As it was earlier mentioned that for development and rejuvenation of parks under AMRUT guidelines the parks registered within the municipality are only eligible. But the number of registered recreational parks available in Ward 3 is just one which is a small playground of around 400 sq. m. in area. So if we consider the amount of recreational area required according to the population is very less. So we need to identify other areas within the ward that can act as recreational areas and serve the population not only within the municipality but also within KMA.

So for this few areas within the ward has been Identified as the new recreational zones where funding from AMRUT can be arranged. Before funds are arranged the municipalities need to register these sites as the potential sites for development as parks and play grounds.

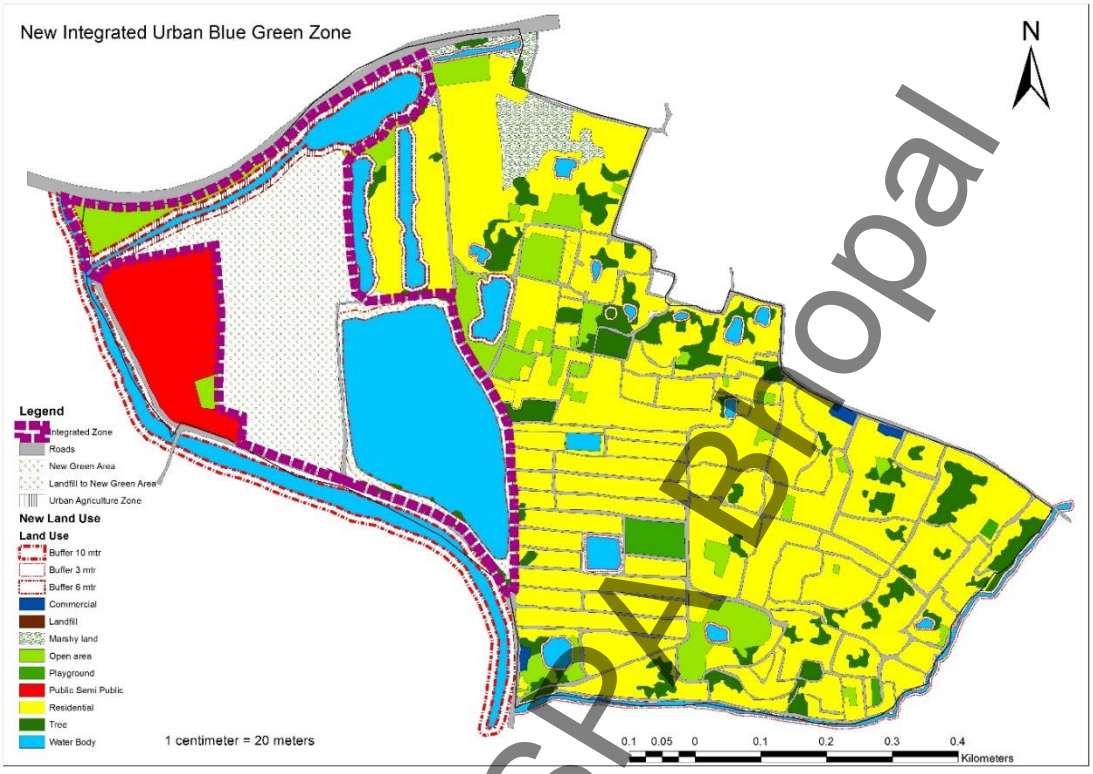
Map 70: Identified locations for future development

According to the Map 70 red circle marked area are the areas that can be developed as new parks and recreational areas. The playground marked in brown is the already developed playground which is being maintained and has an area less than 0.04 ha so it serves less than 500 population. The absolute population of

ward 3 is 14396 as per census 2011 so the amount of maintained recreational area provided by the municipality is much less. Therefore to increase the amount of organised green space needs to be increased. All the red marked areas can be developed according to the AMRUT guidelines and also incorporate the old and new steps as Rejuvenation of Green Spaces and Incorporating the following in different steps for AMRUT so that we can achieve a holistic development.

7.8 Integrated Blue and Green Zone

A zone that will serve as complete multifunctional and sustainable zone not only for the local community but also for other citizens in the municipality. As the analysis for surface temperature proved that conversion of water bodies to play ground with majorly bare soil and grass and few trees is not a good option to improve the urban environmental condition as they result in increased the surface temperature, so we have to change land use in such a way that they will help to restore the ecology of the surrounding and also have a multifunctional aspect that will help people to change the socio economic condition of the people living there. The zone identified for such purpose is the zone consisting of some portion of canal, complete conversion of the landfill area, the largest water body in ward 3 and also involving the local residences living near the land fill in the development zone. The different zones will be the urban agriculture zone, the green park and the lake front. The canal will act as a bio – remediation zone for leachate treatment and supply water for urban agriculture and the lake will from the part of green area and preserve the ecology of both the water and the newly developed green space. The Map 71 shows which land has been incorporated within the integrated blue green zone.



Map 71: Spatial location of the Integrated Zone

7.8.1 Why to convert the landfill area?

The land fill area is an old land fill site which is being used for more than 15 years. The solid waste disposal site is located just near to the Belghoria Express way and is surrounded by SDDM, North Dum Dum Municipality and Baranagar Municipality. As it falls within the residential zone of all the 3 municipality and is just separated by narrow canals only it has created lot of nuisance among the local residences. Newspaper article shows that the local residence are facing problem and have been complaining to the municipalities, but as this waste dumping ground is not only dumping ground of SDDM but it is also the dumping ground of North Dum Dum municipality, New Barrackpore Municipality and many other so the management has become a problem although it lies within the municipal scope of SDDM (Times of India, 2016). As this has become an issue to the local residences so the National Green Tribunal (NGT) have already notified the concern municipality and the Department of Municipal Affairs of Government of West Bengal (GOWB) to monitor the activities of the municipalities and take action to

comply with the Solid Waste Management Rules, 2016 (SWMR 2016) (Regarding Dumping Of Garbage At Rajiv Nagar, North 24 Parganas, 2016).

But as in December 2016 Uttarpara Kotrang Municipality won the C40 mayors summit award for innovation in Solid Waste Management (SWM) under the project Kolkata Solid Waste Management Improvement Project (KSWMIP) conducted in 6 municipalities on the west bank of River Hooghly have resulted the GOWB to take up new Integrated SWM projects for 14 ULBs (Business Standard News, 2017). SDDM is one of the municipality which will be benefited from this new Integrated SWM projects. So it might happen that the Landfill site be no longer be in use. There for new land use can be proposed for this municipality.

Therefore the Integration of canal, large water body and the land fill site will be best option for the municipality.

7.8.2 Conversion of Landfill to Green Area

Landfill conversion is not a common practise in India. As majority of the Indian cities do not have a sanitary landfill site they find it difficult to convert the degraded landfill to convert for some other use. But in many western countries this landfill conversion to green areas have been successfully implemented and completely converted the use of the area. Some examples are Mt. Trash more, Virginia Beach, Hiriya Park in Tel – Aviv, Israel, Port Sunlight River Park in UK (Inhabitat, 2017) and the Millennium Park in New Delhi, India (Bansal, 2014). As India this is not very common and the methods usually applied are costly such effort are not initiated by the urban local bodies (ULBs). But there are different methods for converting landfill one of them is Capping Method which is the most common method to close the old landfill sites while the other method is through Bio – Remediation using bio culture. Although capping method is generally used but it has large number of disadvantages.

Capping mainly involves the placing a cover over contaminated materials like a landfill site or contaminated soil (United States Environmental Protection Agency, 2012). Capping can be done with help of asphalt or concrete, providing vegetative layer through appropriate measures and laying of soil, using geomembrane and clay. But this method has a number of disadvantage as:

1. It does not reduce the toxicity, volume and the hazardous nature of waste and soil.
2. It has a very limited life span up to 50 to 100 years.
3. It has high chances of subsidence of land.
4. It requires constant monitoring.
5. Fluctuating temperature and precipitation can cause soil erosion.
6. Even for placing the geomembrane we need more area than actual contaminated area.
7. It is an expensive method and requires high amount of technical skills.

Advantage:

1. By using this method methane recovery is possible.

Therefore is method is not a very cost effective method for converting land fill sites. The other method is through bio – remediation of old dumping ground. This requires just to treat the old garbage with bio – culture chemicals or manure and convert the old garbage into manure. Segregation of large separable waste can be done before conversion of manure and final segregation can be done after the manure if formed by screening machines and filtering the bio – earth. Therefore the bio – earth or the manure formed from the treatment of old waste will help in supplying organic manure to the urban agriculture zone and also help in generate revenue by selling the manure (Maley, 2005). This process has already been implemented in Mumbai with a costing of about 9 lakh per hectare cost.

The leachate that has been released from the decomposition of waste can be easily collected in separate tank and send to the sewage treatment plant next to the landfill site. Further if some amount leaks to the canal it treated through phytoremediation in the canal. Even the phytoremediation of soil is also possible by practising urban agriculture and cultivating some special type of crops and by using special type of grass.

Treatment process:

1. The waste is treated in layer by Layer method. In this waste is taken out and formed in hips of windrow of about 5 metre wide and 3 metre height.
2. Moisture and temperature is maintained at about 45% and 60°C respectively.

3. Bio culture or cattle manure is spread while forming the hip which initiates the decomposition of the waste.
4. The waste is turned for 2 to 3 weeks with and interval of 7 to 10 days.
5. The turning helps in aerating the waste and thereby allowing aerobic decomposition (Maley, 2005).

Advantages of this process:

1. Purely a biological way to convert the land fill site.
2. High supervision not required.
3. Its expenditure is less expensive than the above method.
4. Reduction of toxicity of soil is possible through phytoremediation.

Disadvantage:

1. Covered area required for the composting and leachate collection and requirement of screening machines, dumpers and loaders are required.

Although such machines are required, but it won't be an issue for municipalities as they already have such equipment for handling their solid waste. So for the conversion of this solid waste dumping site the second method is much more preferred than the capping method.

7.8.3 Treatment of leachate

As leachate is one of the most contaminating kind of waste coming out of the decomposition of the solid waste we should provide a system to collect it from the composting area through proper slope and pipe system and then treat them in treatment plant. As we have a sewage treatment plant just beside the landfill site we can collect the leachate and then transfer them to the treatment plant for further treatment.

No for further prevention and contamination of surface water phytoremediation process of water would help to reduce the load of contamination of water. Plants to be used for phytoremediation are water hyacinths (Eichornia crassipes), common reed (Phragmites karka or Phragmites australis) grown along the water edges (Paz-Alberto & Sigua, 2013).

7.8.4 Soil Contamination Removal

Phytoremediation is the best process to remove the soil contamination as they help in removing heavy metal contamination. As earlier mentioned plants like

Phragmites karka are good phytoremediation plant they help in removing arsenic from soil up to certain concentration (Verma, et al., 2014). Other plants like Indian Mustered and Sun flower also helps in removal of soil contamination by accumulating pollutant in roots and binding the pollutant in roots tissues both physically and chemically and then transporting the contaminate to the growing shoots and thereby preventing contamination (Paz-Alberto & Sigua, 2013). Even grasses like vetiver and carabao grass also tolerant to different pollutant like alkalinity, salinity, lead, zinc, mercury etc. in soil (Paz-Alberto & Sigua, 2013). Such plants help in landscaping the area and also in remove the pollutant.

7.8.5 Urban Framing/ Agriculture

Urban agriculture is defined as the growing of plants, food crops or horticulture products within the municipal areas or in peri urban areas of the city. The urban agriculture helps in removing food security and also use waste water and even sometimes practised by the urban poor to sustain their living. So many parts of Kolkata urban agriculture has been practised and has been successful. Even along the canal it has been seen poor people do practise urban agriculture in small plots. So encouraging people to practise urban agriculture is one of the best solution.

As in ward 3 is a socio economically low area and this ward was added to the municipality in 1999 from a panchayat area it still have few of the families who used to practise agricultural activities before the area join the municipality. From the conversation with the local people it was seen that many families were involved in agricultural activities before the area was incorporated within the municipality and after which they stopped practising it. These families are living for more than 30 years and have changed their livelihood from agriculture to other daily labour works. So involving these families and other socio economically weak families in urban agriculture will help in improving the livelihood condition and also sustain their living.

According to the KEIP it encourages the local people to grow fruit and vegetable crops along the canal bank within small pieces of land. Mainly native trees are preferred for such plantation (Kolkata Municipal Corporation, 2013). According to a study in 3 km stretch on both side of Tolly Nullah (one of the major canals within KMC and KMA) found that it does not have a very rich ecological settings due to

the urbanisation but still some of the major fruit growing trees found were Jack Fruit (Artocarpus integrifolia), Mango (Mangifera indica), Supari (Acecia catechu), Coconut (Cocos nuciferal), Papita (Carica papaya), Banana (Musa sapientam) (Kolkata Environmental Improvement Project, Project Management Unit, 2007). So such trees can be encouraged to be grown in the integrated blue green zone in ward 3 and further cultivate these trees and sell the product and generate revenue. Vegetables that can be grown as a part of urban agriculture are cucumber (Cucumis satinus), Pumpkins (Cucurbita maxima), White Pumpkins (Lagenaria cueeraria), Cauliflower, Cabbage (Bassica oleracea), Man Kachu (Alocasia indica), Tomato (Lycopersium esculentum) (Kolkata Environmental Improvement Project, Project Management Unit, 2007). Out these plants like tomato again help in phytoremediation of soil so can be easily encouraged to be grown by the local people.

7.8.6 Operation and Maintenances

Just like for the KEIP a Social development unit (SDU) has been established at KMC level in the same way a SDU can be established at KMDA and the Executing agencies will be at Municipal level and Irrigation and Waterways Department (I&WD) as in West Bengal the canals fall in the jurisdiction of I&WD. The final activities that needs to be carried out in the field will be by the non-governmental organisation (NGOs). This is the basic structure that has been followed in KEIP project where further implementation has been done through creating a city level program action plan (CLPAP). Such CLPAP can also be implement here but it may not be at the city level but at very local level or ward level and then with further consultation and discussion with the local people this can be looked forward. The institutional arrangement can be as per Figure 3.

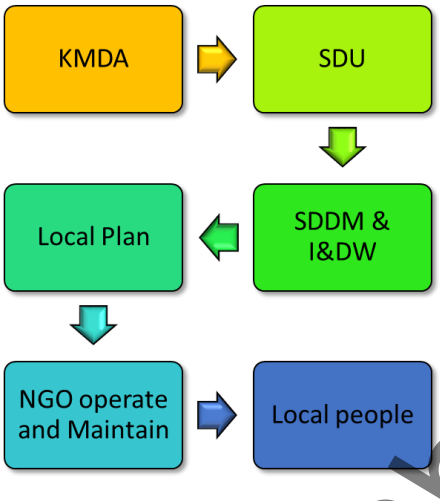


Figure 3: Hierarchy of Institutional Arrangement

In Rajarhat New Town a NGO has incorporated with the Housing Infrastructure Development Corporation (HIDCO) under GOWB and have come up with solutions of urban framing in New Town, Kolkata where they have leased a portion of the canal to an NGO name Karm Yog. If such initiatives can take place in one of the areas of KMA then such can be easily replicated in this ward as it also from a part of KMA where land can be leased out to the NGO for operation and maintenance. This has led to encouragement of neighbourhood and villages to work at the farms and trade facility and help in becoming self-resilient by empowering the locals. Also integrate proper land use that will integrate activates that are compatible to nature and promote localities that preserve open spaces through farming, horticulture, aqua culture and other activities simply by integrating people with low socio economic condition through proper training, vocational education and work opportunity (urban agriculture) that help in preserving the ecological balance.

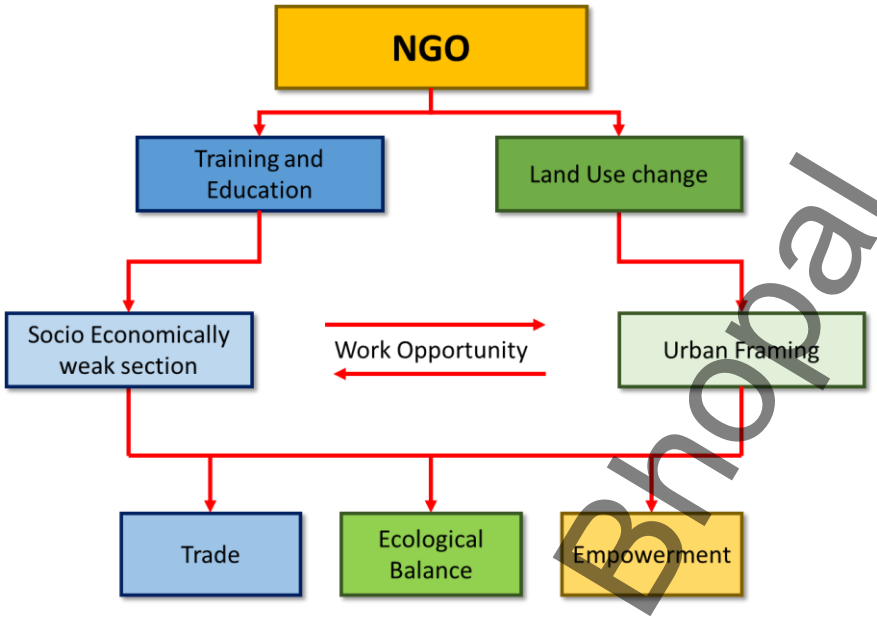


Figure 4: Operation and Maintenance under NGO

Through this strategy the locals can produce organic products, vegetables, fruits and nurseries. The area can be used for cultural events, hold workshops on planting and organic farming practises. Big private trusts have already provided financial assistances in one of such projects in New Town Kolkata, so such structure of work can be easily be incorporated in the operation of such activity (The Telegraph, 2016). As the area will be an eco-friendly area it will be open to the public and use the place as a recreational zone.

Therefore the operation and maintenance will be done by the NGOs and the local socio economically weak section of the area who will be under the NGOs supervision. The Figure 4 shows how to operate and maintain the new integrated blue and green zone.

