Combining Google Earth & GIS Mapping Techniques in a Dengue Surveillance System to Develop Dengue Risk Map for Pune Municipal Corporation (PMC)

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By

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CERTIFICATE

Certified that this project titled **"Combining Google Earth & GIS Mapping Techniques in a Dengue Surveillance System to Develop Dengue Risk Map for Pune Municipal Corporation (PMC)"** is a bonafide work done by Miss ***Sneha Manojkumar Chopda***, at Symbiosis Institute of Geoinformatics under my supervision.

Supervisor Internal & External

(Dr. Navendu Chaudhary

Assistant Professor,

SIG, Pune)

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the project entitled ***"Combining Google Earth & GIS Mapping Techniques in a Dengue Surveillance System to Develop Dengue Risk Map for Pune Municipal Corporation (PMC)"*** for the partial fulfillment of M.Sc. degree submitted in Symbiosis Institute of Geoinformatics is an authentic record of my own work carried out during the period from 1st December 2012 to 31st May 2013 under the supervision of Dr. Navendu Chaudhary, Assistant Professor, Symbiosis Institute of Geoinformatics, Pune

The matter embodied in this work has not been submitted by me for the award of any other degree in this or any other institute.

(Sneha Manojkumar Chopda)

This is to certify that that the above statement made by the candidate is correct to the best of my knowledge.

(*Dr. Navendu Chaudhary,*

***SIG, Pune*)**

Date: 09/06/2013

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CONCLUSIONS AND FUTURE SCOPE

ABSTRACT

Dengue Fever (DF) and Dengue Hemorrhagic Fever (DHF) are important public health problems in the tropic and sub-tropic areas. Rapid urbanization, increasing population movement and lifestyles that contribute to the proliferation of man-made larval habitats of the mosquito are the exacerbated factors for the increasing number of the dengue incidences. In Pune Municipal Corporation (PMC), there has been a global upward trend in incidence of Dengue Hemorrhagic Fever (DHF), an acute and severe form of dengue virus infection, which remains a major public health concern. Dengue is due to an Arbovirus mainly transmitted by Aedes Aegypti, a mosquito living close to human communities. The intensity of the transmission (i.e. number of cases and speed of the spread of the disease) is dependent on the number of vectors, the serotype of the virus, the herd immunity and the environment.

Dengue Fever (DF) and Dengue Hemorrhagic Fever (DHF) are the two most dreaded mosquito-borne viral diseases affecting man. These cases are reported throughout India. The DF/DHF disease is also a public health problem in Pune Municipal Corporation (PMC) where the number of such reported cases has dramatically increased since last year. Remote sensing and Geographic Information System (GIS) technologies have been used in this study to link and update information on the environmental factors, socio-economic factors, weather conditions and the reported number of dengue incidences. These technologies have been widely used in the public health sector for managing and monitoring the problem. Remote sensing data is utilized to manage the problem by incorporating environmental factors such as changes in landuse/land cover, normalized difference vegetation index, land surface temperature, topographic variations, etc. Remote sensing data was also useful in generating the digital elevation model (DEM) and a Google Earth Satellite Imagery base-map on which all other layers were overlaid. These data were stored together with other ancillary data obtained from relevant agencies in the GIS database for further analysis and mapping. The developed Dengue Risk map was then verified by using reported cases in the year 2012 obtained from the PMC Health department which was then overlaid on high resolution remote sensing data to identify the source of mosquito problem (i.e. vector breeding areas). It was found that more than ninety percent of the case samples were in the “Medium” and “High” categories where most of the victims were found to have lived in the

urban and sub-urban areas of the municipality. The developed dengue risk map was then integrated with spatial datasets and temporal datasets of high resolution satellite imagery to identify the influencing factors of the outbreak. The Dengue Risk maps developed in this study would be useful for decision makers to respond, strategize and create preventive action plans to control the dengue transmission.

The study entangles the prime objectives as enlisted below encompassing the criteria outlined in the subsequent paragraph.

1) Combining Google Earth and GIS mapping techniques to map the Dengue disease spread in PMC for three consecutive years- 2010, 2011 and 2012.

2) To identify the pattern of Dengue Incidence Distribution, then to analyze the hotspots locations of the Dengue Incidences and finally mapping the geographic distribution of Dengue Incidences in PMC for the year 2012 using Spatial Statistics tools in ArcGIS 10.

3) To identify the Environmental factors that contribute to the dengue outbreak using remote sensing data then to correlate the identified Environmental factors with dengue occurrence pattern and finally using spatial analysis to predict and map potential high risk areas in PMC for a dengue outbreak using Spatial Analysis-Overlay tools in ArcGIS 10.

4) To identify the Socio- Economic factors that contribute to the dengue outbreak using spatial data, then to correlate the identified with Socio-Economic factors dengue occurrence pattern and finally using spatial analysis to predict and map potential

high risk areas in PMC for a dengue outbreak using Spatial Analysis-Overlay tools in ArcGIS 10.

5) Combining Environmental and Socio-Economic factors that contribute to the dengue outbreak using remote sensing and spatial data and then using spatial analysis to predict and map potential high risk areas for a dengue outbreak in PMC for the year 2013 using Spatial Analysis-Overlay tools in ArcGIS 10.

6) To carry out statistical analysis based on Temperature, Rainfall, Entomology Index, Dengue Incidences, etc. data by creating and comparing the graphs and how they contribute in predicting and mapping potential high risk areas for a dengue outbreak in PMC.

The Dengue Risk Map generated from environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. that were obtained from LANSAT 7 (ETM+) satellite data and Socio-economic factors such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases, Settlements, etc. that were obtained from PMC ‘s Census, Health, Slum, Garden, Housing, etc. Departments was classified as “Low”, “Medium” and “High” risk potential areas of having the dengue outbreak. Here, Weighted and Fuzzy Overlay analysis techniques were used for developing Dengue Risk Maps (DRMs) for Pune Municipal Corporation (PMC).

From the study, it was observed and analyzed that majority of the dengue incidence cases were found in the urban and sub-urban areas with higher population and population density as well. Most of these cases were reported in and around slums, thus it contributes the maximum to the dengue epidemic in PMC due to lack of regular water supply, housing types, etc. Also, the post-monsoon period where temperature is between 16°C to 30°C and this temperature range is very conducive to the mosquito breeding cycle as an increase in the number of times that the mosquito breeds will also increase the likelihood of the emergence of the dengue outbreak. Relative humidity is increased by rainfall particularly following drought. Relative humidity strongly impacts flight and the subsequent host seeking behaviour of mosquitoes. Thus, all these environmental, socio-economic, climatic, etc. factors contribute to the dengue outbreak in PMC, respectively.

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LIST OF ABBREVIATIONS

ANN: Average Nearest Neighbor

ASTER: Advanced Space-borne Thermal Emission and Reflection Radiometer

DEM: Digital Elevation Model

DF: Dengue Fever

DHF: Dengue Hemorrhagic Fever

DSS: Dengue Shock Syndrome

DRM: Dengue Risk Map

ETM+: Enhanced Thematic Mapper Plus

GCPs: Ground Control Points

GIS: Geographic Information System

GDEM: Global Digital Elevation Model

IMD: Indian Meteorological Department

LU/LC: Land Use/Land Cover

LST: Land Surface Temperature

MOH: Ministry of Health

NDVI: Normalized Difference Vegetation Index

NIR: Near Infrared

NIV: National Institute of Virology

PMC: Pune Municipal Corporation

SEA: South East Asia

SOI: Survey of India

TIFF: Tagged Image File Format

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\- **Sneha Manojkumar Chopda**

PREFACE

Dengue virus infection is one of the most important among human Arbovirus infections. The global incidence of Dengue Fever (DF) and Dengue Hemorrhagic Fever (DHF) has increased dramatically in recent decades. Dengue is a mosquito-borne infection which in recent years has become a major international public health concern. Various factors responsible for the resurgence of dengue epidemic in Pune Municipal Corporation are un-precedent human population growth; un-planned and un-controlled urbanization; increasing number of slums inadequate waste-management; water supply mismanagement; increased distribution and densities of vector mosquitoes; lack of effective mosquito control has increased movement & spread of dengue viruses and development of hyper endemicity and deterioration in public health infrastructure.

In this study, a satellite imagery base-map was created using Google Earth downloaded images to identify individual dengue incidence location in the municipality region. On this satellite image all other environmental layers such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc., and socio-economic layers such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases, Settlements, etc were overlaid to carry out further analysis by using Weighted and Fuzzy Overlay analysis techniques to develop Dengue Risk Maps (DRMs). Statistical analysis based on weather, entomology index and dengue cases data was carried out to as an addition to the analysis. Also, field visit was carried to locations where the chances of dengue outbreak are highest as a part of the validation of the study. Hence, this finding is very encouraging as it validates the accuracy of the generated Dengue Risk Map when compared with the reported dengue cases-2012 and 2013 till date within the municipality area of PMC. Spatial statistics was used for analyzing dengue incidences pattern, identifying hot spots locations of the incidences and measuring geographic distribution of the dengue incidences. As an epidemiologist, these results can be used to generate overlays on a weekly, monthly, or yearly basis (or any other time-step) in order to create time-series maps that summarize the spread of a disease.

CHAPTER 1

INTRODUCTION

1.1 PROLOGUE

Dengue is a self limiting acute mosquito transmitted disease characterized by fever, headache, muscle, joint pains, rash, and nausea and vomiting. Dengue Fever (DF) is caused by an Arbovirus and spread by Aedes mosquitoes. Some infections result in Dengue Hemorrhagic Fever (DHF) and in its severe form Dengue Shock Syndrome (DSS) can threaten the patient's life primarily through increased vascular permeability and shock. Over the past two decades, there has been global increase in the frequency of DF, DHF and its epidemics, with a concomitant increase in disease incidence. Various factors responsible for the resurgence of dengue epidemic are: (i) un-precedent human population growth; (ii) un-planned and un-controlled urbanization; (iii) inadequate waste-management; (iv) water supply mismanagement; (v) increased distribution and densities of vector mosquitoes; (vi) lack of effective mosquito control has increased movement & spread of dengue viruses and development of hyper endemicity and (vii) deterioration in public health infrastructure.

Dengue is one of the most important emerging viral diseases of humans in the world afflicting humanity in terms of morbidity and mortality. Currently the disease is endemic in all continents except Europe. The Epidemiology of dengue is a complex phenomenon that mainly depends upon an intricate relationship between the 3 epidemiological factors: the host (man and mosquito), the agent (virus) and the environment (abiotic and biotic factors). The complexity of relationship among these factors eventually determines the level of endemicity in an area. The dengue viruses are the members of the genus flavivirus. These small (50nm) viruses contain single stranded RNA. There are four virus serotypes, which are designated as DEN-1, DEN-2, DEN-3 and DEN-4.Although all four serotypes are antigenicaly similar, they are different enough to elicit cross-protection only for a few months after infection by any one of them. Infection with any one serotype confers lifelong immunity to the virus serotype. Man and mosquito are reservoirs of infection. Transovarian transmission (infection carried over to next progeny of mosquitoes through eggs) has made the control more complicated. At present DEN1 and DEN2 serotypes are widespread in India.

Female Aedes mosquito deposits eggs singly on damp surfaces just above the water line. Under optimal conditions the life cycle of aquatic stage of Aedes Aegypti (the time taken from hatching to adult emergence) can be as short as seven days. The eggs can survive one year without water. At low temperature, however, it may take several weeks to emerge. Aedes Aegypti has an average adult survival of fifteen days. During the rainy season, when survival is longer, the risk of virus transmission is greater. It is a day time feeder and can fly up to a limited distance of 500 -700meters in its entire life time. To get one full blood meal the mosquito has to feed on several persons, infecting all of them. Only females bite in order to obtain protein for egg development.

Life-Cycle of Aedes Aegypti is as follows:

Egg → Larva → Pupa → Adult

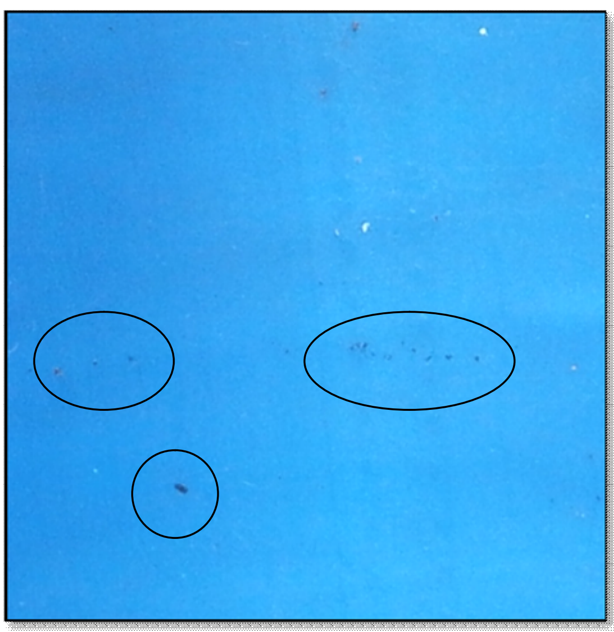


Figure-1.1: Aedes Aegypti Eggs

Figure-1.2: Aedes Aegypti Larvae

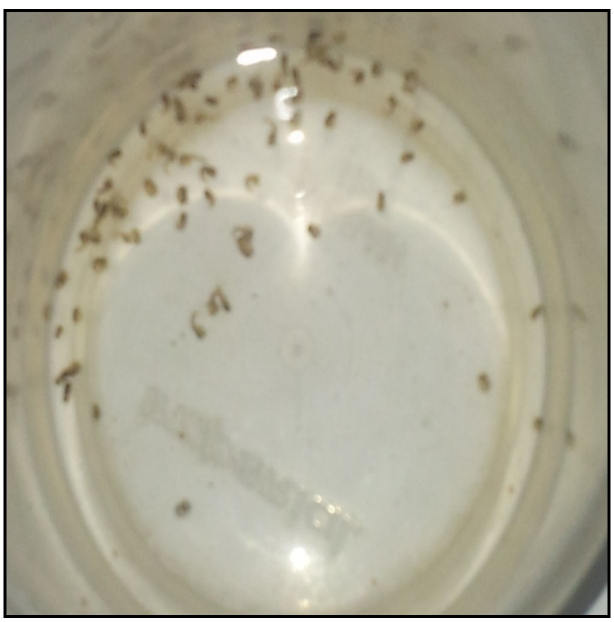


Figure-1.3: Aedes Aegypti Pupae

Figure-1.4: Aedes Aegypti (Adult Mosquito)

The population of Aedes Aegypti fluctuates with rainfall and water storage. Its life span is influenced by temperature and humidity, survives best between 16º-30º C and a relative humidity of 60-80%. Aedes Aegypti breeds in the containers, in and around the houses. Altitude is an important factor in limiting the distribution of Aedes Aegypti; it is distributed between sea level and 1000 ft above sea level. Aedes Aegypti is highly anthropophagic and rests in cool shady places. The rural spread of Aedes Aegypti is a relatively recent occurrence associated with the development of rural water supply schemes, improved transport systems, scarcity of water and like style changes. Aedes Aegypti breeds almost entirely in domestic man-made water receptacles found in and around households, construction sites and factories; natural larval habitats are tree holes, leaf axils and coconut shells. In hot and dry regions, overhead tanks and ground water storage tanks become primary habitats. Unused tyres, flower pots and desert coolers are among the most common domestic breeding sites of Aedes Aegypti. Following images show some of these breeding sites.

Figure-1.5: Open Tank

Firure-1.6: Water Reservoir

Figure-1.7: Tyres

Figure-1.8: Tree Pots

Dengue virus infects humans and several species of lower primates but in India man is the only natural reservoir of infection. All ages and both sexes are susceptible to dengue fever. Secondary dengue infection is a risk factor for DHF including passively acquired antibodies in infants. Travel to dengue endemic area is an important risk factor, if the patient develops fever more than 2 weeks after travel, dengue is unlikely. Migration of patient during viremia to a non endemic area may introduce it into the area. The female Aedes Aegypti usually becomes infected with dengue virus when it takes blood meal from a person during the acute febrile (viremia) phase of dengue illness. After an extrinsic incubation period of 8 to 10 days, the mosquito becomes infected and virus is transmitted when the infective mosquito bites and injects the saliva into the wound of the person. There is evidence that vertical transmission of dengue virus from infected female mosquitoes to the next generation occurs through eggs, which is known as transovarian transmission.

The first evidence of occurrence of DF in the country was reported during 1956 from Vellore district in Tamil Nadu. The first DHF outbreak occurred in Calcutta (West Bengal) in 1963 with 30% of cases showing hemorrhagic manifestations. All the four serotypes i.e. Dengue 1, 2, 3 and 4 have been isolated in India. Aedes Aegypti breeding is more common in urban areas the disease was observed mostly prevalent in urban areas. However, the trend is now changing due to socio economic and man-made ecological changes. It has resulted in invasion of Aedes Aegypti mosquitoes into the rural areas, which has tremendously increased the chances of spread of the disease to rural areas. Recurring outbreaks of DF/DHF have been reported from various States/UTs namely Andhra Pradesh, Delhi, Goa, Haryana, Gujarat, Karnataka, Kerala, Maharashtra, Rajasthan, Uttar Pradesh, Pondicherry, Punjab, Tamil Nadu, West Bengal and Chandigarh, etc.

Dengue fever cases have risen sharply during the current year in the country so far, even when the Government claimed to have stepped up efforts including high-level reviews led by the Union minister for health, to contain the disease. As on November 29, 2012 the number of cases reported from different states stood at 35066 and 216 people died of the disease. However, it showed an increase from 2011 when 18,860 cases were reported and 169 people died. In 2010, the total number of cases reported was 28,292 and death toll was 110, according to the official figures with the Union ministry.

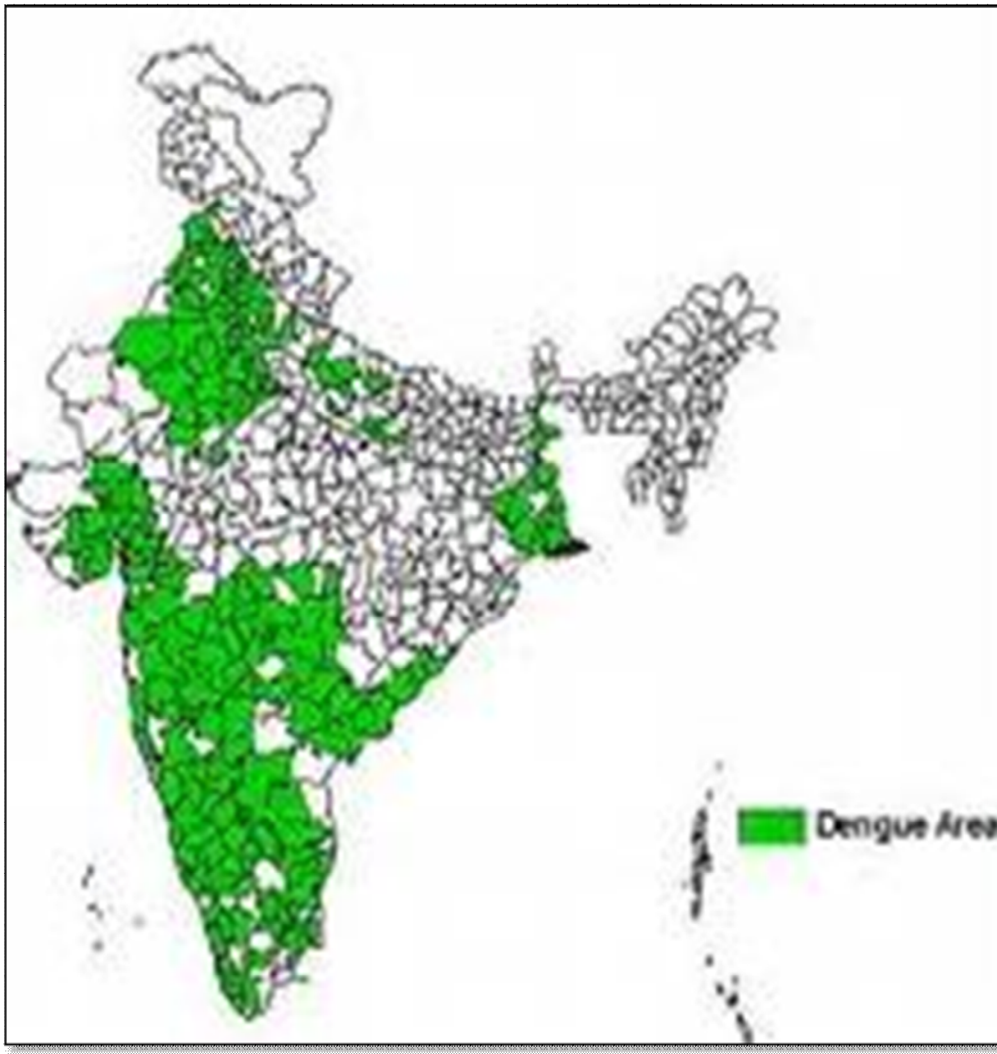


Figure-1.9: District wise Dengue Cases Distribution in India

Among all the States, Tamil Nadu reported highest number of deaths, followed by Maharashtra this year. A total of 9249 cases were reported and 60 people died in Tamil Nadu whereas 59 people died in Maharashtra due to dengue, out of the 1464 cases reported. The damage was specifically bad this time in Tamil Nadu as the State reported only nine deaths last year. Karnataka reported 3482 cases and 21 deaths so far this year. Unprecedented population growth, unplanned and rapid urbanization, inadequate waste management, gaps in public health infrastructure and poor infrastructure to monitor vector mosquito breeding were cited as the main reasons for the rise in the cases. Health ministry said it was working with a long-term and mid-term action plan to contain the disease. Also, it is observed that most of the developing urban areas were found to be hit by dengue outbreak on larger scale as compared to others. In Maharashtra, mainly urban areas i.e. developing areas were reported with maximum dengue incidences. Hence to come up with a concrete and implementable solution, study area was restricted only to Pune city that comes under Pune Municipal Corporation (PMC). As per the MOH PMC, there were 783 dengue cases and 6 death cases reported in the year 2012. As compared to previous years i.e. 2010 and 2011, the number of cases in the year 2012 has drastically changed. This leads GIS experties to carry out spatial and non-spatial analysis for finding out reasons and causes to this vicious circle of dengue epidemic in PMC. So, Pune Municipal Corporation (PMC) was taken up as the study area for this particular study respectively.

1.2 STUDY AREA

As emerged from the defined objectives of the research, the study area has been chosen which encompasses the extent of latitude from 18°27'20.96"N to 18°35'3.02"N latitude and longitude 73°45'39.57"E to 73°55'48.97"E. Pune is a plateau city situated near the western margin of the Deccan Plateau. It lies on the leeward side of Sahyadri (Western Ghats) and located 50 km from crest of the Ghats. It is almost 160 km southeast of Mumbai. It is situated at an altitude of 560 m above the mean sea level near the confluence of Mula and Mutha rivers. The city is surrounded by hills on the west and the south. The Sinhagad-Katraj-Dive Ghats range is the southern boundary of the urban area. The highest point within the city is the Vetal hill whereas the highest point of urban area is the Sinhgad. The main system of the hills and mountains is part of the Sahyadri, which run north south in the western portion of the district. Pune comes under the belt, which is hilly at west and bare open towards east. Two more rivers, Pavana and Indrayani traverse the northwestern outskirts of urban area. Mula and Mutha rivers meet Bhima River and therefore Pune is located in upper Bhima basin.

Climate of Pune is with three distinct seasons- summer, rains and winter, as elsewhere in India. The leeward location of the city with reference to the Western Ghats has made the Climate moderate and pleasant. The average temperature of the hottest month - May is about 23°C to 39°C having peaks about 42°C. The same for the coldest month of December are 12°C to 30°C with lowest about 5°C. The relative humidity ranges from 36% (March) - 81% (August). The annual rainfall as per IMD records is 540 mm per anum; out of which 75% occurs in just four months from June to September.

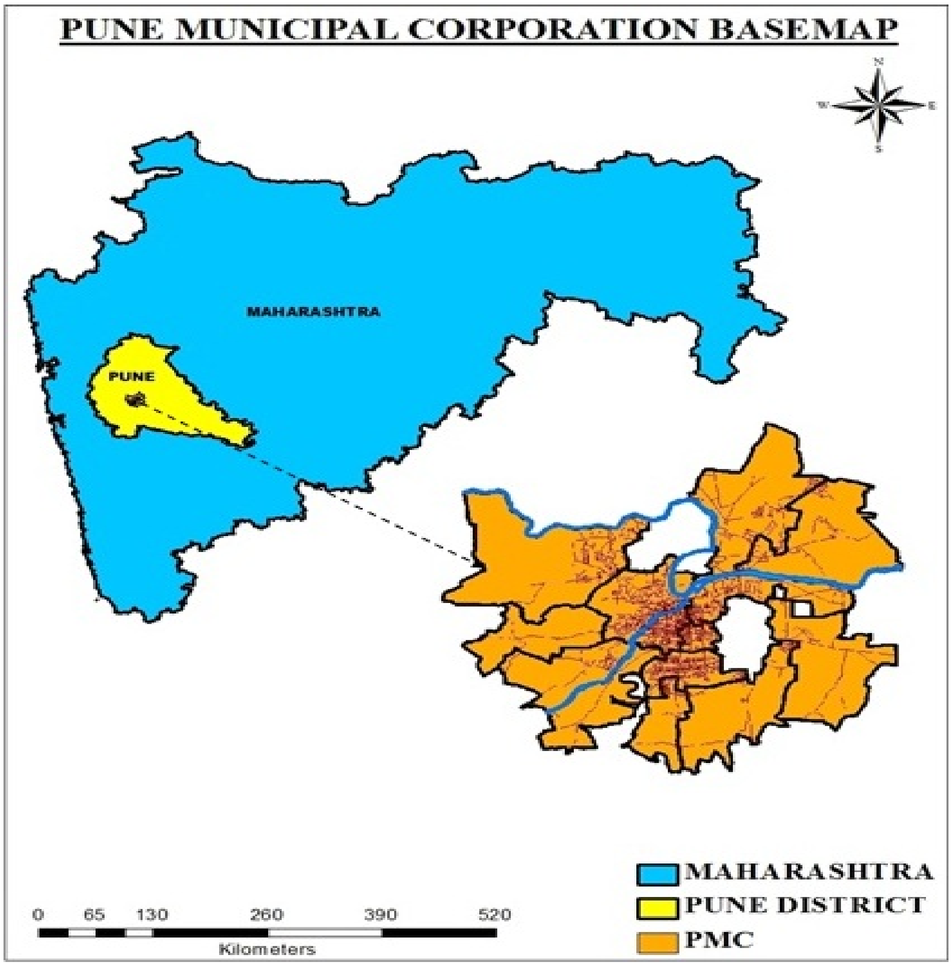


Figure-1.10: Location Map of Pune Municipal Corporation (PMC)

Pune urban area has been expanding peripherally at an average rate of about 500m per year for the last two decades or so. Human habitations are encroaching upon the farm land, orchards of the fringe villages. The characteristic ecosystems of Pune city are scrub plantations on the hills and Acacia groves on the riverbanks along with some green areas in the city. Pollution loads and anthropogenic pressures are posing a pressure onto these systems. Population growth is 3.5 %

per anum as compared to national average of 2.1 %. Migration accounts for 50 % of the growth. 71% of the population is below 35 years. 2021 population projection expects it to be 60 lakhs at current growth rate. The Pune's human population is growing astronomically along with vehicular population. As per the census of 2001, Pune's population was 2.5 million and total number of vehicles was 11 lakhs. Now in 2010, the vehicular population has crossed the mark of 19 lakhs when projected population is about 3.5 million. This growth is very high as compared to any other city in India. The city has experienced steep, massive population growth due to migration of both skilled and unskilled labour catering to the necessities of expanding spheres of industrial and service sectors. This has created tremendous pressure on local public and private transport systems. The central part of the city is experiencing capacity gaps, parking problems, low speed travel, congestion and decay. Road safety issues are on the rise due to lack of footpaths, safe crossing, encroachments, bottlenecks etc. It is one of the reasons for a construction boom in the fringe areas, outskirts of the city. But the solution for traffic has led to many other criticalities of traffic control and services. The emissions from vehicles have very serious effects on the health of the citizens. Respiratory and other ailments caused by auto exhausts, which contain particulates, unburned hydrocarbons, carbon monoxide are taking their toll, indicated by a steep increase in diseases like asthma, bronchitis and other respiratory, cut aneous and ophthalmic ailments. Also, increase in transportation has led to spread of vector-borne diseases like Dengue, Malaria, etc.

1.3 OBJECTIVES

1) Combining Google Earth and GIS mapping techniques to map the Dengue disease spread in PMC for three consecutive years- 2012, 2011 and 2012.

2) To identify the pattern of Dengue Incidence Distribution, then to analyze the hotspots locations of the Dengue Incidences and finally mapping the geographic distribution of Dengue Incidences in PMC for the year 2012 using Spatial Statistics tools in ArcGIS 10.

3) To identify the Environmental factors that contribute to the dengue outbreak using remote sensing data then to correlate the identified factors with dengue occurrence pattern and finally using spatial analysis to predict and map potential high risk areas in PMC for a dengue outbreak using Spatial Analysis- Overlay tools in ArcGIS 10.

4) To identify the Socio- Economic factors that contribute to the dengue outbreak using spatial data, then to correlate the identified factors with dengue occurrence pattern and finally using spatial analysis to predict and map potential high risk areas in PMC for a dengue outbreak using Spatial Analysis-Overlay tools in ArcGIS 10.

5) Combining Environmental and Socio-Economic factors that contribute to the dengue outbreak using remote sensing and spatial data and then using spatial analysis to predict and map potential high risk areas for a dengue outbreak in PMC for the year 2013 using Spatial Analysis-Overlay tools in ArcGIS 10.

6) To carry out statistical analysis based on Temperature, Rainfall, Entomology Index Dengue Incidences, etc. data by creating and comparing the graphs and how they contribute in predicting and mapping potential high risk areas for a dengue outbreak in PMC.

1.4 SOFTWARE USED

1. **ARCGIS 10** was used for GIS analysis and preparing layout maps.

2. **ERDAS IMAGINE 2011 AND IMAGE ANALYST 08.07** was used for digital image processing, geo-referencing and image-to-image registration technique.

3. **GOOGLE EARTH** was used for extracting images having real world coordinates for creation of the satellite imagery base-map.

4. **MS OFFICE EXCEL** was used for making graphs and **MS OFFICE WORD** was used for report preparation.

CHAPTER 2

LITERATURE REVIEW

2.1 FOREWORD

The dengue incidence cases for the considered area have been chosen as the PMC area had reported with maximum number of dengue cases in Maharashtra for the year 2012. To that effect, a series of texts have been read and consulted before taking up the study. The gainful result arrived from the cited literature, which would place the Ministry of Health (MOH) authorities to think and plan in a genuine prospective for the proximate future. The cited work done else-where is briefly narrated in the following texts.

Dengue fever is due to an Arbovirus mainly transmitted by Aedes Aegypti and yearly causing in the tropical area tenths of millions of cases. Since its apparition during the 50's the
Dengue Hemorrhagic Fever (DHF), a severe form of dengue infection, has followed a global upward trend in incidence and has been a main public health problem in South East Asia (SEA) and countries of the tropical zone. Despite in many countries the DHF case fatality rate has decreased, such as in India, from 6-8% in the 1960s to a mere 0.3% in 1996, epidemics still lead to the first cause of children hospitalization in SEA and associated to the persistent endemicity of the disease, induce a high cost to regional economies (15 to 20 million US$ per year in India) linked to the symptomatic treatment of patients and vector control activities. No specific treatment against the virus neither vaccination is available. Along with the setting up of adulticide spraying campaigns to quickly stop the transmission during epidemics, vector control activities chiefly aim at eliminating breeding sites through community participation. However, the efficiency of prevention and control activities is too slow to reach the level sufficient to interrupt the transmission during epidemic periods, since it takes quite a long time to set up these

activities are also difficult to maintain during the non-epidemic periods, due to the defection of the populations towards activities with no perceptible results. In addition, in India and in most of the Southeast Asian countries where the dengue is endemic, the needed infrastructure can be maintained neither permanently nor simultaneously for the whole country.

A quick launch of control activities appears necessary to improve their efficiency but despite the efficient system to survey the DHF (and 60 other diseases) developed by the PMC Ministry of Public Health, the great diversity in the epidemiological pattern of the DHF makes epidemics difficult to predict. The transmission cycle of the disease is the result of a complex system based on several main constituents: the number of vectors, the type of virus, the density of susceptible hosts and the environmental conditions acting on the output of transmission. Two main patterns may describe the fluctuations of DHF incidence. The cyclic pattern corresponds to the seasonal variations of transmission. The incidence reaches a peak during the hot and rainy season (May-October in the Central Plain). The end of the rainy season leads to a return to a lower level of transmission. This phenomenon is repeated every year and characterizes the endemic mode of transmission. The non-cyclic pattern corresponds to important rises in the incidence of DHF and to the very basis of the epidemics characterization; they are non-seasonal increases of variable duration, separated by periods of lower incidence lasting two to five years. To make the best of these control activities, it is important to have them focused on epidemic periods and to intervene as early as possible. This is made difficult as in India the epidemic outbreaks are apparently uncertain and the range of the "normal" seasonal fluctuations is wide. For instance, the average ratio of the monthly minimum number of cases to the monthly maximum was 1/13 in PMC from. Therefore “abnormal” fluctuations of the epidemic sort must be defined in relation to this large amplitude of natural fluctuations. Moreover, spatial variations in incidence add more complexity to the transmission description as the incidence ranged from 0 to 180 cases (per 100 000 inhabitants) in the sub-districts of Maharashtra province during the last ten years. The goal of this study is to describe the epidemiology of DHF in an area where the environment exhibits relatively homogenous features. This region has been chosen because the homogeneity in climate, altitude and activities of inhabitants allows reducing the amplitude of the factors to be studied to describe the DHF epidemiology. From that description, regional common characteristics of DHF transmission are identified and specific analysis is performed. Factors likely to be involved in the spatial and temporal variations of the transmission are described.

2.2 EARLIER RESEARCH

Besides time and person, knowledge of the spatial distribution of communicable disease cases is essential in understanding disease transmission and determinates. Many diseases not caused directly by environmental exposure still cluster geographically. Influences on non-uniformity of disease distribution include physical and environmental factors, social, economic and cultural factors and genetic factors. The integrative features of GIS are incredibly helpful in summarizing the complex relationships between vector-borne disease pathogens, associated vectors and reservoirs, the environment, and human populations [Melnick AL. Introduction to Geographic Information Systems in Public Health. Gaithersburg, Maryland USA: Aspen Publishers Inc.; 2002]. John Snow's cholera study served as a good example of how geographic mapping could provide new insights into communicable-disease aetiology and intervention, helping disease control efforts [Melnick AL. Introduction to Geographic Information Systems in Public Health. Gaithersburg, Maryland USA: Aspen Publishers Inc.; 2002]. Although his map alone did not determine the cause of the 1854 cholera epidemic, it served as a useful tool to summarizes his findings and convince his contemporaries of his conclusions [Melnick AL. Introduction to Geographic Information Systems in Public Health. Gaithersburg, Maryland USA: Aspen Publishers Inc.; 2002].

Epidemiological data and public health resources once mapped, can be integrated with other existing databases including socio-economic (e.g. age of population), environmental (e.g. vector habitat) and infrastructure (e.g. transport routes and accessibility) data, and spatially analyzed to provide intelligence for epidemiological research and vector-borne disease control. In addition, community profiles, containing a snapshot of geography, human services and facilities, population age breakdown, population growth and decline and social and health characteristics, allows epidemiologists to build a picture of how a community compares with similar communities on a range of dimensions [Bryan B. Use of GIS in Communicable Disease Control].

Potential uses for GIS and spatial information within Vector-borne Control include:

- case distribution mapping (incidence/prevalence of notifiable conditions)
- identifying spatial patterns in disease distributions through statistical modeling
- identifying spatial relationships and causal factors in disease distributions
- generating data for input into epidemiological models
- initiating the generation of hypotheses relating to etiology of disease
- support decision making for creating and targeting disease interventions
- communicating known health determinants and outcomes visually for outbreak control teams
- quantifying the impact of disease intervention programs
- generating statistics for inclusion in community and Local Government Area (LGA) profiles.

Automated GIS that collect analyze and map all reportable communicable diseases promise to improve the efficiency of disease control efforts. Such systems can incorporate multiple sources of data, such as:

- routine mandated notifiable disease reports special vector-borne disease studies, such as active surveillance by hospitals for nosocomial infections
- results of active surveillance for sentinel infections, such as drug-resistant infections in hospitalized patients
- data produced by collaborative research between public health agencies and the private sector, including managed care organizations there sources of vector-borne disease data, such as Medicare billing data, etc.
- datasets from other government agencies, e.g. alcohol-related motor vehicle accidents, property boundaries, census data.

Environmental changes have a major contribution to the pattern of dengue incidences distribution. Most of the incidence cases are higher in an area with rapid development and a high density population. There are other environmental factors that have an influence on the dengue outbreak distribution. Previous studies have shown that the factors that contribute to the dengue epidemic problem are population growth, inadequacies in urban infrastructure (including solid waste disposal) and a rise in domestic and international travel [Chua et al. (2005)], in their study had mentioned that the Aedes mosquitoes breed in artificial and natural containers in and around houses and in construction sites. Rapid industrial and economic developments over the last two decades have brought about massive infrastructure changes and had created conducive man-made environments for the breeding of the Aedes mosquito. These were reflected by the reports of most cases of both DF and DHF amongst the urban population (70-80%), with the highest incidences recorded in the working and school-going age groups, which then correlates with the relatively high Aedes index in construction sites, factories and schools (MOH, Annual Report). Therefore, it has been proven that environmental changes can be used as a base indicator to develop a model in order to identify the dengue risk area for surveillance and mitigation planning purposes.

Remote sensing and Geographic Information System (GIS) technologies have been previously used in the public health management field in order to help health authorities in surveillance and mitigation action. The use of remotely sensed data (satellite images and aerial photographs) in epidemiological studies has become more and more frequent in the last decade. As it provides information on the environment, remote sensing offers a huge potential for the study of diseases related to environmental conditions [Cline, 1970; Hay et al., 1997; Curran et al., 2000]. The application of remote sensing in health studies have seen an increase in monitoring, surveillance and risk mapping, particularly of vector-borne diseases. Most of these studies used remote sensing data to explore the environmental factors that might be associated with disease-vector habitats and human transmission risk. Using remote sensing imagery, the information on sea and land surfaces is more easily identified at different spatial scales. The advancement of remote sensing technology, currently offers very high resolution satellite imagery such as the SPOT 5 (2.5m), IKONOS (1m) and Quick Bird (0.6m) satellite data that are able to provide very detailed ground data. GIS technologies are able to integrate, analyze and display spatial and temporal data from various sources into one central location. Advanced GIS analysis and modeling techniques currently allows researchers to predict the risk areas of a dengue outbreak.

GIS technology improves the ability of programmer staff, planners, decision-makers and researchers to organize and link datasets (e.g. by using geocoded addresses, geographic boundaries, or location coordinates) from different sources. Geography provides a near-universal link for integrating records from multiple information sources into a more coherent whole. This ability to link datasets can help dengue programmers integrate data from the five essential components (epidemiology, entomology/vector control, community participation, laboratory, case management) and plan more cost-effective interventions. For example, suppose that a dengue programmer could access the socio-demographic database of the city, which is maintained by the local statistics agency, and also the epidemiological dataset from epidemiological surveillance, and the entomological dataset. Using GIS technology, the dengue programmer can combine these databases, mapping the demographic and social indicators by block, pinpointing the location of breeding sites and related entomological indicators, and including on the map the location of cases by residential address to identify populations at higher risk of dengue transmission and plan focalized action in an efficient way. To take advantage of this potential, any dengue initiative and programmer should establish organizational changes and new collaborative links with institutions and departments in the health sector, units of other sectors, governmental departments at regional, municipality and community levels, and community organizations. A review of the scope and necessary relationship of the dengue programmed information system with other information systems based on a conceptual framework for reduction of dengue transmission is an essential step in improving it.

Spatial analysis capability of GIS (distance, proximity, containment measures) can be used to improve entomology/vector control activities and interventions such as focal treatment, and to search for and destroy transmission sources. For example, suppose the control programmer, as part of its continuous analysis, produces a map of the city by block (the block as the unit of analysis). The socio-demographic dataset is linked (geocoded) to blocks, including the number of houses and population by age group. As a result of an entomological visit, some Aedes Aegypti breeding sites are found and their locations pinpointed on the map. From the epidemiological component, the dengue cases are reported and their residence locations plotted on the same map. Creating a buffer zone at a radius of 500 meters to the location of breeding sites and dengue cases, programmed staff can determine the areas at higher risk of dengue transmission and can answer questions such as how many houses are within the high risk areas, how many houses are within 500 meters of the breeding sites, how many houses are within 500 meters of a house that has a dengue case, how many houses are within an area close to the breeding sites and the house of the dengue case. The answers provide information for deciding the type of action and resources needed. How many children are in these areas, and how many housewives live in the areas? The answers to these questions provide information about the people at risk, and help to determine how soon action should be taken. To complete this scenario, behavioral indicators, community knowledge, attitudes and practices, and availability of health services need to be included. This leads to more evidence based decision-making in the dengue programmed.

GIS technologies have the capability to integrate many types of data and to analyze spatial and temporal data in order to come out with new model. From the public health perspective, GIS is essentially used to determine the health situation of an area, generating and analyzing diseases hypotheses, and identification of high risk diseases affected areas, prioritize areas for mitigation and surveillance plan, programming and monitoring the incidence record, and to visualize the analysis or map in a more interactive manner for better understanding. Through the use of these GIS technologies, the PMC Ministry of Health will have the capability to create efficient programs of dengue prevention and surveillance actions.

CHAPTER 3

METHODOLOGY

3.1 FOREWORD

Methodology is a logical as well as systematic part of the study to guide scientific investigations. This method involves a series of processes in which various stages of collecting data and extraction of information are explained. The sequential steps which are covered in this project are depicted in the following paragraphs and also lucidly explained by pictorial representation. Decision makers have indicated the inaccessibility of required geographic data and difficulties in synthesizing the solutions to spatial problems of mapping and analyzing dengue incidences distribution. The criteria encompass the decision, design and choice phases in determining the qualitative aspects that are analyzed for optimal solution in GIS platform. The criteria evolution examined the Weighted Overlay and Fuzzy Overlay techniques which are described in this chapter.

3.2 DATA USED

a) **Toposheet (47_F_14 & 47_F_15) -** For creation of PMC Topographic Map.

b) **Google Earth Satellite Imagery** - For creation of PMC Satellite Imagery Base Map.

c) **LANDSAT 7 (ETM+) Satellite Image** - For creation of PMC Land Use/ Land Cover (LULC) Map, PMC Normalized Difference Vegetation Index (NDVI), PMC Land Surface Temperature (LST) Map, etc.

d) **ASTER Satellite Image** - For creation of PMC Slope (High Land and Low Land areas) Map.

e) **Epidemiology Dengue Data (2010, 2011 & 2012)** - For creation of PMC Dengue Cases-2010, PMC Dengue Cases-2011 and PMC Dengue Cases-2012 Maps.

f) **PMC Administrative & Electoral Wards Data**- For creation of PMC Administrative and PMC Electoral Wards Maps.

g) **PMC Housing Data (2012)** - For creation of PMC Settlements-2012 Map.

h) **PMC Slums Data (2012)** - For creation of PMC Slums-2012 Map.

i) **PMC Gardens Data (2012)** - For creation of PMC Gardens-2012 Map.

j) **PMC Water Bodies Data** - For creation of PMC Water Bodies Map.

k) **PMC Transportation Data** - For creation of PMC Modes & Means of Transportation Map.

l) **PMC Population Data (2011)** - For creation of PMC Total Population-2011, PMC Population Density-2011, PMC Total Slum Population-2011 and PMC Slum Population Density Maps.

m) **PMC Entomology Index Data** - For creation of graphs showing Wardwise Distribution of Entomology Index and Wardwise Distribution of Entomology Index & Dengue Cases-2012.

n) **PMC Temperature & Rainfall Data** - For creation of graphs showing PMC Temperature Distribution and PMC Rainfall Distribution.

3.3 DATA COLLECTION

Data was collected from the following sources:

a) SOI Toposheet (47_F_14 & 47_F_15) was collected from Survey of India.

b) DEM Data was downloaded from GDEM : ASTER Imagery website for the respective study area (PMC).

c) Satellite Imagery Base-Map Data was downloaded from Google Earth.

d) LANDSAT 7 (ETM+) Data was ordered and downloaded from USGS website for the respective study area (PMC).

e) Entomology Index Data was provided by National Institute of Virology (NIV).

f) Epidemiology Dengue Data (2010, 2011 & 2012) was obtained from PMC Health Department.

g) Housing and Slums Data (2012) were obtained from PMC Housing and Slum Departments.

h) Population Data (2011) was obtained from PMC Census Department.

i) Open Water Bodies and Gardens Data (2012) were obtained from PMC Water Supply and Gardens Departments.

j) Modes & Means of Transportation Data (2012) was obtained from PMC Roads Departments.

k) Temperature and Rainfall Data (2010, 2011 & 2012) was obtained from Indian Meteorological Department (IMD).

Along with the epidemiological dengue data provided by the PMC Health Department, a field visit was carried out with NIV Lab Assistants at few locations were Aedes Aegypti mosquitoes were found. Mainly, data collection in this field visit was done in the slum areas like, Lokseva Mitra Mandal, Tadiwala Road (Dhole Patil Road Ward), Nagpur Chawl, Yerawada (Yerawada Ward), Pandu Laman Vasti, Yerawada (Sangamwadi Ward), Vaidu Wadi, Hadapsar (Hadapsar Ward), Janata Vasahat, Parvati (Tilak Road Ward), etc. As these wards had maximum locations reported with dengue incidence cases in the year 2012.

Figure-3.1: Lokseva Mitra Mandal-Tadiwala Road (Dhole Patil Road Ward)

Figure-3.2: Nagpur Chawl-Yerawada (Yerawada Ward)

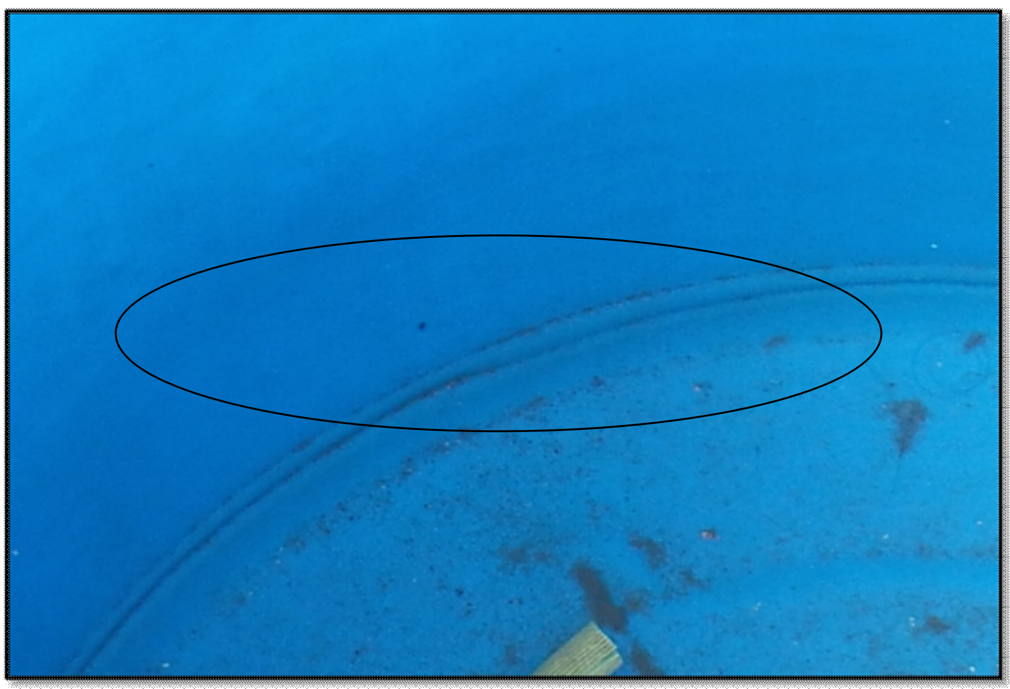


Figure-3.3: Pandu Laman Vasti-Yerawada (Sangamwadi Ward)

Figure-3.4: Vaidu Wadi-Hadapsar (Hadapsar Ward)

Figure-3.5: Janata Vasahat-Parvati (Tilak Road Ward)

3.4 REMOTE SENSING ANALYSIS

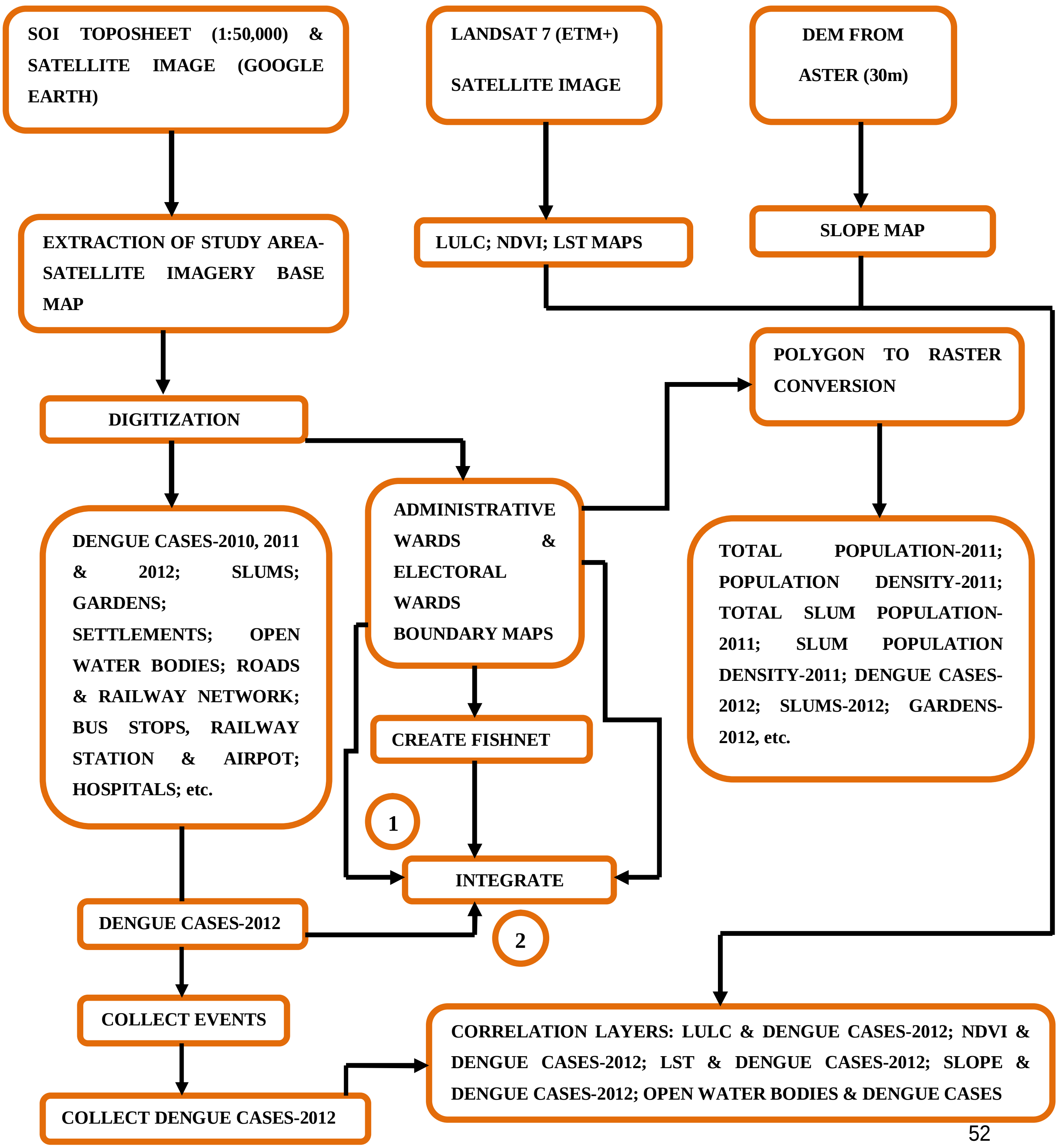
Two sets of Survey of India Toposheet (47_F_14 & 47_F_15) were mosaicked together to create a Topographic base-map then it was geo-referenced and the respective study area (PMC) was extracted. Digital satellite image of LANDSAT 7 (ETM+) comprising of 8 bands for November, 2011 was used for carrying out remote sensing analysis in the further study. All the 8 bands were stacked together to create one composite satellite image and the respective study area (PMC) was extracted. The maps and imageries have been registered and geo-referenced with respect to Survey of India (1:50,000 scale) Toposheet using second order polynomial. LANDSAT Enhanced Thematic Mapper Plus (ETM+) consists of:

1. A panchromatic band with 15 m (49 ft) spatial resolution (band 8),
2. Visible (reflected light) bands in the spectrum of blue, green, red, near-infrared (NIR), and mid-infrared (MIR) with 30 m (98 ft) spatial resolution (bands 1-5, 7),
3. A thermal infrared channel with 60 m spatial resolution (band 6) and
4. Full aperture, 5% absolute radiometric calibration.

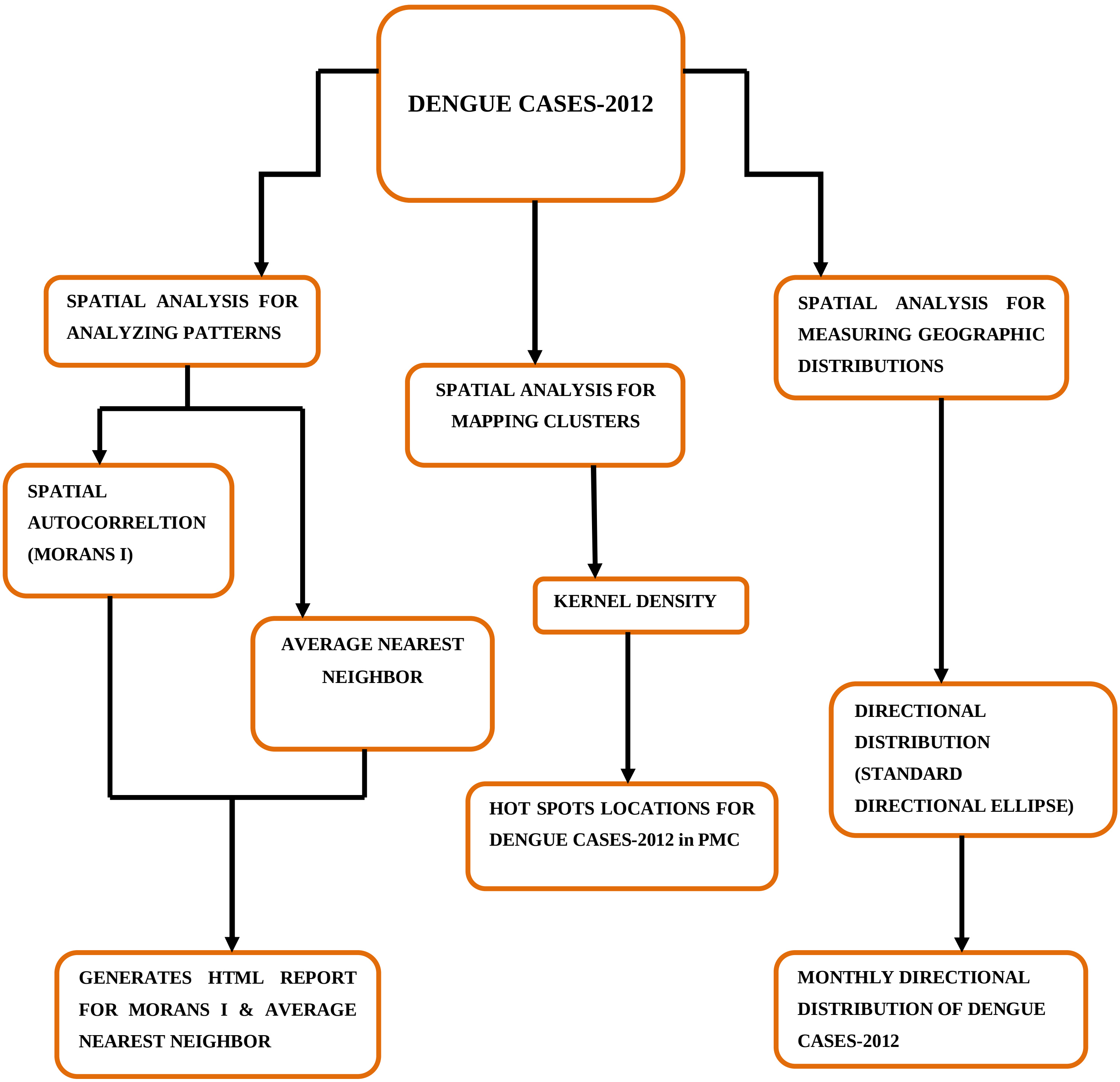
ERDAS IMAGINE 2011 image processing software has been used to perform the image processing. The digital satellite data is first geo-referenced with the Survey of India Toposheet with more than 25 Ground Control Points (GCPs) using 2nd order affine transformation model and a root mean square error less than 0.5 pixels has been obtained using the nearest neighborhood re-sampling technique. Then other layers were co-registered using image-to-image registration technique.

3.5 METHODOLOGY FLOWCHART

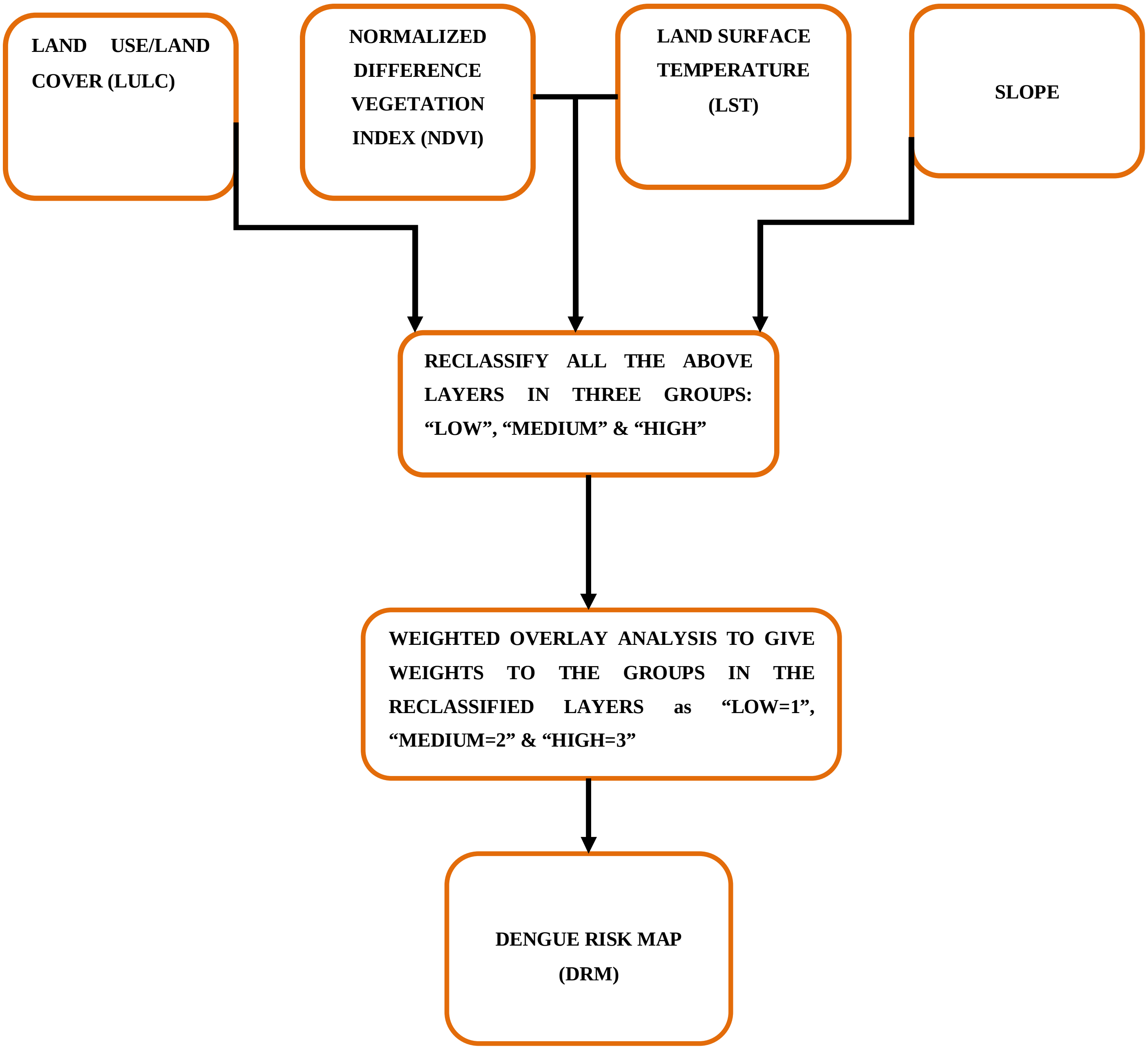
Flowchart-1.1: Methodology Flowchart for Data Creation & Correlation Analysis



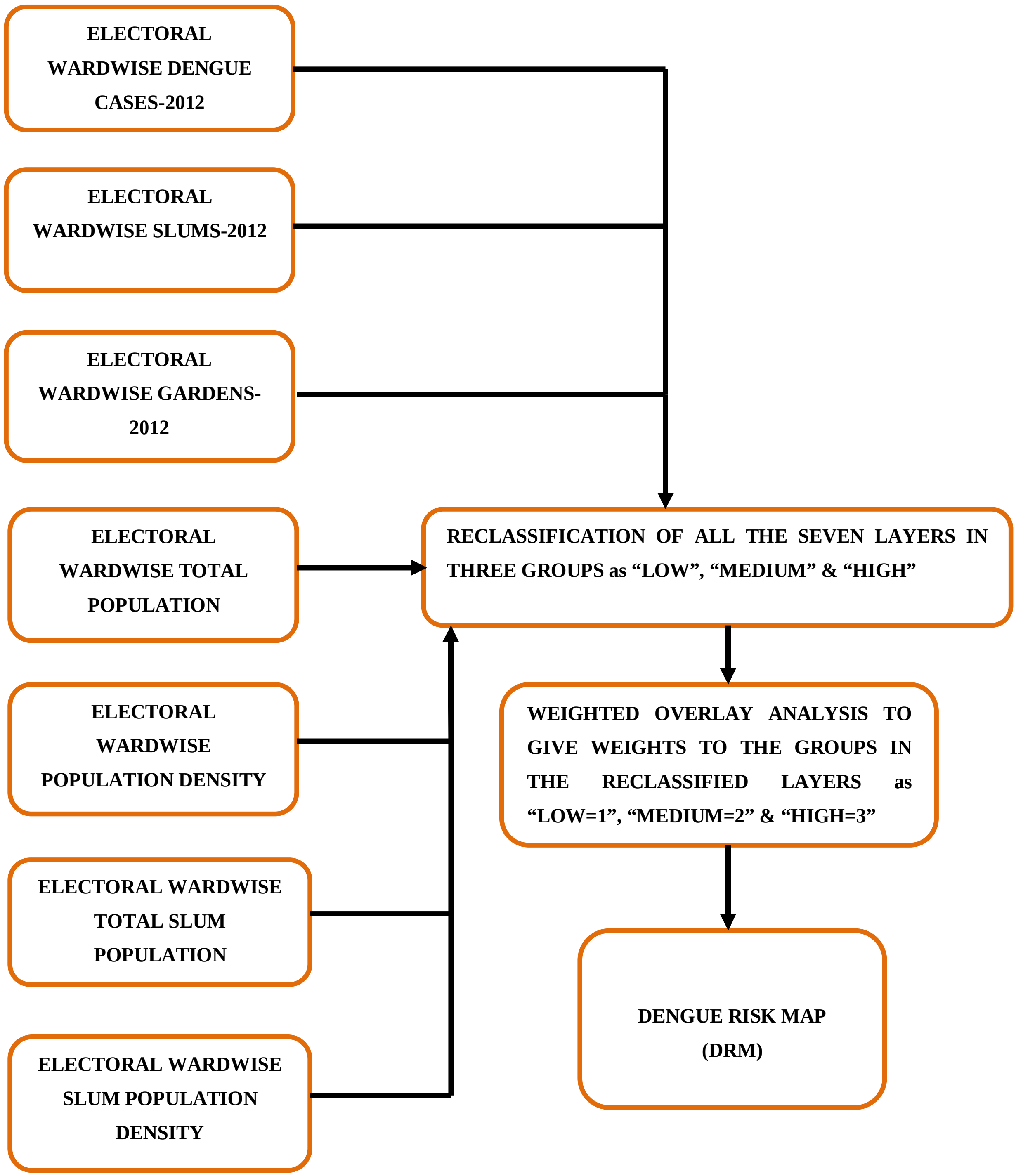
Flowchart-1.2: Methodology Flowchart for Spatial Statistical Analysis



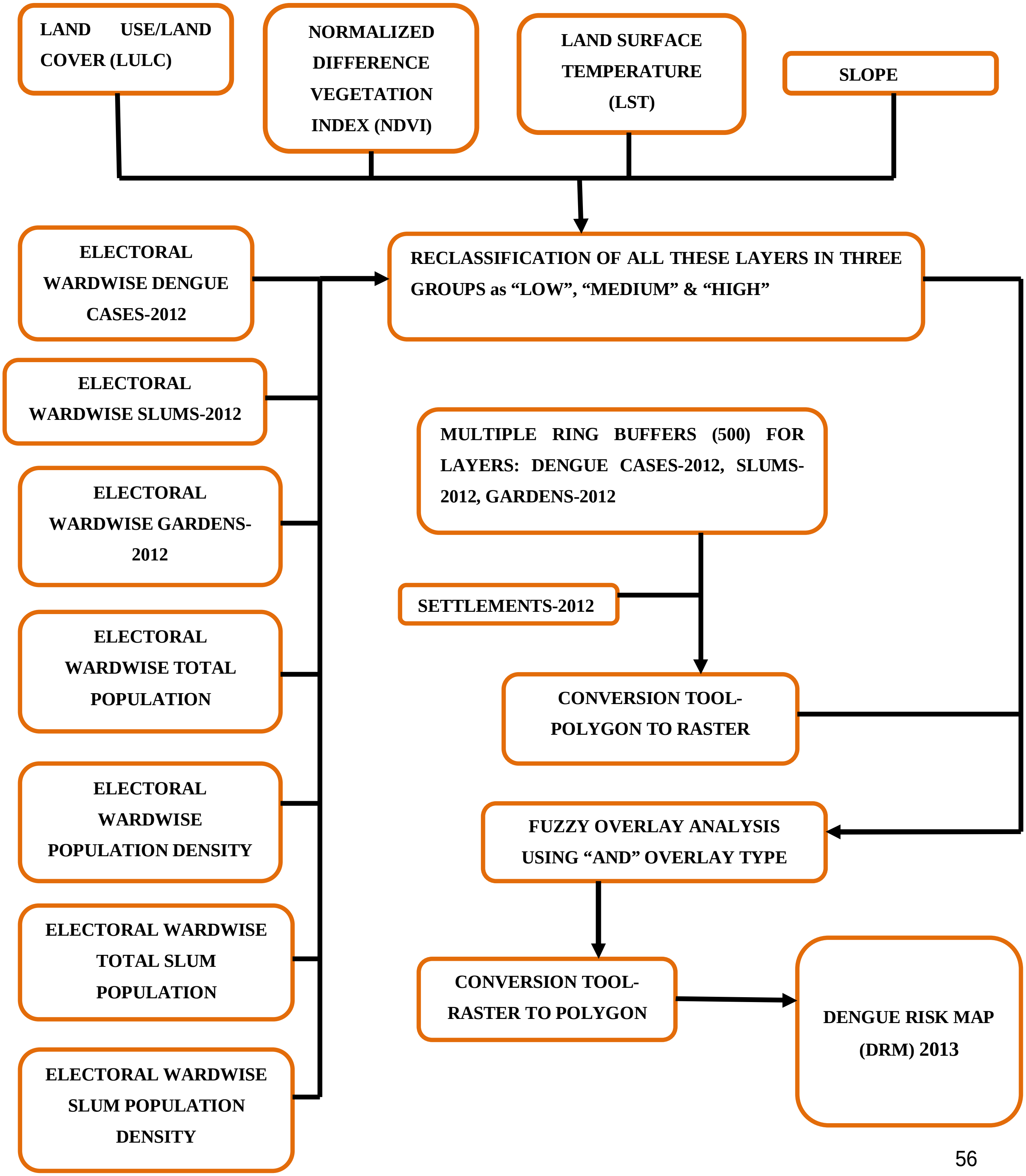
Flowchart-1.3: Methodology Flowchart for Development of Dengue Risk Map Based On Environmental Factors



Flowchart-1.4: Methodology Flowchart for Development of Dengue Risk Map Based On Socio-Economic Factors



Flowchart-1.5: Methodology Flowchart for Development of Dengue Risk Map for 2013



3.6 DATA CREATION

a) **TOPOGRAPHIC MAP-** The mask of the area was prepared by digitization and was mosaicked and clipped from Toposheet (47_F_14 and (47_F_15). All other layers were geo-referenced with the base-map so created.

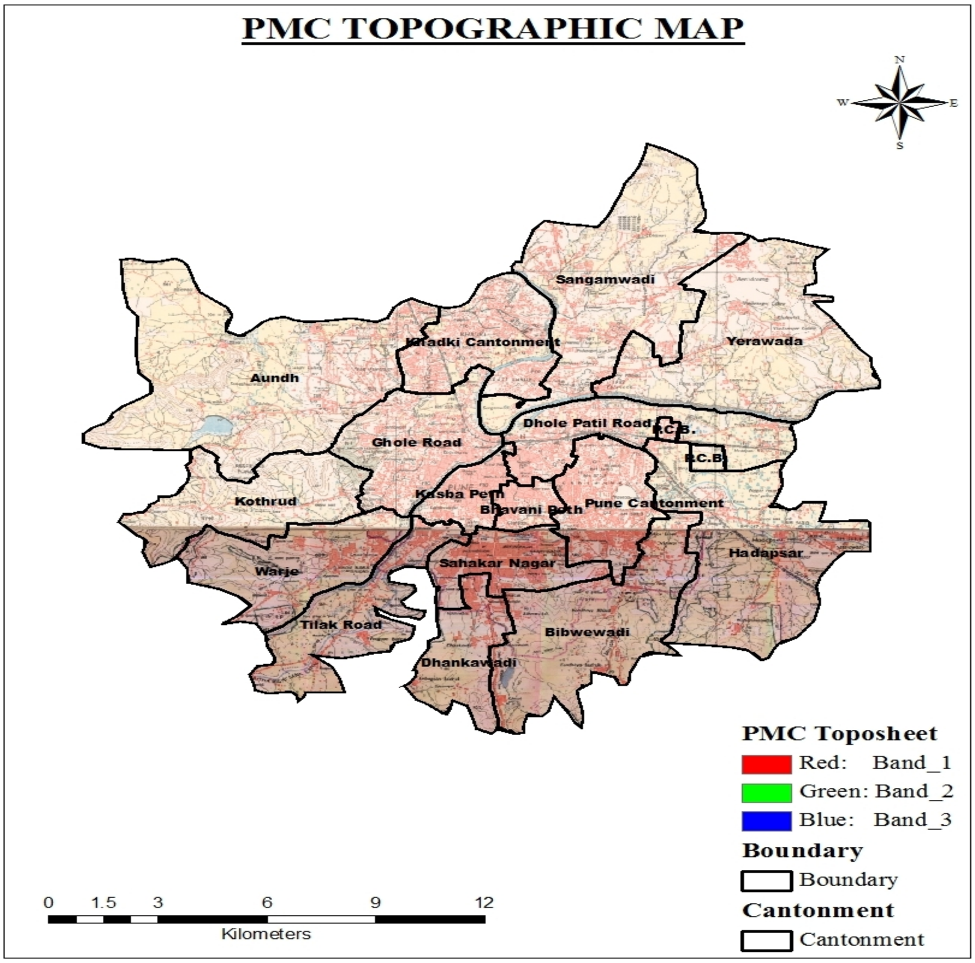


Figure-3.6: PMC Topographic Map

b) **SATELLITE IMAGERY BASE MAP-** A base-map was created using the composite of multiple downloaded Google Earth images that were geo-referenced. PMC area was first identified using Google Earth 7.0.3 satellite imagery, the add polygon feature was used to draw a polygon that covered the entire municipality, then this polygon was divided into grids and JPEG images of each grid square were captured (at 5000ft). Total 350 snapshots (i.e. 350 JPEG images) were taken. These JPEG images were converted to TIFF format using Image Station Raster Utilities (Many-Raw File Converter) software. A complete image of PMC was reconstructed in Image Analyst 08.07 software using the snapshots of TIFF images. Each image was manipulated and overlapped with another image by using a common feature in both the images so as to ensure that both the images were properly aligned to create a fluid composite image. Each row comprising of 10 images was geo-referenced and then all the 35 rows were mosaicked one-by-one. At the completion of this step, the satellite image was one composite image with a resolution of 60 cm per pixel. From this satellite image, PMC area including cantonments areas as well was extracted and thus, the final satellite imagery base-map of PMC was created. The purpose of capturing snapshots of the satellite images in Google Earth and then reconstructing the image in Image Analyst 08.07 was to work with the complete satellite base-map without the necessity for an Internet connection and also to identify each individual home at this resolution.