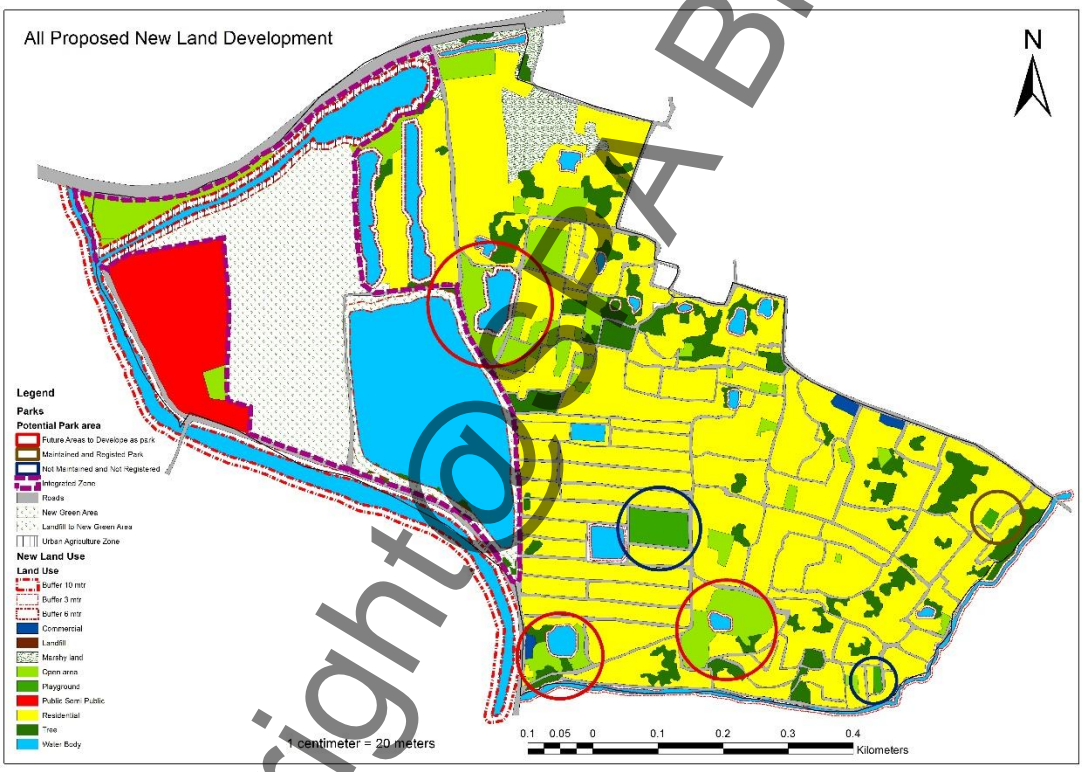
7.8.7 Revenue Generation

As this integrated area will have an operation and maintenance expenditure, so for this it needs to maintain and revenue source which will serve as the main source of operation and maintenance cost rather than directly depending on government source of funds. There can be 3 sources of revenue:

1. Selling compost generated by composting of old waste of the landfill site. In general organic manure generated in compost plant of the KSWMIP project at Uttarpara Kotrang Municipality is sold at rupees 2.75 /- per kilogram.

2. Generating revenue by selling fruits, vegetables and aquaculture products at the local market.
3. Allowing this integrated site to be open for visitor, promoting tourism and other recreational activities by incorporating entry fee system.

As the site is well connected with a very important expressway and is connected by bus from Dunlop More to Airport and Noapara Metro Station it will attract people and help in improving the condition of the area and further it might help in increase the property value. The Map 72 shows all the spatial location of all the recommendation within ward 3. Now if we improve the



Map 72: Spatial location of all Proposal

The integrated blue and green zone will serve as a community park to a district park in area and parks will serve as housing parks and neighbourhood parks. As the Municipality has a population of about 4.3 lakh therefore this development will help to serve around 2 lakh population as per area specified in URDPFI guidelines for organised green spaces in urban areas located in plain land. Also if carefully seen this integrated zone proposed is on a land which is surround by total 5 municipality. Thereby the proposal will not only be a benefit to South Dum Dum Municipality but also the other 5 municipality.

7.9 Conclusion

It is clear from the study that major environmental degradation is being caused in the low socio economic status but it does not mean that our high status areas are not in environmental stress. The study just highlights those areas which are getting more disturbed in an urban context but such research further needs to be applied in other cities so that the larger picture of this degradation is clear. Developments like integrated blue green zone within the city area will help us to increase environmental quality not only by increasing green cover but also it will help us to reduce the surrounding temperature of the atmosphere. Such development will also help to improve socio economic condition, for which we do not need to follow our traditional development strategies. Therefore green and blue areas are important for our city and in some respect they do change with respect to the socio economic condition of an area.

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Background and Need of Study

Urban Green Space: They are public and private open spaces mainly covered by vegetation which are directly and indirectly available to the users. They include both urban forest and green patches, green corridors etc. (Source: Urban green spaces and an integrative approach to sustainable environment,2011)

Urban Blue spaces- They are defined as all surface water within a city which includes ponds, lakes or river. (Source: Evidence for the temperature mitigating capacity of urban blue spaces- a health geographic perspective, 2013)

Spatial Inequality – It is defined as uneven distribution of resources and different standards of living both socially and economically. (Source: spatialinequalitygeo.weebly.com)

Environmental Inequality – It is the condition of unevenness in sharing of environmental opportunities between different group of people. (Source: lsx.org.uk)

Challenges with Blue & Green Spaces

- Pressure on urban blue and green spaces due to densification of Urban structure.
- Decrease in natural green and blue area due to Urban sprawl in fringe area.
- Inappropriate use cause degradation and pollution

Other Challenges

- Demographic challenges like rapid urbanization and population growth.
- Socio- Spatial challenges which leads to spatial inequality, urban sprawl and unplanned peri urbanization.

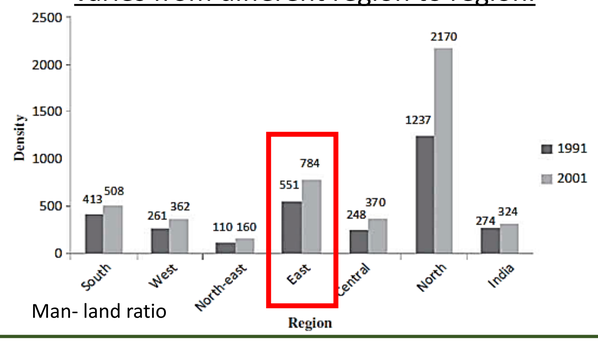
Spatial Inequality

Spatial Inequity and Development Overview of UNU- WIDER project, 2005:
It shows disparities between rural and urban area, and also between geographically advantaged and disadvantaged regions. Some examples, like in Peru the coastal districts are have less percentage of poverty while higher altitude have greater percentage of poverty.

Environmental Inequality

The Political Ecology of Uneven Urban Green Space, Nik Heynen, 2006:
Inequitable distribution of urban trees in relation to race and ethnicity is a form of urban environmental inequality. It gives an insight of the urban political ecology which tells social formations produce uneven environment in urban area.

In India Spatial Inequality is very high and varies from different region to region.



Man- land ratio

Population, Development and Environment in India, Lakshmana, 2013:
In the Eastern part of India Man land Ratio has increase but as per author in Kolkata it is opposite and environmental degradation is high. In eastern region available arable land decreased to 198.61 in 2006 from 246.99 in 1996 in lakh hectares.

- Urban socio- economic and demographic variables can be used to establish relation between canopy cover in composite and comprehensive manner. – **USA**
- Socio-economic status is related to land use, land cover and significant environmental changes in residential area which can influenza different urban environmental quality. – **U.K**

Socio- Economic ⟷ Environment

UN- Habitat paper on Adequate Open Public Spaces in Cities
A Human Settlement Indicator for Monitoring the Post- 2015 Sustainable development agenda indicates:

- ✓ Public spaces are important to maintain city's productivity, social cohesion and inclusion.
- ✓ Symbiotic relation between the public and private spaces helps city to function in efficient, equable and sustainable manner.
- ✓ Low share of public spaces is a result of uncontrolled urbanization.

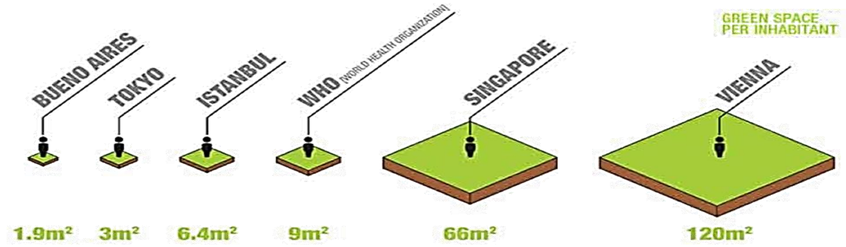
UN- Habitat III - Social and Spatial Inequality hinders sustainable development
UN Sustainable Development Goals 15 - Sustainably Manage Forest, halt and reserve land degradation and halt biodiversity loss.

As per URDPFI:

- ✓ The percentage of area allocated for open spaces and there function will depend on the type of city that is being developed. Example- Sports city, cantonment, Small Towns to Large Towns etc.
- ✓ Open Spaces can include recreational spaces, organised green and common open spaces like vacant land forest etc.

As per URDPFI guidelines Water Bodies are considered to be Eco sensitive area and Needs to be protected. (Source: URDPFI)

Organised Green In Plain Area			
Sl. No	Category	Population Served per Unit	Area Requirement (Ha)
1.	Housing Area Park	5000	0.50
2.	Neighbourhood Parks	15000	1.00
3.	Community Parks	1 lakh	5.00
4.	District Parks	5 lakh	25.00
5.	Sub City Parks	10 lakh	100.00



Problems faced in Kolkata

- ❖ Kolkata has **open space ranging 1% to 2%** according to Centre for Contemporary Communication
- ❖ **DCR** says "**No canals, ponds and water bodies shall be filled**", but the **surrounding green vegetative** area are **disappearing** at a fast rate.
- ❖ **Regulations for open green spaces are missing** from the **DCR**.
- ❖ Traditional **water bodies** are being **replaced** due to **unplanned development results** in **ecological imbalance and increase pollution**.
- ❖ News paper reports and other research shows there has been **huge loss of tree cover** in KMA.

"Studies reveal that the Socio- Economic dimension of Urban Landscape change needs further exploration which is completely missing in Indian Context."

Aim, Objective and Methodology

Aim: To analyse the linkages between the socio- economic condition and environmental quality (Blue and green spaces) of an urban area.
Key Words: Socio- Economic condition, Environmental Quality.

Objective 1

- To identify and analyse different socio- economic indicators and create clusters (micro area) of similar socio- economic condition in South Dum Dum Municipality.

Objective 2

- To analyse the land use, land cover and environmental quality within the identified micro area.

Objective 3

- To find a relationship between the socio- economic condition, land use, land cover change and environmental quality within the identified micro area.

Objective 4

- To prepare planning strategies and guidelines for blue and green spaces based on the outcome

Methodology

Background Study and Current Status of India and City
- Spatial Inequality, Environmental Inequality.
- Urban Green and Blue Spaces
- Per capita requirement of Open spaces World wide
- Planning Guidelines
- Status of Urban green and blue spaces in India and Kolkata

Aim and Objective → **Preparing Base Map** → **Identification of Socio-Economic Indicators** → **Literature Review**

Data Collecting
- Census Data
- Municipal Data
- Environmental Data

→ **Mapping the Socio-Economic Data Ward wise** → **Analysis of Socio Economic Indicator**
- Ranking Each indicator ward wise
- Finding mean of all the ranks in each ward.

Clustering of Area with same socio- economic condition

Temporal Analysis of Land Use, Land Cover
- Land Use- Each grid is assigned a distinct land use.
- Cluster of grid having same land use is assigned with a land cover type

Analysis of Environmental Indicator
- Surface temperature is calculated using thermal Imagery
- Surface runoff is calculated using rainfall data
- Diversity calculated from land use classification using Shannon Index.

Create Spatial Matrix
- Identified clusters are selected
- 20X20 metre grids are created using GIS

Selecting Environmental Indicators:
Based on Literature:
- Surface Temperature
- Surface Runoff
- Diversity of green area

Selected Study area

Socio- Economic Condition – Study ↔ **Land Use and Land Cover** ↔ **Environmental Indicators**

Strategies of Blue and Green Spaces Based on Outcome

Guidelines for cities future development

Revisiting the DCR

Scope
Selected socio-economic and environmental indicators considered for detail study.
Limitation
Due to time constrain micro study area are focused on few clusters (4ward).

Literature Review

Urban Green Spaces

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Urban Green Spaces and an Integrated Approach to sustainable Environment, Shah Md. Atiqul Haq, 2011	The paper discuses the benefits and the challenges of urban green spaces and how they play an important role in sustainable development.	Literature Review	Highlights the type of cites where Urban Green and Natural Green area are more and with help of an Integrative approach will lead to environmental sustainability.
2.	UN- Habitat III, Issue Paper on Public spaces,2015	The paper discuses the key facts and figure regarding public spaces in cities which includes the urban green areas and how they help in creating an inclusive, sustainable environment and generate economy.	Based on review of UN polices and other literatures.	Highlights the focus areas that needs to be strengthened and how we lead urban development based on public spaces.

Urban Blue Spaces

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Evidence for the temperature- mitigating capacity of Urban Blue spaces- A health geographic perspective	The main finding of the paper is how urban blue spaces helps in reducing heat stress in urban areas.	Comparative study of different articles, Meta- analysis by using data of the papers	Temperature difference by Bowler method.

Spatial Inequity

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Spatial Inequity and Economic Development: Theories, Facts, and Polices, Sukkoo Kim, 2008	The paper theoretically examines what is spatial inequality and investigates policies that improves spatial inequality and identifies whether these policies can be implemented to reduce spatial inequality.	Comparison study of Urban and Regional Economic, Literature based studies	Gini Coefficient used to measure spatial inequality, different patterns of inequality, gives a stronger base about what is spatial inequality and what allows spatial inequality to occur.
2.	Spatial Inequality and Development overview of UNU- Wider Project	The paper analyses the evidence of spatial inequality 50 developing countries and also disparities between rural urban and geographically advantaged and disadvantaged areas.	Facts of different countries, comparison between different countries	Give a strong base that spatial inequality exist in developing countries and shows due to this inequality who are benefited and who are not.

Environmental Inequity

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Environmental inequities in Canada: The double burden of Pollution and poverty, Kaitlyn Mitchell, Canadian Environmental Law Association	A presentation that gives brief about environmental justices and highlights the issue that environmental inequity results in environmental injustice. The presentation provides maps to show the distribution environment inequity.	Map based presentation	Map highlight regional differences in a country and helps to establish a background and need of study.
2.	Spatial Disparities in the Distribution of Parks and Green Spaces in USA, Ming Wen, 2013	It examines the spatial access od parks and green spaces with the percentage of Blacks, Hispanic and Low income residence.	Census data used to track level of parks and green spaces, Statistical tool	Justifies the unequal distribution of parks and green spaces between different demographic groups both in urban and rural perspective, Linear mixed Regression Model

Literature Review

Socio- Economy linked with Environmental quality

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Modelling the environmental impacts of urban land use and land cover change – a study in Merseyside, UK, Stephan Pauleit, 2003	The study emphasizes the loss of green cover in 11 case study site where the sites have been grouped into High and low status residential areas and then correlating the loss of green cover status of society and the density of residential area.	Aerial Photograph, Spatial Matrix, Statistical tools	Land use land cover change through spatial matrix, Surface temperature study through satellite imagery, Hydrological model for runoff calculation, Diversity model using Shannon Index, Rate of Evaporation.
2.	"City from and natural process"- Indicators for the ecological performance of urban area and their application to Merseyside, UK, V. Whitford, 2000.	The paper qualifies effect of urbanization on basis of ecological performance indicator and how some of the indicator have a poor performance in affluent areas.	Energy Balance equation, SCS method for calculation of Surface runoff, Carbon Sequestration, Shannon-Weiner Index for biodiversity.	Identification of different ecological indicators, modelling techniques like Shannon Weiner Index and SCS method for hydrology calculation.
3.	The political Ecology of Uneven Urban Green Spaces, the impact of political economy on race and ethnicity in producing environmental Inequality in Milwaukee, Nik Heynen, 2006	The result of the study shows how there is unequal distribution of urban tree with respect to race and ethnicity of an urban area which directly links to urban environmental inequality.	Remote sensing data, Spatial sampling method called dot method, GIS, Aerial Photography	Method used to calculate tree canopy cover in and area through GIS, different types of social indicators that can be used.

Indian Socio- Economic Inequality

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Spatial inequality in Big Indian Cities, Pranav Sidhwani, Review of Urban Affairs, 2015	The study uses census ward level data to identify the residential segregation in 10 most populated sites of Indian and justifies how these residential segregation is correlated to access basic public, private and other goods.	Literature Based, Index of dissimilarity, Gerard Index of Segregation.	Different index to calculate social segregation at ward level.
2.	Population, Development and environment in India	The study focuses of population pressure on Indian's environment based on land mass ratio in 6 different regions of India.	Conceptual framework for environmental degradation, Census data.	The conceptual framework gives clear idea how rapid population growth, urbanization, industrialization etc. results in environmental degradation.

Kolkata and its present condition

Sl No.	Topic Title, Author and Year	Key Findings	Techniques Used	Relevance to the thesis
1.	Destruction of urban greenery of Indian Cities- A study of two wards of Kolkata Through GIS and Remote sensing, Biraj Kanti Mondal, 2013	It is a micro level study which analyses the greenery or vegetation profile of Kolkata which shows that in some areas the greenery has depleted by 4.79%.	GIS and Remote sensing	Justifies need for study with respect to green spaces in Kolkata, Method used for analysis.
2.	Effect of Urban Sprawl on Human Habitation in urban fringes and Peri- Urban areas in Kolkata Metropolitan area, Sourav Sen, 2011	The paper analyses the increase in demand of land price, real estate property and rising incapability of affordable proper housing in small towns.	Statistical Analysis	Indirectly justifies the inequality that is being created in land value, property rate and type of housing in different parts Kolkata metropolitan area, land value as indirect economic indicator of analysis.
3.	Impact of Urbanisation on Biodiversity Case studies from India, WWF report, 2011	The report discusses the effect of urbanisation on land use changes in city, the resent problems related to East Kolkata wetland and impact of urbanisation on Sundarbans.	Literature Based, GIS mapping and based on facts and figures.	Highlighting the currents environmental issues in Kolkata, Identifying areas where biodiversity loss is taking place.
4.	Recent decline in water bodies in Kolkata and surrounding, Subhanil Guha, 2016	The study delineates the zones in which there has been more loss of water bodies with respect to Kolkata and its surrounding.	Satellite imagery study, water density mapping	The study justifies that there is recent decrease in water bodies in and around Kolkata, Water density mapping for analysis.

South Dum Dum Municipality

City Biodiversity Index Calculation: (2 parameters)

Proportion of Natural Area= (Total Area of Natural Area) / (Area of City)X100
= (0.833/15.6)x100 = 5.34% (Between 1%-6% is considered to be less as per URDPFI)
Regulation of Quality of Water= (Total Permeable Area) / (total Terrestrial Area of the City)
= (0.825/15.6 = 0.0529 (If < 0.307 then is again Less as per URDPFI)
Both Indicator show a low biodiversity of the study area.

Year	Population	Growth %
1971	1,74,342	
1981	2,27578	30.00
1991	2,31,204	01.59
2001	3,92,150	69.61
2011	4,03,316	2.84

Issues:

As per the Draft development plan the South Dum Dum Municipality has identified some of the Issues

- Need regulatory control for insanitary water course and filling up of tanks.
- Existing wet land and lakes have been highly polluted.
- Large scale encroachment of open spaces.
- Increase in unauthorised construction.