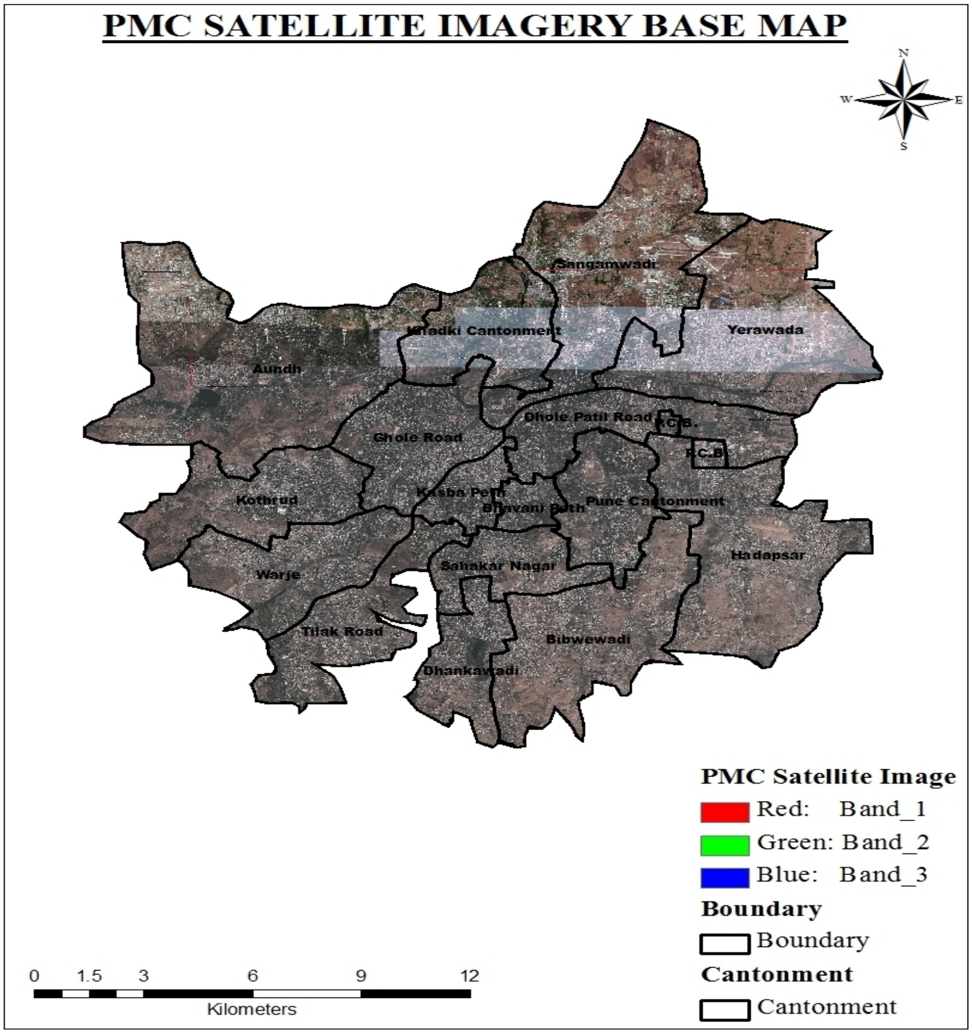


Figure-3.7: PMC Satellite Imagery Base Map

c) **LAND USE/LAND COVER MAP-** LANDSAT 7 (ETM+) digital satellite image of November, 2011 was classified using supervised minimum distance algorithm with a set of user-defined spectral signatures to classify an image and was rectified with correct ground points for each class. Five types of land use patterns were identified in the entire study area, which includes ***Sub-Urban, Urban, Vegetation, Waste Land and Water Bodies*** respectively. The spectral signatures were derived from training areas that were created by interactively delineating features of interest on the PMC image. The spectral properties of the training sets along with previous knowledge, data from field studies and higher resolution images were all combined to perform a supervised classification taking homogenous area points, several training sites within each information class. Several land cover classes or themes were used to produce thematic maps of the land cover present in the image. Normally, multispectral data are used to perform the classification and indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization [Lillesand and Kiefer, 1994]. The objective of image classification was to identify and portray, the features occurring in an image in terms of the object or type of land cover and what these features actually represent on the PMC ground.

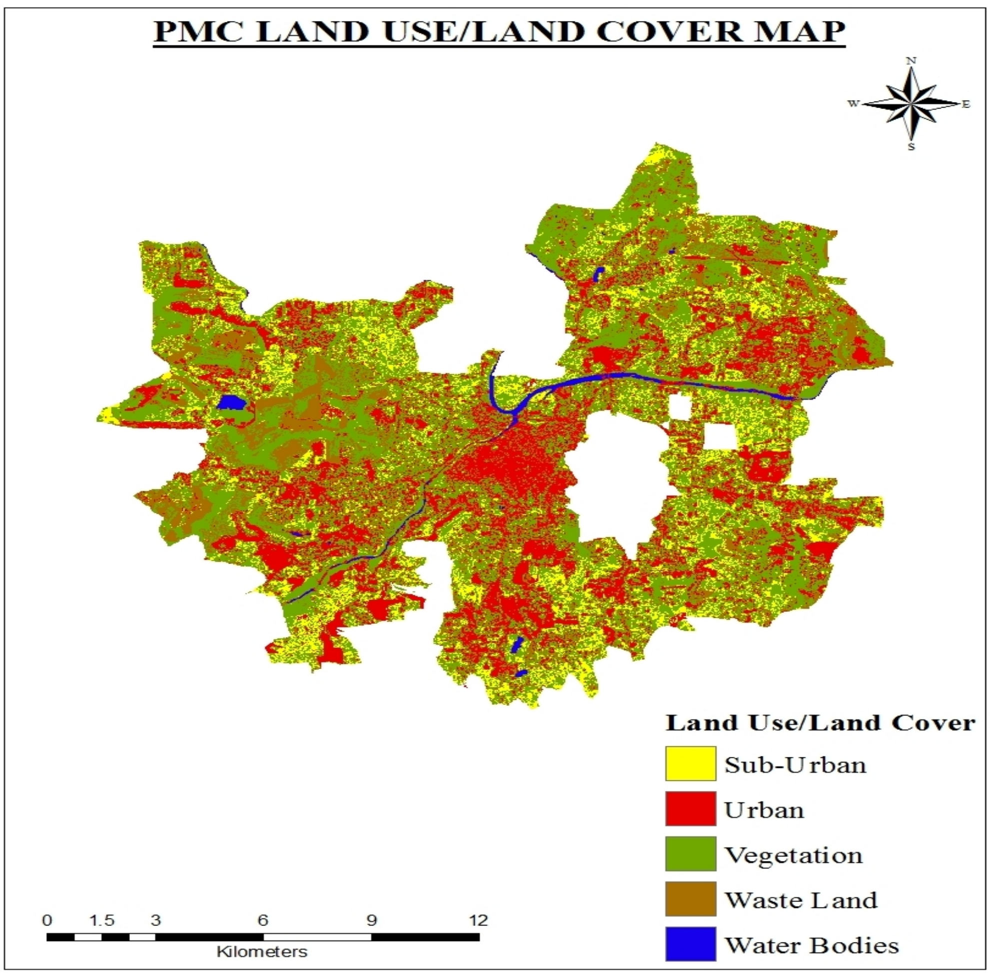


Figure-3.8: PMC Land Use/Land Cover Map

d) **NORMALIZED DIFFERENCE VEGETATION INDEX** (**NDVI**) **MAP-** Live green vegetation absorbs visible light (solar radiation) as part of photosynthesis. At the same time plants scatter (reflect) solar energy in the near infrared. This difference in absorption is quite unique to live vegetation and provides a measure of the greenness of the vegetation. NDVI is an index which measures this difference, providing a measure of vegetation density and condition. It is influenced by the fractional cover of the ground by vegetation, the vegetation density and the vegetation greenness. It indicates the photosynthetic capacity of the land surface cover. NDVI is calculated from the red and near-infrared reflectance i.e. rRed and rNIR as

$$NDVI = (rNIR - rRed) / (rNIR + rRed)$$

NDVI model was built in Model Maker of ERDAS IMAGINE 2011 software. This model was designed to subject the stacked image of LANDSAT 7 (ETM+) to the NDVI equation and produce the resulting NDVI image. After the NDVI model was built, the stacked image was “ran-through” the model. The output from the stacked image being run-through the model is the desired NDVI image as shown in figure-3.9

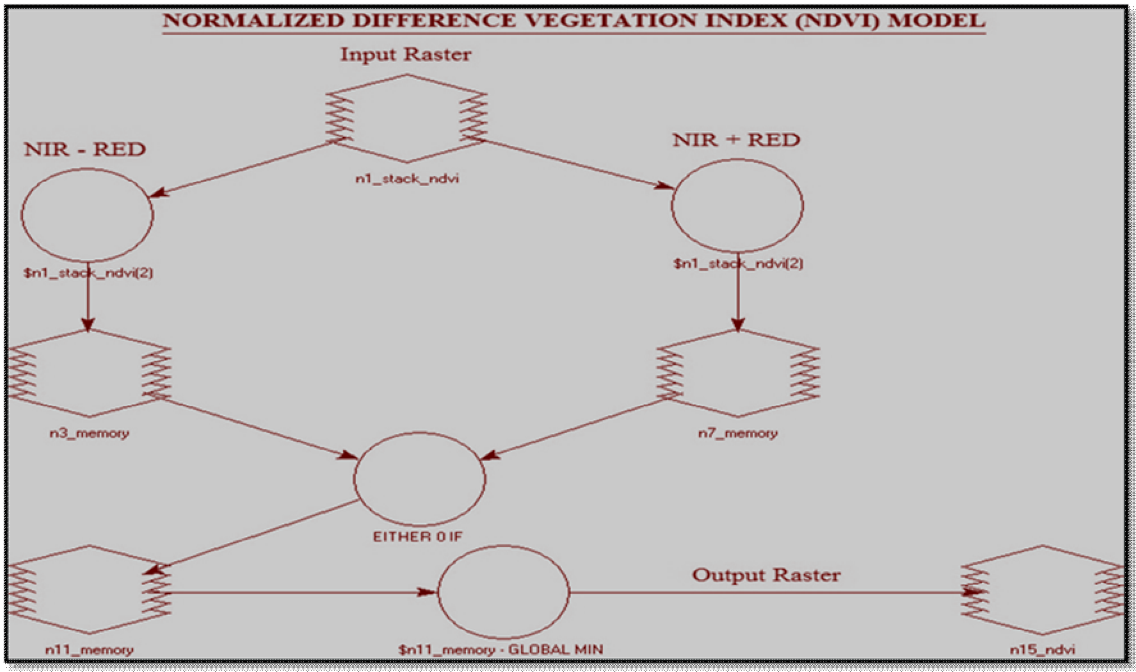


Figure-3.9: Normalized Difference Vegetation Index (NDVI) Model

The NDVI map was derived from LANDSAT 7 (ETM+) digital satellite image of November, 2011 by using the reflectance of visible red and near infra-red bands. This NDVI information was used to differentiate vegetated areas from non-vegetated areas [Openshaw **S**, 1996]. Its value is always between -1 and +1. Vegetation NDVI in PMC typically ranges from 0.07 up to 0.5, with higher values associated with greater density and greenness of the plant canopy. NDVI decreases as leaves come under water stress, become diseased or die. Bare soil values are close to zero, while Water Bodies and Non-Vegetated areas (Urban area) have negative values.

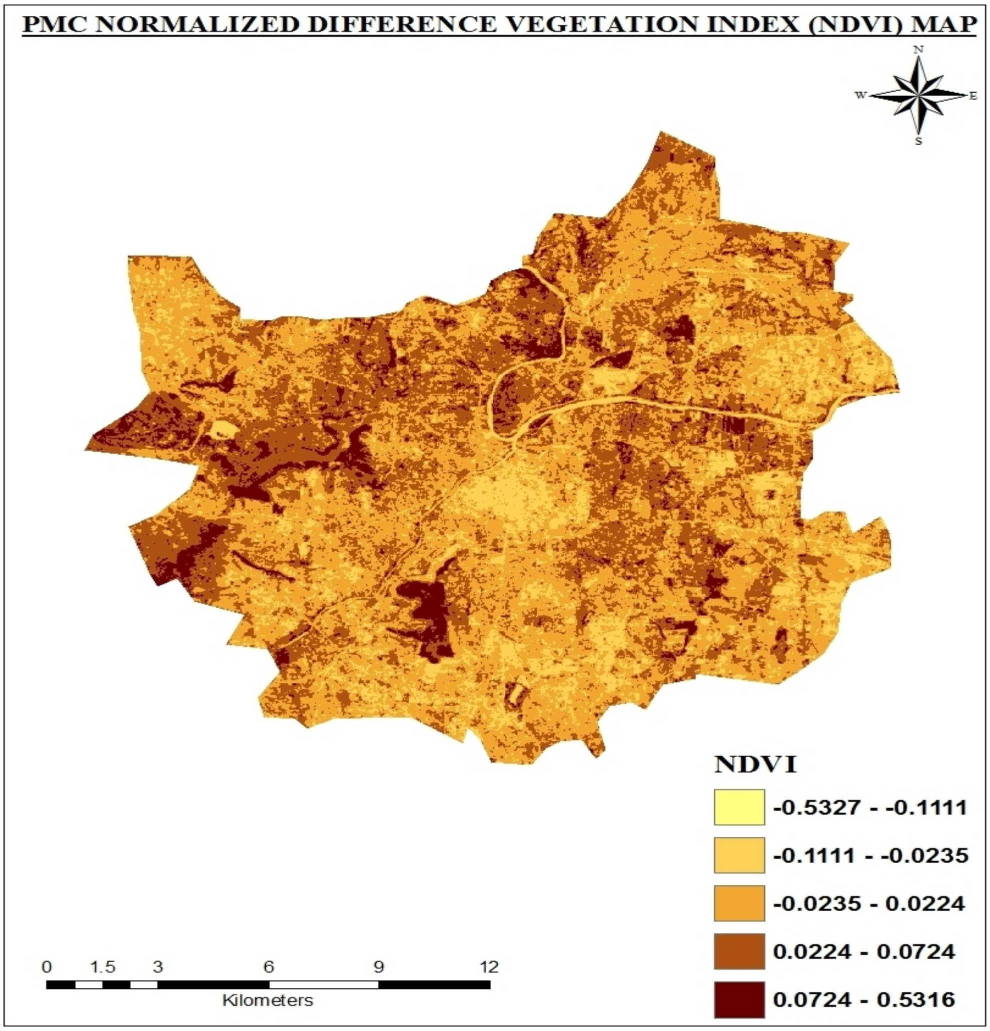


Figure-3.10: PMC Normalized Difference Vegetation Index (NDVI) Map

e) **LAND SURFACE TEMPERATURE (LST) MAP-** Land Surface Temperature (LST) is how hot the "surface" of the Earth would feel to the touch in a particular location. From a satellite's point of view, the "surface" is whatever it sees when it looks through the atmosphere to the ground. It could be snow and ice, the grass on a lawn, the roof of a building, or the leaves in the canopy of a forest. Thus, Land Surface Temperature (LST) is not the same as the air temperature that is included in the daily weather report.

LST model was built in Model Maker of ERDAS IMAGINE 2011 software. This model was designed to subject the thermal band (band 6) of LANDSAT 7 (ETM+) to the equation which converts Digital Number (DN) to Spectral Radiance (L), then

Spectral Radiance (L) to Temperature in Kelvin and finally converts Kelvin to Celsius and finally produce the resulting LST image. After the LST model was built, the thermal band (band 6) was "ran-through" the model. The output from the thermal band (band 6) being run-through the model is the desired LST image as shown in figure-3.11

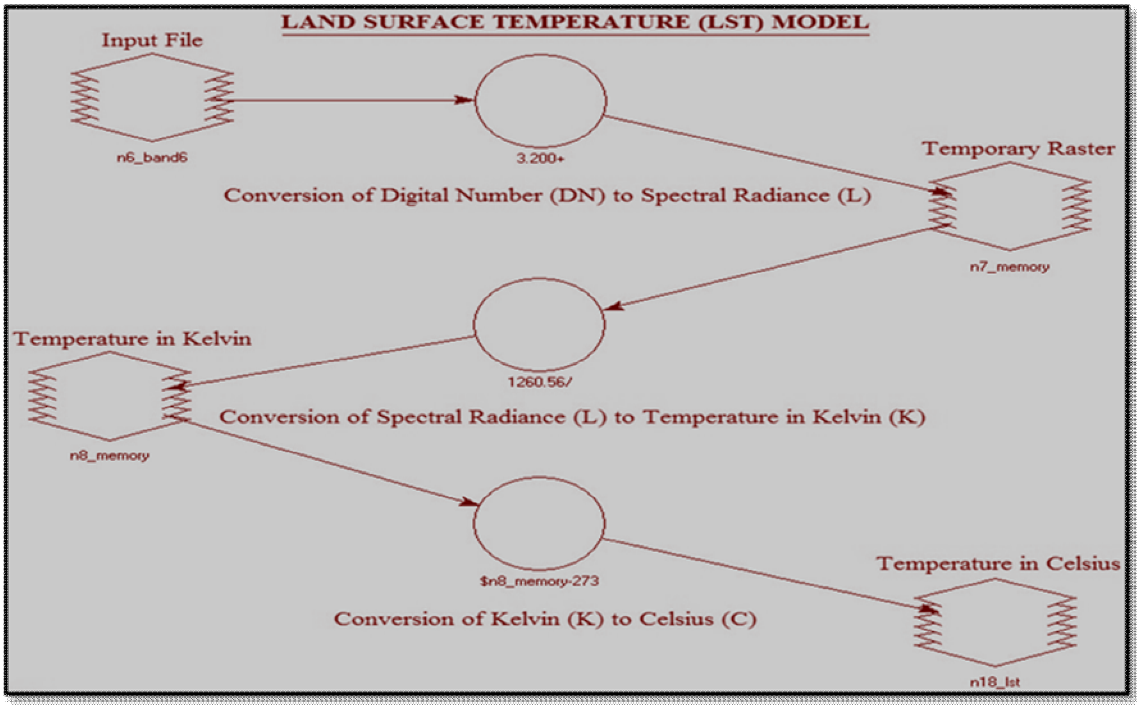


Figure-3.11: Land Surface Temperature (LST) Model

The LST map was derived from thermal band (band 6) of LANDSAT 7 (ETM+) digital satellite image of November, 2011 by using its minimum and maximum Spectral Radiance (L). Fourier transformations were typically used for the removal of noise such as striping, spots, or vibrations in the band by identifying periodicities (areas of high spatial frequency). The temperature profile of the land surface over the study area is shown in the LST map in Figure-3.12. The areas with high levels of LST (in darker shades of brown) can be correlated to Urban areas, while the areas with low levels of LST (in darker shades of yellow) can be either a Vegetated area or a Water Body. The LST map shows that the temperature ranges from -33.0ºC to 37.0ºC.

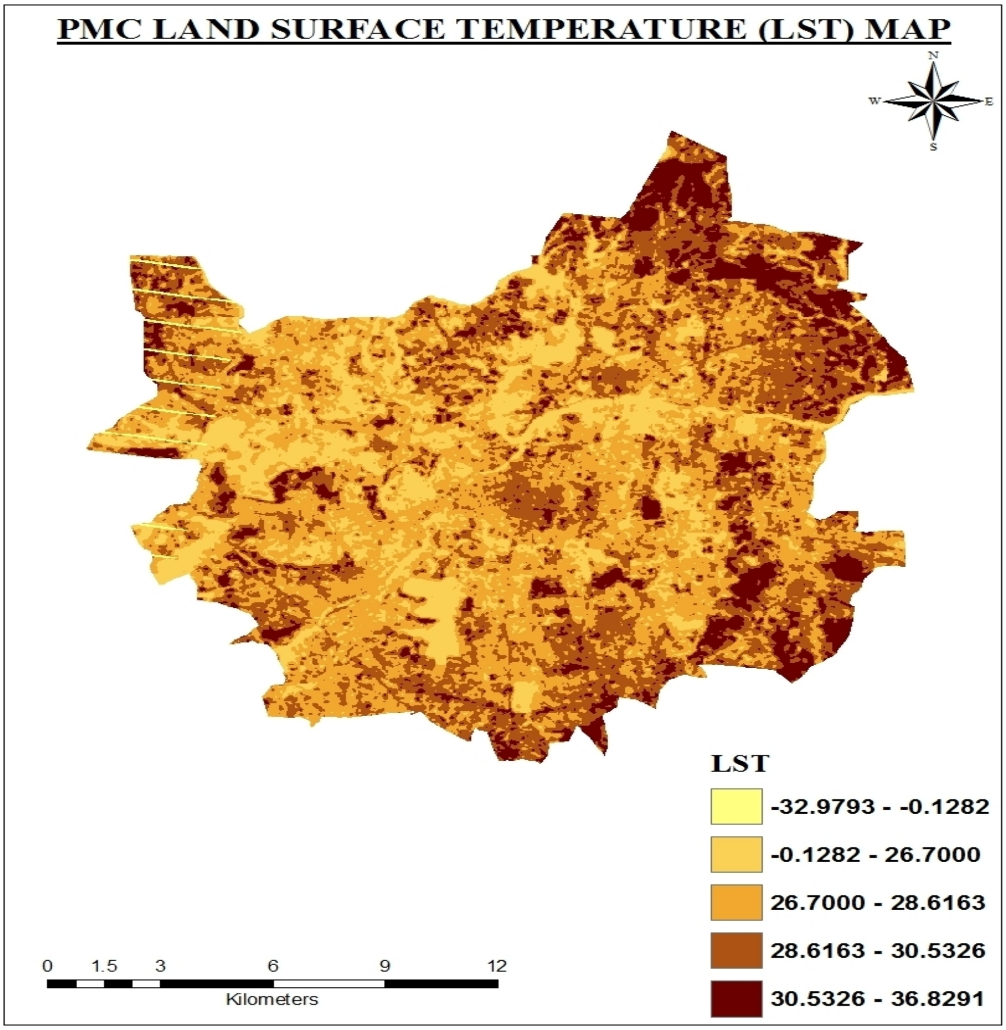


Figure-3.12: PMC Land Surface Temperature (LST) Map

f) **SLOPE MAP-** Topographical information was used to indicate low land areas, which were prone to forming stagnant water pools. These stagnant water pools could provide suitable mosquito breeding sites. To detect such topographical high or low land areas, Digital Elevation Model (DEM) was used to generate the Slope of the study area. The Slope map was derived in percent rise also referred to as percent slope from DEM in ArcGIS 10 software using spatial analysis slope tool.

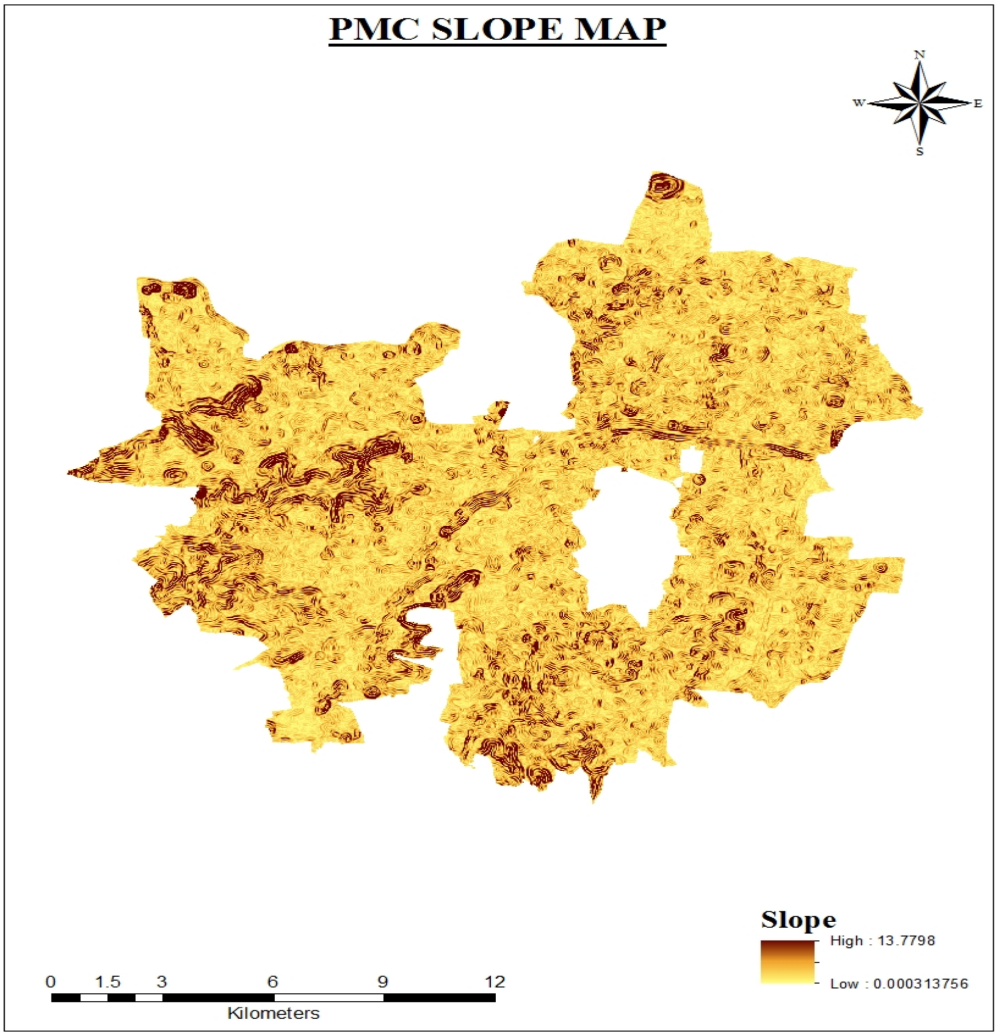


Figure-3.13: PMC Slope Map

g) **PMC ADMINISTRATIVE WARDS MAP-** There are 14 Administrative Wards under Pune Municipal Corporation (PMC). All these administrative wards of the year 2012 as identified by the PMC's Administrative Department with detailed information such as Ward Name, Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases-2012, Total Slums-2012, Total

Gardens-2012, etc. were marked (digitized) and overlaid as polygon data on the satellite imagery base-map of PMC.

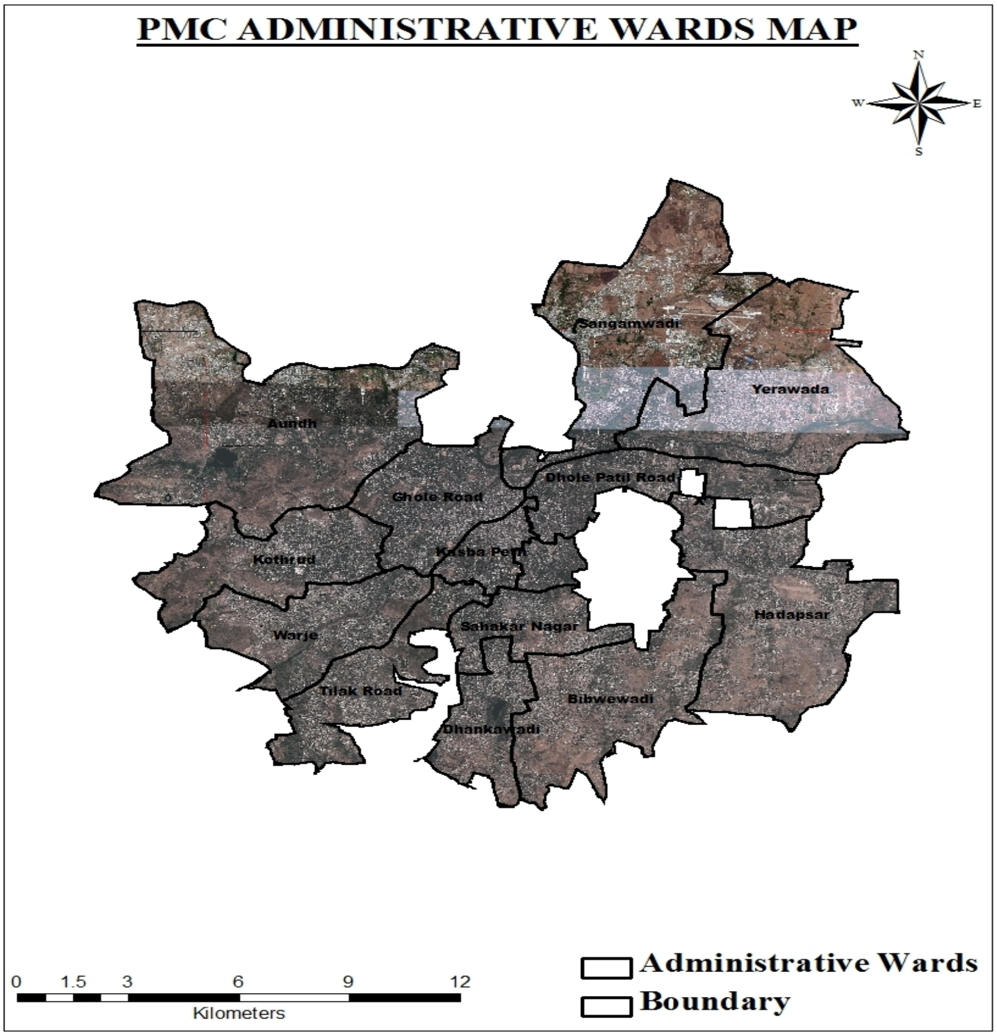


Figure-3.14: PMC Administrative Wards Map

h) **PMC DENGUE CASES-2010 MAP-** The location of Dengue incidence cases of the year 2010 identified by the Ministry of Health (MOH) in PMC with detailed information such as Ward Name, Address, Age, Gender, Month, Date, Hospital, etc. were marked (digitized) and overlaid as point data on the satellite imagery base-map of PMC. This data included information about all the suspected and confirmed DF/DHF cases reported during the year 2010 in PMC area. In 2010, total 52 Dengue Cases were reported.

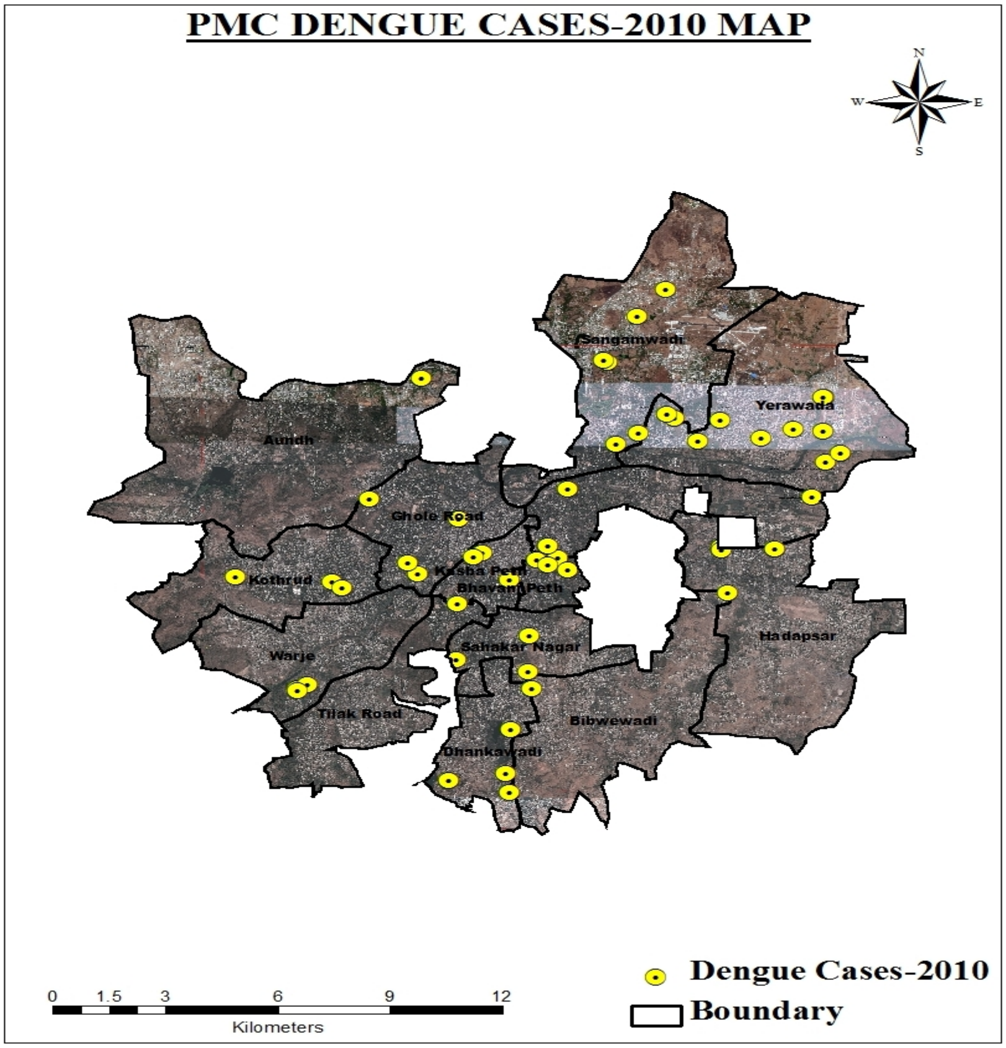


Figure-3.15: PMC Dengue Cases-2010 Map

i) **PMC DENGUE CASES-2011 MAP**- The location of Dengue incidence cases of the year 2011 identified by the Ministry of Health (MOH) in PMC with detailed information such as Ward Name, Address, Age, Gender, Month, Date, Hospital, etc. were marked (digitized) and overlaid as point data on the satellite imagery base-map of PMC. This data included information about all the suspected and confirmed DF/DHF cases reported during the year 2011 in PMC area. In 2011, total 56 Dengue Cases were reported.

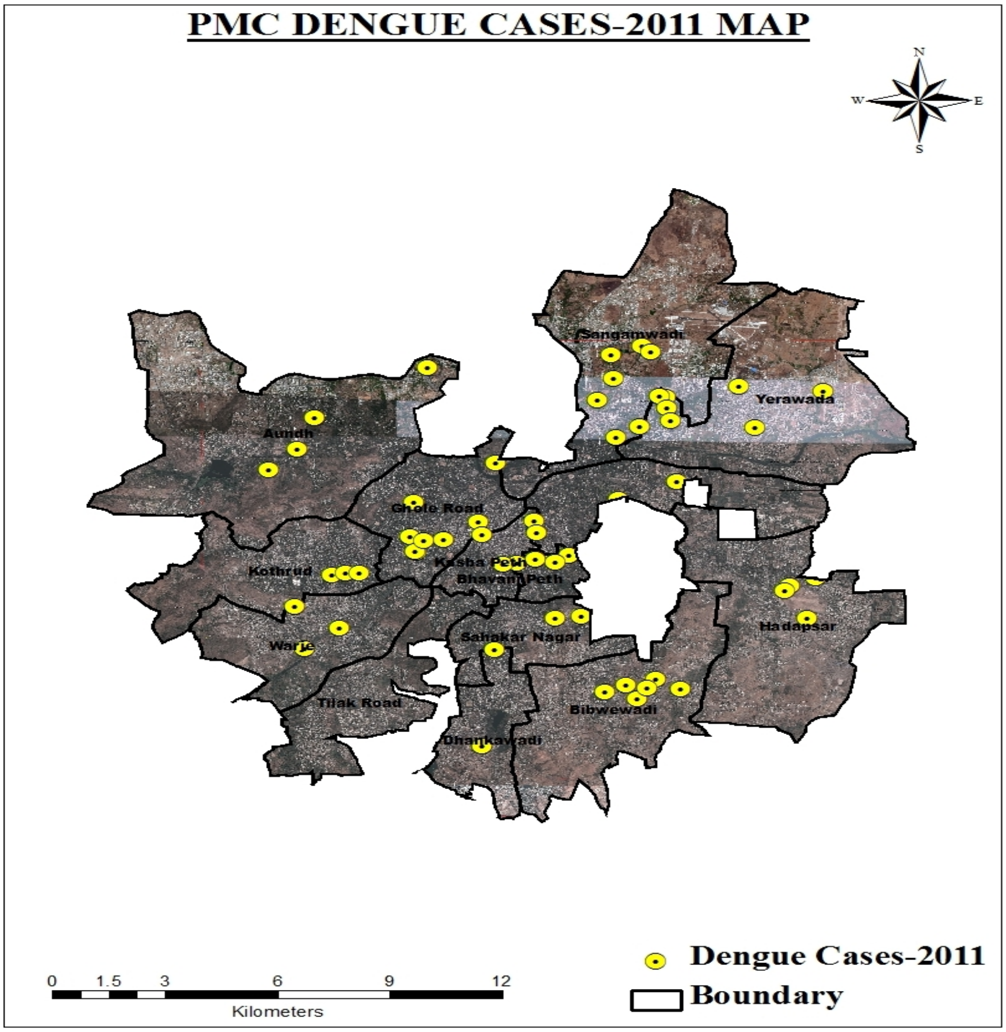


Figure-3.16: PMC Dengue Cases-2011 Map

j) **PMC DENGUE CASES-2012 MAP-** The location of Dengue incidence cases of the year 2012 identified by the Ministry of Health (MOH) in PMC with detailed information such as Ward Name, Address, Age, Gender, Month, Date, Hospital, etc. were marked (digitized) and overlaid as point data on the satellite imagery base-map of PMC. This data included information about all the suspected and confirmed DF/DHF cases reported during the year 2012 in PMC area. In 2012, total 783 Dengue Cases were reported out which 6 cases died.