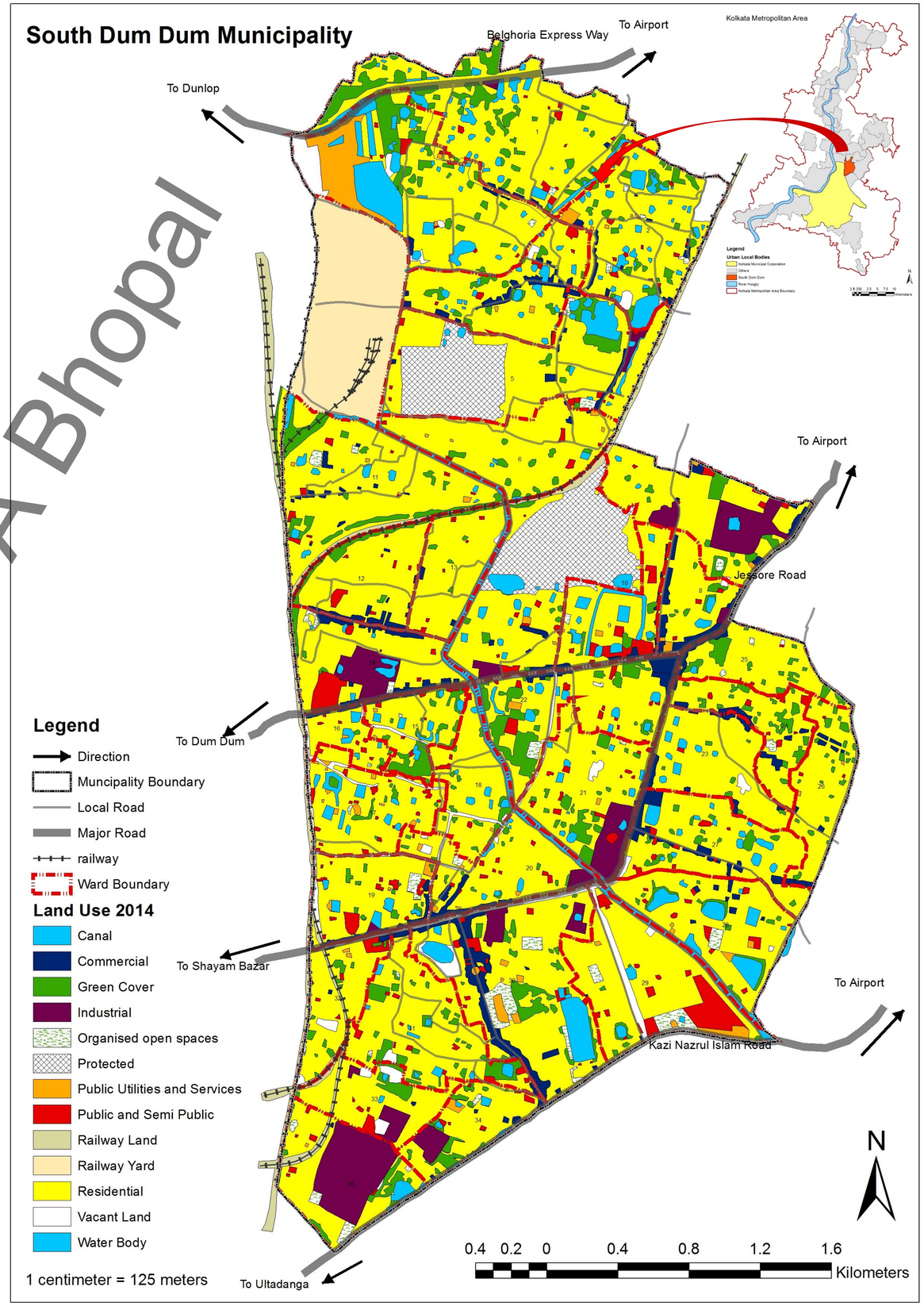
Sustainability and Urban Development requirement

As per URDPFI Guideline

- It emphasis on developing green belt, vegetation belt in urban area.
- Even presences of Natural environment helps in reducing heat island effect and demand of storm water systems.

Data Collected

Sl. No.	Data Type	Specification	Zone	Office	Collected
1	Working Population	Census - 2011, 2001, 1992	Ward level	Census Office	Yes
2	Non Working Population	Census - 2011, 2001, 1993	Ward level	Census Office	Yes
3	Other Working Population	Census - 2011, 2001, 1994	Ward level	Census Office	Yes
4	Literacy level	Census - 2011, 2001, 1995	Ward level	Census Office	Yes
5	Main Worker		Ward level	Census Office	Yes
6	Household condition		Ward level	Census Office	Yes
7	No of BPL House hold		Ward level	Municipality	Yes
8	Housing demand	Under PMAY	Ward level	Municipality	Yes
9	Property tax Rate per Sq. ft		Ward level	Municipality	Yes
10	Average property Tax		Ward level	Municipality	Yes
11	Property Circle rate per sq. ft		Ward level	Municipality	Yes
12	Property Market rate per sq. ft		Ward level	Municipality	Yes
13	Land Value per Katha		Ward level	Municipality	Yes
14	Real estate rate per Sq. ft		Ward level	Municipality	Yes
15	Thermal imagery	Landsat	Study area	USGS website	Yes
16	Temperature Minimum, Maximum	Last 15 years	Study area	IMD office	Yes
17	Soil Map		Study area	WISE soil database	Yes
18	Surface Runoff Zone		Study area	KMDA	Yes
19	Drainage Design DPR		Study area	KMDA	Yes
20	Flow Calculation		Study area	KMDA	Yes
21	Rainfall intensity calculation		Study area	KMDA	Yes
22	Rainfall maximum, Minimum, Average		Study area	IMD office	Yes
23	List of Parks		Ward level	Municipality	Yes
24	List if Ponds		Ward level	Municipality	Yes
25	Land use Map	year - 2006, 2014	Ward level	KMDA, Municipality	Yes
26	Land Cover Map	Satellite Imagery	Study area	USGS website	Yes



Objective 1

To identify and analyse different socio- economic indicators and create clusters (micro area) of similar socio- economic condition in South Dum Dum Municipality.

Literature and Indicators →

Literature	Indicators
Social Indicators and Environmental Dimension, Tiril Vogt, Central Bureau of Statistics of Norway, 1984	Sex
	Age
	Urban
	Rural
	Geogrphical Area
	National or ethnic origin
	Size and type of family
	Size and type of Household
	Level of Education
	Type of Education
	Land Use
	Land Tenure
	Transportation
	Land Value
	Property Value
	Income
	Labour Force
	Business and industry
	Municipal and Social Services related cost
Assessing the Relationship between Socio-economic conditions and Urban Environmental Quality in Accra, Ghana, Julius Fobil, 2010	Economic Activity Status
	Education attainment
	Occupation
	Place of Work
	Marital Status
	Ethnicity
United Nation Statistics Division, List of environmental and related socio-economic indicators.	Real GDP per capita growth
	Population living in absolute poverty
	Adult literacy rate
	Stock of shelter and infrastructure

Analysis → **Low Rank – 1, Medium Rank – 2, High Rank – 3 →** **Results**

Social

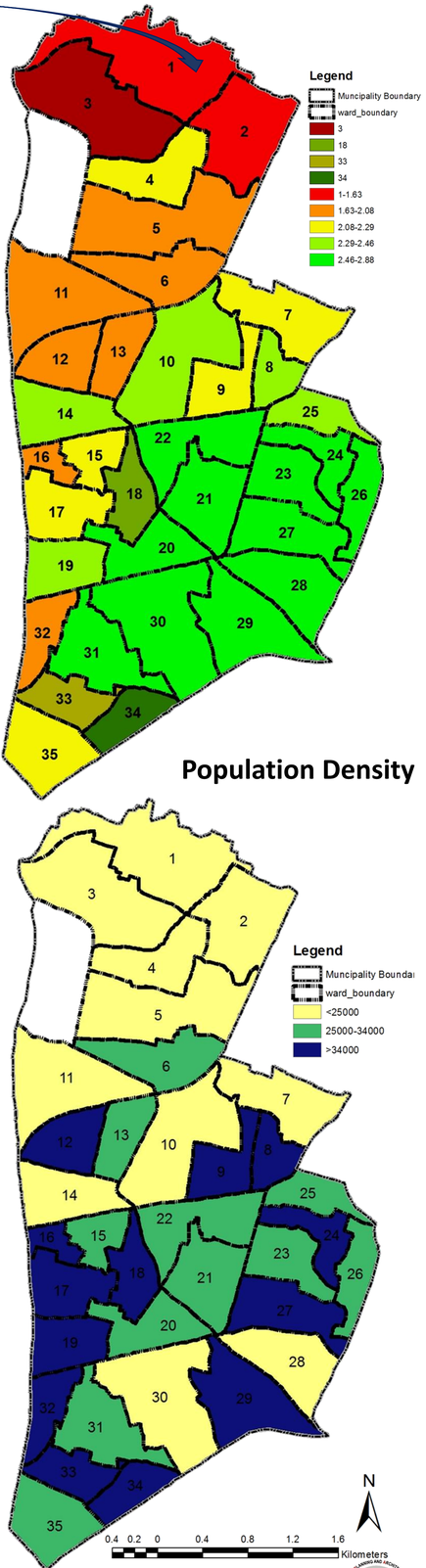
Indicators	Range	Rank	Remarks
Working Population	34%-36%	1	Low Working population
	37%-39%	2	Medium Working population
	40%-41%	3	High Working population
Literacy Level	<= 80%	1	Low literacy level
	81%-86%	2	Medium literacy level
	>=87%	3	High literacy level
No of BPL Household	10% - 11%	1	High no of BPL HH
	3%-6%	2	Medium Level of BPL HH
	0%-2%	3	Low Level of BPL HH
Housing Demand under PMAY	>=10%	1	High demand for Housing
	5%-9%	2	Medium demand for Housing
	<= 4%	3	Low demand for Housing

Economic

Indicators	Range	Rank	Remarks
Average property tax paid per household in Rs in year 2011	< 500 /-	1	Low tax paid
	500-999/-	2	Medium Tax paid
	>1000/-	3	High tax paid
Municpality property (market) rate in Rs / sq ft	< 3000 /-	1	Low property value
	3000-3999	2	Medium property value
	> 4000 /-	3	High property value
Land Value in Lakh per Katha (1 Katha = 720 Sq. Ft)	>20 lakh	1	Low land value
	20-30 lakh	2	Medium Land value
	>30 lakh	3	High Land value

Ward No	Average Rank Socio-Economic
1	1.63
2	1.50
3	**1.00**
4	2.25
5	2.04
6	1.88
7	2.21
8	2.42
9	2.29
10	2.42
11	1.83
12	1.96
13	2.08
14	2.42
15	2.25
16	2.00
17	2.13
18	**2.38**
19	2.46
20	2.58
21	2.58
22	2.58
23	2.71
24	2.71
25	2.33
26	2.58
27	2.58
28	2.63
29	2.75
30	2.75
31	2.71
32	2.04
33	**2.13**
34	**2.88**
35	2.21

Average Socio- Economic Rank After Analysis Selected Wards



Indicators Used for Analysis:

- **Social –** Working Population, Literacy Level, Number of BPL Household, Housing demand under PMAY.
- **Economic –** Average Property tax paid, Municipal Property (Market Rate), Land Value

Parameters	Wards Selected			
	3	18	33	34
Avg Pop. Density (SDDM)	28455	28455	28455	28455
Pop. Density	18246	37014	61354	45915
Social	Low	High	Low	High
Economic	Low	Low	High	High

Objective 2

To analyse the land use, land cover and environmental quality within the identified micro area.

Land Use Mapping Using Grid Rules:

- Categorise land use of the area.
- Use Areal Imagery. In this case using Google Earth Pro image.
- Place grid of Size 20m X 20m on the selected area.
- If a single grid has more than one land use the dominant land use is identified and marked.
- In case the cell contains more than one land use then whatever comes in the mid point of the cell is assigned.
- As the land use that we assign are generally more than size of 20X20 m so this will result in potential error of less than 1% (Sekliziotis, 1980)

Land Use Category:

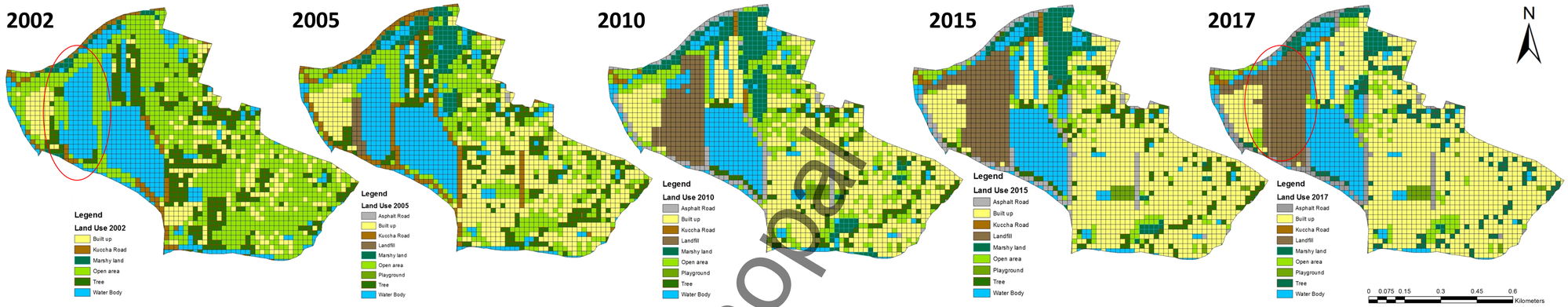
1. Built up – mainly consisting of both residential and Commercial area.
2. Roads
   - Kuccha Road
   - Asphalt/ concreate road
3. Water Bodies
4. Playground, parks and recreation land
5. Tree covered area.
6. Marshy Land – land having small patches of water bodies whose size generally varies and also having tall grasses and other herb like plants.
7. Open Land – Mainly forming vacant unused land.
8. Land fill – Mainly considering dumping grounds which are insanitary.
9. Railway Land – having both railway yard and railway line.
10. Factories / Industry

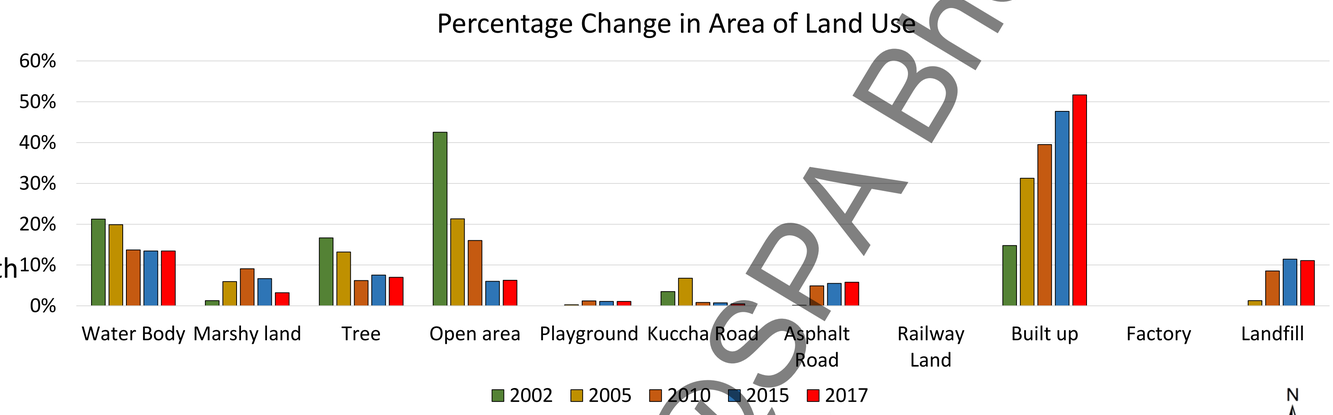
Final List

Built up, Kuccha Road, Asphalt Road, Water bodies, Playground, Tree cover, Marshy land, Open land, Landfill, Railway land, Factories.