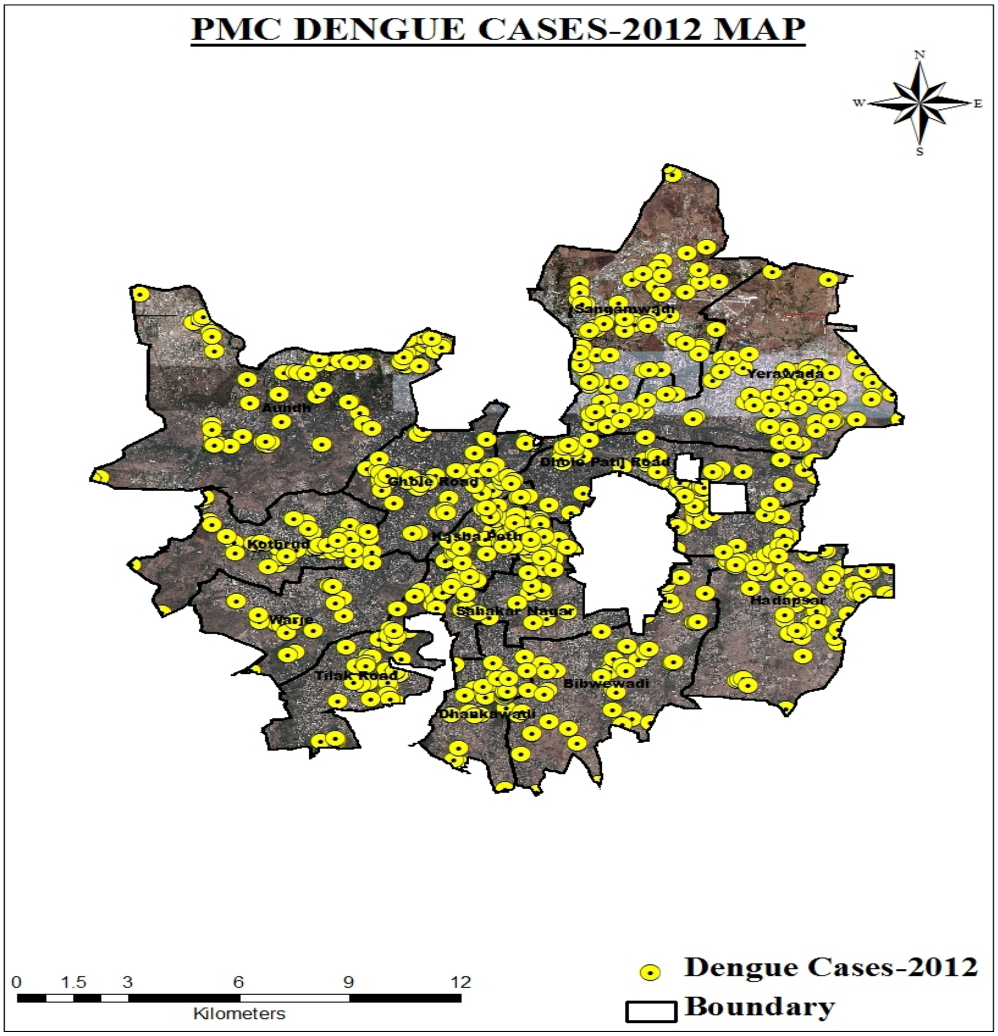


Figure-3.17: PMC Dengue Cases-2012 Map

k) **PMC RESIDENTIAL AREA MAP-** The location of Residential areas in PMC of the year 2012 as identified by the PMC's Housing Department with detailed information such as Ward Name, Name, Address, Total Population-2011, Population Density-2011, etc. were marked (digitized) and overlaid as polygon data on the satellite imagery base-map of PMC. This data included information about all the residential areas including declared and non-declared slums, recorded during the year 2012 in PMC area.

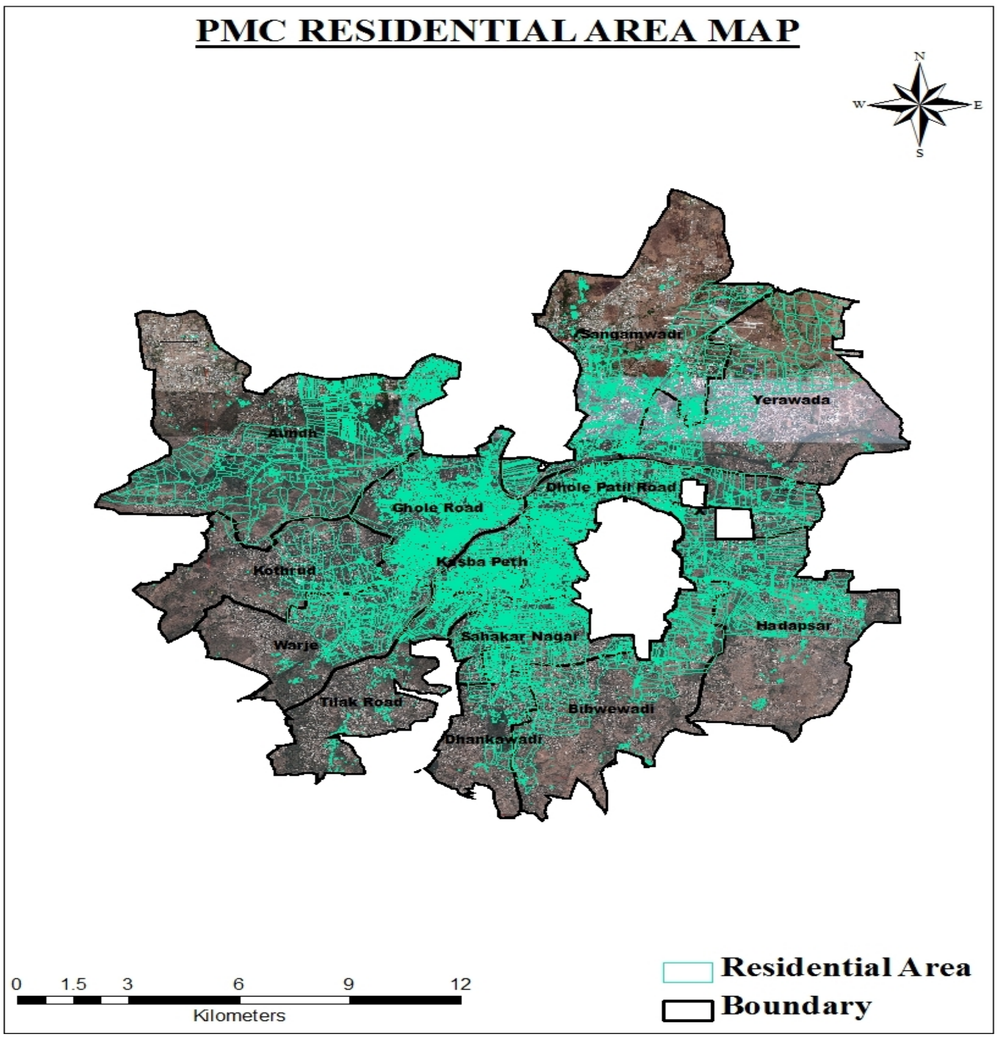


Figure-3.18: PMC Residential Area-2012 Map

l) **PMC SLUMS MAP-** The location o**f** Slums in PMC of the year 2012 as identified by the PMC's Slum Department with detailed information such as Ward Name, Name, Address, Ownership, Total Population-2011, Population Density-2011, etc. were marked (digitized) and overlaid as polygon data on the satellite imagery base-map of PMC. This data included information about all the slums including declared and non-declared slums as well, recorded during the year 2012 in PMC area. In 2012, total 489 slums were recorded out which 237 slums were recorded as declared and 252 slums were recorded as non-declared. Due to lack of water supply, all the houses in these slums have one or more containers to store fresh and clean water either for drinking or other purposes.

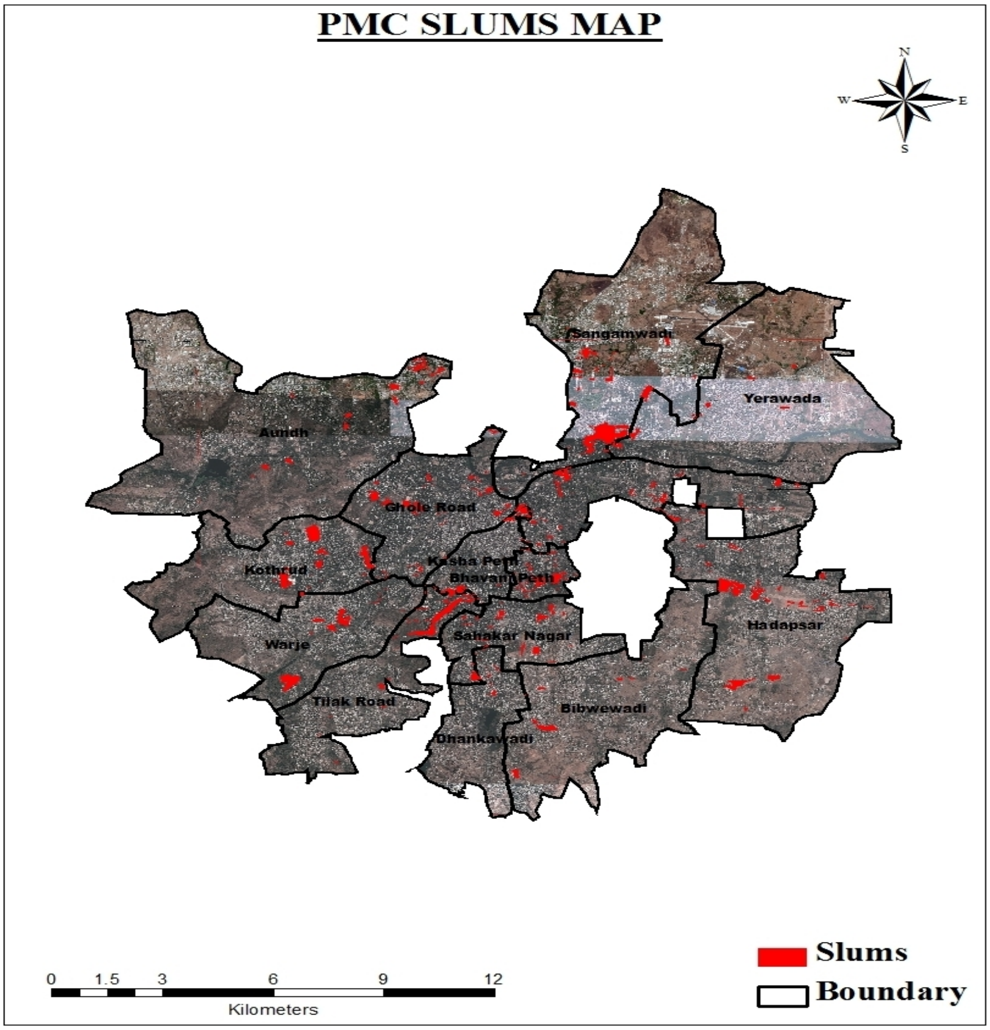


Figure-3.19: PMC Slums-2012 Map

m) **PMC GARDENS MAP-** The location of Gardens in PMC of the year 2012 as identified by the PMC's Garden Department with detailed information such as Ward Name, Name, Address, etc. were marked (digitized) and overlaid as point data on the satellite imagery base-map of PMC. This data included information about all the gardens recorded during the year 2012 in PMC area. In 2012, total 89 gardens were recorded. Also, each of these gardens either have a fountain or a pond or a tank, etc. were fresh and clean water is stored and thus, this contributes to the dengue mosquito breeding site.

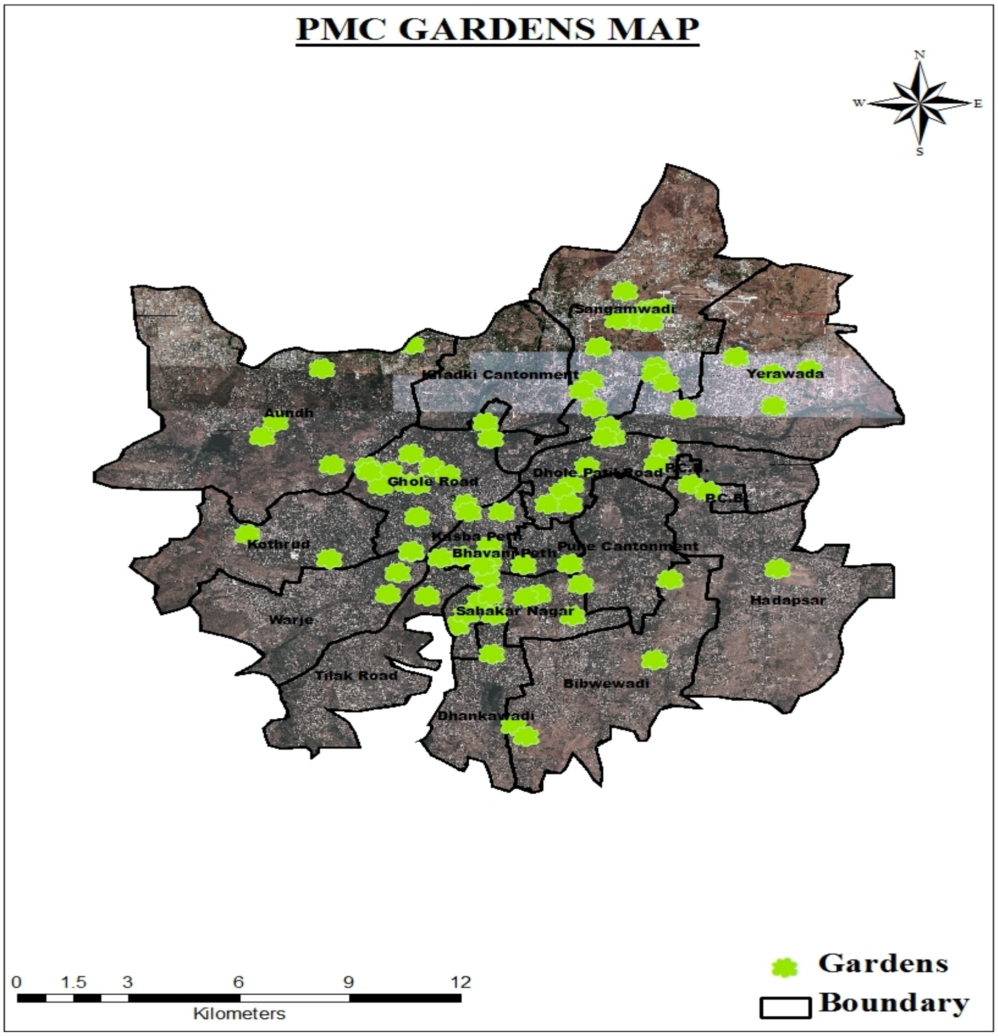


Figure-3.20: PMC Gardens-2012 Map

n) **PMC OPEN WATER BODIES MAP-** The location of River, Canals, Lakes, Tanks, Reservoirs, etc. in PMC as identified by the PMC's Water Department with detailed information such as Name, Ward Name, Type, etc. were marked (digitized) and overlaid as line and polygon data on the satellite imagery base-map of PMC. This data included information about all the open water bodies recorded during the year 2012 in PMC area. Mula-Mutha River along-with Canals, Tanks, Lakes such as Pashan, Lohegaon, Katraj, Khadakwasla, etc and other reservoirs forms a part of PMC's drainage network and water supply.

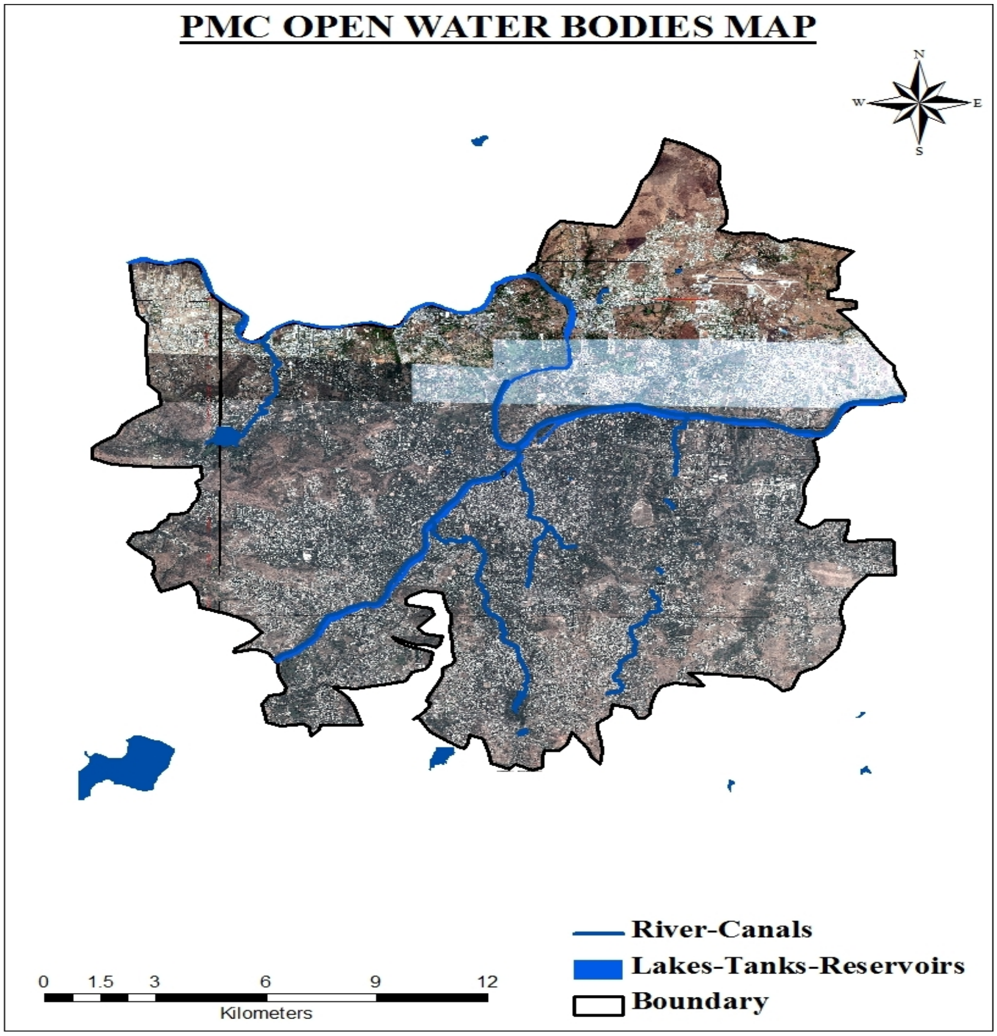


Figure-3.21: PMC Open Water Bodies-2012 Map

o) **PMC MEANS & MODES OF TRANSPORTATION MAP-** Mobility is an essential part of routine urban life. It is the main access to city services, social opportunities, access to employment as well as social integration. This rising mobility pattern and increase in population has led to inadequacy of public transport. Road Network, Railway Network, Bus Stops, Railway Stations, Airports, etc. were marked (digitized) and overlaid as lines and point data on the satellite imagery base-map of PMC. Means and Modes of Transportation data is taken into consideration as it is one of the main reasons for spreading of the vector-borne diseases like Dengue.

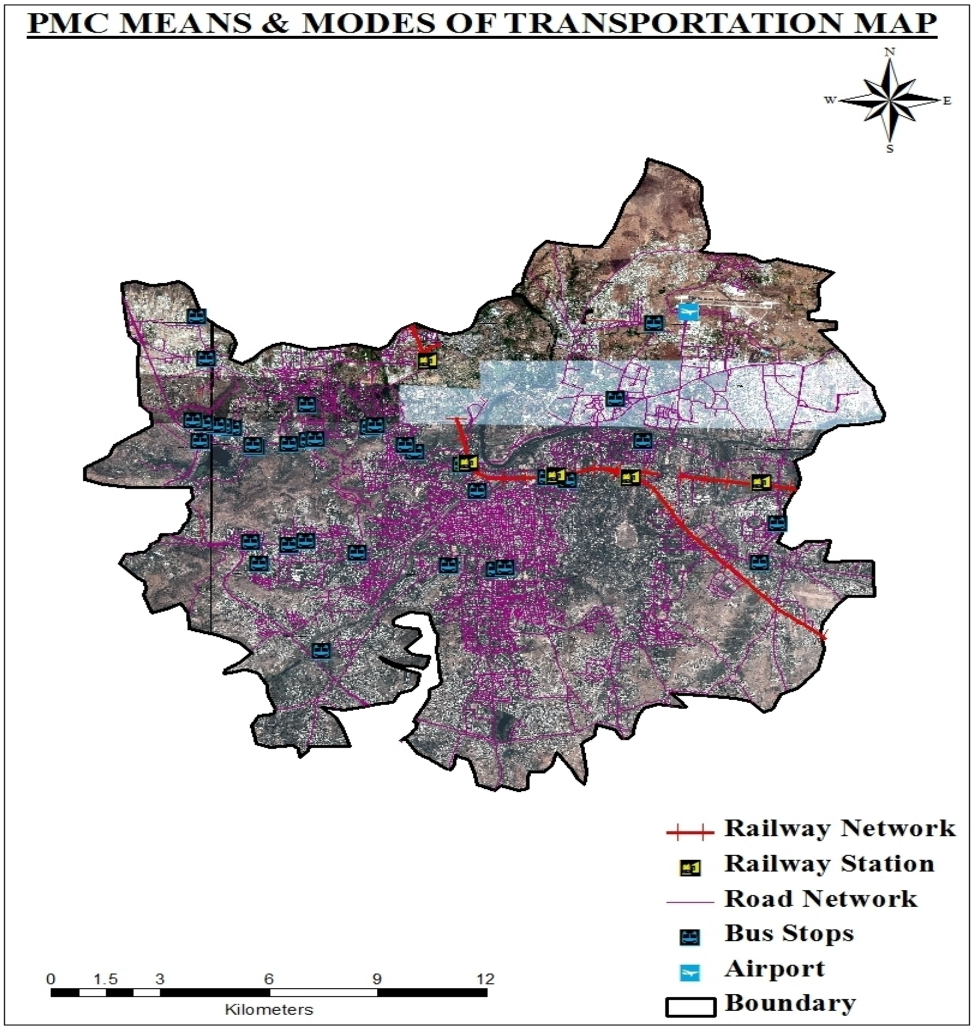


Figure-3.22: PMC Means & Modes of Transportation-2012 Map

p) **PMC DENGUE HOSPITALS MAP-** The locations of hospitals for dengue treatment in PMC as identified by the PMC's Health Department with detailed information such as Name, Ward Name, Type (Private/Municipal), etc. were marked (digitized) and overlaid as polygon data on the satellite imagery base-map of PMC. This data included information about all the hospitals in which dengue cases were reported during the year 2012 in PMC area. As per the PMC Health Department, there total 51 hospitals in the municipality area were treatment for dengue is available. Out of the total dengue hospitals there are 50 private hospitals and only hospital i.e. Dr. Naidu Hospital (marked in beryl green color) comes under Municipal Corporation as shown in figure-3.23.

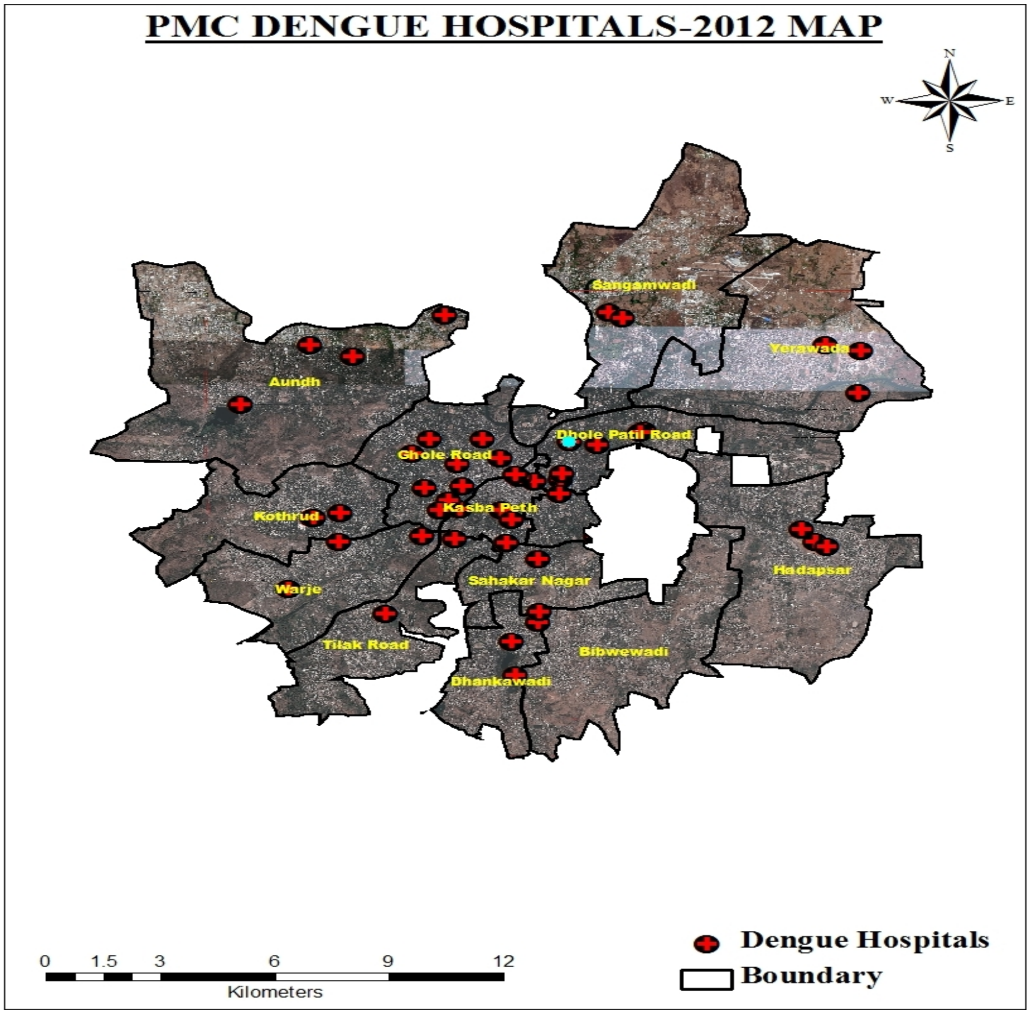


Figure-3.23: PMC Dengue Hospitals-2012 Map

q) **PMC ELECTORAL WARDS MAP-** There are 144 Electoral Wards under Pune Municipal Corporation (PMC). All these electoral wards of the year 2012 as identified by the PMC's Administrative Department with detailed information such as Name, Ward Name, Address, Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases-2012, Total Slums-2012, Total Gardens-2012, etc. were marked (digitized) and overlaid as polygon data on the satellite imagery base-map of PMC.

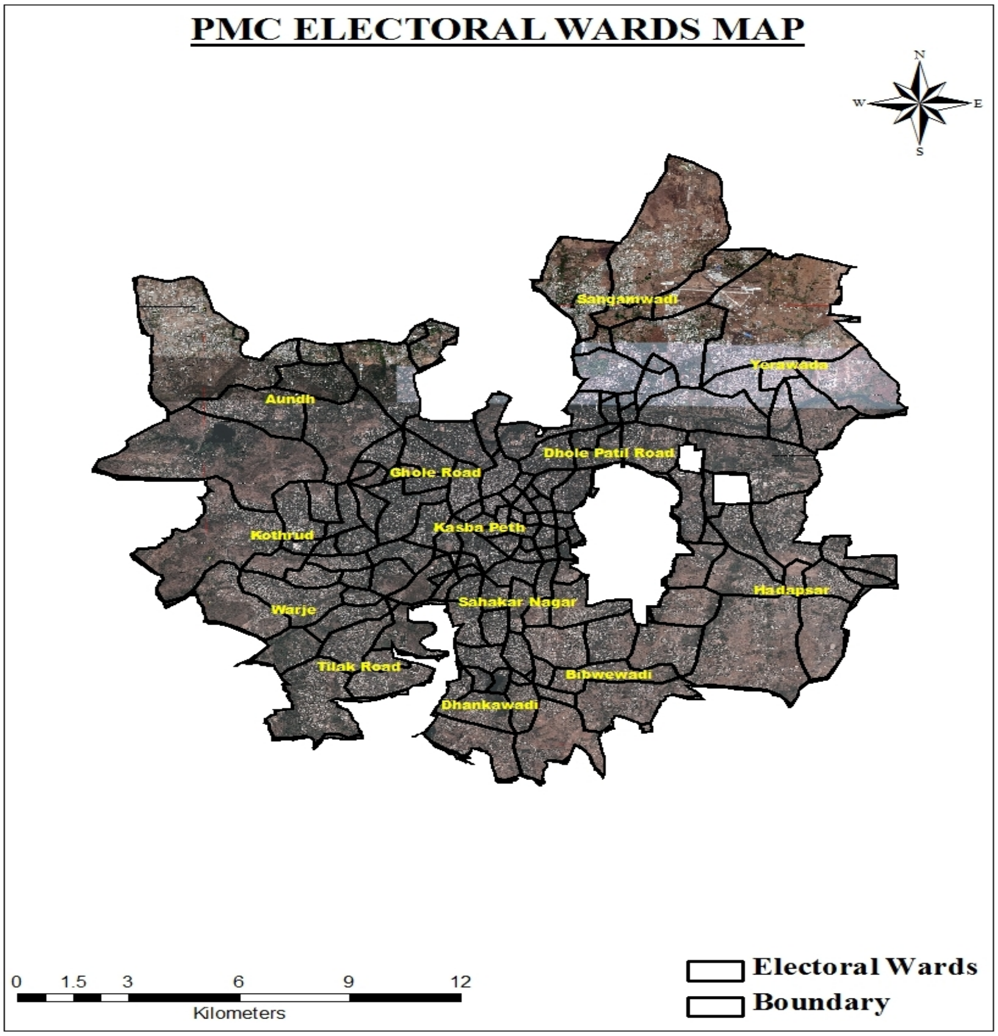


Figure-3.24: PMC Electoral Wards Map

PMC Electoral Wards Map was used for further data creation such as:

1. **PMC ELECTORAL WARDWISE TOTAL POPULATION MAP-** The total population of Pune Municipal Corporation (PMC) is 33,00,000 lakhs as per 2011 census. The following figure-3.25 shows the Electoral Wardwise distribution of the total population in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Total Population-2011.

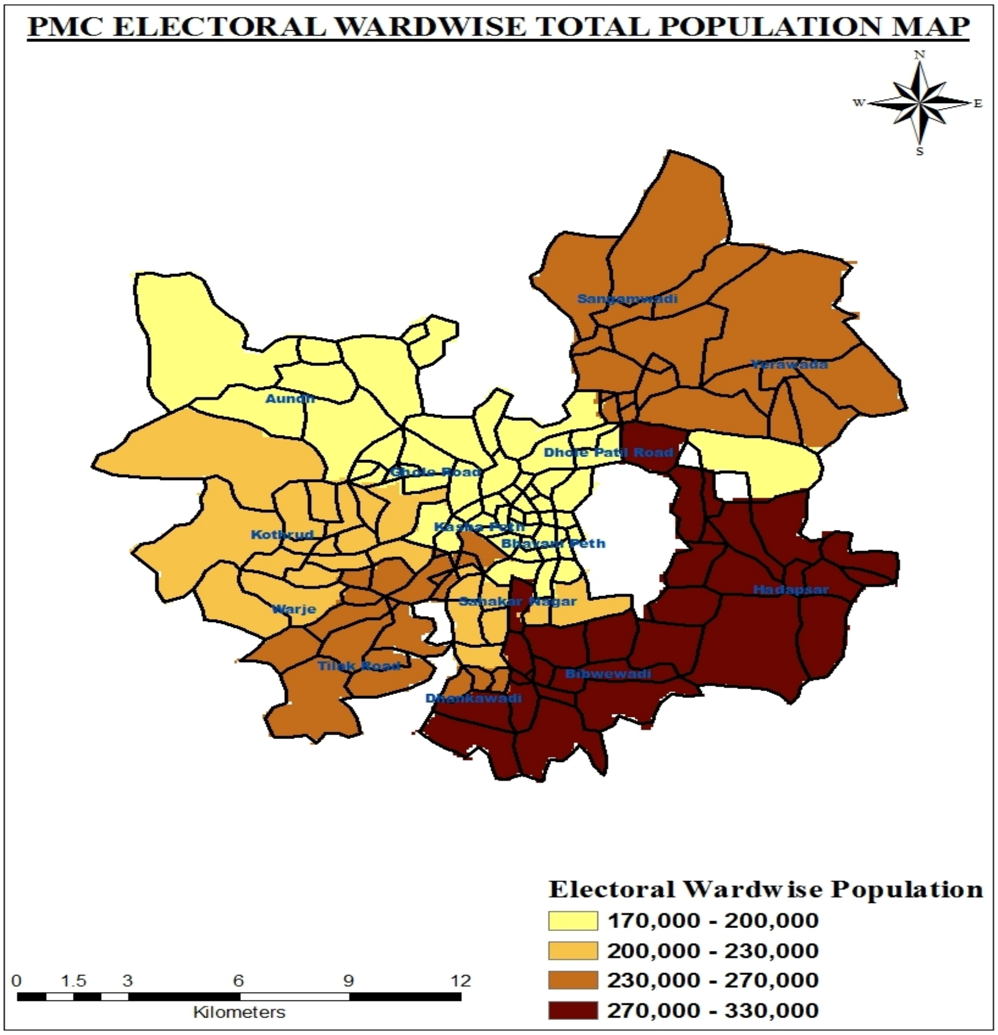


Figure-3.25: PMC Electoral Wardwise Total Population Map

2. **PMC ELECTORAL WARDWISE POPULATION DENSITY MAP-** The total population density of Pune Municipal Corporation (PMC) is 4,731 people per sq.km as per 2011 census. The following figure-3.26 shows the Electoral Wardwise distribution of the population density in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Population Density-2011.

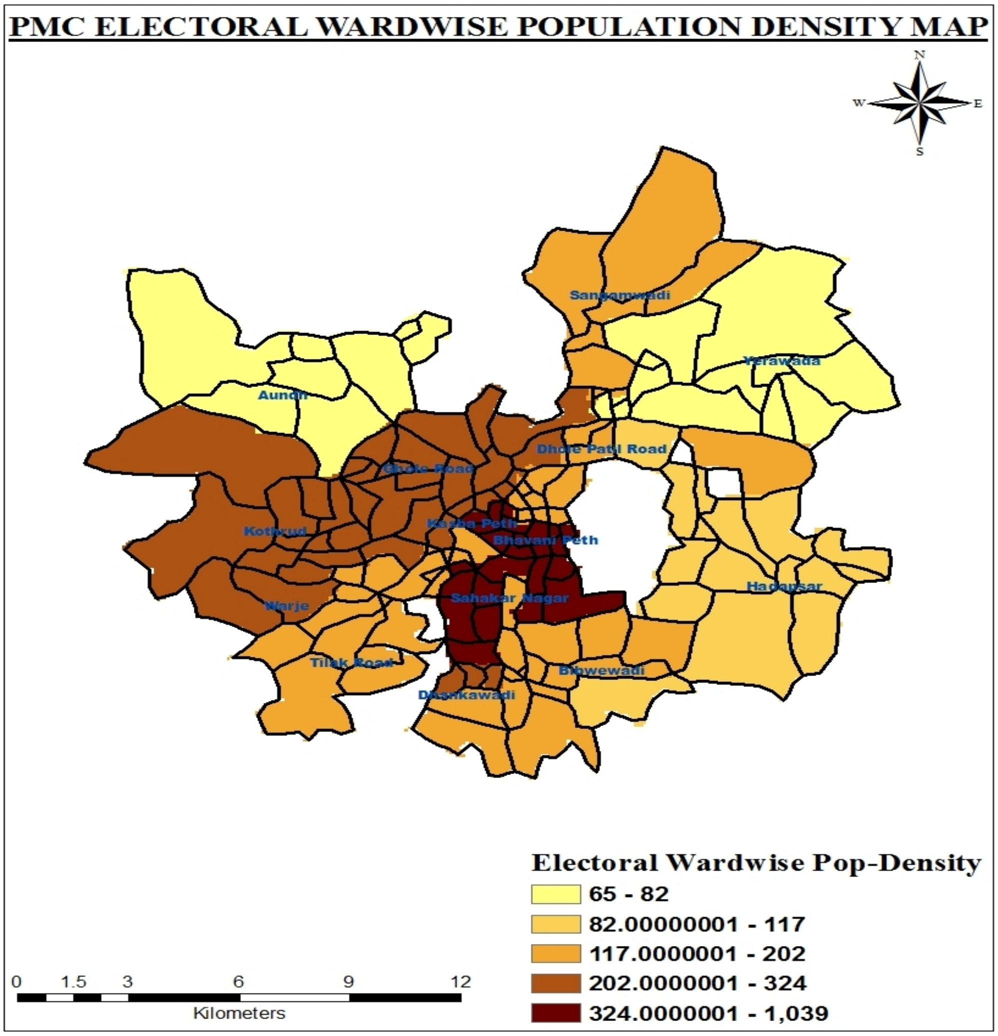


Figure-3.26: PMC Electoral Wardwise Population Density Map

3. **PMC ELECTORAL WARDWISE TOTAL SLUM POPULATION MAP -** The total slum population of Pune Municipal Corporation (PMC) is 8, 03,405 lakhs as per 2011 census. The following figure-3.27 shows the Electoral Wardwise distribution of the total slum population in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Total Slum Population-2011.