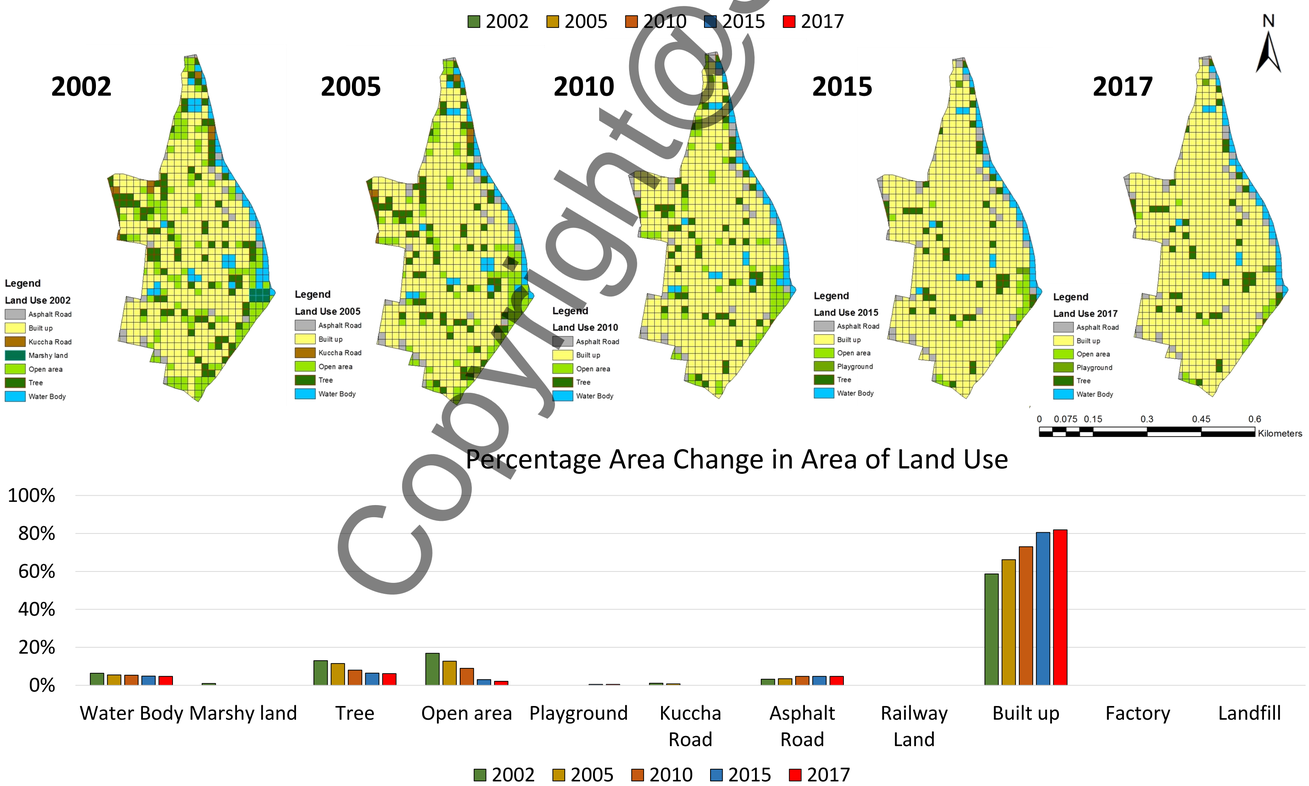
Land Use Analysis

Ward - 3





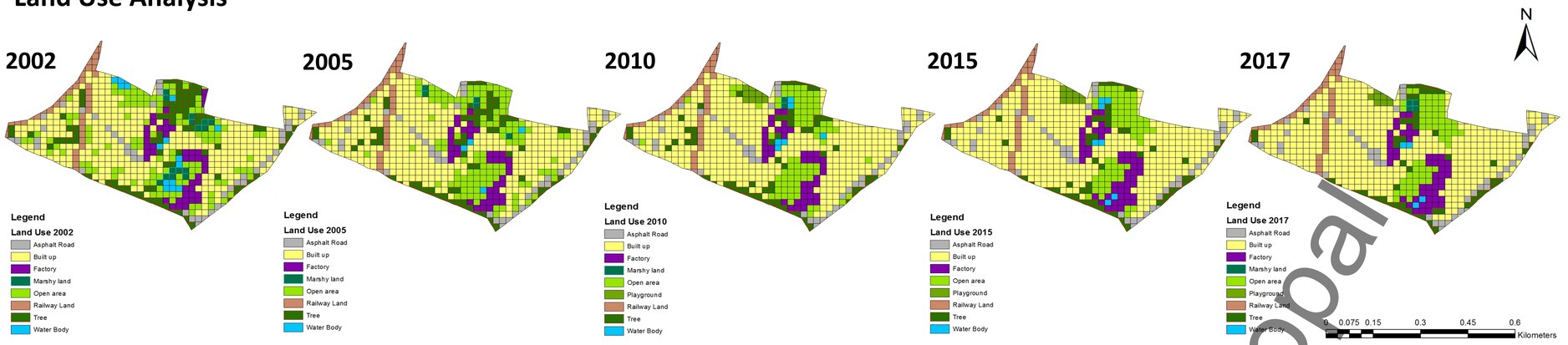
Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.1675	0.1565	0.1079	0.1058	0.1057
Marshy land	0.0099	0.0468	0.0717	0.0526	0.0253
Tree	0.1311	0.1038	0.0489	0.0592	0.0552
Open area	0.3350	0.1679	0.1260	0.0472	0.0494
Playground	0.0000	0.0020	0.0096	0.0084	0.0084
Kuccha Road	0.0277	0.0532	0.0064	0.0056	0.0036
Asphalt Road	0.0000	0.0009	0.0385	0.0432	0.0456
Railway Land	0.0000	0.0000	0.0000	0.0000	0.0000
Built up	0.1163	0.2462	0.3112	0.3753	0.4070
Factory	0.0000	0.0000	0.0000	0.0000	0.0000
Landfill	0.0000	0.0100	0.0672	0.0900	0.0872
Total	**0.7875**	**0.7875**	**0.7875**	**0.7875**	**0.7875**

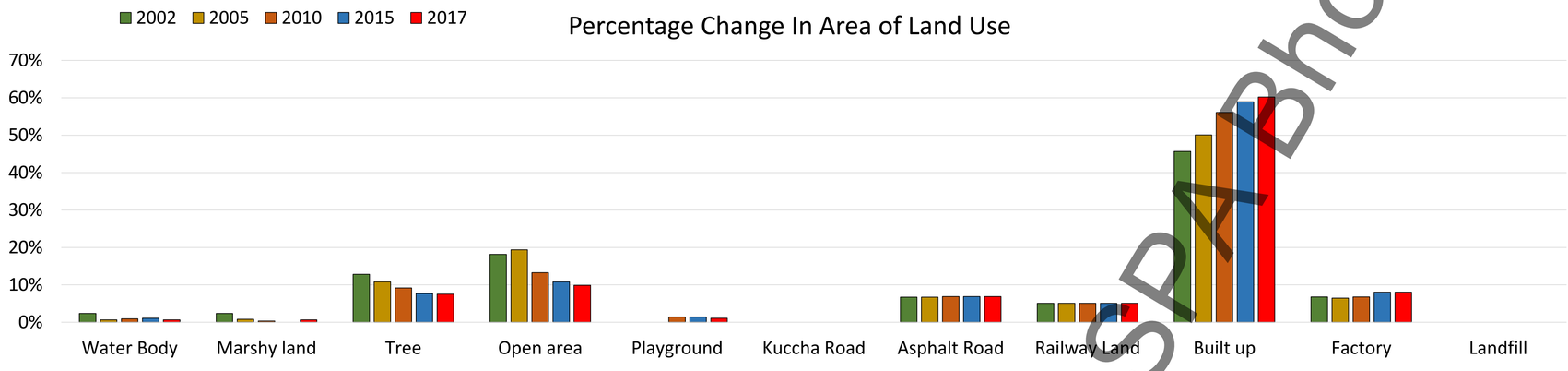


Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.0165	0.0141	0.0138	0.0126	0.0122
Marshy land	0.0024	0.0000	0.0000	0.0000	0.0000
Tree	0.0336	0.0297	0.0207	0.0166	0.0158
Open area	0.0437	0.0328	0.0231	0.0078	0.0054
Playground	0.0000	0.0000	0.0000	0.0012	0.0012
Kuccha Road	0.0027	0.0020	0.0000	0.0000	0.0000
Asphalt Road	0.0083	0.0091	0.0123	0.0123	0.0123
Railway Land	0.0000	0.0000	0.0000	0.0000	0.0000
Built up	0.1520	0.1716	0.1893	0.2088	0.2124
Factory	0.0000	0.0000	0.0000	0.0000	0.0000
Landfill	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.2592**	**0.2592**	**0.2592**	**0.2592**	**0.2592**

Objective 2

Land Use Analysis





Inference:

In all the analysis it is highlighting that in a span of 15 years the built up has increase. The maximum increase have taken place in Ward-3 from 15% to 52% while Ward- 34 has the least increase from 54% to 65%. In the same way open spaces, tree cover all has decreased and highest decrease in ward – 3 and is just left with 6% of open area. But although the decrease in open spaces in ward – 18 is not much still the ward least percentage of open spaces which is just 2%.

Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.0060	0.0016	0.0024	0.0028	0.0016
Marshy land	0.0060	0.0020	0.0008	0.0000	0.0016
Tree	0.0324	0.0273	0.0232	0.0194	0.0190
Open area	0.0460	0.0491	0.0336	0.0274	0.0250
Playground	0.0000	0.0000	0.0036	0.0036	0.0028
Kuccha Road	0.0000	0.0000	0.0000	0.0000	0.0000
Asphalt Road	0.0170	0.0170	0.0174	0.0174	0.0174
Railway Land	0.0129	0.0129	0.0129	0.0129	0.0129
Built up	0.1156	0.1268	0.1420	0.1492	0.1524
Factory	0.0172	0.0164	0.0172	0.0204	0.0204
Landfill	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.2531**	**0.2531**	**0.2531**	**0.2531**	**0.2531**

Land Use	Area in Sq Km				
	2002	2005	2010	2015	2017
Water Body	0.0144	0.0140	0.0136	0.0068	0.0032
Marshy land	0.0000	0.0000	0.0000	0.0000	0.0000
Tree	0.0212	0.0204	0.0174	0.0170	0.0146
Open area	0.0281	0.0281	0.0299	0.0180	0.0068
Playground	0.0052	0.0044	0.0040	0.0040	0.0180
Kuccha Road	0.0000	0.0000	0.0000	0.0000	0.0000
Asphalt Road	0.0171	0.0171	0.0171	0.0199	0.0199
Railway Land	0.0000	0.0000	0.0000	0.0000	0.0000
Built up	0.1235	0.1255	0.1287	0.1458	0.1490
Factory	0.0205	0.0205	0.0193	0.0185	0.0185
Landfill	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**0.2301**	**0.2301**	**0.2301**	**0.2301**	**0.2301**

Objective 2

Land Cove Analysis

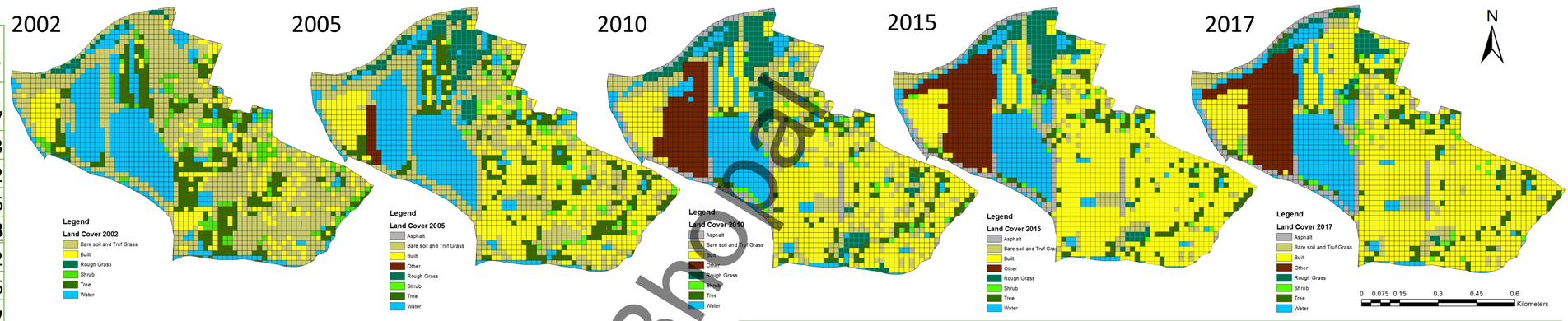
Land Cover:

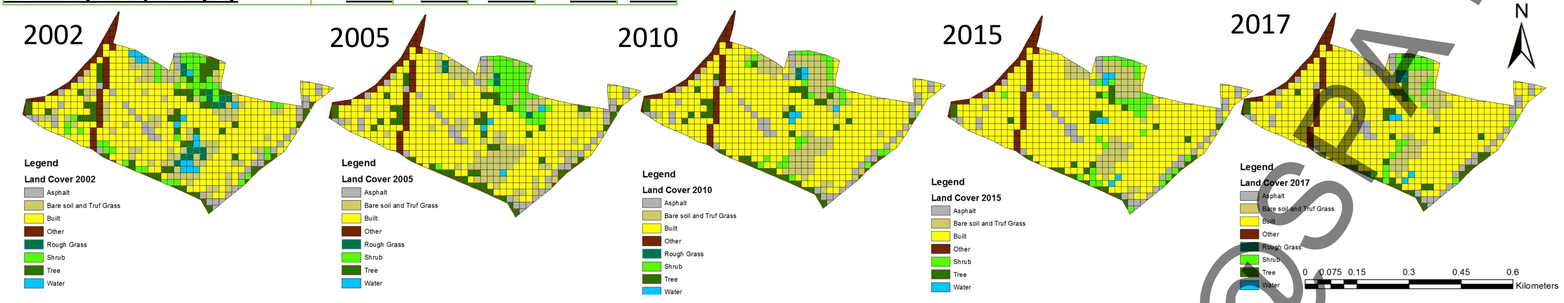
- It shows the physical surface cover of the land as per Sekliziotis land cover grid method which is same as Land Use Method.

The Land Cover types used here are:

Asphalt	Built		Bare Ground and Turf Grass			Shrubs		Rough Grass	Trees	Others		Water
Asphalt Road	Factory	Built up	Kaccha Road	Open spaces	Play Grounds	Opens Spaces	Trees	Marshy Land	Trees	Landfill	Railway Land	Water Bodies

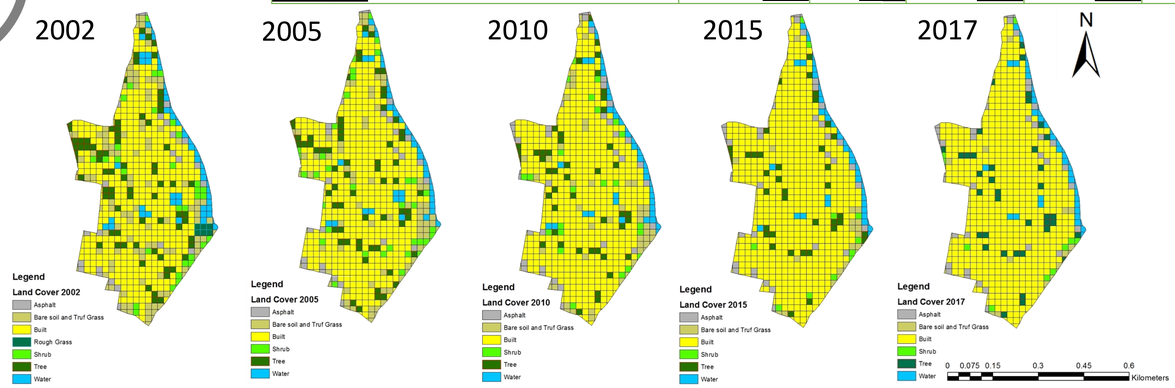
Types of Spaces	Percentage Area-(Ward 3)				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.42	0.27	0.17	0.07	0.07
Rough Grass	0.01	0.06	0.09	0.07	0.03
Shrub	0.06	0.03	0.02	0.01	0.02
Tree	0.15	0.12	0.05	0.07	0.06
Total Green Space (A)	**0.64**	**0.47**	**0.33**	**0.22**	**0.18**
Built (B)	0.15	0.31	0.40	0.48	0.52
Asphalt (C)	0.00	0.00	0.05	0.05	0.06
Built Environment (D= B+C)	**0.15**	**0.31**	**0.44**	**0.53**	**0.57**
Built Environment/ Total Green Space (E= D/A)	**0.23**	**0.66**	**1.33**	**2.42**	**3.19**

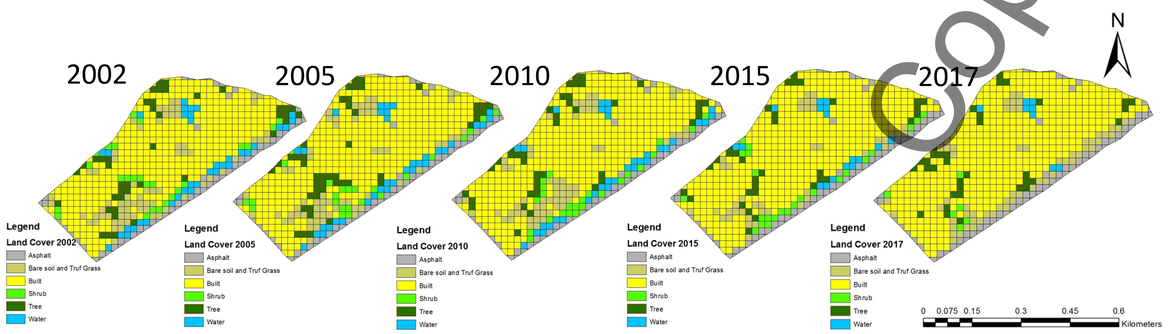




Types of Spaces	Percentage Area - Ward 33				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.15	0.15	0.13	0.10	0.08
Rough Grass	0.02	0.01	0.00	0.00	0.01
Shrub	0.07	0.07	0.04	0.06	0.05
Tree	0.24	0.00	0.00	0.00	0.00
Total Green Space (A)	**0.48**	**0.23**	**0.18**	**0.15**	**0.14**
Built (B)	0.52	0.57	0.63	0.67	0.68
Asphalt (C)	0.07	0.07	0.07	0.07	0.07
Built Environment (D= B+C)	**0.59**	**0.63**	**0.70**	**0.74**	**0.75**
Built Environment/ Total Green Space (E= D/A)	**1.24**	**2.76**	**3.92**	**4.77**	**5.50**

Types of Spaces	Percentage Area- Ward 18				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.15	0.11	0.07	0.03	0.02
Rough Grass	0.01	0.00	0.00	0.00	0.00
Shrub	0.05	0.05	0.03	0.02	0.01
Tree	0.29	0.00	0.00	0.00	0.00
Total Green Space (A)	**0.50**	**0.16**	**0.10**	**0.04**	**0.03**
Built (B)	0.59	0.66	0.73	0.81	0.82
Asphalt (C)	0.03	0.03	0.05	0.05	0.05
Built Environment (D= B+C)	**0.62**	**0.69**	**0.78**	**0.85**	**0.87**
Built Environment/ Total Green Space (E= D/A)	**1.24**	**4.32**	**7.67**	**20.29**	**28.76**





Types of Spaces	Percentage Area- ward 34				
	2002	2005	2010	2015	2017
Bare soil and Turf Grass	0.12	0.11	0.11	0.07	0.10
Rough Grass	0.00	0.00	0.00	0.00	0.00
Shrub	0.04	0.04	0.04	0.04	0.01
Tree	0.16	0.00	0.00	0.00	0.00
Total Green Space (A)	**0.33**	**0.15**	**0.15**	**0.11**	**0.11**
Built (B)	0.63	0.63	0.64	0.71	0.73
Asphalt (C)	0.07	0.07	0.07	0.09	0.09
Built Environment (D= B+C)	**0.70**	**0.71**	**0.72**	**0.80**	**0.81**
Built Environment/ Total Green Space (E= D/A)	**2.12**	**4.73**	**4.65**	**7.09**	**7.22**

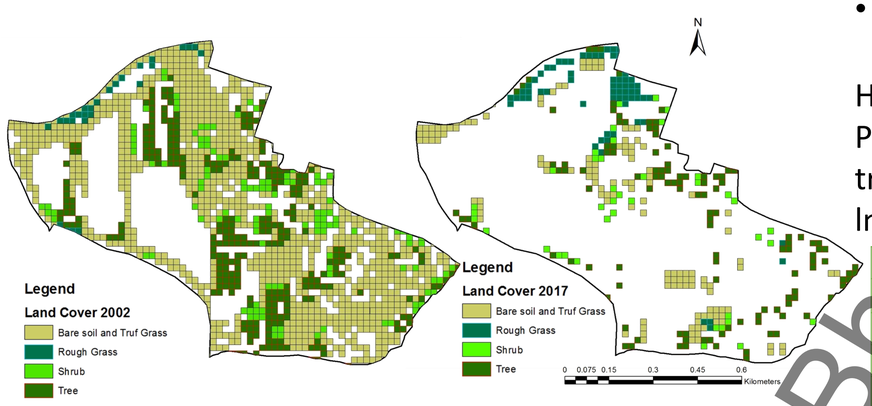
Objective 2

Diversity of Area
Diversity Model

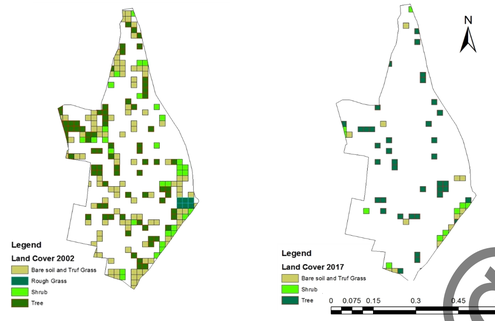
- Biodiversity is affected by no of factors like overall size and types greenspaces and its spatial distribution.
- The diversity model here used asses the biodiversity potential of the site which uses greenspace cover and the diversity as a function.