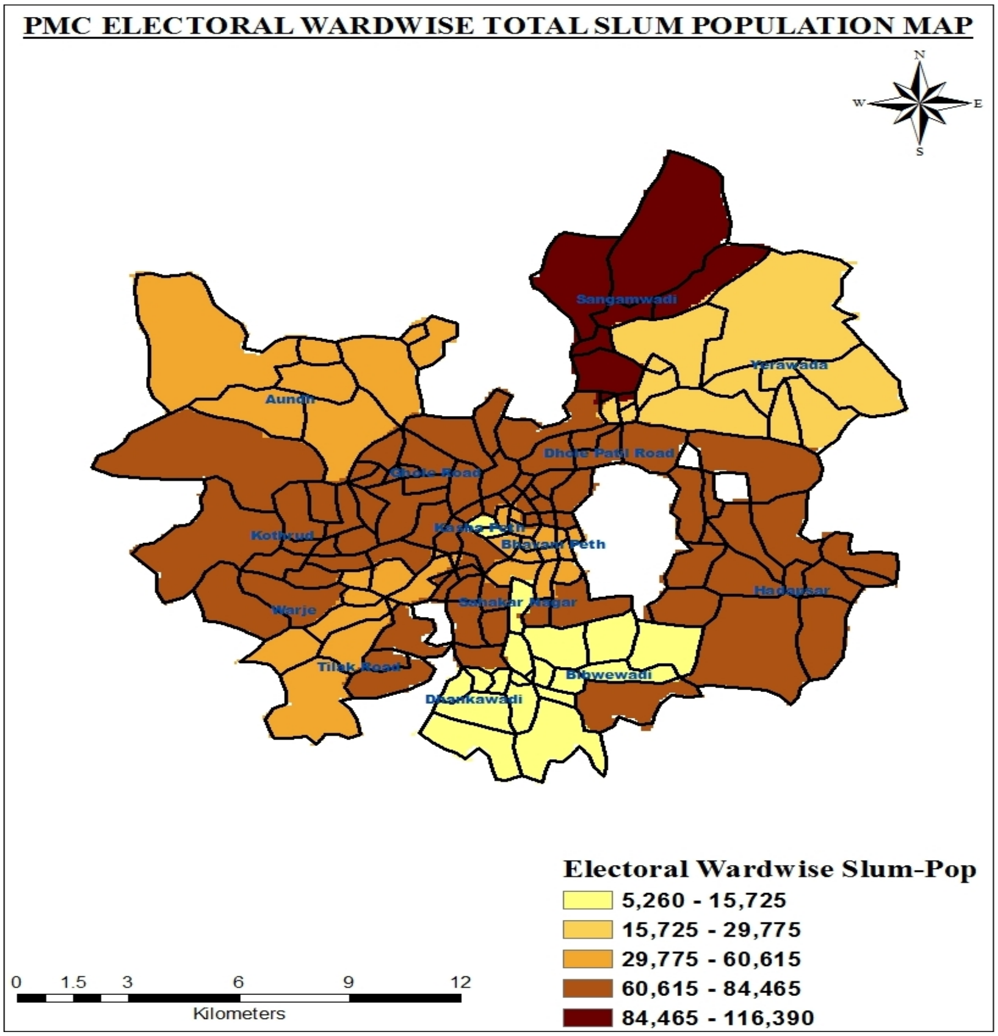


Figure-3.27: PMC Electoral Wardwise Total Slum Population Map

4. **PMC ELECTORAL WARDWISE SLUM POPULATION DENSITY MAP-** The total slum population density of Pune Municipal Corporation (PMC) is 4,183 people per sq.km as per 2011 census. The following figure-3.28 shows the Electoral Wardwise distribution of the slum population density in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Slum Population Density-2011.

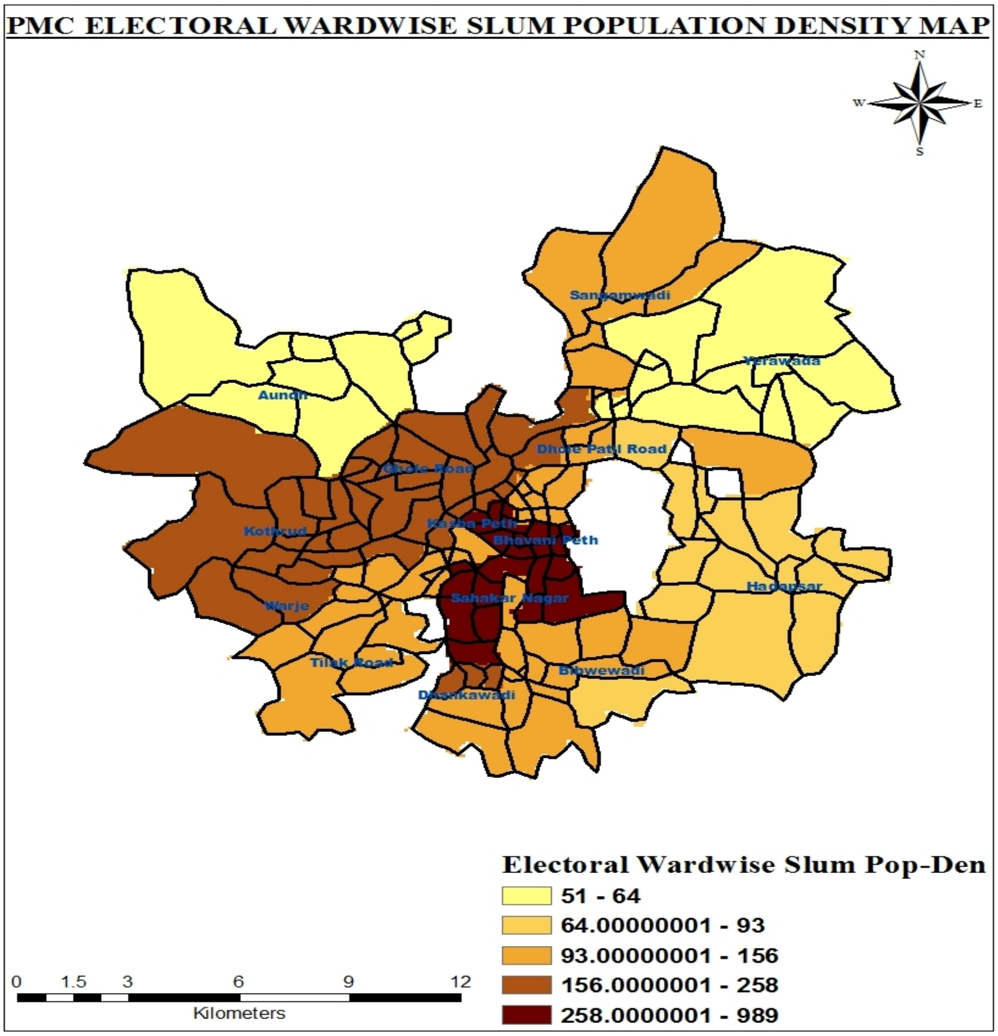


Figure-3.28: PMC Electoral Wardwise Slum Population Density Map

5. **PMC ELECTORAL WARDWISE DENGUE CASES-2012 MAP-** The total dengue cases of the year 2012 reported in Pune Municipal Corporation (PMC) is 783 as per PMC's Health Department. The following figure-3.29 shows the Electoral Wardwise distribution of the dengue cases-2012 in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Dengue Cases-2012.

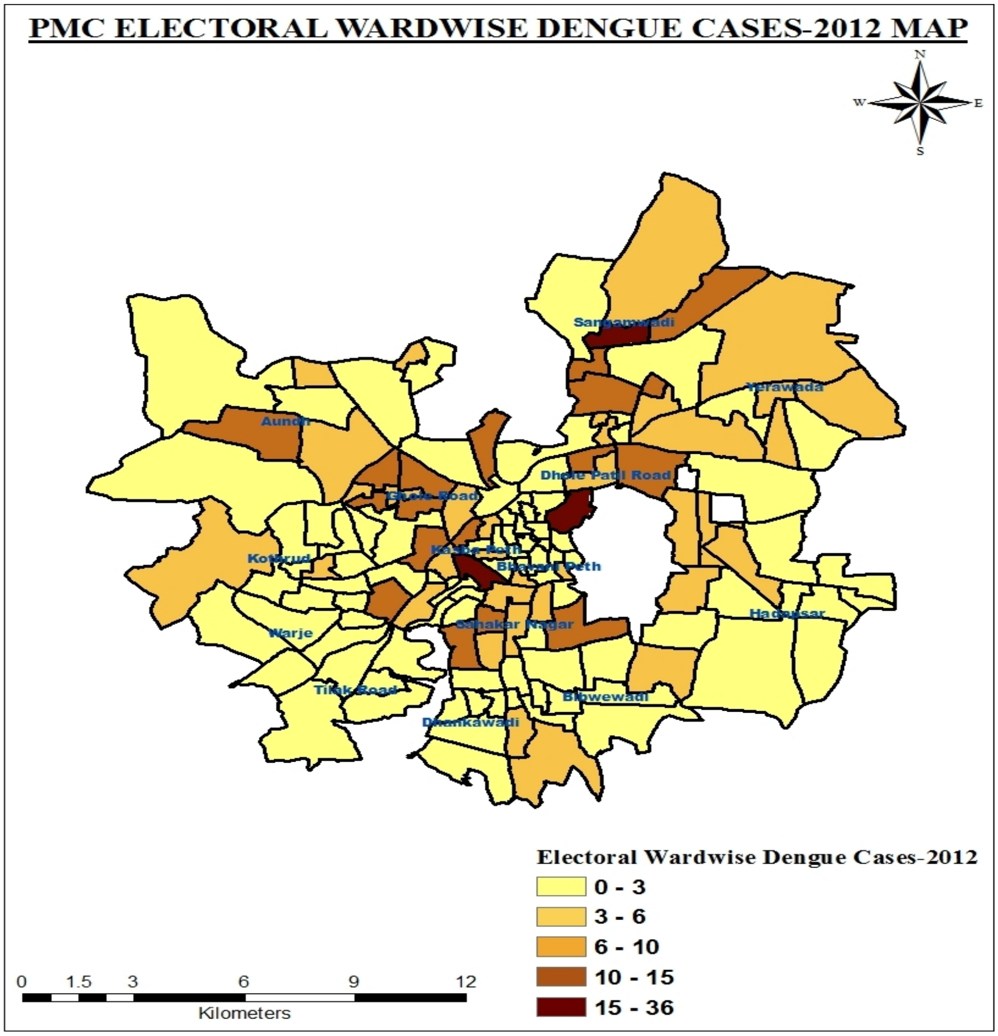


Figure-3.29: PMC Electoral Wardwise Dengue Cases-2012 Map

6. **PMC ELECTORAL WARDWISE TOTAL SLUMS-2012 MAP-** The total slums of the year 2012 recorded in Pune Municipal Corporation (PMC) is 489 out which 237 slums were recorded as declared and 252 slums were recorded as non-declared as per PMC’s Health Department. The following figure-3.30 shows the Electoral Wardwise distribution of the total slums of the year 2012 in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Total Slums-2012.

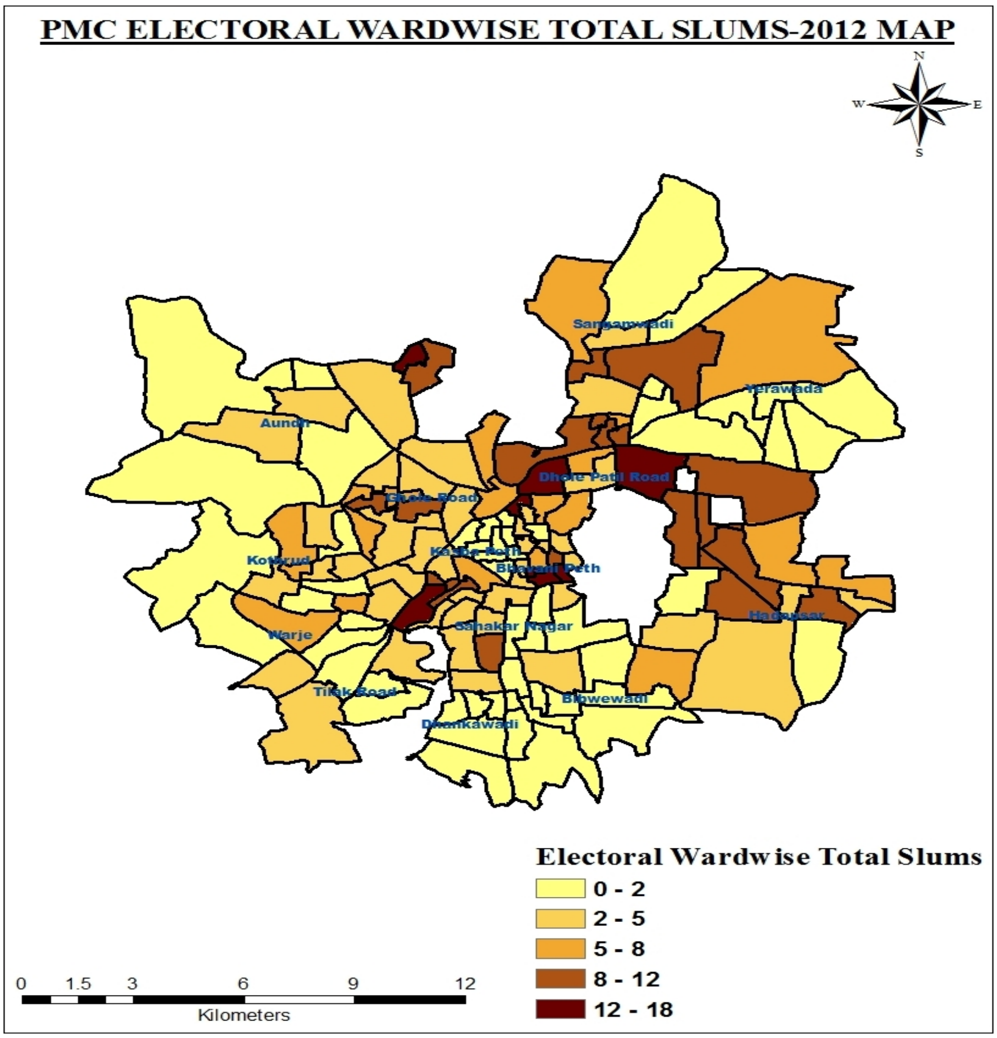


Figure-3.30: PMC Electoral Wardwise Total Slums-2012 Map

7. **PMC ELECTORAL WARDWISE TOTAL GARDENS-2012 MAP-** The total gardens of the year 2012 recorded in Pune Municipal Corporation (PMC) is 89 as per PMC's Garden Department. The following figure-3.31 shows the Electoral Wardwise distribution of the total gardens of the year 2012 in PMC. For this, the Conversion tool i.e. Polygon to Raster that converts polygon input feature dataset to a raster dataset was used and the value field given was Total Gardens-2012.

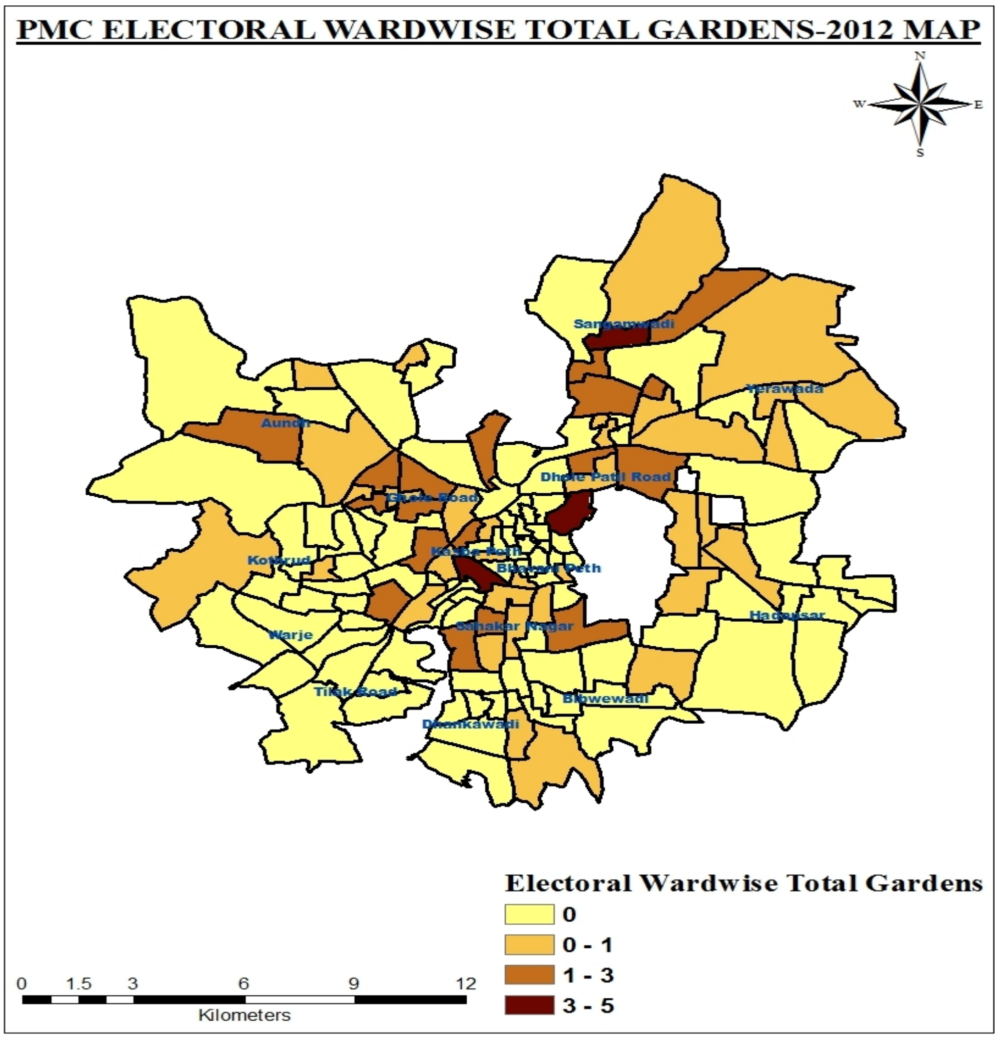


Figure-3.31: PMC Electoral Wardwise Total Gardens-2012 Map

3.7 DATA PROCESSING

As observed from the above data created, it is obvious that there was a vicious circle of dengue epidemic in the year 2012. Hence, the dengue incidence cases for the year 2012 were considered for further analysis.

a) **SPATIAL ANALYSIS FOR ANALYZING PATTERNS-** In this type of analysis, the spatial distribution of dengue incidence cases for the year 2012 within Pune Municipal Corporation (PMC) was examined using Spatial Autocorrelation (Moran's I) and Average Nearest Neighbor methods (tools).

1. ***Spatial Autocorrelation***: A global spatial autocorrelation method which is Moran's I was used to test whether the dengue cases within PMC area were spatially correlated or not. Moran's I measures spatial autocorrelation and it is usually applied to area unites where numerical ratio or interval data are available. This index measures spatial autocorrelation based on both feature location and feature values simultaneously. Thus, it is determined by calculating a mean for observation and then comparing the value of each incident with the value at all other locations [Nakhapakorn K, Jirakajohnkool S 2006]. It can be defined as:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

Where N is the number of cases; X_i is the variable value at particular location *i* and X_j is the variable value at another location *j*; $\bar{X}$ is the mean of variable; and W_{ij} is a weight indexing location of *i* relative to *j*. The value of Moran's I range from -1 for strong negative spatial autocorrelation to +1 for strong positive spatial autocorrelation. A value near 0 would indicate a spatially random pattern.

Moran's I test on dengue incidence cases for PMC indicated that there was positive spatial autocorrelation among dengue incidence cases within the municipality. The Moran's I for dengue cases is 0.057 ($p<0.01$) while the z-score is 3.10 ($p<0.01$). From the report generated as shown in figure-3.32, it can be concluded that the null hypothesis is rejected because the spatial distribution of dengue cases in the municipality is more spatially clustered.

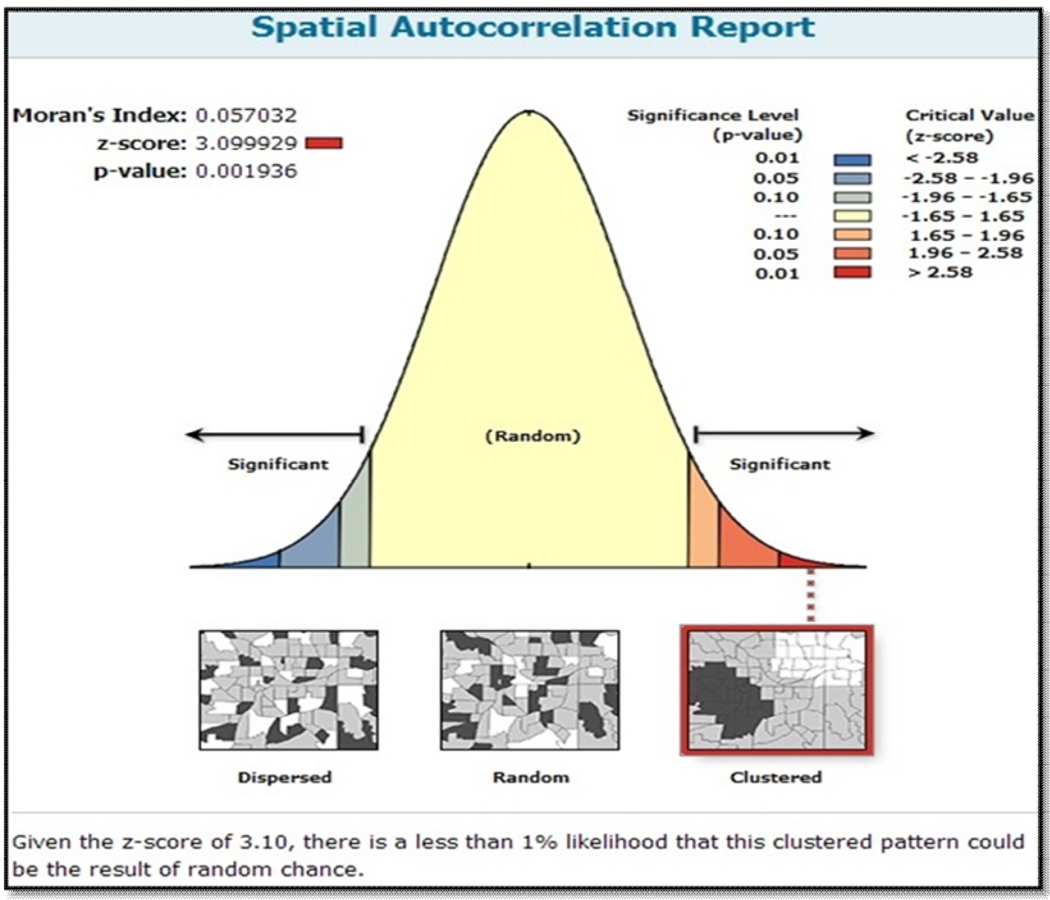


Figure-3.32: Spatial Autocorrelation Report

2. ***Average Nearest Neighbor:*** Average nearest neighborhood (ANN) was used to analyze whether the dengue incidence cases are clustered or not. The ANN tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. The average nearest neighbor ratio is calculated as the observed average distance divided by the expected average distance (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area).

The Average Nearest Neighbor ratio is given as:

$$ANN = \frac{\bar{D}_O}{\bar{D}_E} \quad (1)$$

where $\bar{D}_O$ is the observed mean distance between each feature and their nearest neighbor:

$$\bar{D}_O = \frac{\sum_{i=1}^{n} d_i}{n} \quad (2)$$

and $\bar{D}_E$ is the expected mean distance for the features given a random pattern:

$$\bar{D}_E = \frac{0.5}{\sqrt{n/A}} \quad (3)$$

In the previous equations, d_i equals the distance between feature i and its nearest feature, n corresponds to the total number of features and A is the total study area.

The z_{ANN}-score for the statistic is calculated as:

$$z_{ANN} = \frac{\bar{D}_O - \bar{D}_E}{SE} \quad (4)$$

where:

$$SE = \frac{0.26136}{\sqrt{n^2/A}} \quad (5)$$

SE

where:

$$SE = \frac{0.26136}{\sqrt{n^2/A}} \quad (5)$$

From ANN test, it is found out that the dengue cases within the municipality are spatially clustered. Results from ANN analysis showed that the average nearest neighbor ratio is less than 1 which is 0.55 ($p < 0.0001$). From this result, it can be concluded that the dengue cases pattern in PMC is exhibiting a cluster pattern. The z-score for dengue incidence cases within the municipality is -23.81 ($p < 0.0001$). The z-score is a test of statistical significance that helps to decide whether or not to reject the null hypothesis. In this study, the null hypothesis is that there is no spatial pattern among dengue cases within PMC. With small z-score, there will be small probability which is less than 1% likelihood that this clustered pattern could be a result of random chance; so, we can reject the null hypothesis.

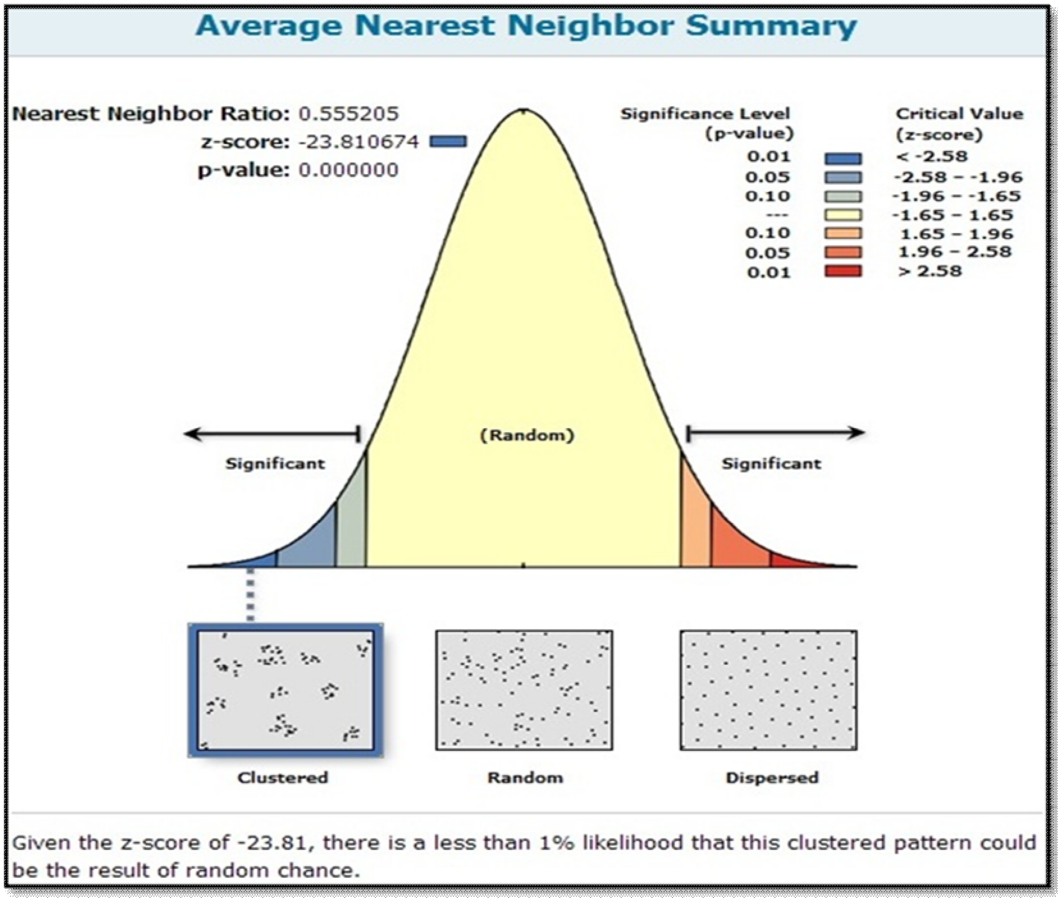


Figure-3.33: Average-Nearest Neighbor Report

b) **SPATIAL ANALYSIS FOR MAPPING CLUSTERS-** For this type, a Hot Spot analysis using Kernel Density estimation interpolation technique was done.

1. ***Kernel Density***: Kernel Density estimation is a technique, used to generalize incident locations to the entire study area. According to [Bithell, J. F. 1990], kernel density estimation is an effective tool to identify high-risk areas within point patterns of disease incidence cases by producing a smooth, continuous surface that defines the level of risk for that area. Kernel density estimation is an interpolation that is appropriate for individual point locations. It calculates the density of point features around each output raster cell. According to [Bithell, J. F. 1990] the kernel estimate is

a better “Hot Spot” identifier than the cluster analysis. Kernel density estimation is a useful method as it helps to precisely identify the location, spatial extent and intensity of dengue disease hotspots.

Kernel density estimation was applied in this study to locate “Hot Spots” for dengue incidence cases of the year 2012 in PMC. The encircled dark brown color areas in Figure-3.34 are the hotspots identified with maximum dengue incidence cases density. Hence, with the help of dengue density map it was easy to target specific areas within PMC showing highest incidence cases. Overall picture of dengue density variation within the PMC can be known with the help of kernel density map. From the result, it was easy to identify the areas those were most affected by dengue disease.

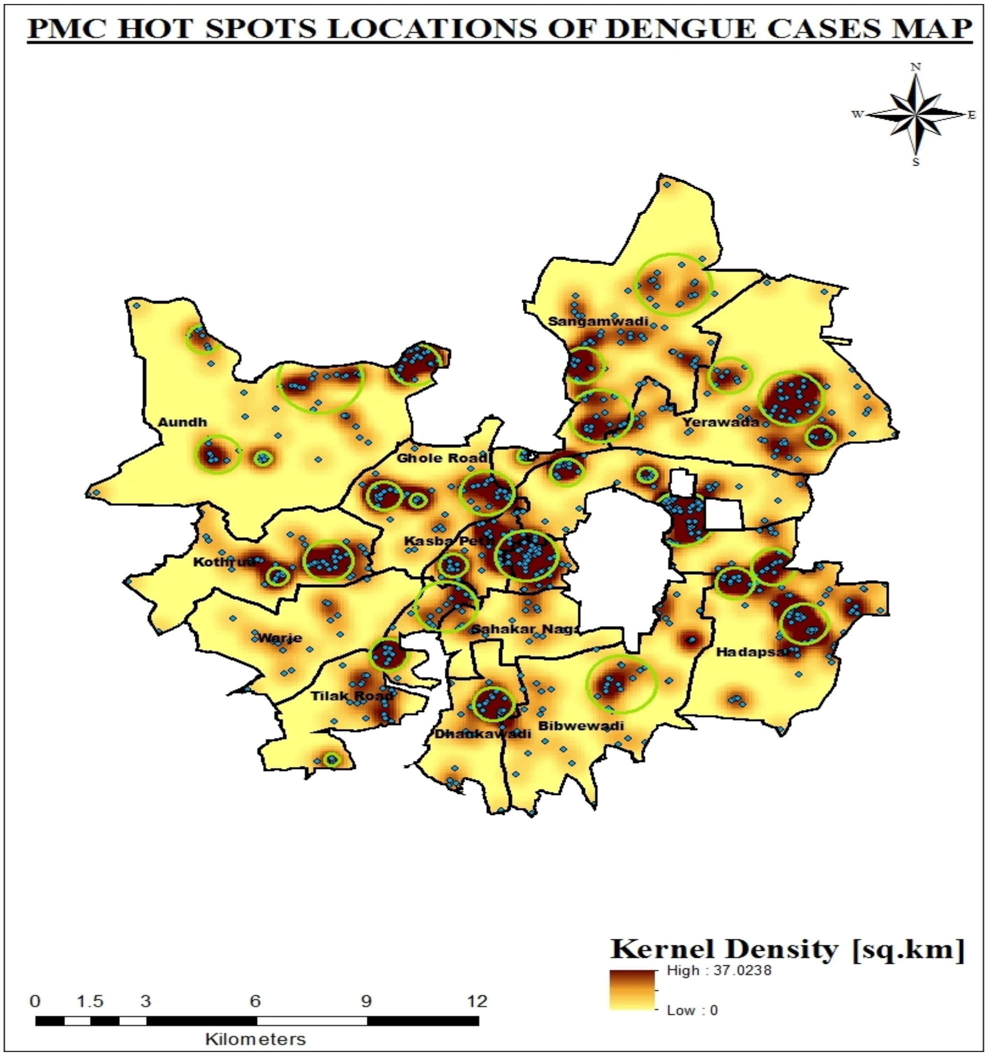


Figure-3.34: PMC Hot Spots Locations of Dengue Cases-2012 Map

The Kernel Density raster layer showed in figure-3.35 displays areas with a higher density of cases in dark brown and then grading to areas of lowest density of cases in yellow. Here, Zoom In and Identify tools were used to query the values of the Kernel Density layer. The graphic below in figure- shows the Identify tool with the Pixel value displayed for the location “X” in the map. At that location there is a density of 36.2659 dengue cases per square kilometer.

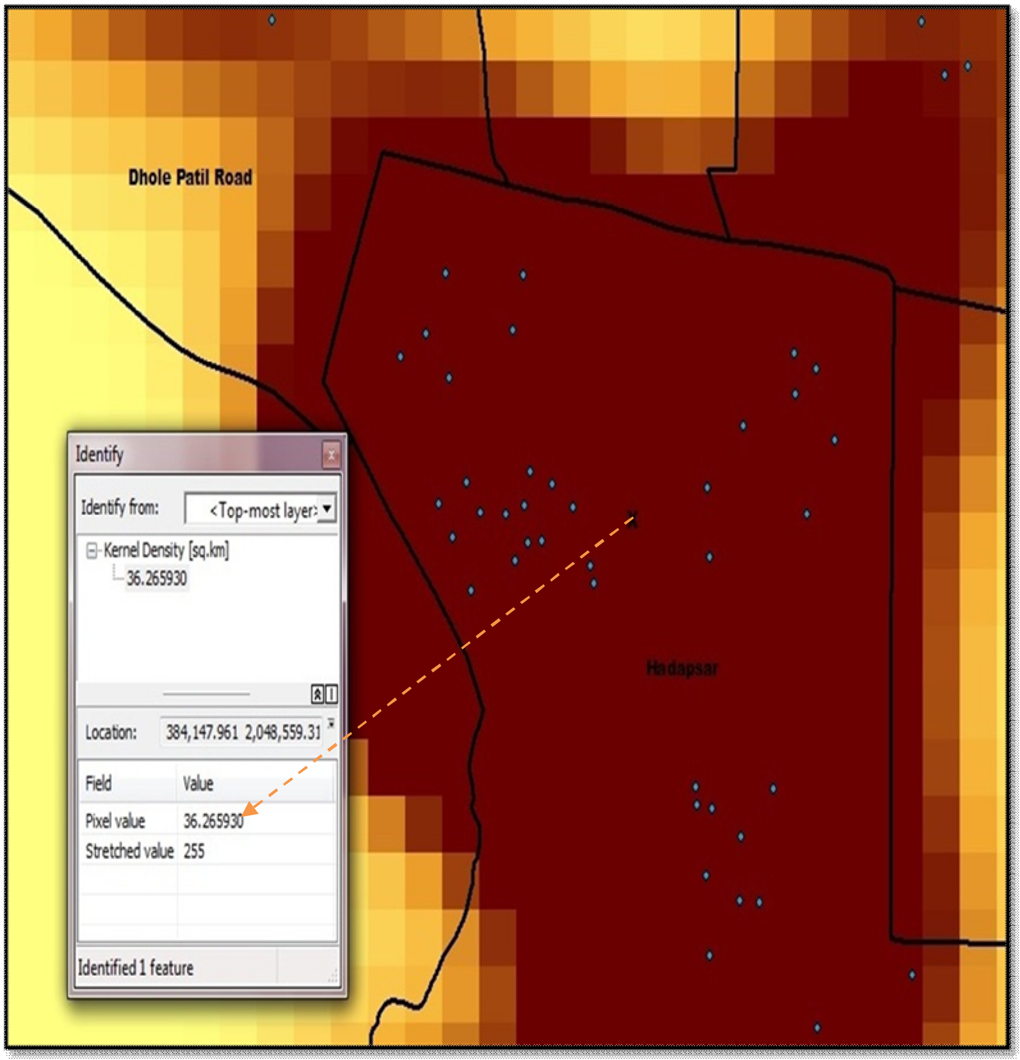


Figure-3.35: Kernel Density for Location "X"

c) **SPATIAL ANALYSIS FOR MEASURING GEOGRAPHIC DISTRIBUTIONS-** In this type of analysis, Directional Distribution was used to measure the geographic distribution of dengue incidence cases of the year 2012 in the municipality. It was used to create standard deviational ellipses to summarize the spatial characteristics of geographic features: central tendency, dispersion, and directional trends.