Total Green Spaces and Difference

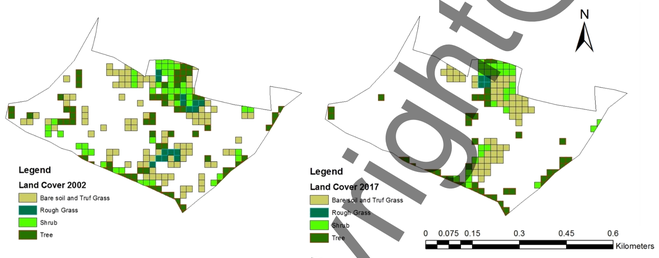
Types of Green Spaces	Percentage Area Ward 3		Difference
	2002	2017	
Bare soil and Turf Grass	0.42	0.07	-0.36
Rough Grass	0.01	0.03	0.02
Shrub	0.06	0.02	-0.04
Tree	0.15	0.06	-0.08
Total Green Space	**0.64**	**0.18**	**-0.46**



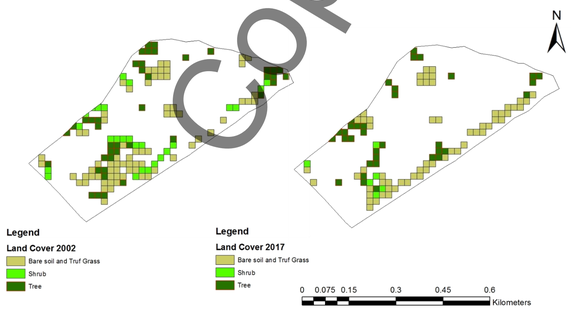
Types of Green Spaces	Percentage Area Ward 18		Difference
	2002	2017	
Bare soil and Truf Grass	0.15	0.02	-0.13
Rough Grass	0.01	0.00	-0.01
Shrub	0.05	0.01	-0.03
Tree	0.29	0.00	-0.29
Total Green Spaces	**0.50**	**0.03**	**-0.47**



Types of Green Spaces	Percentage Area Ward 33		Difference
	2002	2017	
Bare soil and Truf Grass	0.15	0.08	-0.06
Rough Grass	0.02	0.01	-0.02
Shrub	0.07	0.05	-0.03
Tree	0.24	0.00	-0.24
Total Green Space	**0.48**	**0.14**	**-0.34**



Types of Green Spaces	Percentage Area Ward 34		Difference
	2002	2017	
Bare soil and Truf Grass	0.12	0.10	-0.02
Rough Grass	0.00	0.00	0.00
Shrub	0.04	0.01	-0.03
Tree	0.16	0.00	-0.16
Total Green Space	**0.33**	**0.11**	**-0.22**



Structural Diversity and Over all index of Biodiversity.

- Structural diversity is achieved by musing Shannon Index
- The index is a mathematical measure of species diversity in a community.
- It measures the heterogeneity of the sites.
- The over all index of biodiversity is achieved by the multiplying the total greenspace and the Shannon index.

H= $-\sum_{i=1}^{5} pi \log_2 pi$ (P1= proportion area of bare ground and turf grass, P2= proportion of rough grass, P3- proportion of shrub, P4= proportion of trees, P5= proportion of built environment).

ln(5)= 1.609, Evenness = H/(ln(5))

Shannon Index value – Ward 3		
Year	H	Evenness
2002	1.22	0.76
2005	1.33	0.83
2010	0.98	0.73
2015	0.98	0.61
2017	0.86	0.53
Difference	**-0.36**	

Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.50	1.22	0.62
2005	0.37	1.33	0.50
2010	0.26	1.17	0.31
2015	0.17	0.98	0.17
2017	0.14	0.86	0.12
Difference			**-0.49**

Shannon Index value – Ward 18		
Year	H	Evenness
2002	1.02	0.63
2005	0.86	0.54
2010	0.42	0.41
2015	0.42	0.26
2017	0.38	0.24
Difference	**-0.63**	

Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.08	1.02	0.08
2005	0.07	0.86	0.06
2010	0.04	0.66	0.03
2015	0.03	0.42	0.01
2017	0.02	0.38	0.01
Difference			**-0.08**

Shannon Index value – Ward 33		
Year	H	Evenness
2002	1.10	0.68
2005	1.00	0.62
2010	0.73	0.52
2015	0.73	0.46
2017	0.74	0.46
Difference	**-0.36**	

Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.08	1.10	0.09
2005	0.08	1.00	0.08
2010	0.06	0.84	0.05
2015	0.05	0.73	0.04
2017	0.05	0.74	0.04
Difference			**-0.06**

Shannon Index value – Ward 34		
Year	H	Evenness
2002	0.82	0.51
2005	0.81	0.50
2010	0.63	0.49
2015	0.63	0.39
2017	0.61	0.38
Difference	**-0.21**	

Total Vegetative Area * Shannon Index			
Year	Total Vegetative Area	Shannon Index	TVA * SI
2002	0.05	0.82	0.04
2005	0.05	0.81	0.04
2010	0.05	0.79	0.04
2015	0.04	0.63	0.02
2017	0.04	0.61	0.02
Difference			**-0.02**

Inference:

From the temporal analysis it is clear that the areas are losing their heterogeneity and becoming more even.

Objective 2

Surface Runoff

- Surface runoff is the water from the rain, snowmelt and other sources of water that flows over the land.
- Runoff in urban areas increase due to increase in built up area and decrease in vegetative area.
- Surface runoff is calculated as per Rational Method

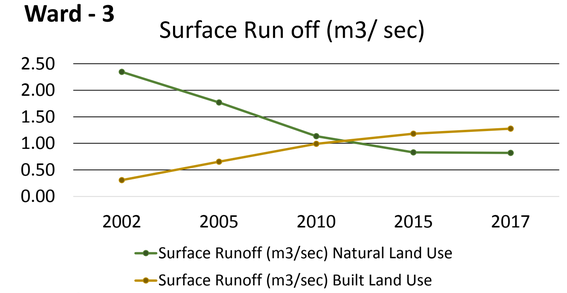
Formula **Q = 0.278CiA**

C – Runoff Coefficient, i – Intensity of Rainfall, A – Area

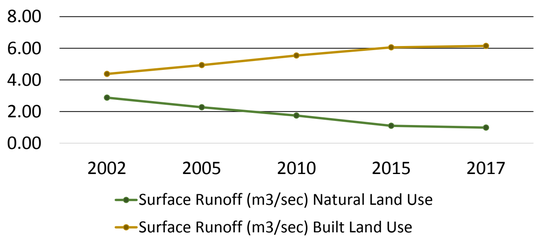
Results

Natural Vs Built Land Use

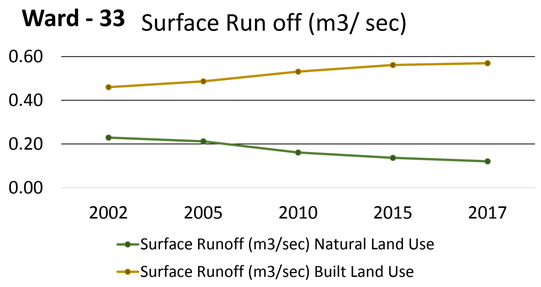
Ward - 3



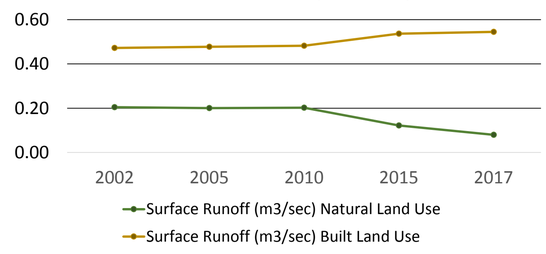
Ward - 18



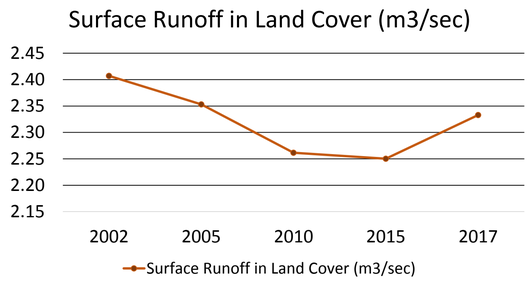
Ward - 33

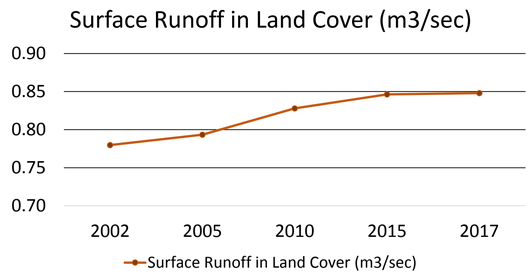


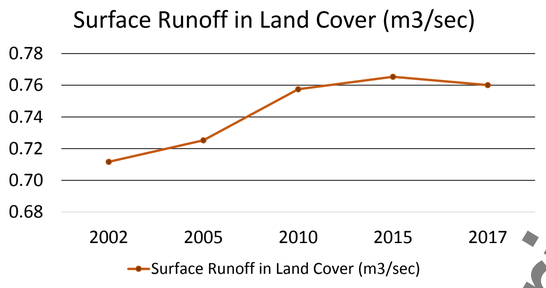
Ward - 34

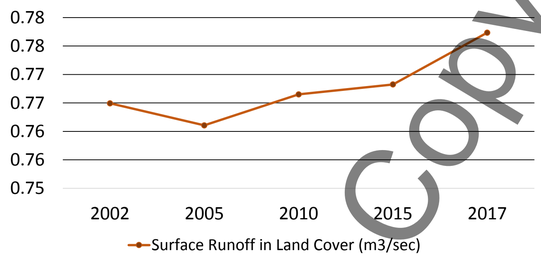


Land Cover







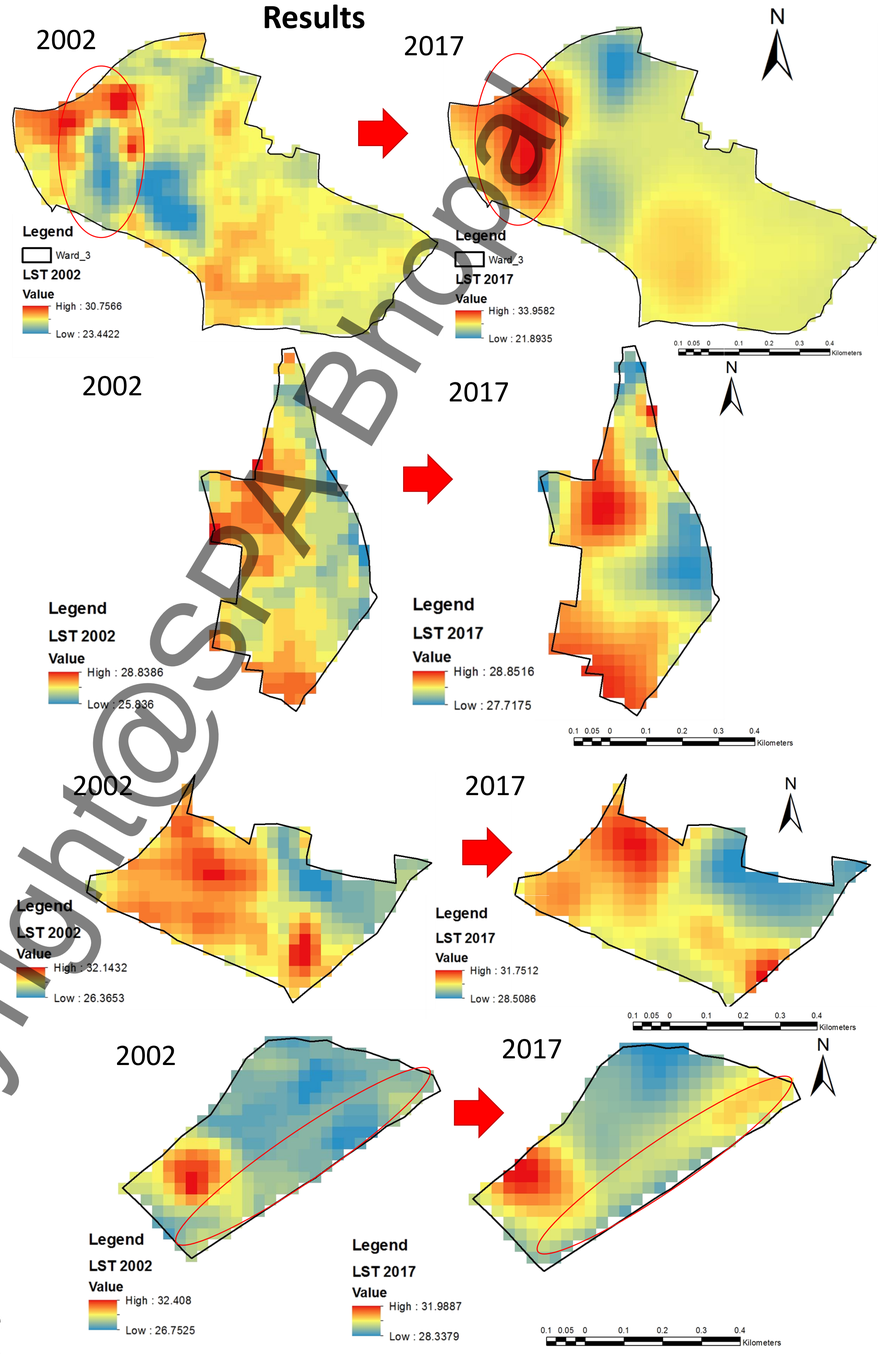


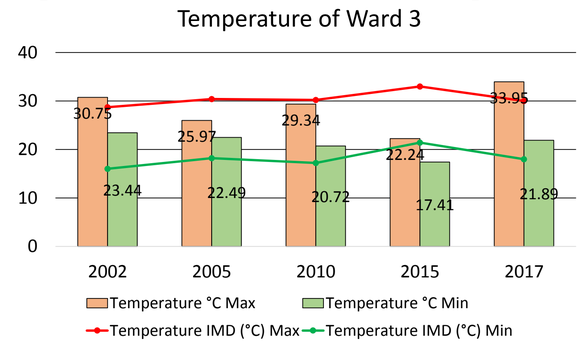
Inferences: In all cases the surface runoff in Natural areas have decrease while the runoff has increase in the built land use areas. But when we consider overall increase in surface runoff we find that in Ward 3 the surface runoff has decrease. This may be because of the consideration of detached housing category while other ward neighbourhood have been considered.

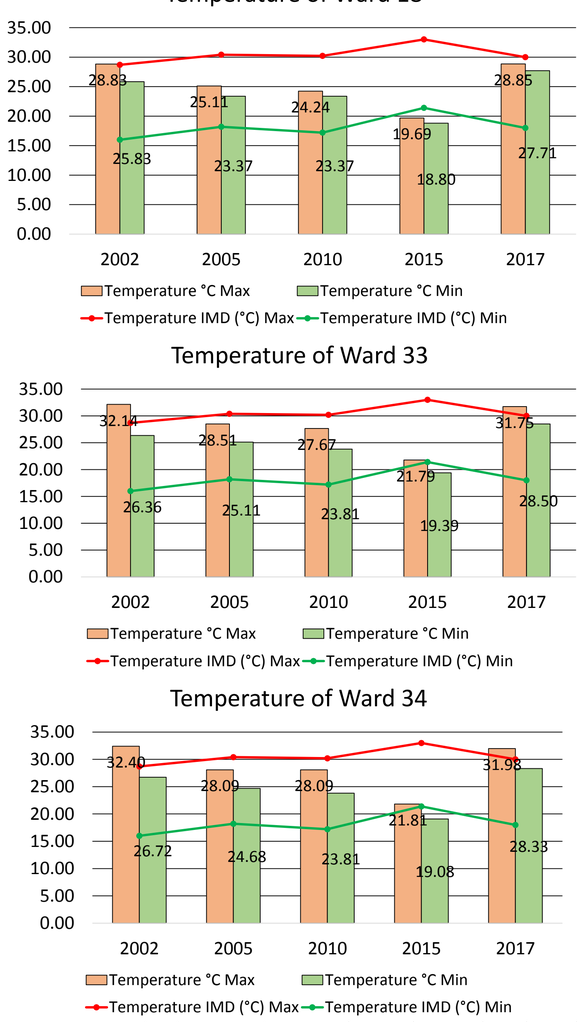
Land Surface Temperature

- The land surface temperature is the radiative skin temperature of ground.
- It depends on the vegetative cover, soil moisture and albedo effect.
- Land surface temperature is calculated by interpreting the thermal band of satellite image of the area.

Results







Inferences: In most of the ward it is visible the local minimum temperature is increasing rather than the local maximum temperature. Therefore it is decreasing the temperature variation between day and night is decreasing there by increase the discomfort in the area. This is exception in case of ward 3 where minimum temperature has decrease and maximum temperature has increased.

Objective 3

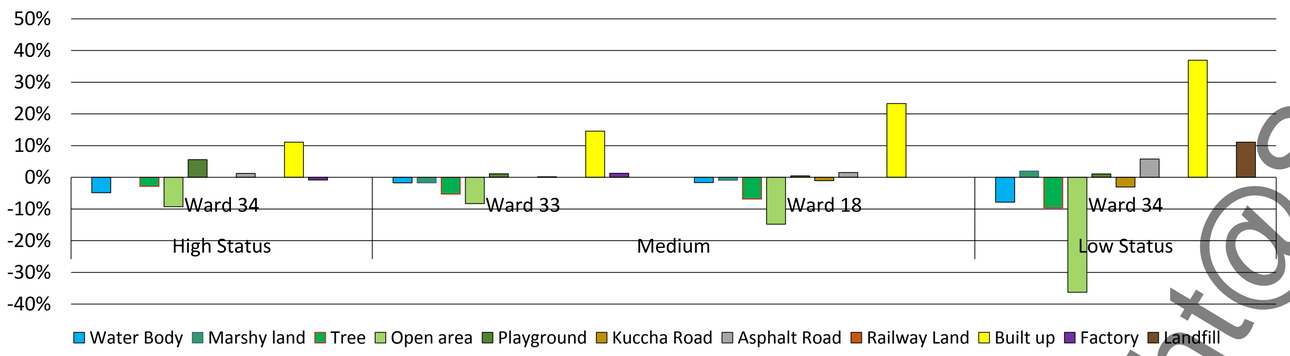
To find a relationship between the socio- economic condition, land use, land cover change and environmental quality within the identified micro area.