1. ***Directional Distribution (Standard Deviational Ellipse):*** The spatial distribution of dengue cases was examined using Directional Distribution spatial statistics tool to generate quantitative measures of the geographic distribution of dengue cases. By calculating these measures and mapping and examining them visually, it allowed summarizing the spread of the dengue disease and determining if any geographic trends exist in the dengue positive households over time and whether the trends are related to any other spatial observations such as elevation, etc.

   Directional Distribution tool is a script that measures the standard deviation of point features from the mean center for the x-coordinates and y-coordinates separately. The graphic result is a standard deviational ellipse drawn in the map display as a new layer using the coordinates of the mean center (of the selected point features), the standard distance of each axis, and the angle of rotation of the ellipse.

   With this, eight standard deviational ellipses were generated based on the Month field as a way to summarize the geographic distribution of the cases by Month or Date grouping as depicted in figure-3.36. Majority of the ellipses of dengue cases were found mostly in and around the urban areas i.e. in areas with low elevation. Ideal mosquito breeding habitats can change over time due to a combination of vector control eradication efforts, changes in the weather and rainfall patterns and collection of standing water in previously well-drained areas.

   As an epidemiologist or public health specialist, we can use the standard deviational ellipse spatial statistic to generate ellipse overlays on a weekly, monthly, or yearly basis (or any other time-step) in order to create time-series maps that summarize the spread of a disease.

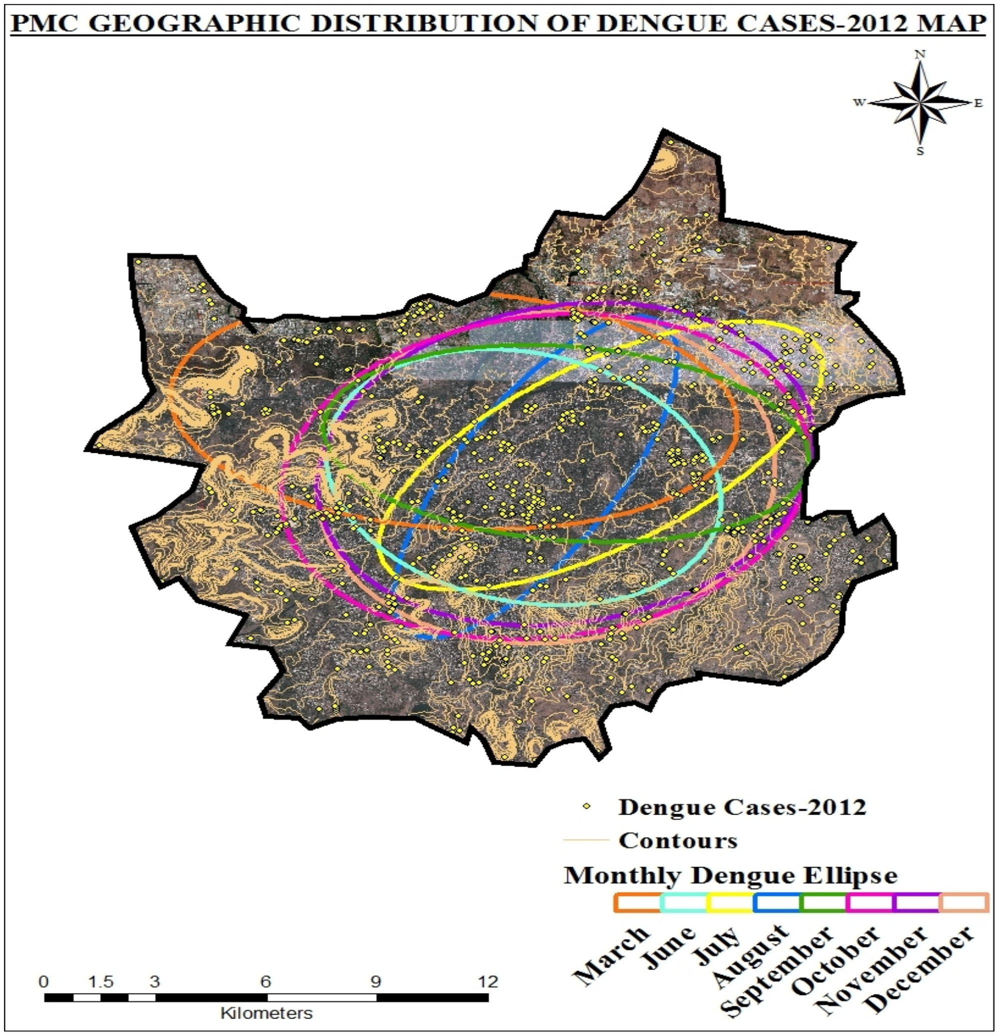


Figure-3.36: PMC Geographic Distribution of Dengue Cases-2012 Map

In the attribute table shown in figure-3.37, there are eight records corresponding to the eight ellipse features in the map. The new output table fields provide 1) the mean center XY coordinates of the point features within each month (ellipse), 2) the standard distance (in map units) of the X and Y axes for each month (ellipse) and 3) the angle of rotation of the ellipses for each month. These calculations and the ellipse size are based on the earlier selection of 1 Standard Deviation. The orientation of the each ellipse is calculated by applying a trigonometric function that determines the best fit of both axes among the point features so that the distance from the points to the axes is minimized.

Monthly Dengue Ellipse

OBJECTID *	Shape *	Shape_Length	Shape_Area	CenterX	CenterY	XStdDist	YStdDist	Rotation	Month
1	Polygon	28147.459677	43957381.653831	380238.03	2048037.4	2242.7766	6239.7397	32.203838	August
2	Polygon	37099.392457	108915392.320909	380524.5	2048007.4	5539.5522	6258.7456	73.808434	December
3	Polygon	32267.421057	64214797.420285	382000.06	2048754.5	2956.6724	6914.0781	56.739971	July
4	Polygon	30374.600853	71306340.990599	379909.81	2048023.1	5480.0239	4142.0996	109.64059	June
5	Polygon	37620.905426	96363902.756763	378016.41	2050292	7691.8374	3988.1631	94.851517	March
6	Polygon	38253.520147	113682443.132076	381048.47	2048465.5	5298.8188	6829.4961	73.384796	November
7	Polygon	39822.565074	122280051.809375	380489.25	2048051.6	5394.3813	7215.8755	78.190247	October
8	Polygon	31910.677086	67750354.351824	381063.75	2049161.5	6608.9121	3263.4214	96.078659	September

Figure-3.37: Attribute Table of Monthly Dengue Ellipse Layer

d) **SPATIAL ANALYSIS FOR CORRELATING ENVIRONMENTAL FACTORS-** For this, create Fishnet tool was used to create a polygon grid with each grid having cell size as 1000 so, as to cover entire PMC boundary by setting the coordinate system of the output same as the Boundary layer and the geometry was set to polygon in order to get polygon feature as the output as in figure-3.38.

Then Integrate tool was twice used to maintain the integrity of shared feature boundaries 1. The Fishnet layer and the Electoral Wards layer 2. The Electoral Wards layer and the Dengue Cases-2012 layer by making either of both these features coincident if they fall within the specified XY tolerance (here value of XY tolerance was given as 400 for the first output and null for the second output) as shown in figure-3.39 and figure-3.40. Features those falls within the specified XY tolerance were considered identical or coincident. This tool inserts common coordinate vertices for features that fall within the given XY tolerance and add vertices where feature segments intersect. The value for XY tolerance is critical—a tolerance that is too large may collapse and delete polygons or lines, or move vertices that should not be moved. Thus, to minimize error, the value chosen for XY tolerance was kept as small as possible.

Lastly, Collect Events tool was used to combine coincident points by creating a new output feature class i.e. Collect Dengue Cases-2012 layer shown in figure- containing all of the unique locations found in the input feature class i.e. Dengue Cases-2012 layer. It then adds a field named ICount to hold the sum of all the dengue incidence cases at each unique location. This tool combines features that have the exact same X and Y centroid coordinates. Thus, this tool converts event data, such as dengue disease incidents, to weighted point data. Beryl green circles represent areas that experienced a dengue outbreak as depicted in figure-3.41. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa. This layer was overlaid with all other environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), Water Bodies, etc.

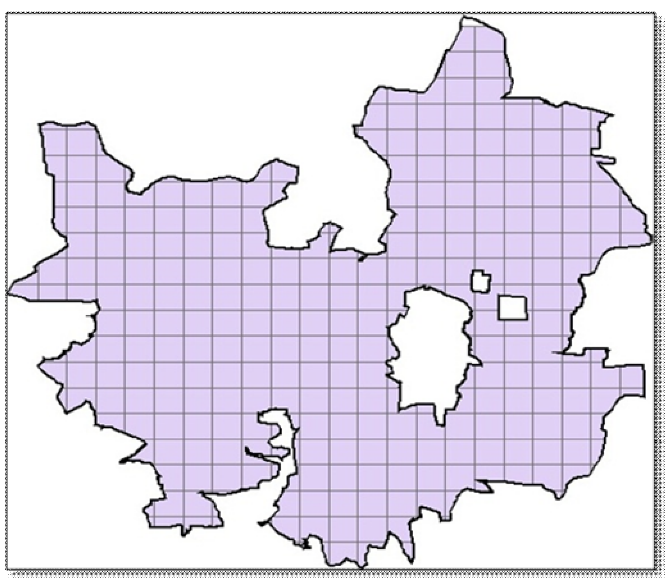


Figure-3.38: Fishnet Layer

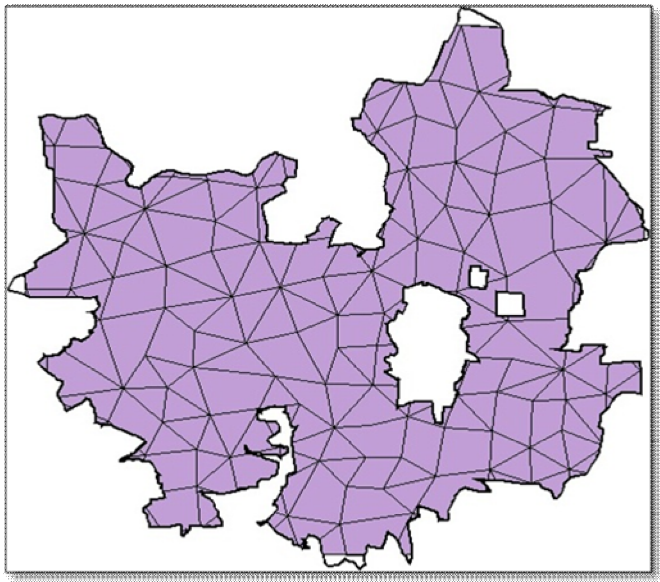


Figure-3.39: Integration of Fishnet Layer & Electoral Wards Layer

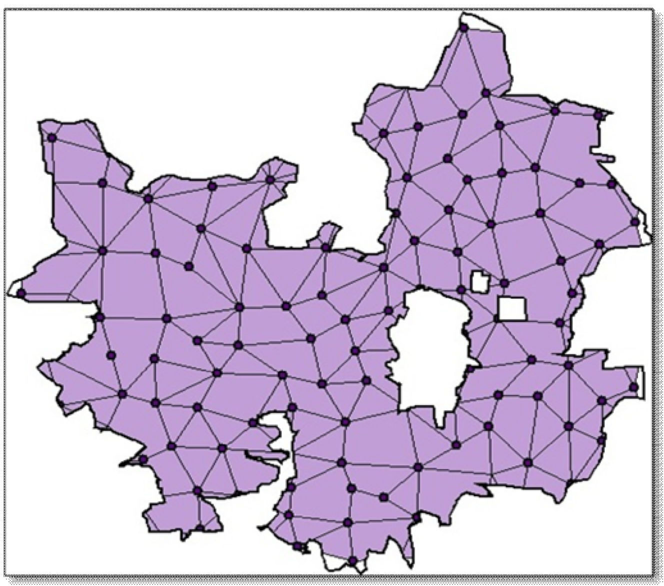


Figure-3.40: Integration of Electoral Wards Layer & Dengue Cases-2012 Layer

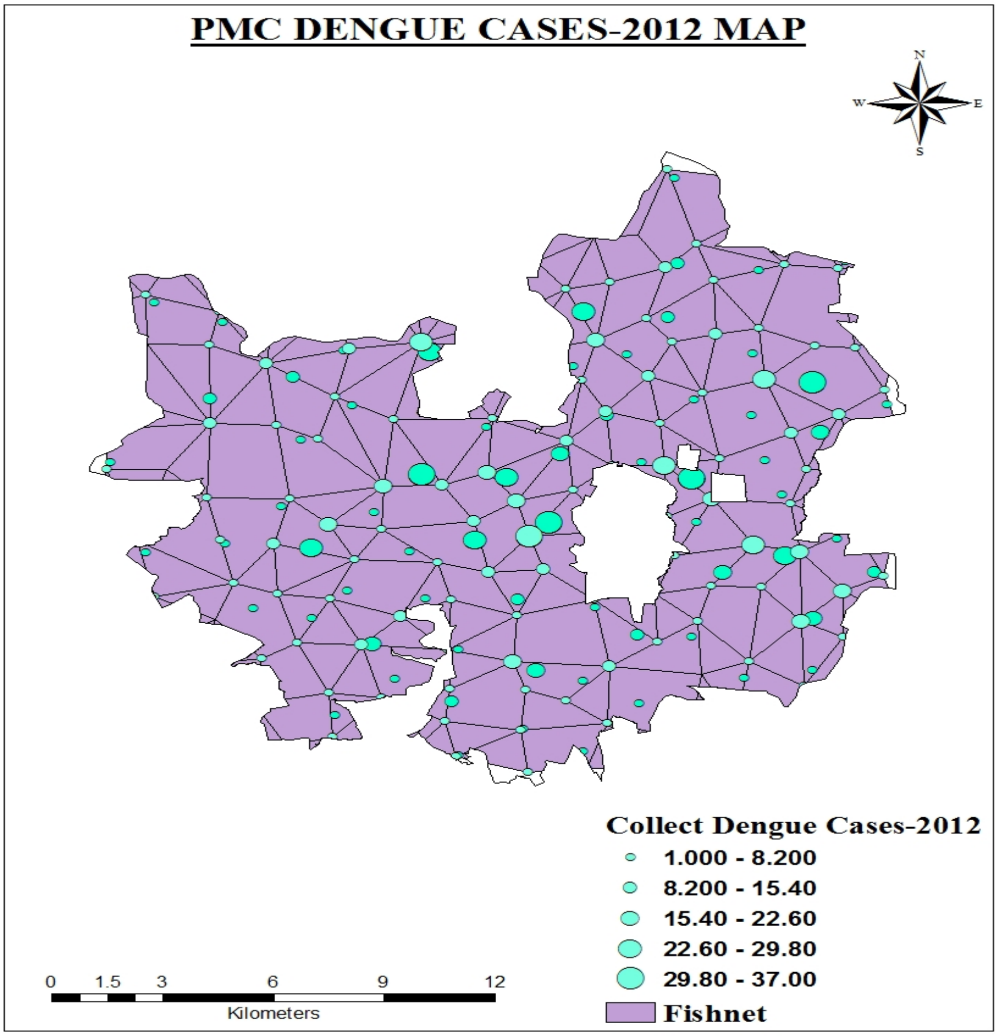


Figure-3.41: Collect Dengue Cases-2012 Layer

1. ***Correlation between Dengue Incidences Distribution (2012) & Land Use/Land Cover (LULC)***: Figure-3.42 shows the collect dengue cases-2012 layer created as mentioned above overlaid on the land use and land cover layer obtained from LANDSAT 7 (ETM+) satellite image. Beryl green circles represent areas that experienced a dengue outbreak. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa.

From the classification result, it was found that most cases occurred in urban areas, followed by sub-urban areas and some in construction areas. Just a few cases were reported in the industrial and vegetated areas. The reason why dengue cases occur mostly in urban areas can be explained by a number of factors. For an urban area, proper infrastructure such as a good drainage system is very important. A poor drainage system will create pools of stagnant water, which are suitable breeding grounds for mosquitoes [Gong Peng X B**,** 2006]. The same problem occurs in construction areas and squatter areas. In areas with a high population density (such as flats, apartments and condominiums), the population density per square meter is high. As a result dengue transmission can and will occur rapidly [Gong Peng X B**,** 2006].

The figure-3.42 shows the positive correlation contribution of urban and sub-urban areas to the dengue outbreak distribution pattern. Most of the reported cases had occurred near such areas. This is supported by findings conducted by MOH. The Aedes breeding sites identified by MOH are construction sites, slums, recreational areas, cleared land areas, schools, government offices, and abandoned housing projects, places of worship, shops and dumpsites.

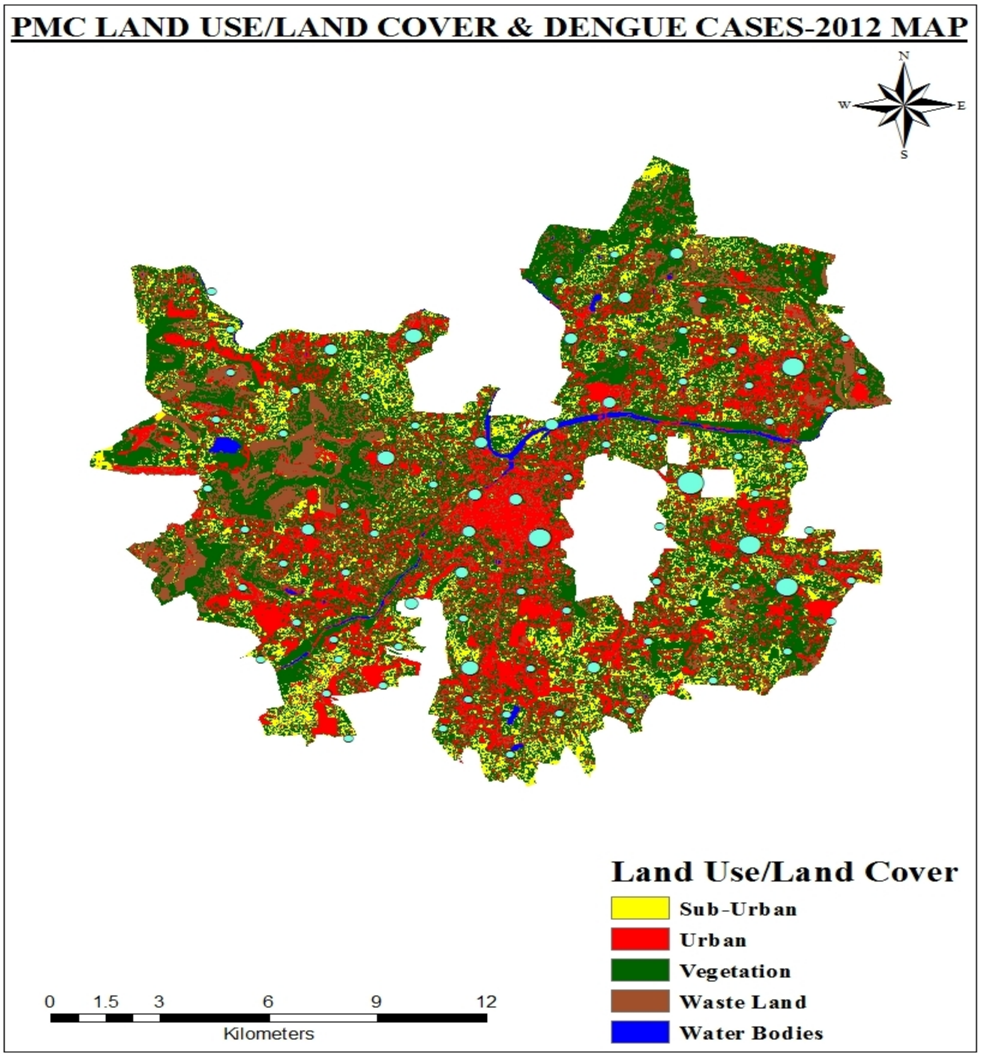


Figure-3.42: Correlation between Dengue Cases-2012 & Land Use/Land Cover Map

2. ***Correlation between Dengue Incidences Distribution (2012) & Land Surface Temperature (LST)**:* The Land Surface Temperature (LST) map that was generated from the thermal band (band 6) of LANDSAT 7 (ETM+) satellite represents the temperature distribution of the land surface over the study area. Figure-3.43 shows the collect dengue cases-2012 layer created as mentioned above overlaid on the land surface temperature layer. Beryl green circles represent

areas that experienced a dengue outbreak. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa. The comparison between the LST obtained with the pattern distribution of dengue incidence cases shows that the number of incidence cases is mainly influenced by the trend of LST distribution, whereby areas with high LST readings show more cases recorded within that area itself when compared to areas with low LST readings. The distribution trend of recorded high incidence cases is pursuant with the high LST trend distribution. The results show that the LST is an important environmental factor that needs to be used to determine the potential areas for a dengue outbreak. The high LST areas are what the Aedes mosquito needs in order for it to breed quickly.

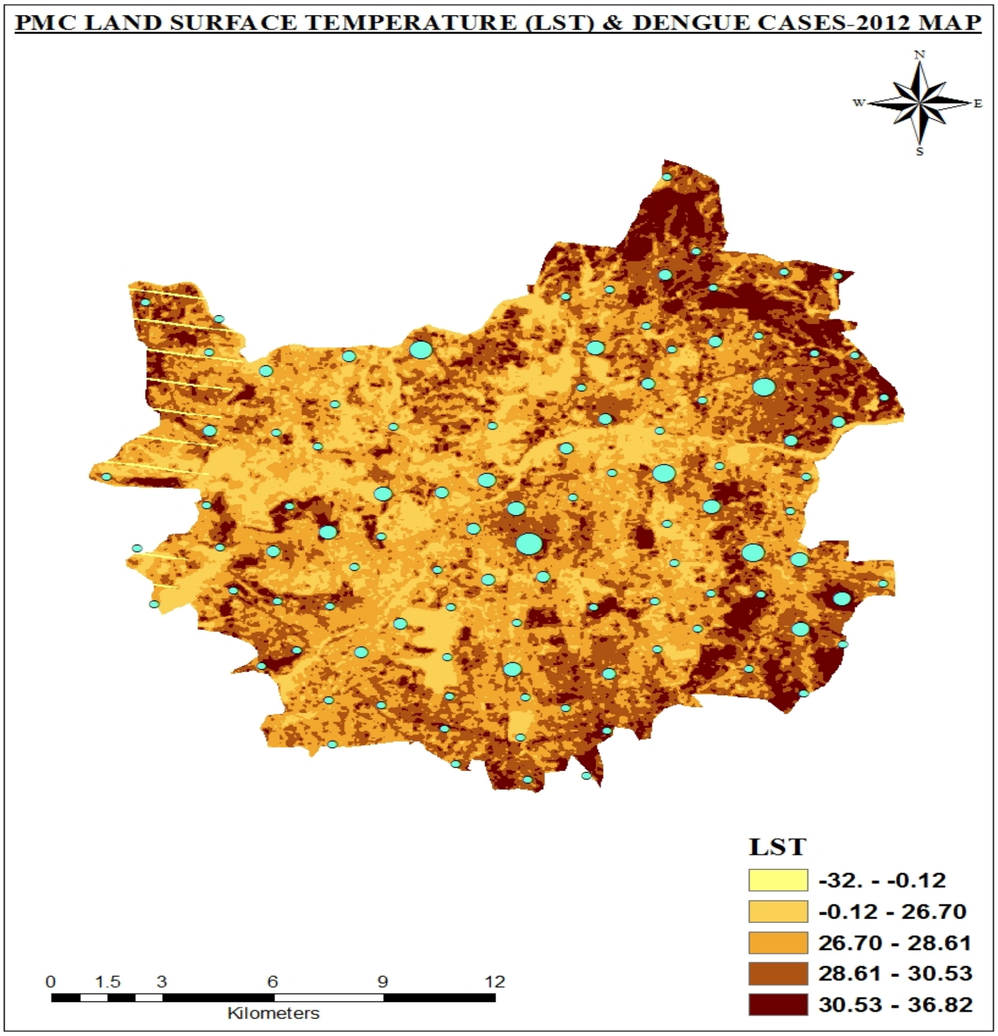


Figure-3.43: Correlation between Dengue Cases-2012 & Land Surface Temperature Map

3. ***Correlation between Dengue Incidences Distribution (2012) & Normalized Difference Vegetation Index (NDVI)**:* When the collect dengue cases-2012 layer created as mentioned above was overlaid with the NDVI map, the result shows that most of the cases had occurred in the non-vegetated areas. This means that vegetation is not a major indicator to predict a dengue outbreak area as most of the cases had occurred in urban areas [Maynard N.G., 2002]. Beryl green circles

represent areas that experienced a dengue outbreak. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa.

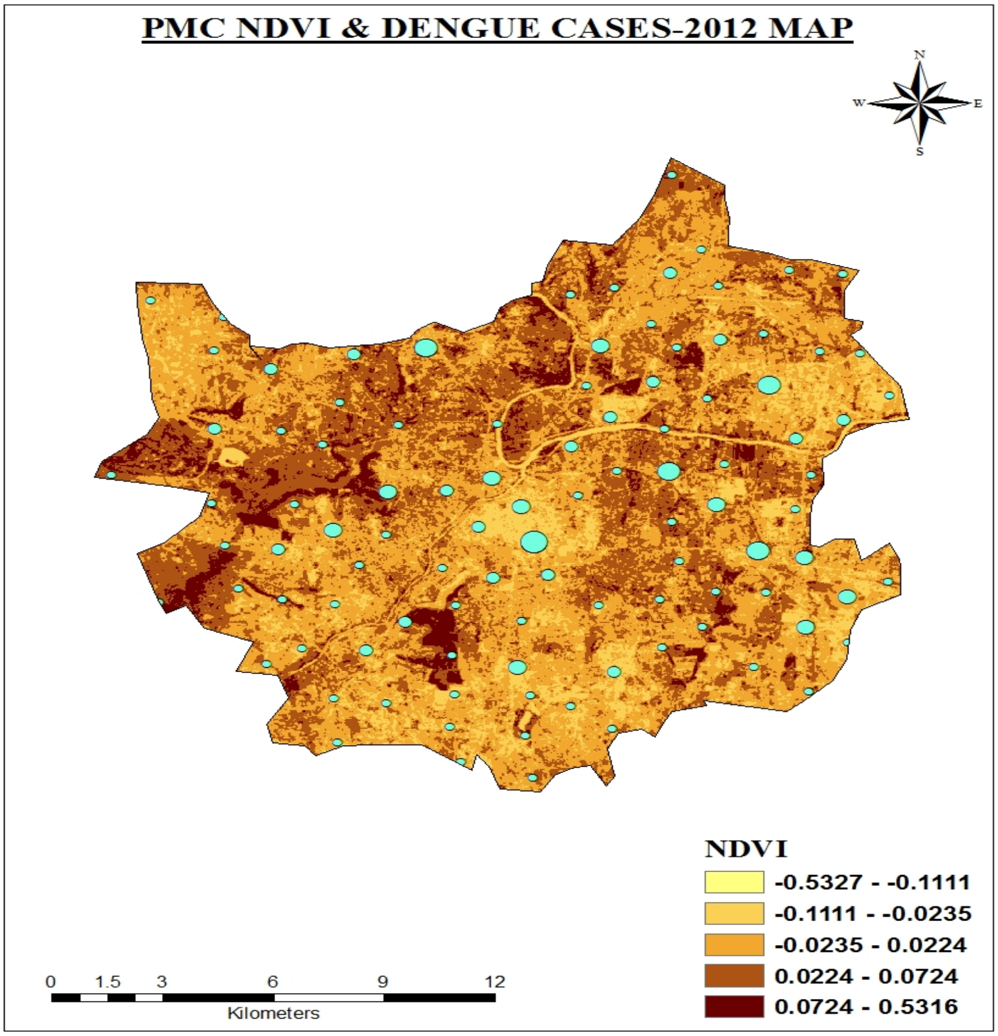


Figure-3.44: Correlation between Dengue Cases-2012 & NDVI Map

4. ***Correlation between Dengue Incidences Distribution (2012) & Slope:*** Figure- shows the collect dengue cases-2012 layer created as mentioned above overlaid on the slope layer obtained from DEM data. Beryl green circles represent areas

that experienced a dengue outbreak. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa. In this study area however, its elevation is not very important as most of the dengue cases were reported in low land areas but still needs to be taken into account in the dengue risk map developing analysis [Maynard N.G., 2002].

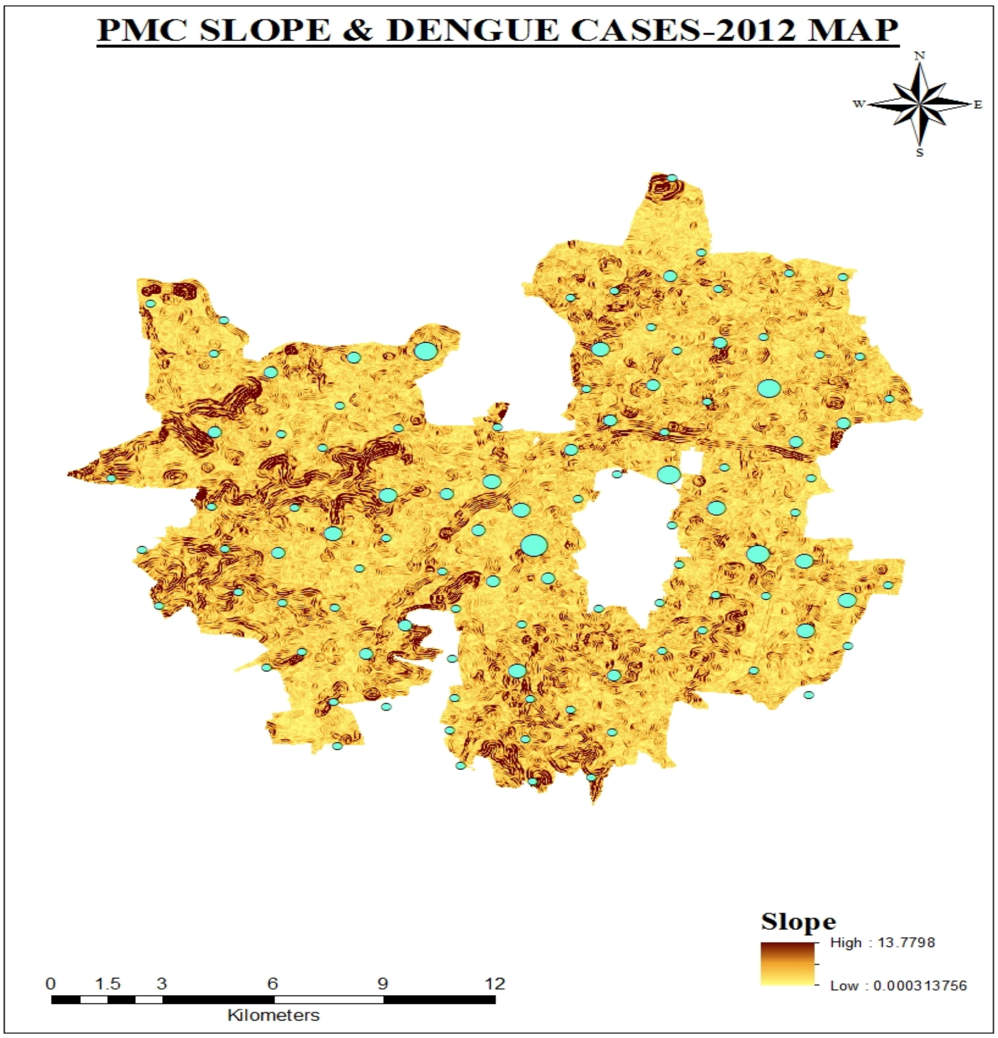


Figure-3.45: Correlation between Dengue Cases-2012 & Slope Map

5. ***Correlation between Dengue Incidences Distribution (2012) & Open Water Bodies:*** Figure-3.46 shows the collect dengue cases-2012 layer created as mentioned above overlaid on the open water bodies layer obtained from PMC's Water Supply Department data. Beryl green circles represent areas that experienced a dengue outbreak. The size of the circle represents the severity of the outbreak with big circles representing major outbreak areas and vice versa. In this study area however, its open water bodies are not very important as the dengue mosquito does not breed in open drains and also most of the dengue cases were reported away from the open water bodies [Maynard N.G., 2002].

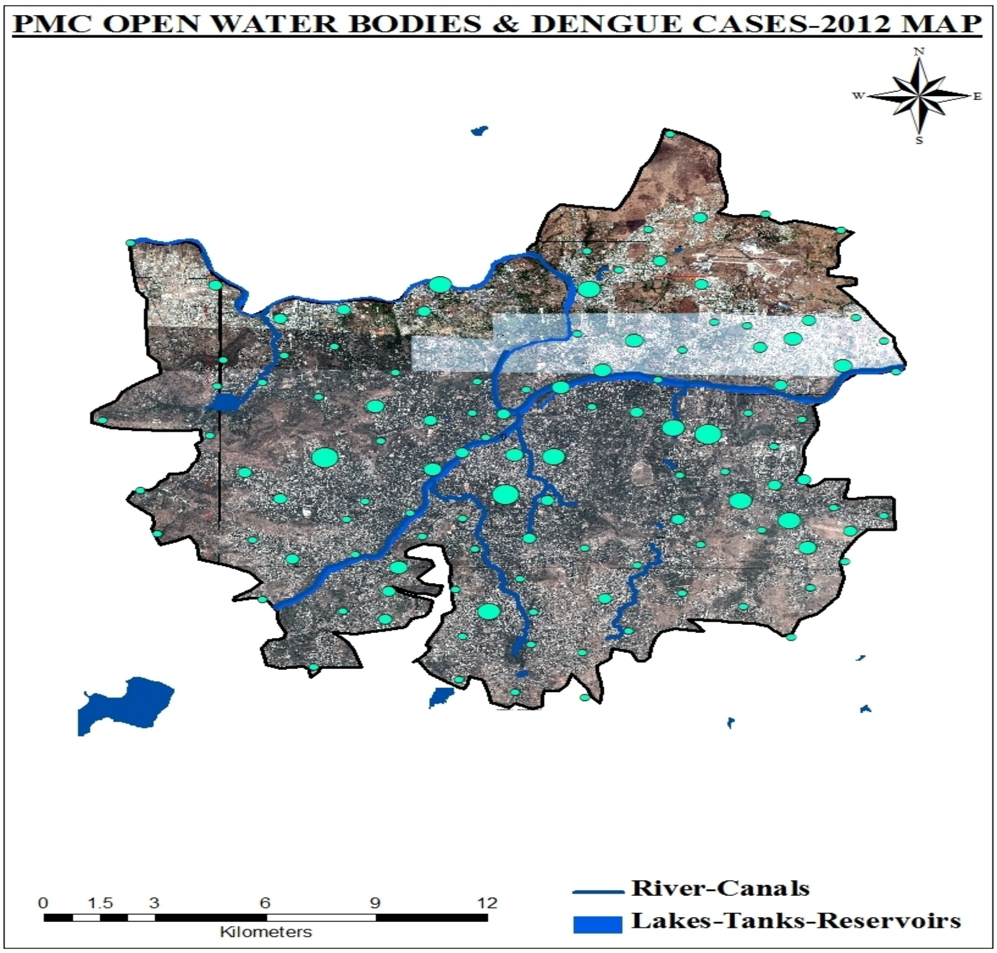


Figure-3.46: Correlation between Dengue Cases-2012 & Open Water Bodies Map

e) **SPATIAL ANALYSIS FOR DEVELOPING DENGUE RISK MAP (DRM) BASED ON ENVIRONMENTAL FACTORS-** The Dengue Risk Map generated from environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. that were obtained from LANDSAT 7 (ETM+) satellite data was classified as "Low", "Medium" and "High" risk potential areas of having the dengue outbreak.

For this, firstly all the four environmental layers as mentioned above were reclassified using Reclassify tool in order to classify each of the above mentioned layers as "Low" having value as "1", "Medium" having value as "2" and "High" having value as "3" risk potential areas of having dengue outbreak.

Finally, each of the four reclassified environmental layers was tested using the Weighted Overlay Function technique in the ArcGIS 10 software. This technique is usually used for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. The priority value was ranked as "Low", "Medium" and "High" (1 to 3) for each layer. A low value means the sub variable had a low intensity influence; a medium value equated to a greater risk influence to the outbreak and a high value equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The detailed weighting values for all four environmental variables that were identified as an indicator factor of dengue outbreak are presented in Figure-3.55.

1. ***Reclassification of Land Use/Land Cover (LULC) Layer**:* The Reclassify tool was used to classify Land Use/ Land Cover (LULC) layer into three as shown in figure-3.47. The variables in the LULC layer were classified: Water Bodies and Vegetation as "Low" with pixel value as "1", Waste Land as "Medium" with pixel value as "2" and Urban and Sub-Urban as "High" with value as "3" as shown in figure-3.47. A low value means Water Bodies and Vegetation variables have a low intensity influence; a medium value means Waste Land variable is equated to a greater risk influence to the dengue outbreak and a high value means Urban and Sub-Urban variables are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified land use/land cover layer is shown in figure-3.48.

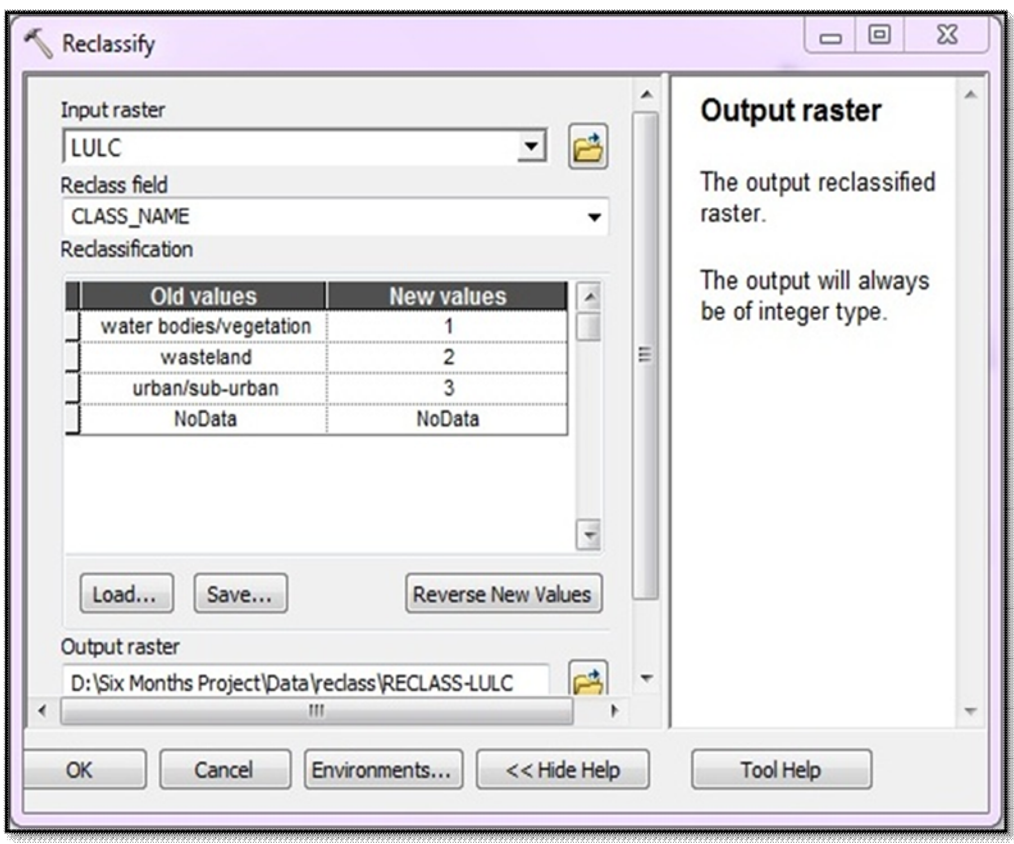


Figure-3.47: Reclassification of Land Use/Land Cover (LULC) Layer

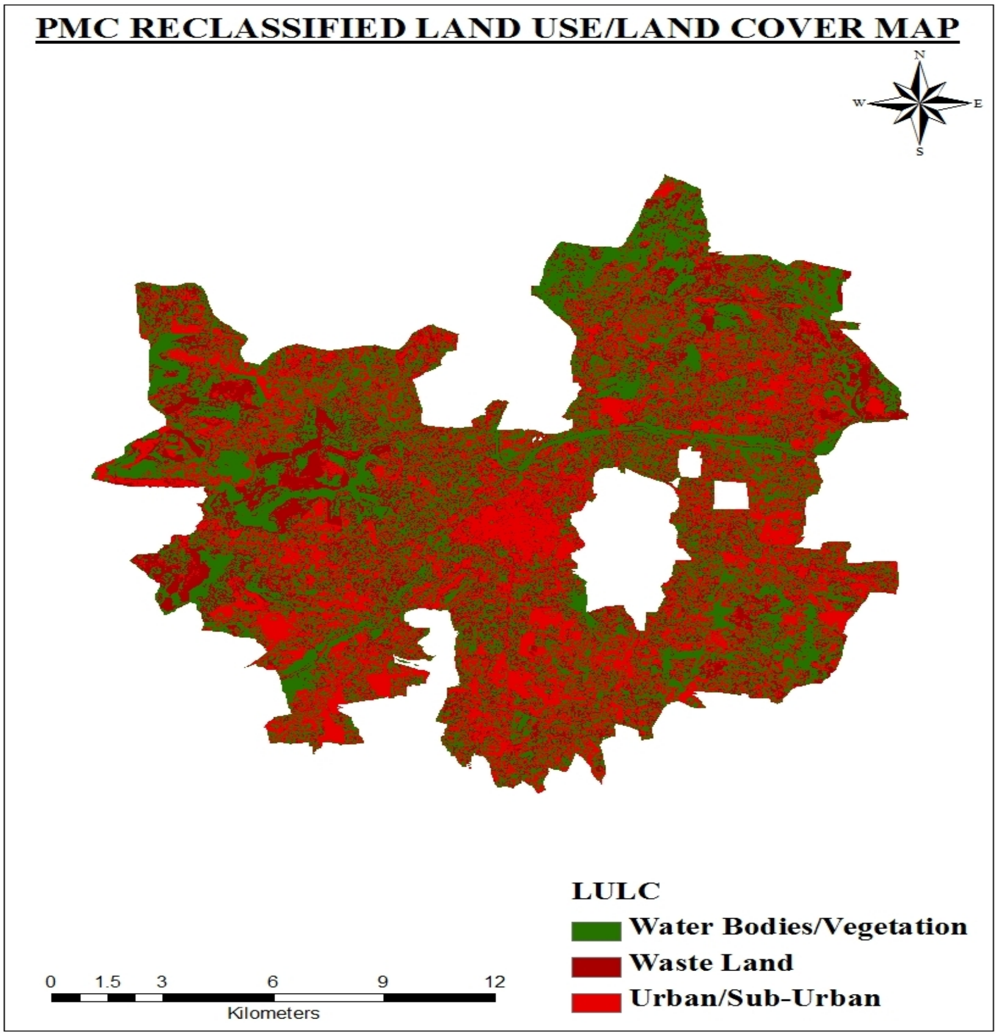


Figure-3.48: PMC Reclassified Land Use/Land Cover (LULC) Map

2. ***Reclassification of Land Surface Temperature (LST) Layer****:* The Reclassify tool was used to classify Land Surface Temperature (LST) layer into five classes as shown in figure-3.49. The variables in the LST layer were classified: temperature variables from -32.9793 to 26.7000 as "Low" with pixel value as "1", temperature variables from 30.5326 to 36.8291 as "Medium" with pixel value as "2" and

temperature variables from 26.7000 to 30.5326 as "High" with value as "3" as shown in figure-3.49. A low value means temperature variables from -32.9793 to 26.7000 have a low intensity influence; a medium value means temperature variables from 30.5326 to 36.8291 are equated to a greater risk influence to the dengue outbreak and a high value means temperature variables from 26.7000 to 30.5326 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified land surface temperature (LST) layer is shown in figure-3.50.

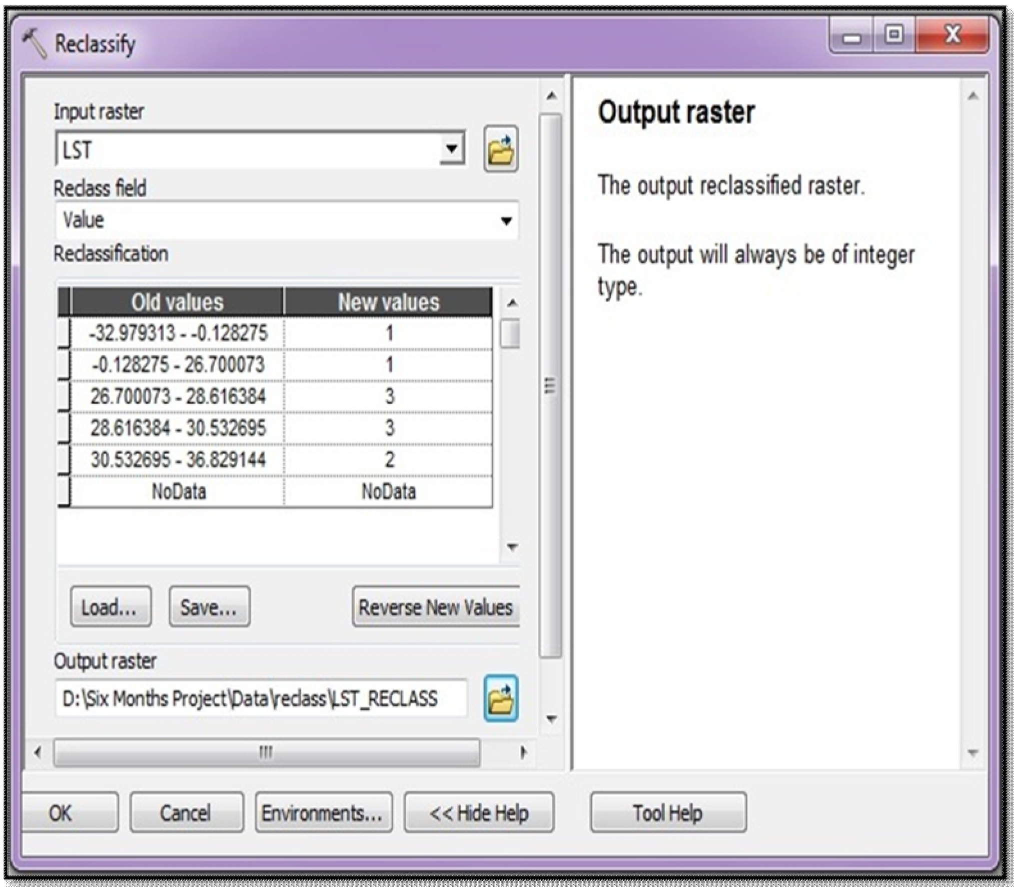


Figure-3.49: Reclassification of Land Surface Temperature (LST) Layer

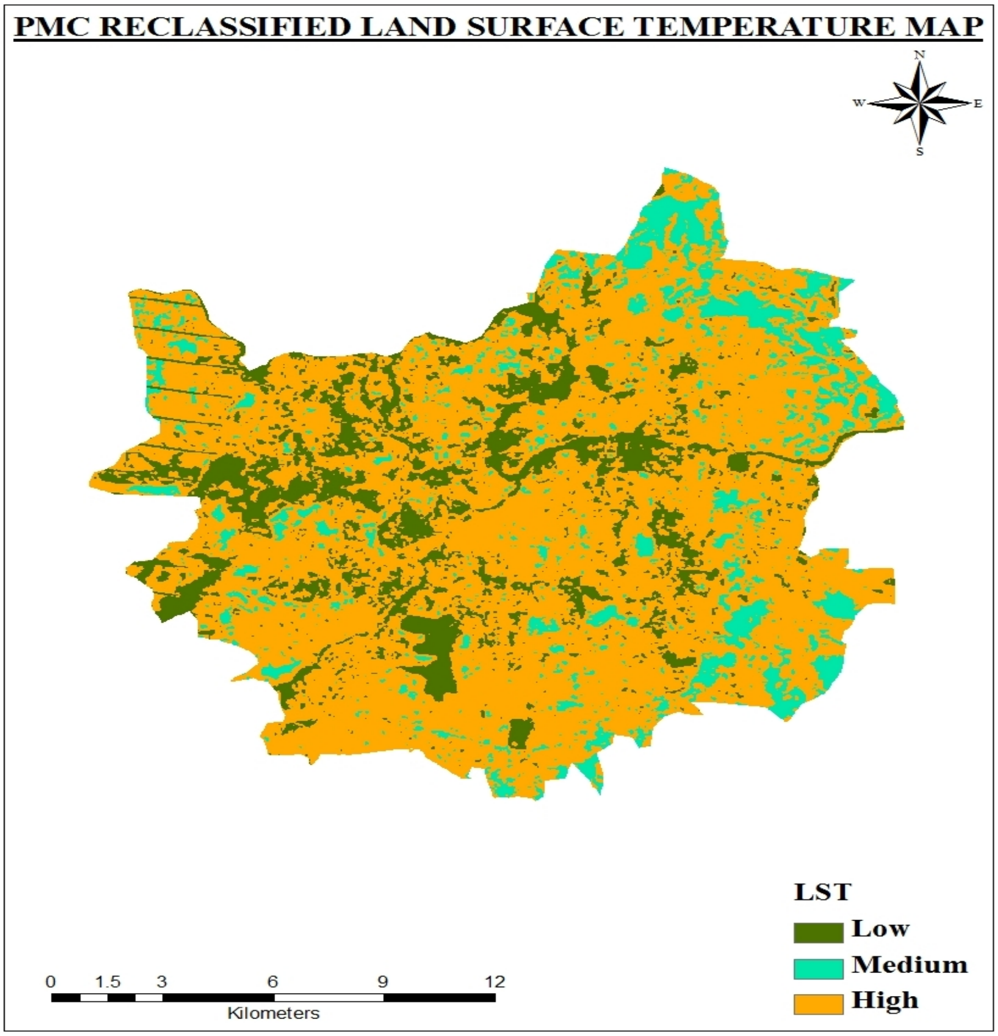


Figure-3.50: PMC Reclassified Land Surface Temperature (LST) Map

3. ***Reclassification of Normalized Difference Vegetation Index (NDVI) Layer***: The Reclassify tool was used to classify Normalized Difference Vegetation Index (NDVI) layer into seven classes as shown in figure-3.51. The variables in the NDVI layer were classified: NDVI variables from 0.0576 to 0.5316 as "Low" with pixel value as "1", NDVI variables from 0.0160 to 0.0576 as "Medium" with

pixel value as “2” and NDVI variables from -0.5327 to 0.0160 as “High” with value as “3” as shown in figure-3.51. A low value means NDVI variables from 0.0576 to 0.5316 have a low intensity influence; a medium value means NDVI variables from 0.0160 to 0.0576 are equated to a greater risk influence to the dengue outbreak and a high value means NDVI variables from -0.5327 to 0.0160 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Normalized Difference Vegetation Index (NDVI) layer is shown in figure-3.52.

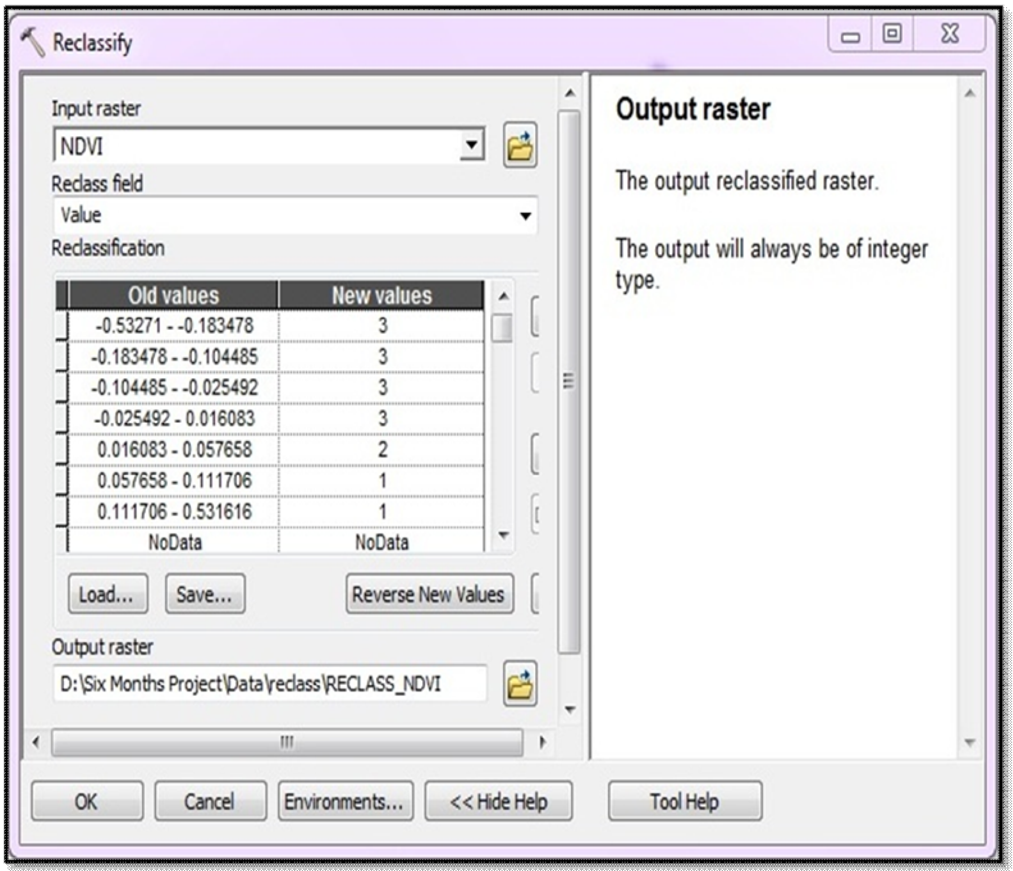


Figure-3.51: Reclassification of Normalized Difference Vegetation Index (NDVI) Layer

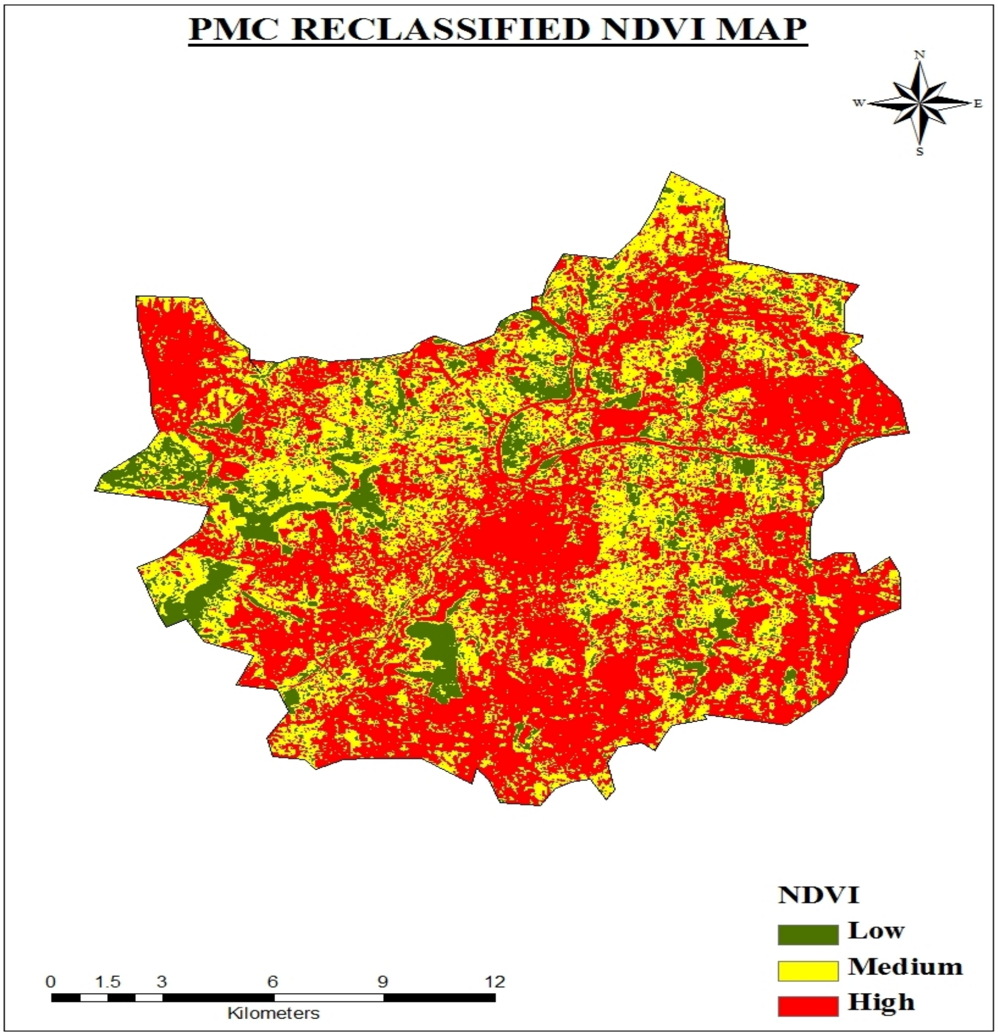


Figure-3.52: PMC Reclassified Normalized Difference Vegetation Index (NDVI) Map

4. ***Reclassification of Slope (High Land and Low Land areas)****:* The Reclassify tool was used to classify Slope layer into twelve classes as shown in figure-3.53. The variables in the Slope layer were classified: Slope variables from 0.0576 to 0.5316 as "Low" with pixel value as "1", Slope variables from 0.0160 to 0.0576 as "Medium" with pixel value as "2" and Slope variables from -0.5327 to 0.0160 as "High" with value as "3" as shown in figure-3.53. A low value means Slope

variables from 0.0576 to 0.5316 have a low intensity influence; a medium value means Slope variables from 0.0160 to 0.0576 are equated to a greater risk influence to the dengue outbreak and a high value means Slope variables from -0.5327 to 0.0160 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Slope layer is shown in figure-3.54.

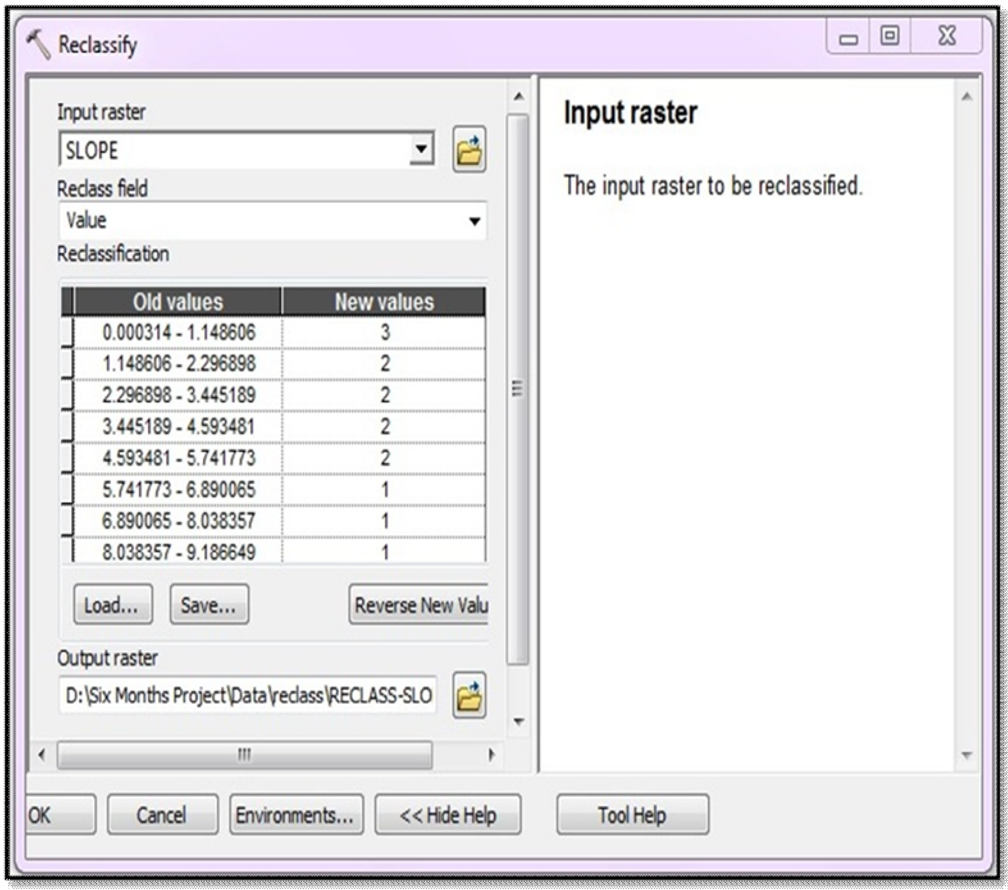


Figure-3.53: Reclassification of Slope Layer

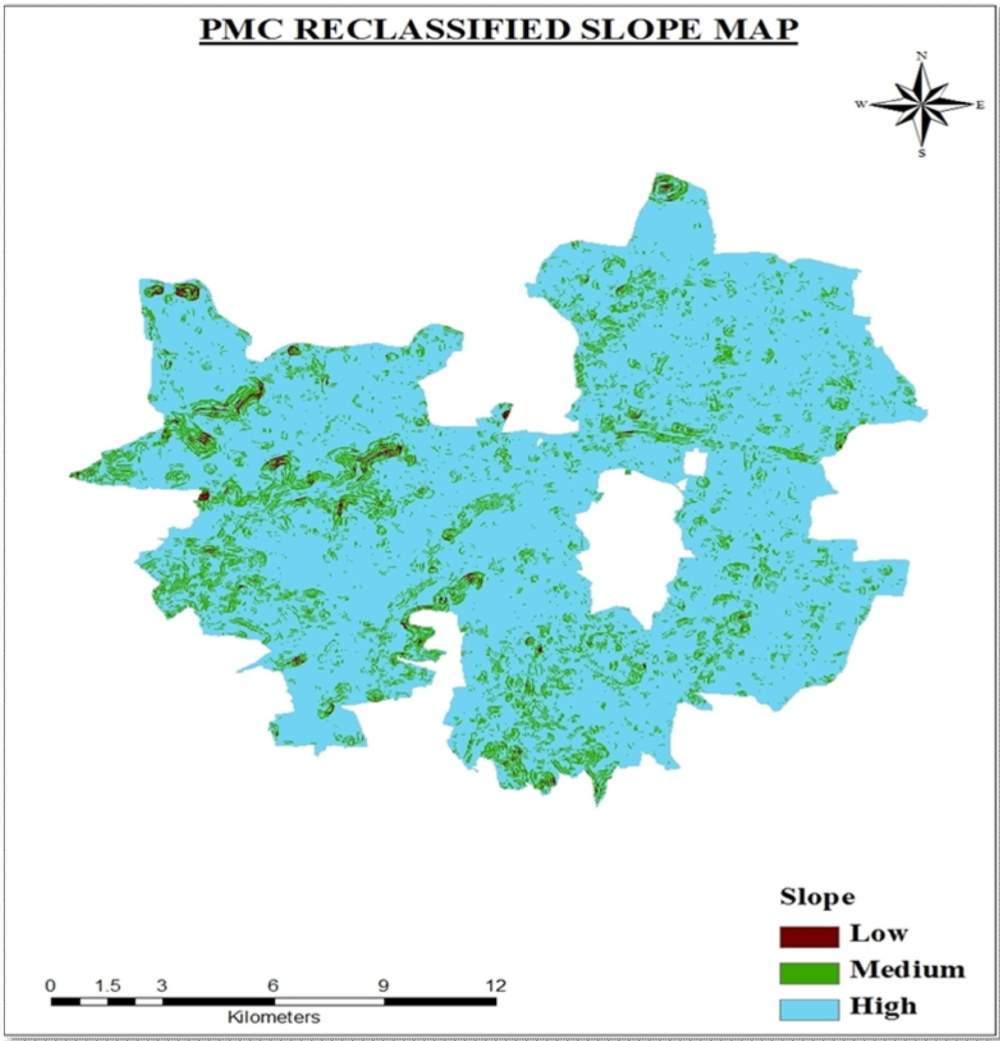


Figure-3.54: PMC Reclassified Slope Map

5. ***Development of Dengue Risk Map Using Weighted Overlay Analysis:*** Weighted Overlay technique overlays several raster datasets using a common measurement scale and weights each according to its importance. Here, all the reclassified environmental layers such as Land Use/Land Cover (LULC), Normalized

Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. were tested.

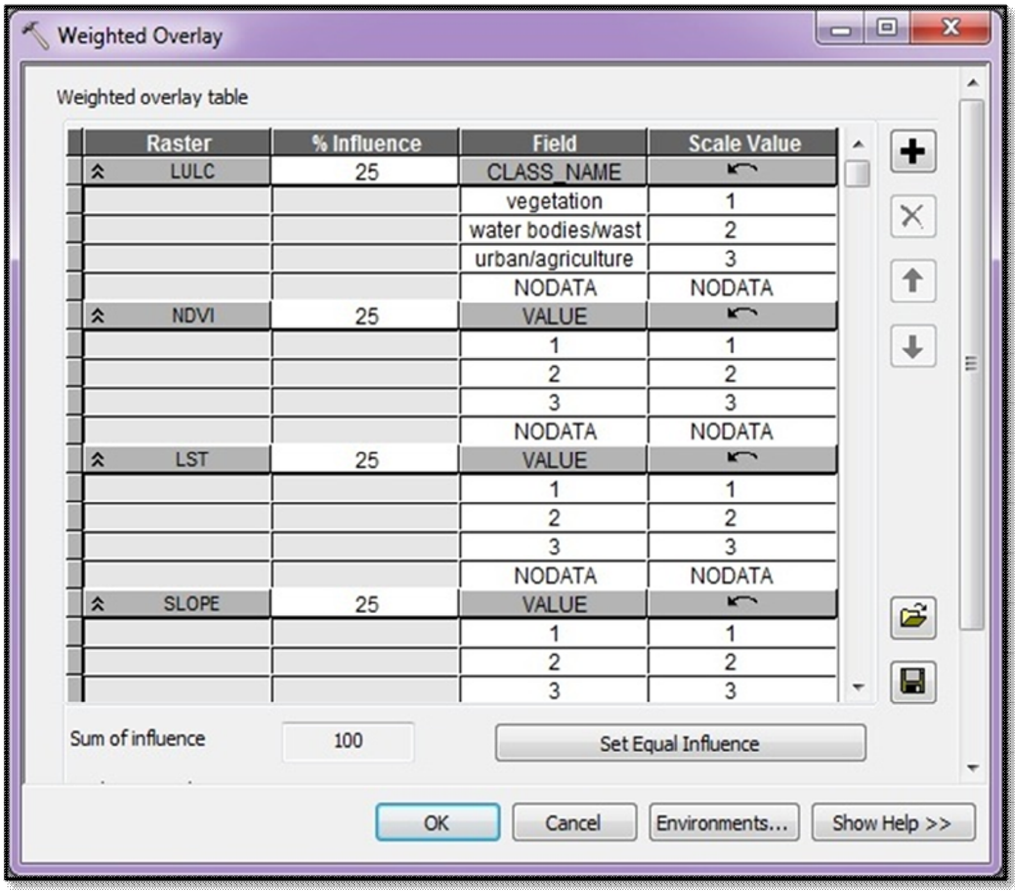


Figure-3.55 Weighted Overlay Table

The Dengue Risk Map generated from environmental factors that were obtained from remote sensing data was classified as “Low”, “Medium” and “High” risk potential areas of having the dengue outbreak. For the information obtained, the following algorithm was used to develop the dengue risk map from each environmental indicator as shown below.

Dengue Risk Map= LULC (A) + NDVI (B) + LST (C) + SLOPE (D)

The Dengue Risk Map that was generated based on environmental factors shows a strong connection with the reported (real) dengue incidence case locations or recorded outbreak areas for the year 2012. Figure-3.56 shows the Dengue Risk Map with the point location of the dengue incidence cases-2012 as a verification of the dengue risk map areas. The results shows that most of the dengue incidences had occurred in the high risk areas categorize in the dengue risk map generated from the environmental factors. This means that the Dengue Risk Map can be used as a tool to identify the potential areas of a dengue outbreak occurrence. All major reported dengue outbreak areas were found to fall within areas identified in the Dengue Risk Map as being “High”, and in some cases “Medium”. This finding is very encouraging as it validates the accuracy of the generated Dengue Risk Map when compared with the reported dengue cases-2012 within the municipality area of PMC.

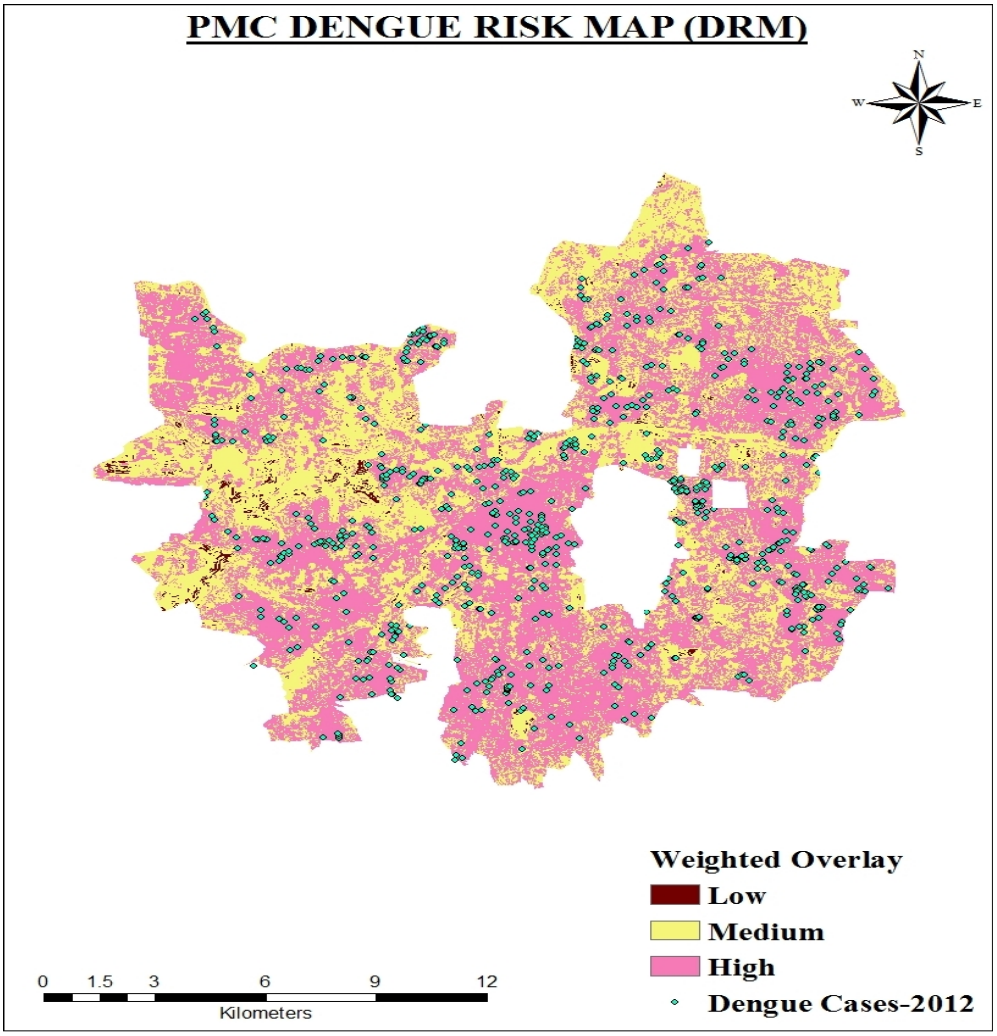


Figure-3.56: PMC Dengue Risk Map (DRM)

f) **SPATIAL ANALYSIS FOR DEVELOPING DENGUE RISK MAP (DRM) BASED ON SOCIO-ECONOMIC FACTORS-** The Dengue Risk Map generated from socio-economic factors such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases-2012, Total Slums-2012, Total Gardens-2012, etc. that were obtained from PMC 's Census, Health, Slum, Garden, etc. Departments was classified as “Low”, “Medium” and “High” risk potential areas of having the dengue outbreak.

For this, firstly all the seven socio-economic layers as mentioned above were reclassified using Reclassify tool in order to classify each of the above mentioned layers as “Low” having value as “1”, “Medium” having value as “2” and “High” having value as “3” risk potential areas of having dengue outbreak.

Finally, each of the seven reclassified socio-economic layers was tested using the Weighted Overlay Function technique in the ArcGIS 10 software. This technique is usually used for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. The priority value was ranked as “Low”, “Medium” and “High” (1 to 3) for each layer. A low value means the sub variable had a low intensity influence; a medium value equated to a greater risk influence to the outbreak and a high value equated to a very significant influence on the dengue outbreak pattern **[**Napier M**,** 2003]. The detailed weighting values for all four environmental variables that were identified as an indicator factor of dengue outbreak are presented in Figure-3.71.

1. ***Reclassification of Dengue Cases-2012:*** The Reclassify tool was used to classify Dengue Cases-2012 layer into eleven classes as shown in figure-3.57. The variables in the Dengue Cases-2012 layer were classified: Dengue Cases variables from 0 to 5 as “Low” with pixel value as “1”, Dengue Cases from 5 to 10 as “Medium” with pixel value as “2” and Dengue Cases from 10 to 36 as “High” with value as “3” as shown in figure-3.57. A low value means Dengue Cases from 0 to 5 have a low intensity influence; a medium value means Dengue Cases from 5 to 10 are equated to a greater risk influence to the dengue outbreak and a high

value means Dengue Cases from 10 to 36 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Dengue Cases-2012 layer is shown in figure-3.58.