Ward No	3	18	33	34
Social	Low	High	Low	High
Economic	Low	Low	High	High

Land Use and Socio – Economic Status

Land Use	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Water Body	6%	1%	-5%	2%	1%	-2%	6%	5%	-2%	21%	13%	-8%
Marshy land	0%	0%	0%	2%	1%	-2%	1%	0%	-1%	1%	3%	2%
Tree	9%	6%	-3%	13%	8%	-5%	13%	6%	-7%	17%	7%	-10%
Open area	12%	3%	-9%	18%	10%	-8%	17%	2%	-15%	43%	6%	-36%
Playground	2%	8%	6%	0%	1%	1%	0%	0%	0%	0%	1%	1%
Kuccha Road	0%	0%	0%	0%	0%	0%	1%	0%	-1%	4%	0%	-3%
Asphalt Road	7%	9%	1%	7%	7%	0%	3%	5%	2%	0%	6%	6%
Railway Land	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%
Built up	54%	65%	11%	46%	60%	15%	59%	82%	23%	15%	52%	37%
Factory	9%	8%	-1%	7%	8%	1%	0%	0%	0%	0%	0%	0%
Landfill	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%	11%

Change in Land Use 2002-2017



Inference:

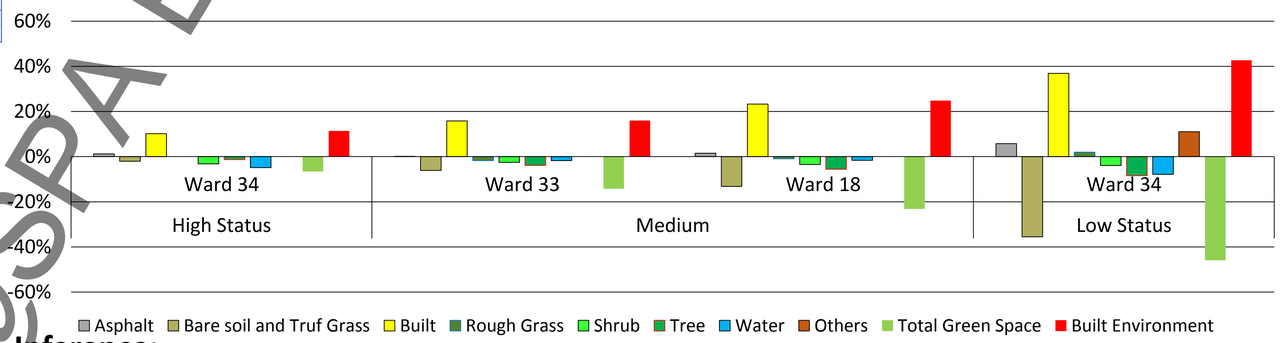
There has been significant increase in built up rather than increase in area of roads mainly asphalt road. But loss in open area is significantly high. It is clearly visible that in a low socio- economic condition the loss of open spaces and water bodies area high in the same time the increase in built up area is high. But in case of high status area there is increase in playgrounds.

Bio-diversity Indicators	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Total Green Space (vegetative area)	0.33	0.11	-0.22	0.84	0.48	-0.36	0.82	0.22	-0.60	5.04	1.42	-3.62
Structural Diversity	0.82	0.61	-0.21	1.10	0.74	-0.36	1.02	0.38	-0.63	1.22	0.86	-0.36
Vegetative area X Structural Diversity	0.45	0.24	-0.21	0.93	0.36	-0.57	0.84	0.09	-0.75	6.15	1.22	-4.94

Land Cover and Socio – Economic Status

Land Cover	High Status			Medium Status						Low Status		
	Ward 34			Ward 33			Ward 18			Ward 3		
	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference	2002	2017	Difference
Asphalt	7%	9%	1%	7%	7%	0%	3%	5%	2%	0%	6%	6%
Bare soil and Truf Grass	12%	10%	-2%	15%	8%	-6%	15%	2%	-13%	42%	7%	-36%
Built	63%	73%	10%	52%	68%	16%	59%	82%	23%	15%	52%	37%
Rough Grass	0%	0%	0%	2%	1%	-2%	1%	0%	-1%	1%	3%	2%
Shrub	4%	1%	-3%	7%	5%	-3%	5%	1%	-3%	6%	2%	-4%
Tree	7%	6%	-1%	9%	5%	-4%	11%	6%	-6%	15%	6%	-8%
Water	6%	1%	-5%	2%	1%	-2%	6%	5%	-2%	21%	13%	-8%
Others	0%	0%	0%	5%	5%	0%	0%	0%	0%	0%	11%	11%

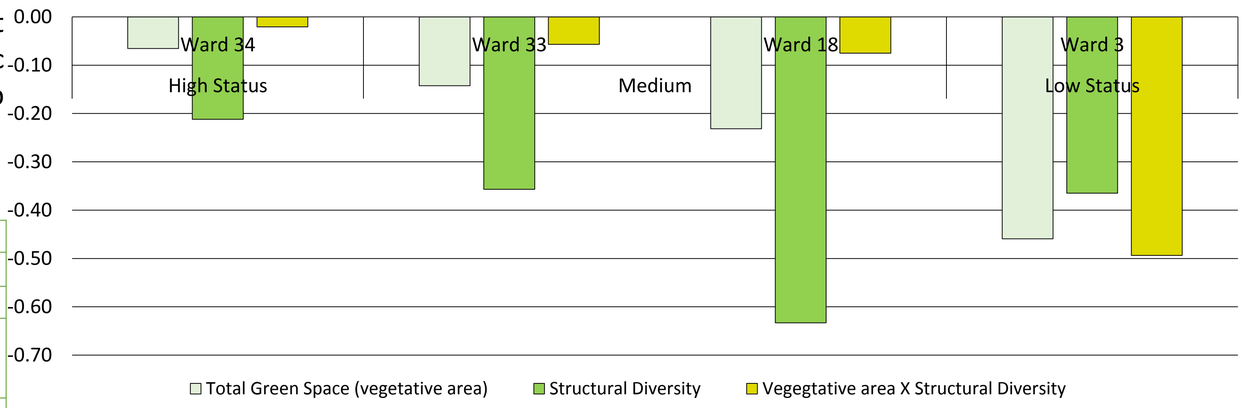
Change in Land Cover 2002-2017



Inference:

The amount of change in Bare soil and turf grass is more in case of Low status areas than high and middle status areas. But if we notice there has been least tree cover loss in high status area.

Change in Diversity Indicator 2002-2017



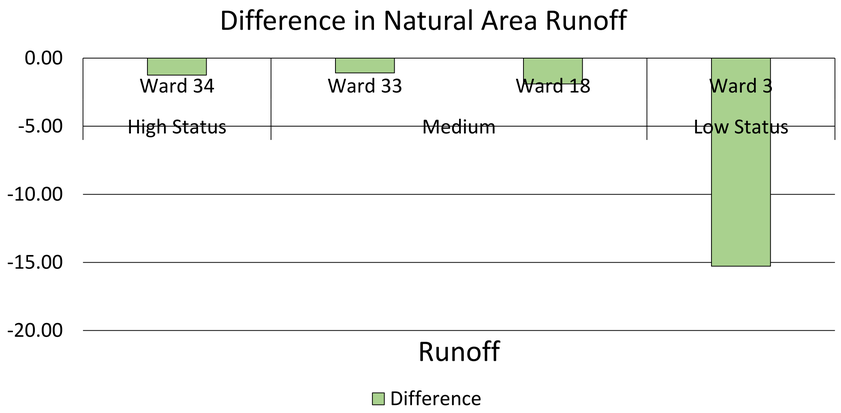
Inference:

The change structural diversity do not highlight any significant relation with status of an area but as we multiply it with total green spaces it shows that in low status the decline is greater than high status. The loss in total green spaces around -1.20, structural diversity is -0.39 and Vegetative area x Structural diversity is -1.62.

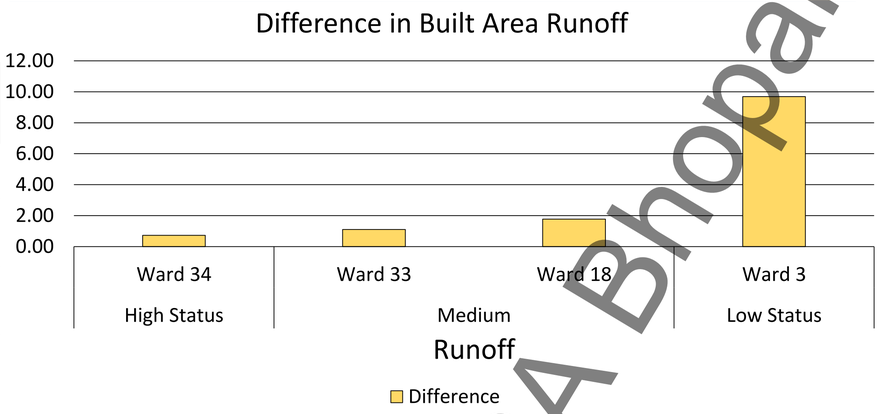
Objective 3

Surface Runoff and Socio – Economic Status

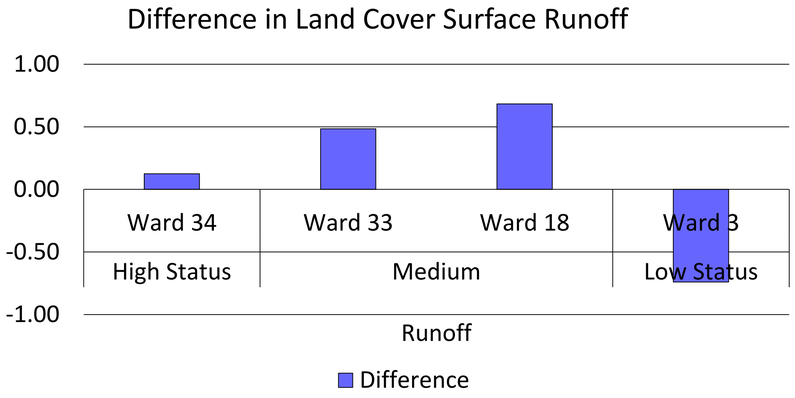
Natural Area				
Surface Runoff (m3/sec)	High Status	Medium		Low Status
	Ward 34	Ward 33	Ward 18	Ward 3
Difference	-1.25	-1.09	-1.89	-15.28



Built Area				
Surface Runoff (m3/sec)	High Status	Medium		Low Status
	Ward 34	Ward 33	Ward 18	Ward 3
Difference	0.73	1.10	1.77	9.69



Land Cover				
Surface Runoff (m3/sec)	High Status	Medium		Low Status
	Ward 34	Ward 33	Ward 18	Ward 3
Difference	0.12	0.48	0.68	-0.74

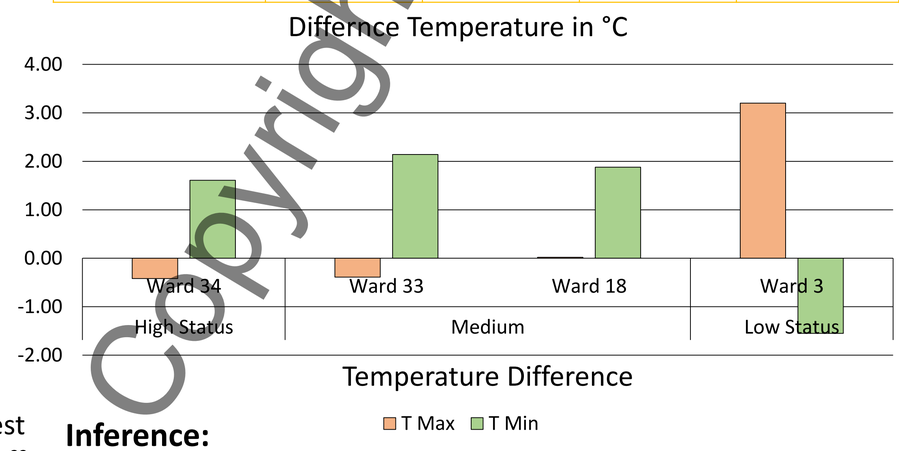


Inference:

It is clear from the graph that the low status area has highest decrease in run off in natural areas and highest increase in run off in built up area which is least in case of the high status area. But when runoff is considered in overall in low status area runoff has decreased while maximum increase of runoff has taken place in the medium status areas.

Land Surface Temperature and Socio – Economic Status

Difference in Temperature °C	High Status	Medium		Low Status
	Ward 34	Ward 33	Ward 18	Ward 34
T Max	-0.42	-0.39	0.02	3.20
T Min	1.61	2.14	1.88	-1.55



Inference:

Both in High status and the medium status the there has been huge increase in minimum temperature. But in low status area the minimum temperature has reduced. But in ward 18 both minimum and maximum temperature has increased there by reducing the range of temperature in the area.

Ward No	3	18	33	34
Social	Low	High	Low	High
Economic	Low	Low	High	High

Low Status:

- ✓ Increase in Built up and Asphalt road area.
- ✓ Conversion of large water bodies to landfill sites.
- ✓ Reduction in Tree canopy of the area.
- ✓ Decrease in bare soil and tough grass area.
- ✓ Decrease in shrub type land cover also.
- ✓ Huge decrease in total green spaces.
- ✓ Highest decrease in value of vegetative area and Shannon index.
- ✓ Highest decrease in surface runoff in natural area and maximum increase in runoff in built up area. Overall there is decrease in runoff.
- ✓ Maximum increase maximum temperature and decrease in minimum temperature over the years.

Medium Status:

- ✓ Increase in built up is more in case of high social and low economic area.
- ✓ Decrease in tree cover and bare soil and turf grass is more in high social and low economic area.
- ✓ Decrease in heterogeneity is more in high social and low economic than the low social and high economic area.
- ✓ Both areas have seen a large increase in surface runoff.
- ✓ But in case temperature both area are facing increase in minimum temperature which is a characteristic of UHI.

High Status:

- ✓ From all other areas there has been least increase in built up area.
- ✓ There has been increase in playground by converting few water bodies.
- ✓ As tree cover area is very less there has been decrease in tree cover but it is least with respect to other areas.
- ✓ Not much decrease in bio- diversity indicator of the area.
- ✓ The minimum land surface temperature have increase in the area which indicates UHI characteristic.
- ✓ Also from map it is visible that conversion water bodies to playgrounds have increase the amount of bare soil in that place and there fore there is an increase in land surface temperature.

So from all the analysis it is clear there is rapid degradation of environmental quality in low status area that the other areas. In case of high status area environmental components are low so rate of degradation is least.

Objective 4

To prepare planning strategies and guidelines for blue and green spaces based on the outcome

Issues Identified

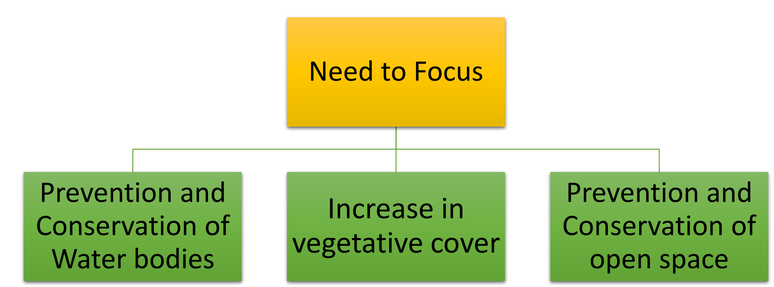
- Only few areas have been identified as Parks and Public Open Spaces under municipality although there are open grounds that can be declared as Parks and Public open spaces.
- Although no ponds, water bodies and no canal shall be filled but yes narrowing of water channels are taking place for construction and construction of metro bridge is also taking place over the canal.
- Sick and closed industrial land are converting to Real estate development zones.
- And no consideration for maintain tree cover and deforestation as a part of DCR.

Small Parks ad Public Spaces = up to 1500 Sq. Mt	Medium Parks ad Public Spaces = 1500 Sq. Mt to 7000Sq Mt	Large Parks ad Public Spaces = above 7000 Sq . Mt
Ward 3= 1 No (Listed in Municipality)	Ward 34= 1 No (Listed in Municipality)	Ward 33= 1 No (Listed in Municipality)
Ward 18= 1 No (Listed in Municipality)		Ward 34= 2 No (Listed in Municipality)
Ward 33= 1 No (Listed in Municipality)		
Ward 34= 1 No (Listed in Municipality)		

Ponds (No Hierarchy as per DCR)		
	Ward 3= 2 No (Listed in Municipality)	Ward 3= 4 No (Listed in Municipality)
	Ward 3= 3 No (Listed in Municipality)	Ward 34= 1 No (Listed in Municipality)

No Development Zones as Per Land Use Development Control Plan

- Parks and Public Open spaces if recorded in Municipality
- Parks and Playground within Railway Colonies, Defence area.
- Cremation, Burial and last rites performing grounds.
- Plots and premises being used as Industries even if identified sick, closed etc.
- No pond, water bodies or wetland and no canals shall be filled.



Open Space Reservation, Water Body Zoning and Tree Plantation

Govt. Tamil Nadu under Town and Country Planning Act, 1971

Focuses on Reserving land for recreational purpose as parks, play grounds for the communities

Extent of Site	Up to 2500 sq m site	Above 2500sq m site
Reservation	Nil	10% of area with min dimension of 10m

Draft Development Plan 2034, Greater Mumbai, under MR & TP Act 1966

For the purpose of development of Public Open spaces in Residential and Commercial Zone

1	From 1001 to 2500 sq m	15% for ROS
2	From 2501 to 10000 sq m	20% for ROS
3	Above 10000sq m	25% for ROS
Tree plantation	5 tree per 100 Sq m	1 tree per 80 sq m.

DCR of Bangalore, under KTCP Act, 1961

For the purpose of environmental Conservation

Water Bodies	No Development Zone	Need to have 30m buffer
Residential Development	10% for Park and Open Space	Relinquished to the authority free of cost
Tree Plantation	1 tree for site more than 2400 sq ft.	2 tree for site 4000 sq ft.

Revised Master Plan for Core Area of HMDA

For the purpose of Natural Conservation (green buffer along water bodies) and Parks, Playground

Water Bodies	No Development Zone	Need 30m buffer
Property tax Exemption	Private land owners with 1000 sq m and above – 25%, Register Society – 50%	Develop or maintain open spaces

Rejuvenation of Green Spaces and Parks Under AMRUT

Step- 1 (Asses Service Level Gap)

- Policies and Plans and Scheme Documents.
- Discussion with citizens and officials
- Physical Assessment of Park under current situation.
- Service level Status (Per person open space as per URDPFI)

Questions:

- Consider Socio – Economic Condition for Assessment?
- Include Environmental Indicators for Assessment?

Step- 2 (Bridging the Gap)

- Bridge the gap by listing all initiatives taken under any program, project, development plan.
- 1 park to be developed for Children, youth and elderly.

Question:

- Can one park be developed to restore Biodiversity?

Step- 3 (Examine Alternative and Estimate Cost)

Step- 4 (Citizens Engagement)

Step- 5 (Prioritize Project)

- Priority based on Funds, programs and schemes and approach?

Question:

- Why not also priorities on bases of environmental condition?

Step- 6 (Conditionality)

Step- 7 (Resilience)

- Talks about environmentally sustainable, safety and Security.
- Type of material to be used for construction.

Question:

- How to achieve environmental sustainability?
- Why sustainability not considered in all respect?

Step- 8 (Financial Plan)

Identification (register & Unregister)

Open Spaces | Water Bodies

↓

Changes to Be Incorporated

DCR | Policies

↓

New Land Use patterns

Open Spaces | Water Bodies

↓

Finances Mechanism

Taxation | Revenue

↓

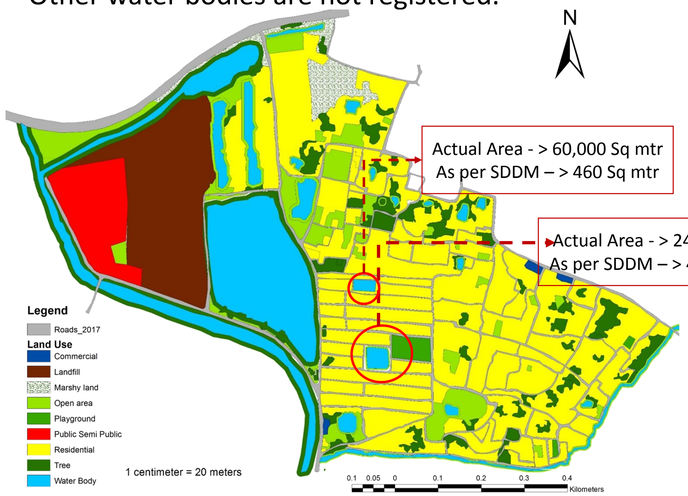
Applied in Most Critical Ward (Ward 3)

(Social – Low and Economically – Low)

Objective 4

Conservation and Prevention of Water Bodies

- Only 2 water bodies Identified by Municipality.
- Area less than the original area.
- Other water bodies are not registered.



Gardens and Water Bodies

Proper maintenances by owners

Inspection by authority

Increase Vegetative Cover

Tax Exemption for Residential Sector

Single Detached (Below 1000 Sq m) 10% area	Up to 90%
Private Owner (1000 - 5000 Sq m) 25% area	Up to 50%
Registered Society (> 5000 Sq m) 10% area	Up to 50%
Residential Development (> 5000 Sq m) Not < 10% area	100% relinquished to authority

Tree Plantation

Reason

- Deforestation
- Construction for new development
- Planting trees with less shade for beautification

Incorporate in LUDCP

For every 80 Sq mtr Plot size or less	1 Tree
For every > 100 Sq mtr area	Trees to be planted on set back
For every Large Construction	1 tree cut 3 tree planted

Only native species

New Regulation in LUDCP (Land use development control plan)

- ✓ Have hierarchy system to identify the water body
- ✓ Have buffer zone for all water bodies.

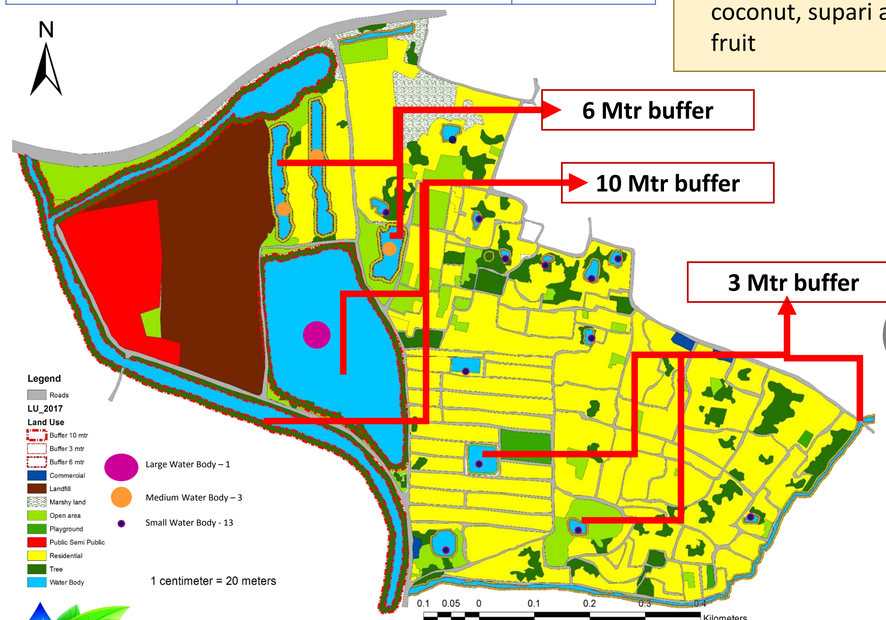
Hierarchy of Water Bodies (Area)		
Type	Area Range (Sq Mtr)	Buffer (Mtr)
Large pond / Lake	Above 10000 Sq Mtr	10 Mtr
Medium Pond	2500 - 10000 Sq Mtr	6 Mtr
Small Pond	Below 2500 Sq Mtr	3 Mtr

Buffer for Canals (Width)		
Type	Width of Canal (Mtrs)	Buffer (Mtr)
Wide Canal	Above 20 Mtrs	10 Mtr
Medium Wide Canal	10 - 20 Mtrs	6 Mtr
Narrow Canal	Below 10 Mtrs	3 Mtr

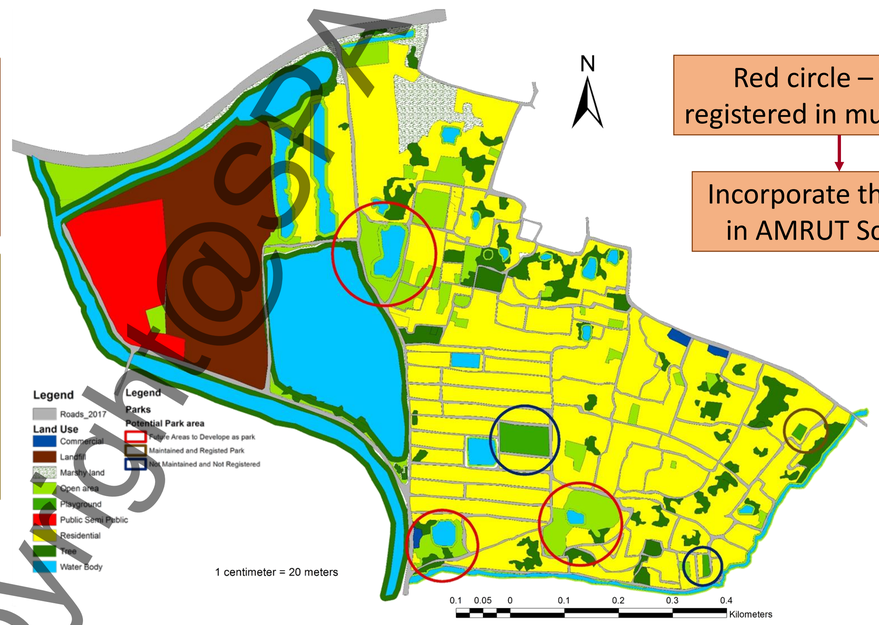
Already Incorporated in Kolkata Environmental Improvement Project But just for Kolkata Municipal Corporation Area

Allowed Used:

- No development along banks
- Used for the purpose of growing trees like - banana, coconut, supari and Jack fruit



Potential areas for New Park and Play ground development



Under AMRUT South Dum Dum Municipality:

- 3 Park development project
- Amount approved 50 lakhs
- DPR prepared but work yet not started
- One park in Ward no 3
- Park Marked in Blue circle will be developed by the Municipality under AMRUT.
- Till date amount distributed is 23.750.

Source: State Annual Action plan (2016-17) AMRUT

No progress seen in park development during visual survey

Red circle – To be registered in municipality

Incorporate the areas in AMRUT Scheme

Prioritized based on assessment

Finance Based on Priority

Develop Parks

Assessment of Park

- **Physical**
  - Area
  - Current Facility
  - Equipment
  - Maintenance
  - Accessibility
- **Socio Economic**
  - User group
  - Type of Neighbourhood
  - Surrounding Income group
  - Land Value
  - Employment
- **Environment**
  - Natural Area
  - Natural features
  - Planted Development
  - Waste disposal
  - Health

Objective 4

Integrated Blue and Green Zone

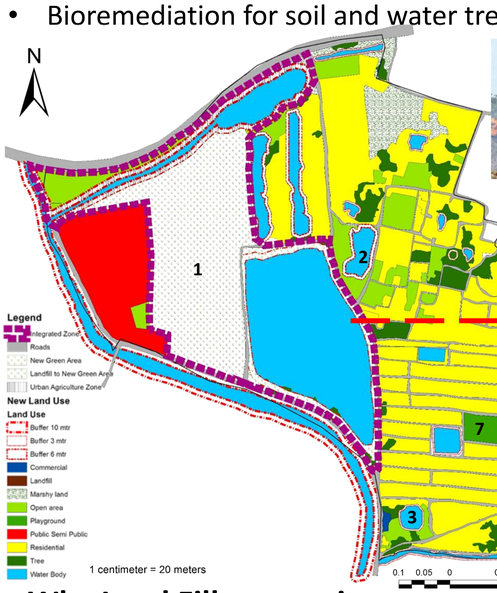
- ✓Multifunctional and Sustainable zone
- ✓Restores Ecology
- ✓Helps in improving socio economic condition of people.

Areas Included in Integrated Blue Green Zone

- Land fill area.
- Largest water body
- Portion of Canal
- Buffer area of both canal and water bodies
- Include socio economically weak sections of society

Different Activates within the Integrated zone

- Urban Agriculture
- Green Recreational Area
- Compost plant for manure production
- Lake for aquaculture
- Leachate treatment.
- Bioremediation for soil and water treatment.



Why Land Fill conversion

- ➢ Land fill being used for more than 15 years
- ➢ It is being used by more than one municipality.
- ➢ It is surrounded by residential zone of other municipality also.
- ➢ NGT has already notified about the area to the Municipal Affairs.
- ➢ Govt. of West Bengal Announced new integrated solid waste management project for 14 ULBs which includes SDDM.


THE TIMES OF INDIA
CITY

Garbage mountain on fire, thousands despondent

Shounak Ghosal| TNN | Jun 5, 2016, 12.11 AM IST


Business Standard

Bengal takes up 10 solid waste management projects

IANS | Kolkata
February 27, 2017 Last Updated at 21:34 IST

Conversion of Land Fill

Type	Land fill Conversion Technique	
	Capping Method	Bioremediation
Soil Toxicity	No	Yes
Subsidence	Yes	No
Area Requirement	More than actual	Same area
Temperature	Fluctuating	Constant
Technical Skill	High	Low
Cost	Expensive	Low
By Products	Methane	Organic Manure

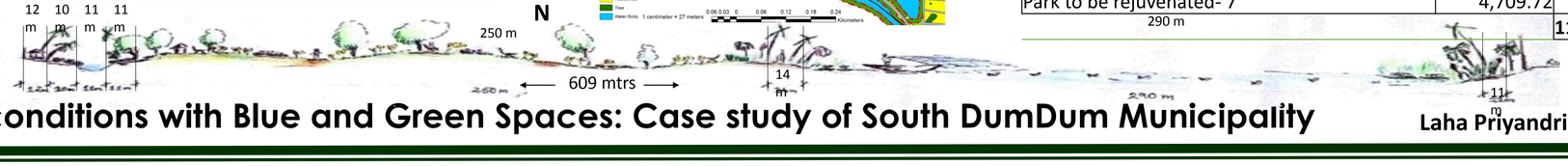
Conversion of old waste through Bioremediation

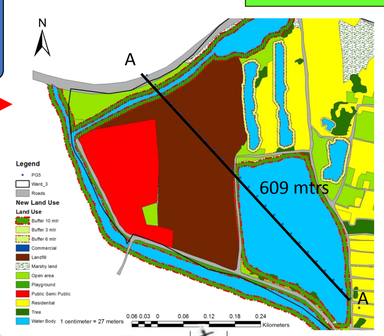
LAYER

- Excavate Old Waste
- From Windrow hips
- Maintain temperature 60°C
- 45% moisture
- Spray Bio culture
- 7th day turn waste hip
- Repeat for 2 3 weeks
- Bio – earth will settle at the bottom
- Planation on bio earth
- Segregate separable matter

Amount of Culture Required	
Waste Type	**Grams / tonne**
Old Waste	250 gm/ tonne
Fresh waste	500 gm/ tonne
Type of Bio Culture	**Grams / Sq Mt**
Rapidcom BC -28	200 gm / sq Mt

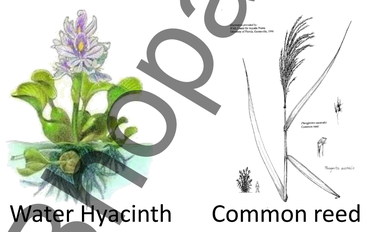
SECTION





Leachate Treatment

- Collect leachate separately
- Send leachate for leachate treatment.
- For uncollected leachate treat through phytoremediation
- Plants used – Water Hyacinths and Common Reed


Water Hyacinth

Common reed

Urban Agriculture

- Help in removing soil toxicity
- Involve socio economically weak section of Society.
- Encourage under KEIP on canal bank, but only for KMC area
- Therefore can also be encouraged in other parts of KMDA

Native plants allowed to be grown on canal side


Cauliflower


Cabbage


Pumpkin


Man Kachu

Vegetables


Papaya


Coconut


Banana


Jack Fruit


Supari


Mango

Fruits

Revenue:

- Selling Fruits and vegetables grown
- Sell of manure form old waste at rate of Rs 2.75/- per Kg
- Zone open for visitors

Parks, Playground and Green Space	Area in Sq. m	in Ha	Population
Integrated Blue Green (IBG) no water bodies -1	81,421.32	8.142132	162843
Park with water body just near IBG - 2	9,122.68	0.912268	13684
Park beside road with Water body - 3	6,020.69	0.602069	6021
Park with small water body in middle - 4	9,345.81	0.934581	14019
Playground not maintained - 5	462.72	0.046272	463
Registered Park -6	483.66	0.048366	484
Park to be rejuvenated- 7	4,709.72	0.470972	4710
290 m		**11.15666**	**2,02,222.17**

Remove Soil Contamination

Purely through phytoremediation

PLANTS

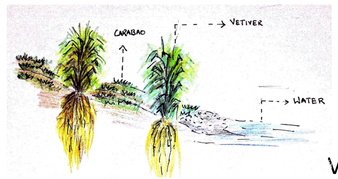

Indian Mustard Plant


Sunflower


Tomato

Accumulate Pollutant in their root

GRASS



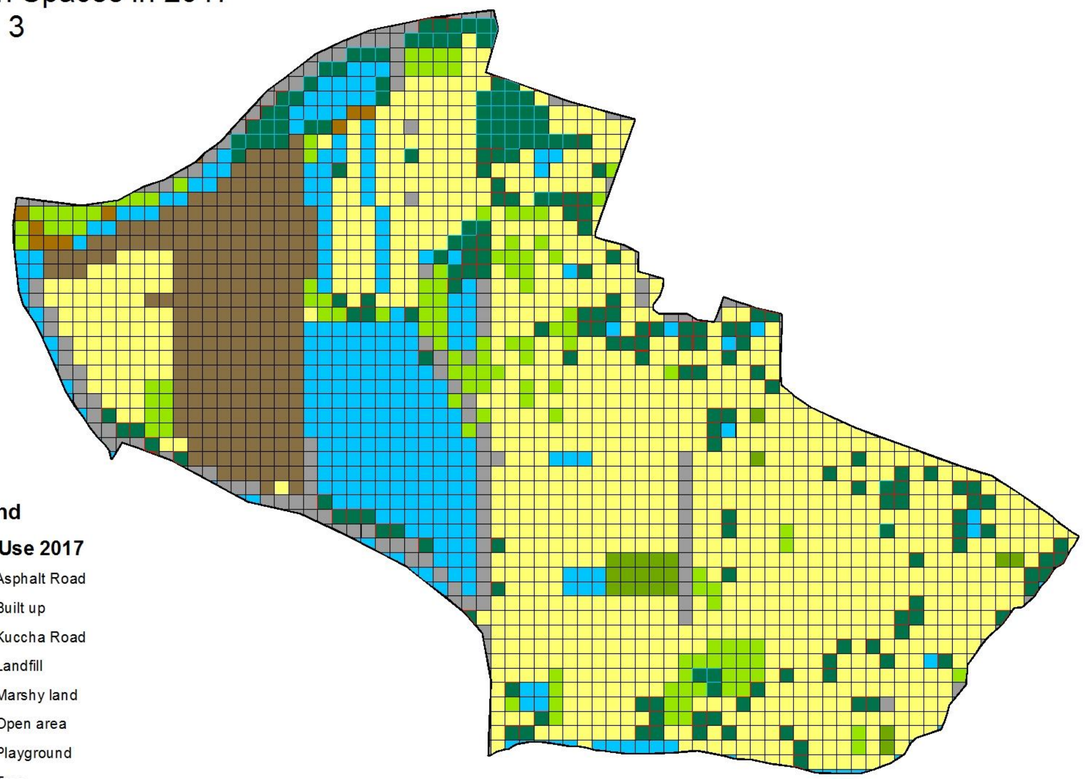

Vetiver Grass


Carabao grass

Remove Heavy Metal contamination

Operation and Maintenance

Green Spaces in 2017
Ward 3



Legend

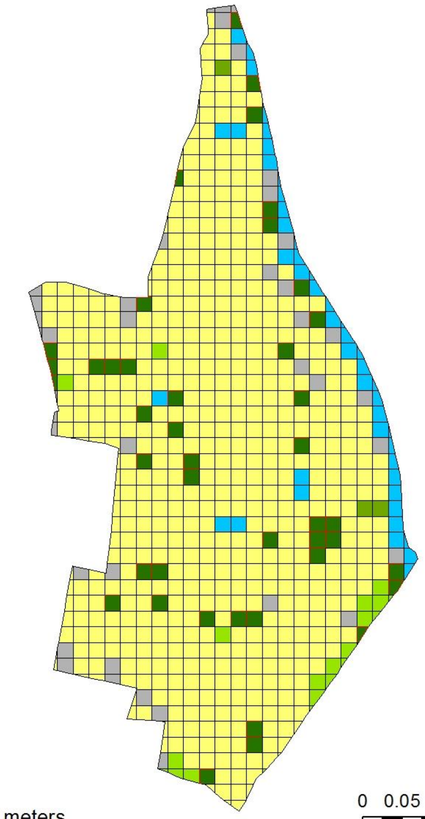
Land Use 2017

- Asphalt Road
- Built up
- Kuccha Road
- Landfill
- Marshy land
- Open area
- Playground
- Tree
- Water Body

1 centimeter = 60 meters

0 0.05 0.1 0.2 0.3 0.4
Kilometers

Green Spaces in 2017
Ward 18



Legend

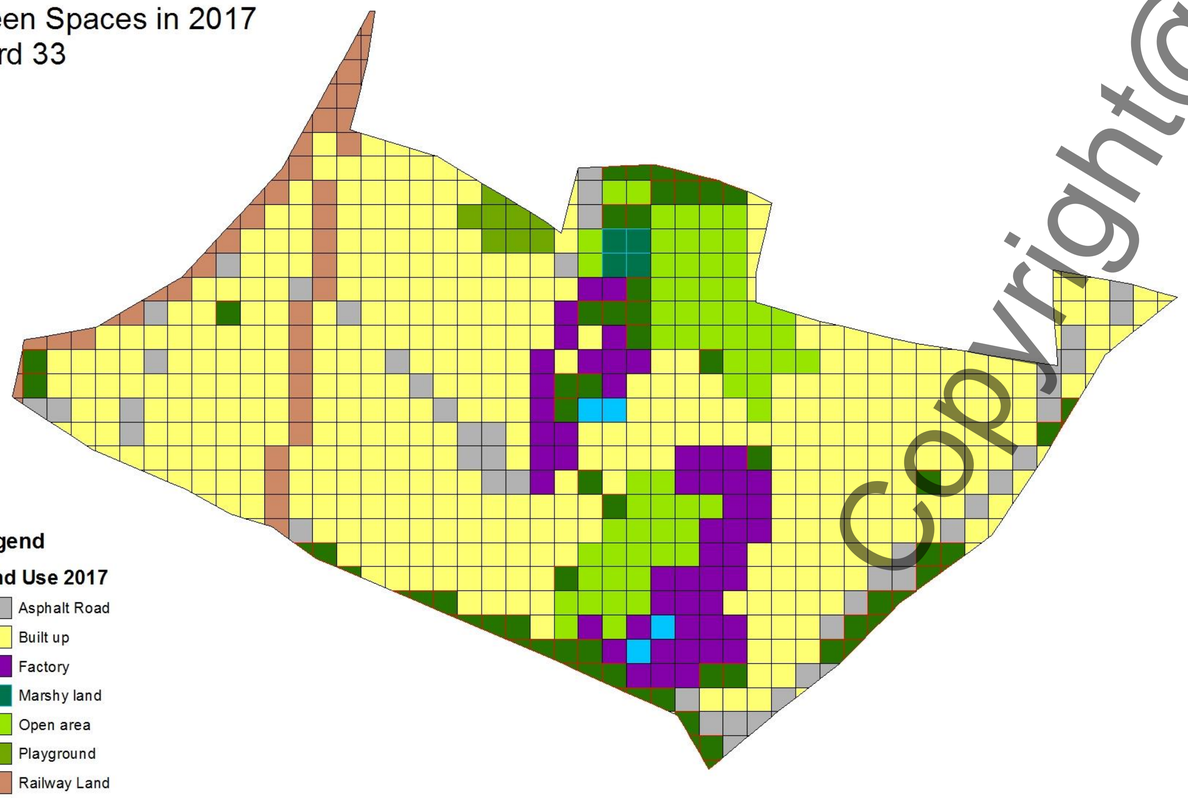
Land Use 2017

- Asphalt Road
- Built up
- Open area
- Playground
- Tree
- Water Body

1 centimeter = 55 meters

0 0.05 0.1 0.2 0.3 0.4
Kilometers

Green Spaces in 2017
Ward 33



Legend

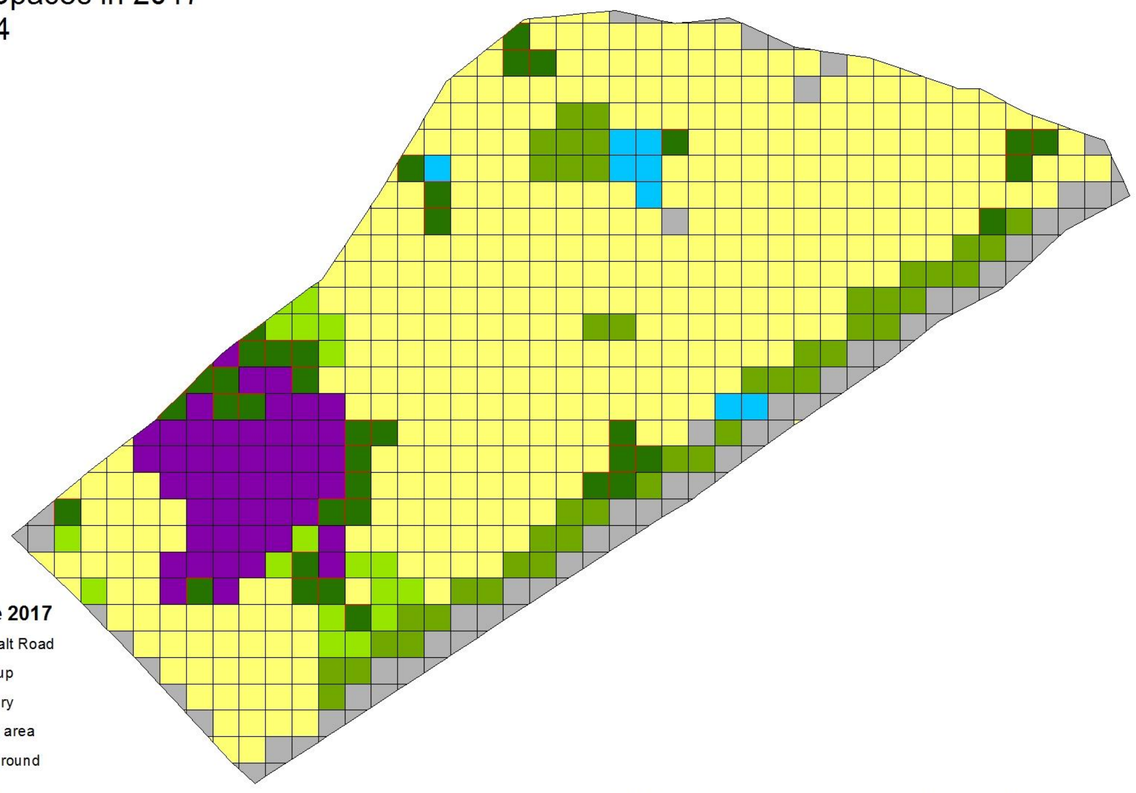
Land Use 2017

- Asphalt Road
- Built up
- Factory
- Marshy land
- Open area
- Playground
- Railway Land
- Tree
- Water Body

1 centimeter = 36 meters

0 0.0475 0.095 0.19 0.285 0.38
Kilometers

Green Spaces in 2017
Ward 34



Legend

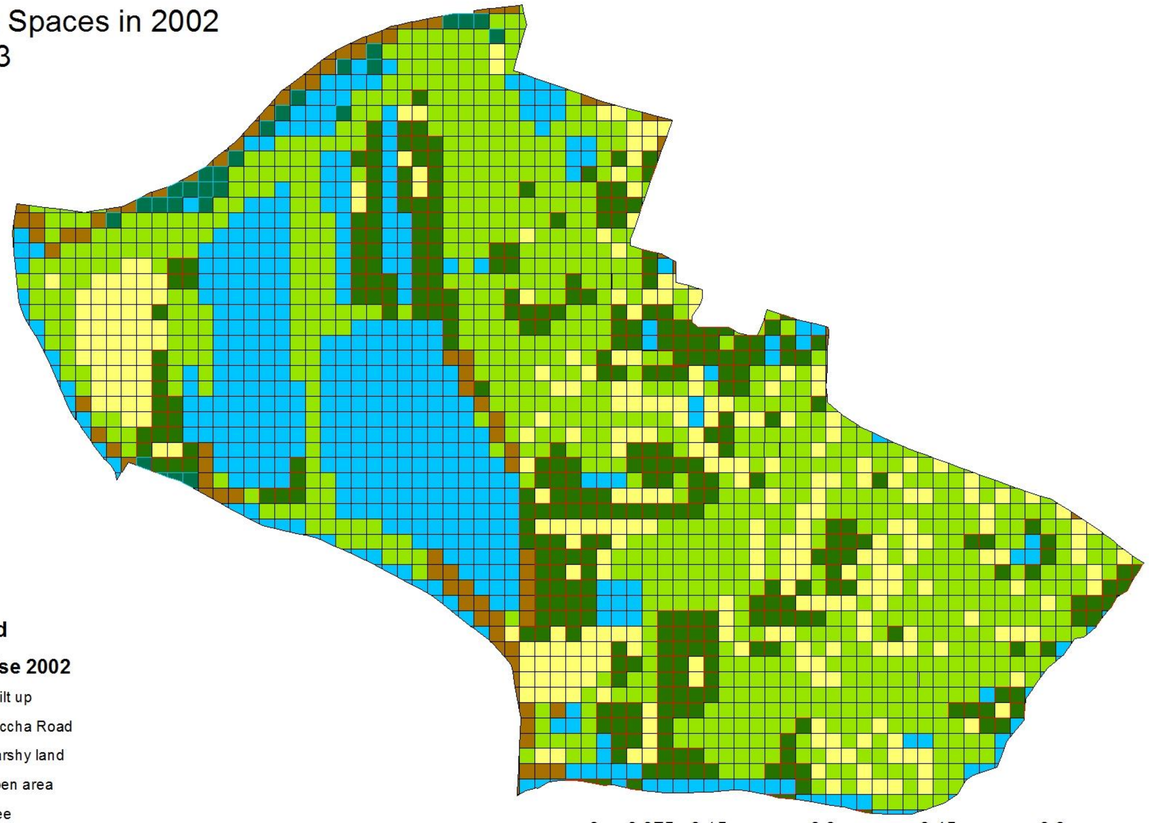
Land Use 2017

- Asphalt Road
- Built up
- Factory
- Open area
- Playground
- Tree
- Water Body

1 centimeter = 33 meters

0 0.0425 0.085 0.17 0.255 0.34
Kilometers

Green Spaces in 2002
Ward 3



Legend

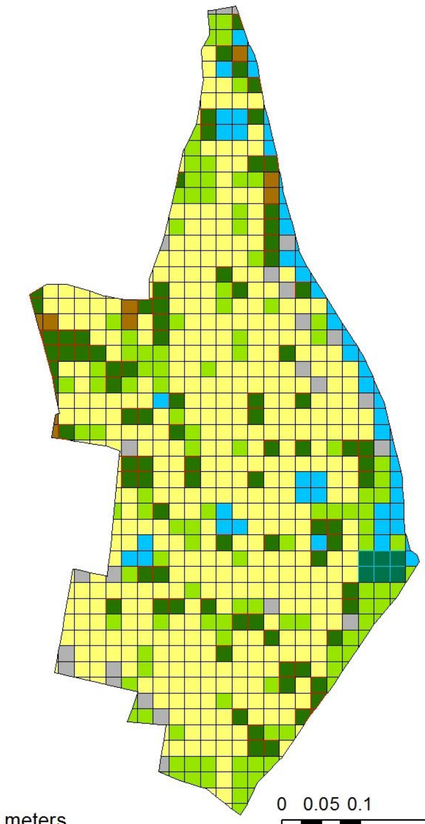
Land Use 2002

- Built up
- Kuccha Road
- Marshy land
- Open area
- Tree
- Water Body

1 centimeter = 57 meters

0 0.075 0.15 0.3 0.45 0.6
Kilometers

Green Spaces in 2002
Ward 18



Legend

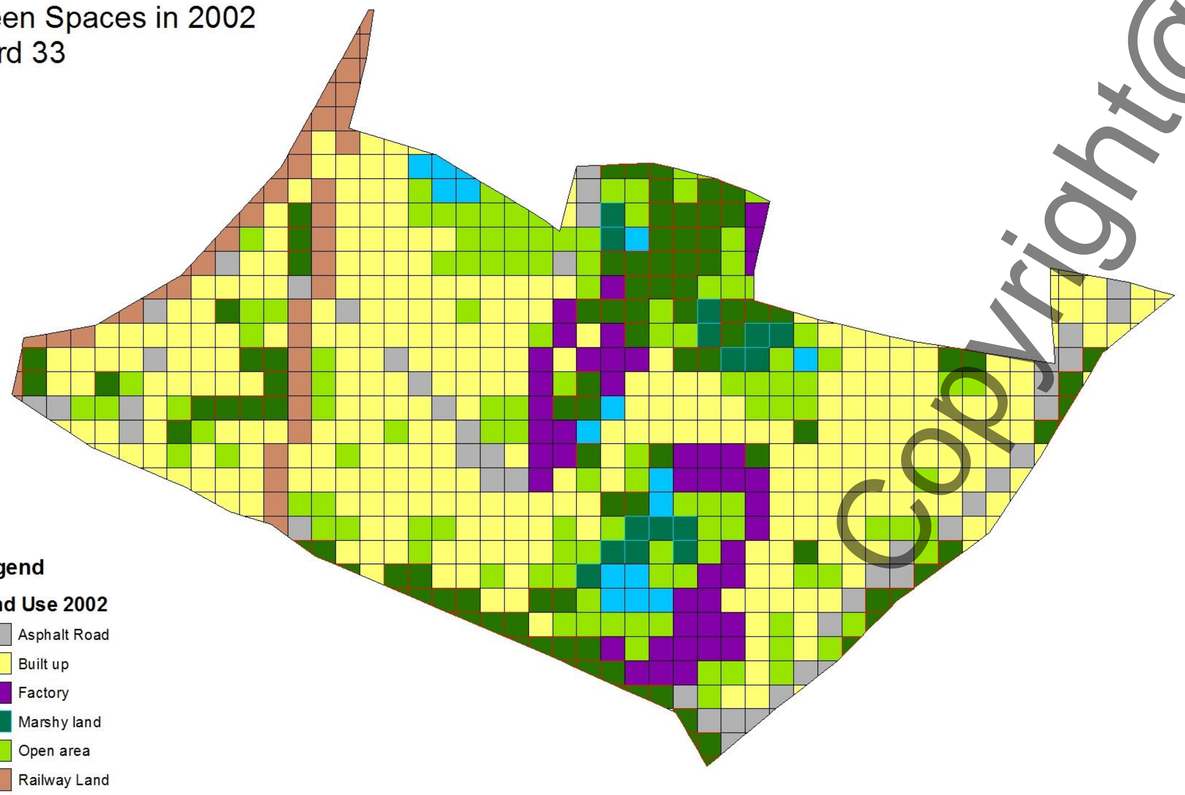
Land Use 2002

- Asphalt Road
- Built up
- Kuccha Road
- Marshy land
- Open area
- Tree
- Water Body

1 centimeter = 55 meters

0 0.05 0.1 0.2 0.3 0.4
Kilometers

Green Spaces in 2002
Ward 33



Legend

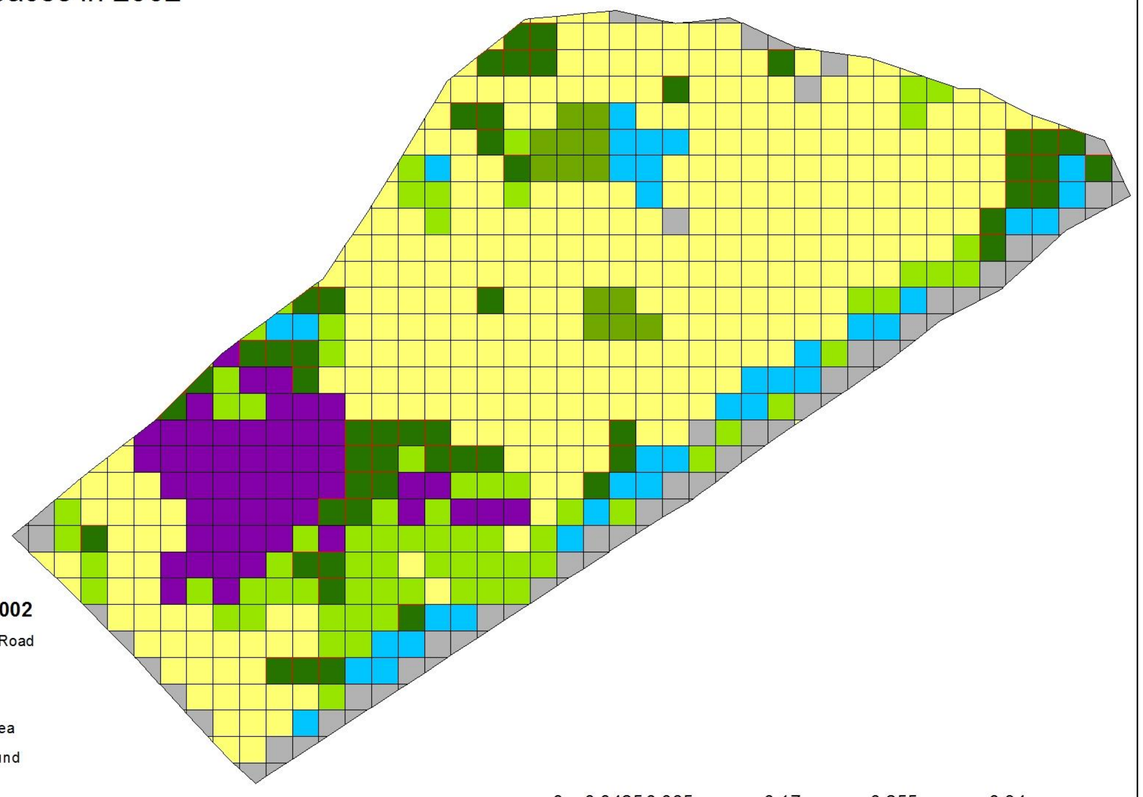
Land Use 2002

- Asphalt Road
- Built up
- Factory
- Marshy land
- Open area
- Railway Land
- Tree
- Water Body

1 centimeter = 36 meters

0 0.0475 0.095 0.19 0.285 0.38
Kilometers

Green Spaces in 2002
Ward 34



Legend

Land Use 2002

- Asphalt Road
- Built up
- Factory
- Open area
- Playground
- Tree
- Water Body

1 centimeter = 33 meters

0 0.0425 0.085 0.17 0.255 0.34
Kilometers