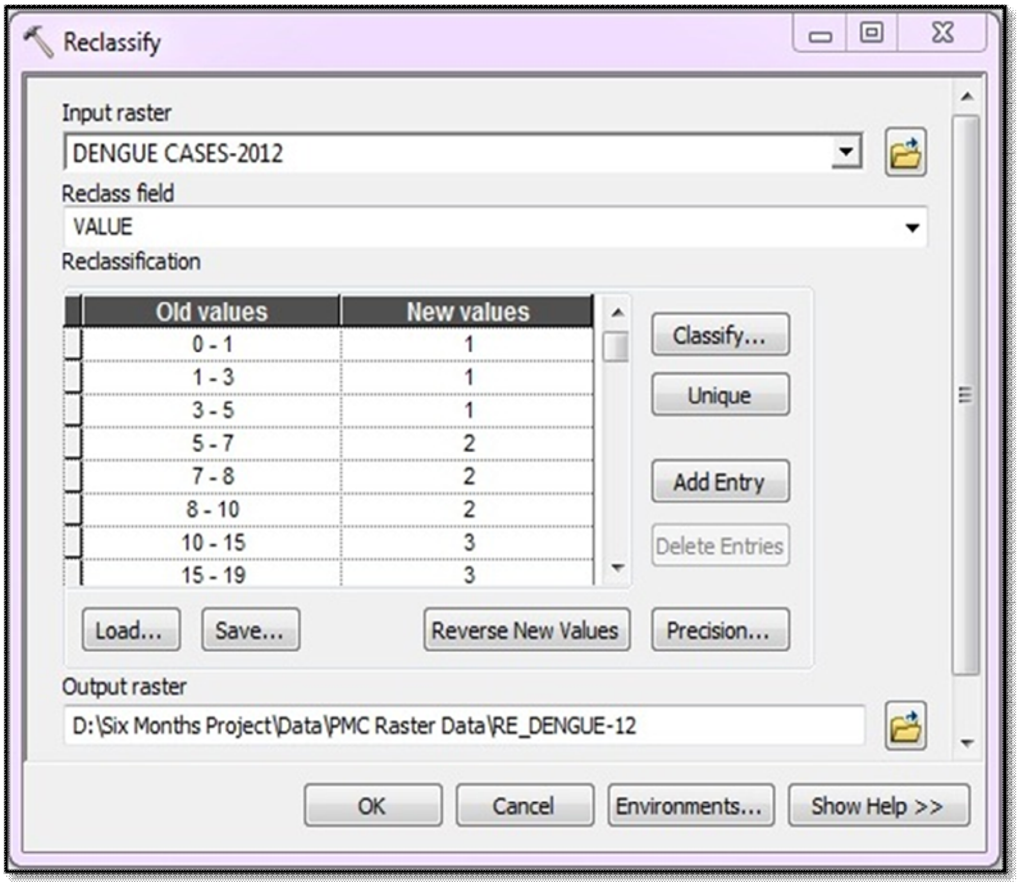


Figure-3.57: Reclassification of Dengue Cases-2012 Layer

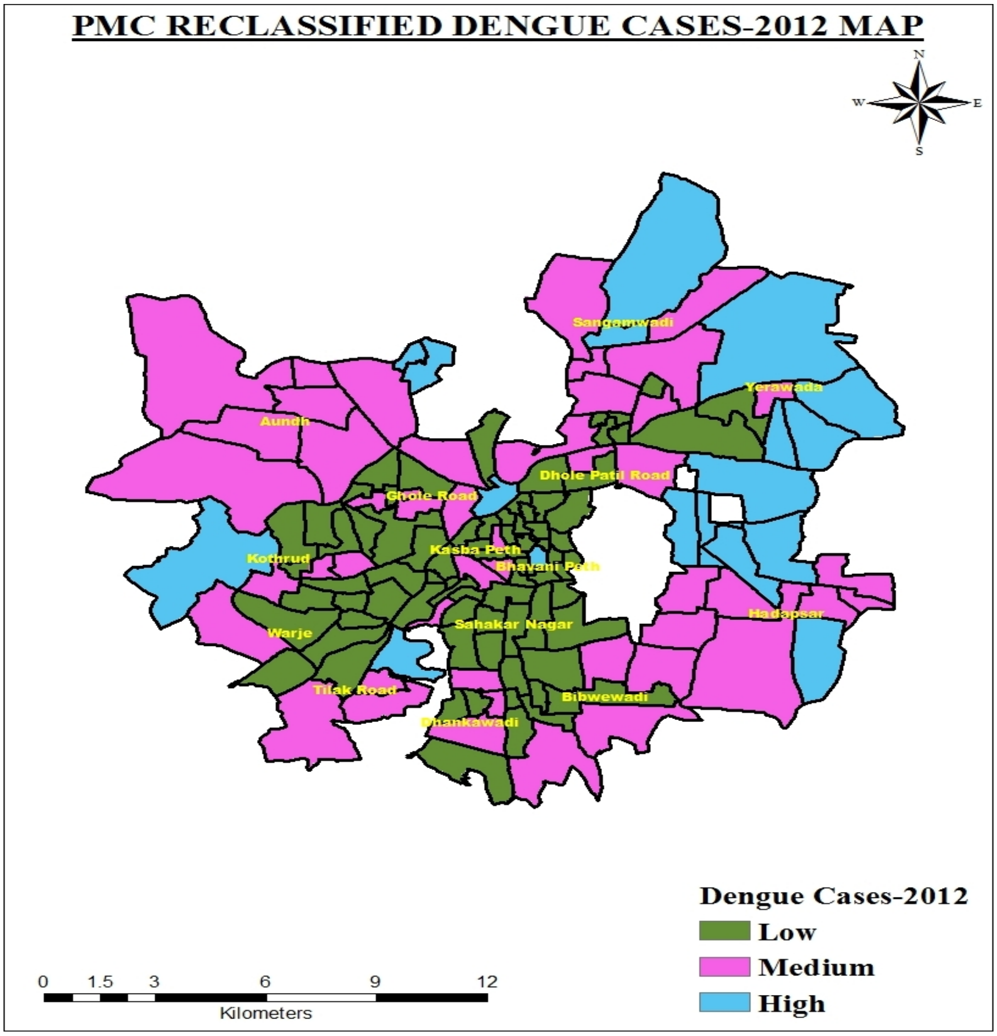


Figure-3.58: PMC Reclassified Dengue Cases-2012 Map

2. ***Reclassification of Total Slums-2012***: The Reclassify tool was used to classify Total Slums-2012 layer into five classes as shown in figure-3.59. The variables in the Total Slums-2012 layer were classified: Slum variables from 0 to 2 as "Low" with pixel value as "1", Slum variables from 2 to 5 as "Medium" with pixel value

as “2” and Slum variables from 5 to 18 as “High” with value as “3” as shown in figure-3.59. A low value means Slum variables from 0 to 2 have a low intensity influence; a medium value means Slum variables from 2 to 5 are equated to a greater risk influence to the dengue outbreak and a high value means Slum variables from 5 to 18 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Total Slums-2012 layer is shown in figure-3.60.

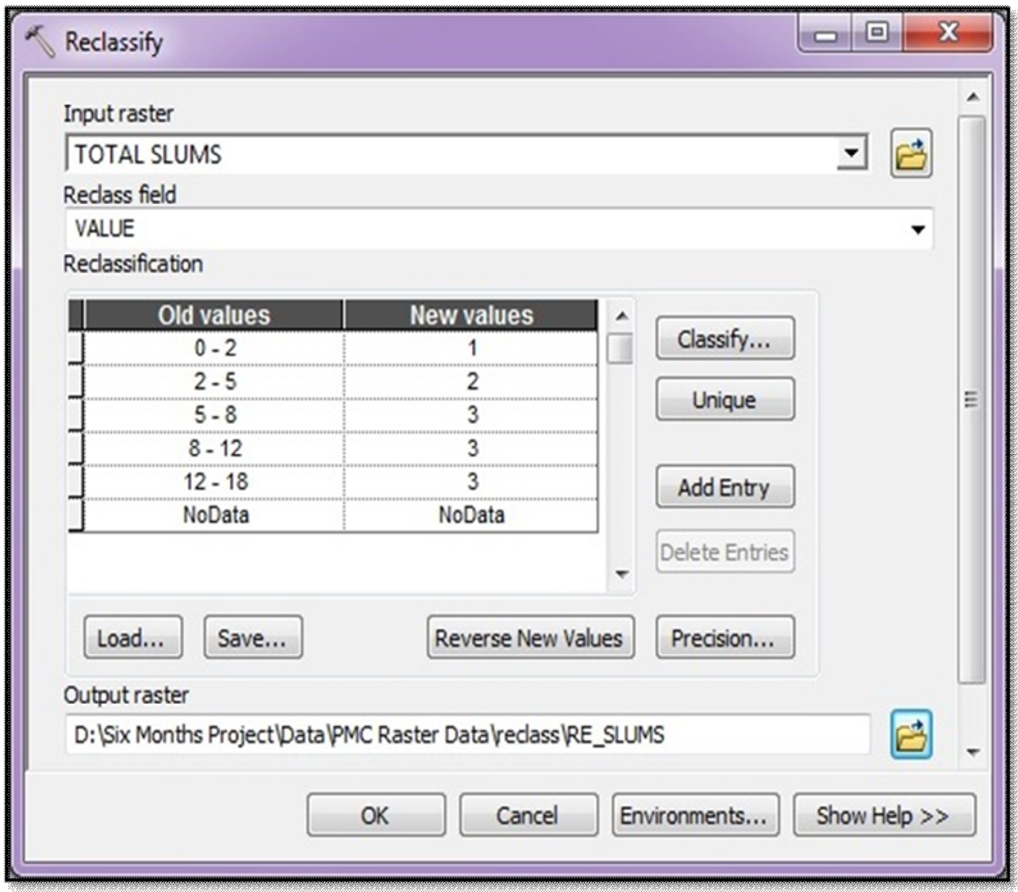


Figure-3.59: Reclassification of Total Slums-2012 Layer

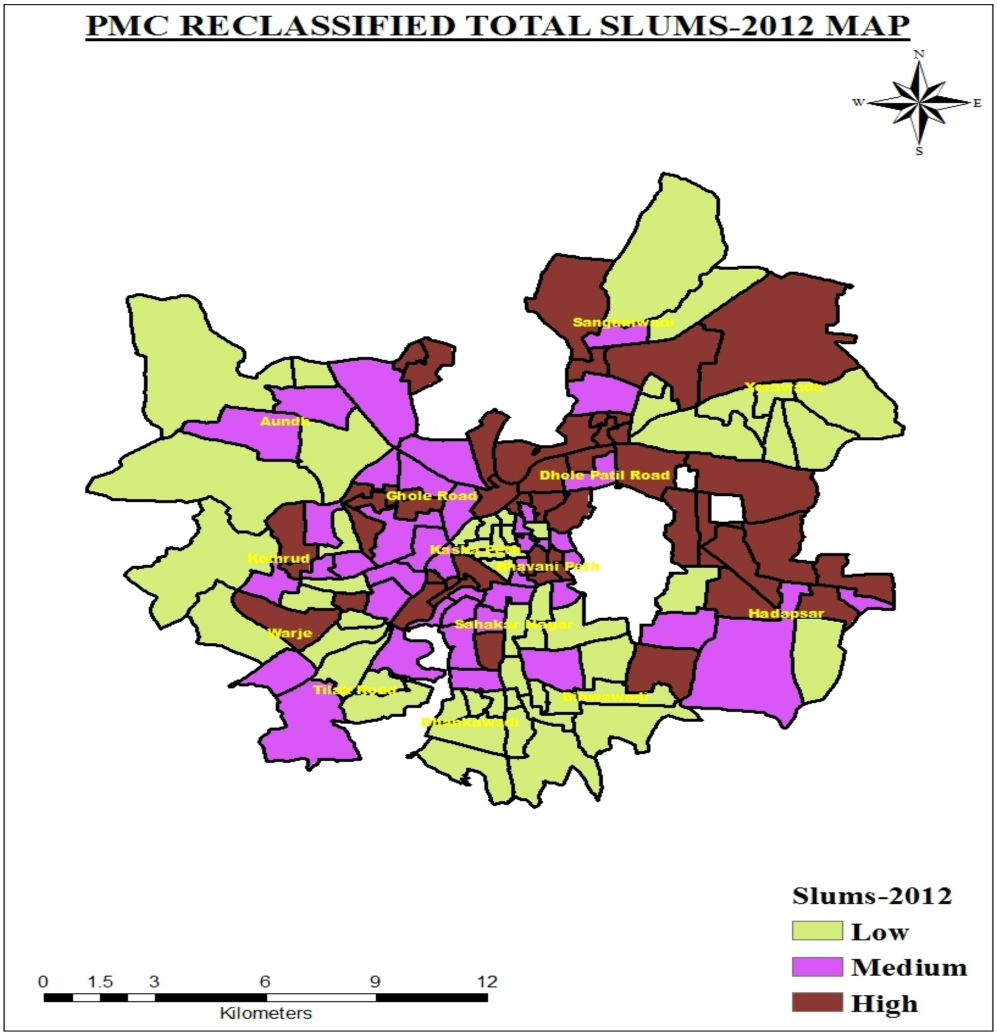


Figure-3.60: PMC Reclassified Total Slums-2012 Map

3. ***Reclassification of Total Gardens-2012:*** The Reclassify tool was used to classify Total Gardens-2012 layer into four classes as shown in figure-3.61. The variables in the Total Gardens-2012 layer were classified: Garden variables 0 as "Low" with pixel value as "1", Garden variables from 0 to 3 as "Medium" with pixel value as "2" and Garden variables from 3 to 5 as "High" with value as "3" as

shown in figure-3.61. A low value means Garden variables 0 have a low intensity influence; a medium value means Garden variables from 0 to 3 are equated to a greater risk influence to the dengue outbreak and a high value means Garden variables from 3 to 5 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Total Gardens-2012 layer is shown in figure-3.62.

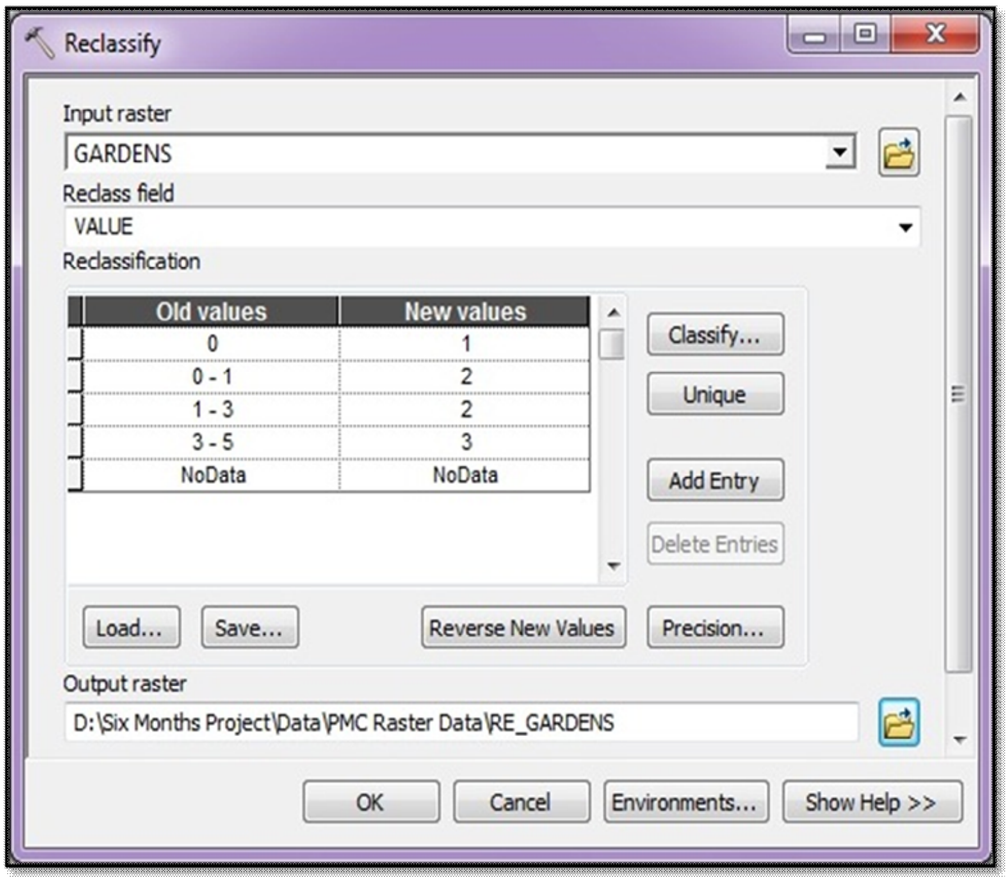


Figure-3.61: Reclassification of Total Gardens-2012 Layer

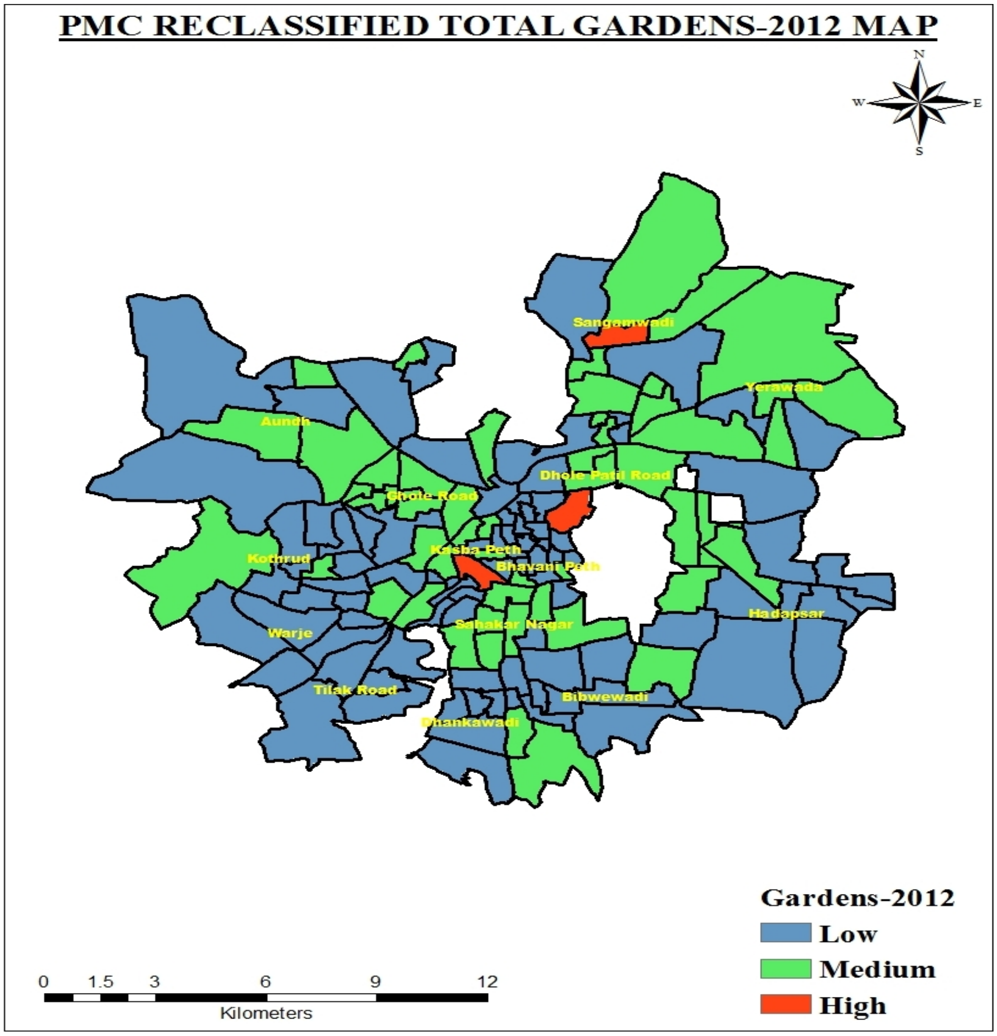


Figure-3.62: PMC Reclassified Total Gardens-2012 Map

4. ***Reclassification of Total Population****:* The Reclassify tool was used to classify Total Population layer into four classes as shown in figure-3.63. The variables in the Total Population layer were classified: Population variables from 170000 to 200000 as “Low” with pixel value as “1”, Population variables from 200000 to 230000 as “Medium” with pixel value as “2” and Population variables from

230000 to 330000 as “High” with value as “3” as shown in figure-3.63. A low value means Population variables from 170000 to 200000 have a low intensity influence; a medium value means Population variables from 200000 to 230000 are equated to a greater risk influence to the dengue outbreak and a high value means Population variables from 230000 to 330000 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Total Population layer is shown in figure-3.64.

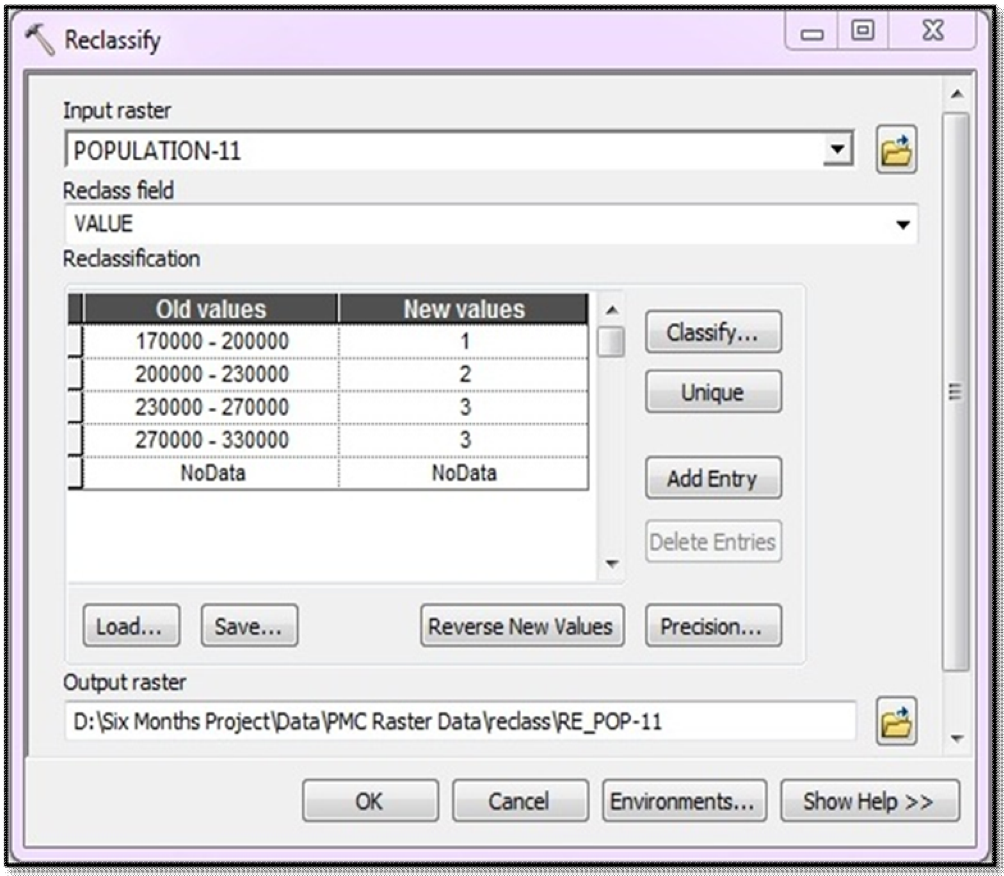


Figure-3.63: Reclassification of Total Population Layer

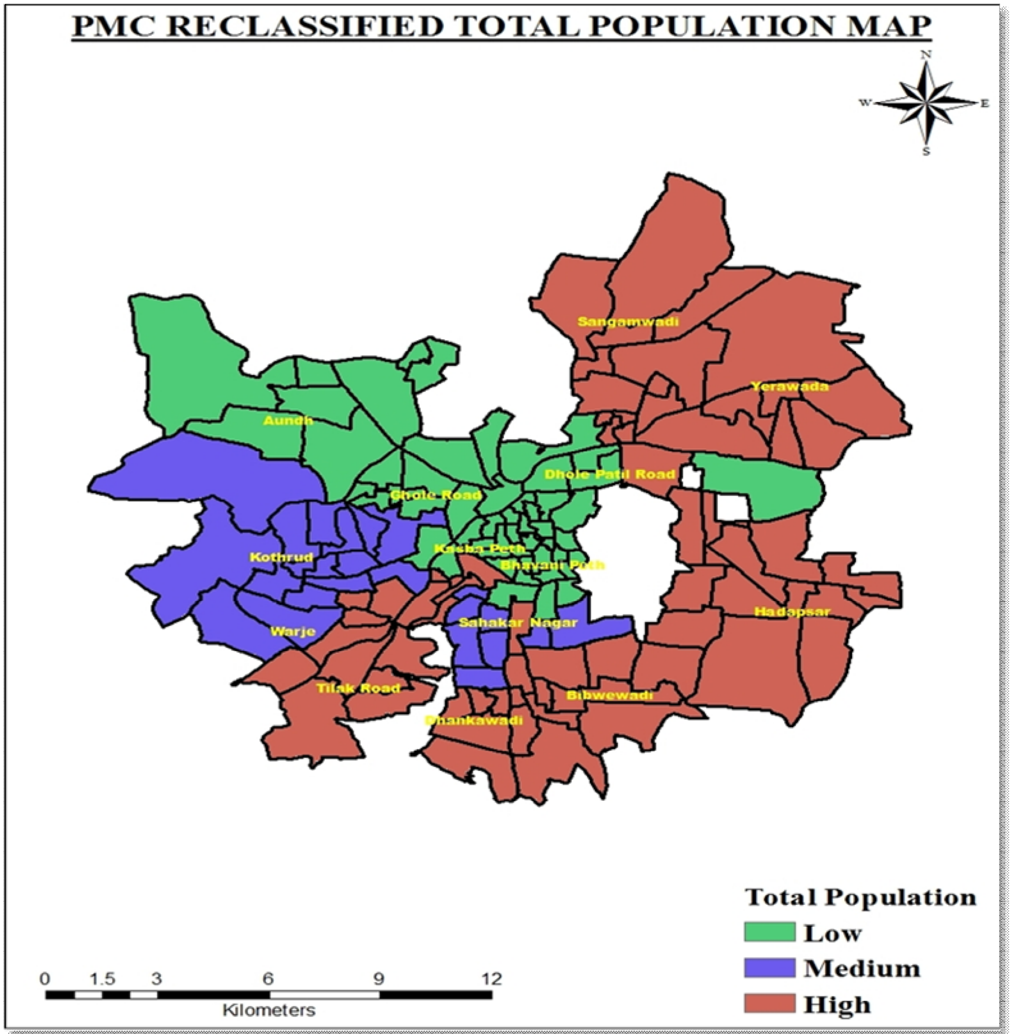


Figure-3.64: PMC Reclassified Total Population Map

5. ***Reclassification of Population Density:*** The Reclassify tool was used to classify the Population Density layer into five classes as shown in figure-3.65. The variables in the Population Density layer were classified: Population density variables from 65 to 82 as “Low” with pixel value as “1”, Population density

variables from 82 to 117 as “Medium” with pixel value as “2” and Population density variables from 117 to 1039 as “High” with value as “3” as shown in figure-3.65. A low value means Population density variables from 65 to 82 have a low intensity influence; a medium value means Population density variables from 82 to 117 are equated to a greater risk influence to the dengue outbreak and a high value means Population density variables from 117 to 1039 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Population Density layer is shown in figure-3.66.

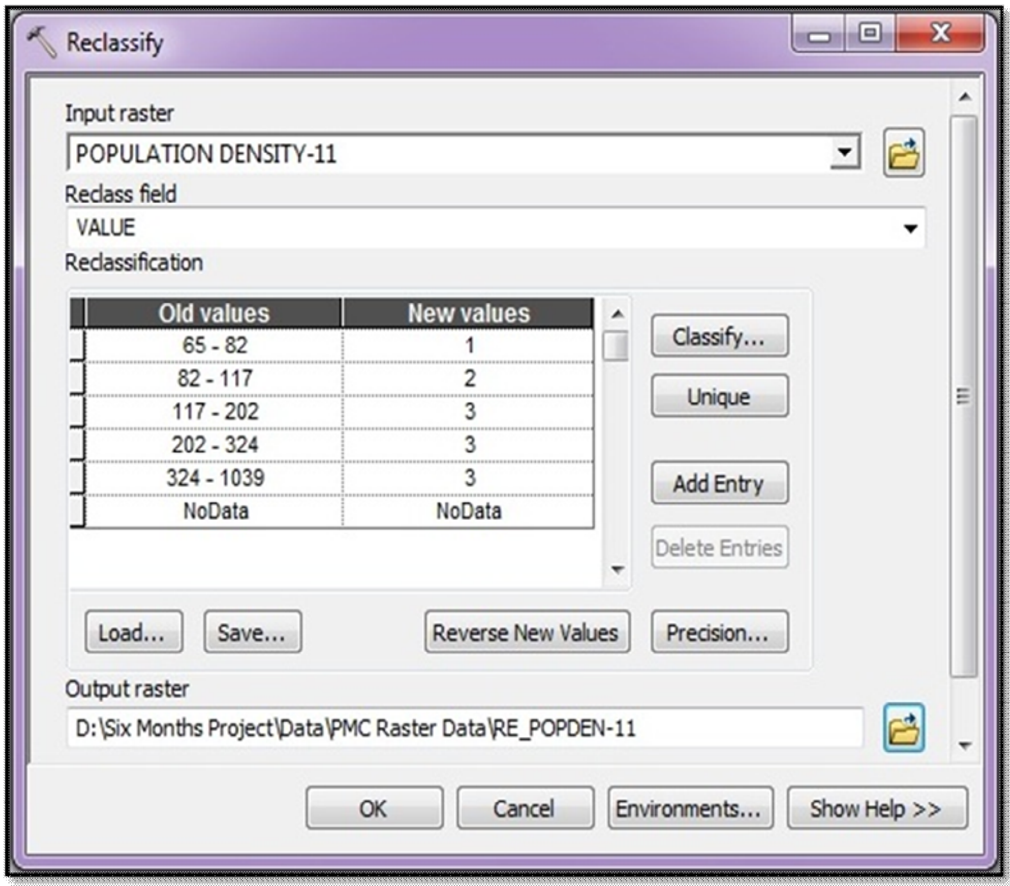


Figure-3.65: Reclassification of Population Density Layer

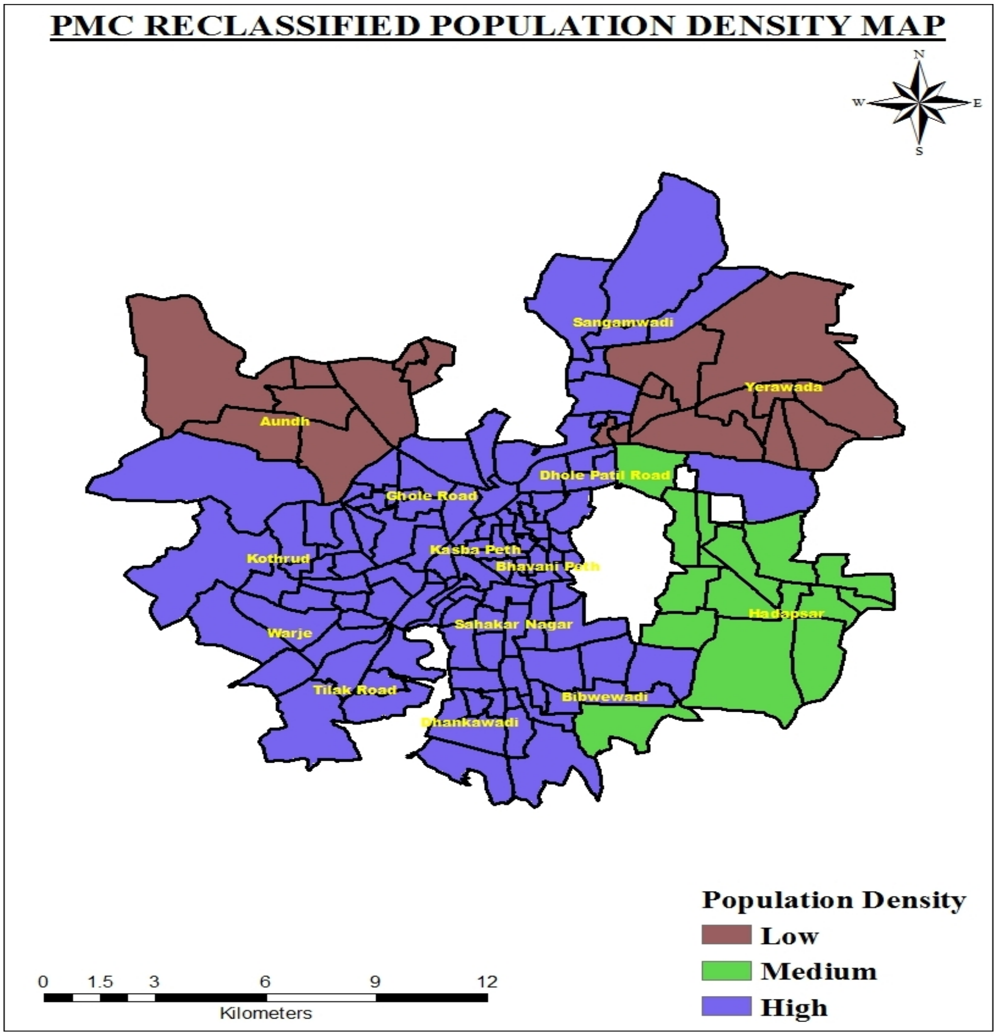


Figure-3.66: PMC Reclassified Population Density Map

6. ***Reclassification of Total Slum Population:*** The Reclassify tool was used to classify the Total Slum Population layer into five classes as shown in figure-3.67. The variables in the Total Slum Population layer were classified: Slum Population variables from 5260 to 15725 as "Low" with pixel value as "1", Slum Population

variables from 15725 to 29775 as “Medium” with pixel value as “2” and Slum Population variables from 29775 to 116390 as “High” with value as “3” as shown in figure-3.67. A low value means Slum Population variables from 5260 to 15725 have a low intensity influence; a medium value means Slum Population variables from 15725 to 29775 are equated to a greater risk influence to the dengue outbreak and a high value means Slum Population variables from 29775 to 116390 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Total Slum Population layer is shown in figure-3.68.

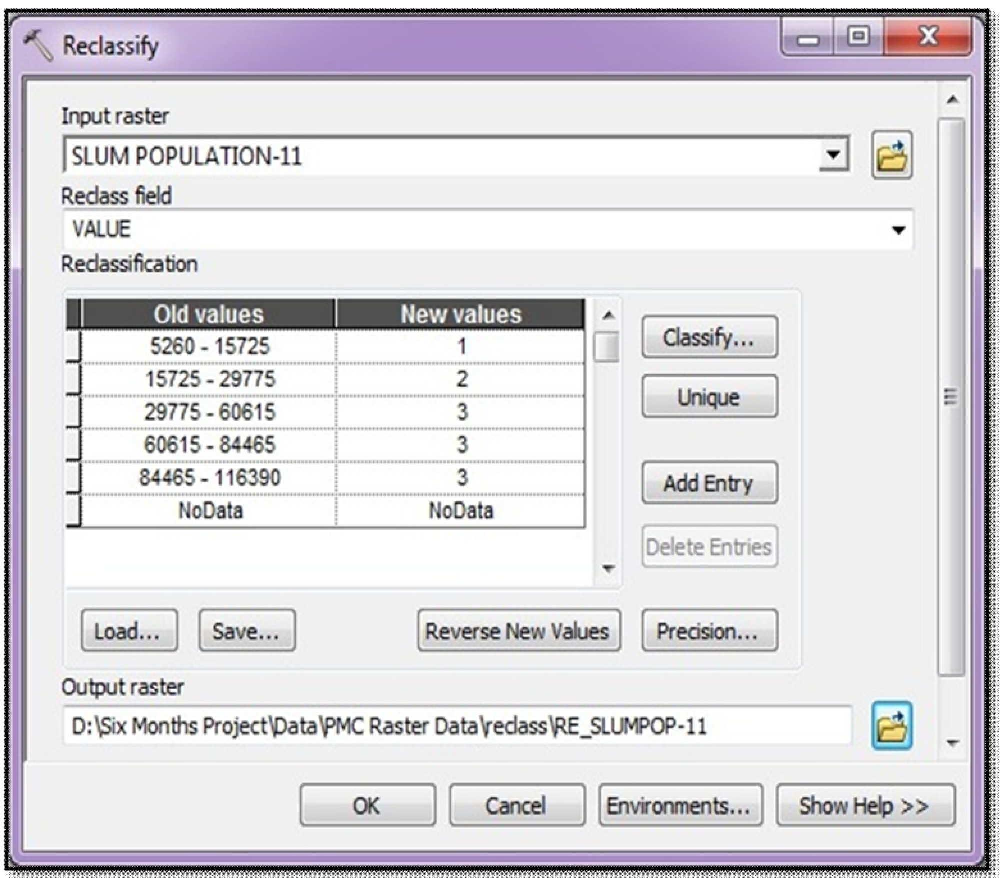


Figure-3.67: Reclassification of Total Slum Population Layer

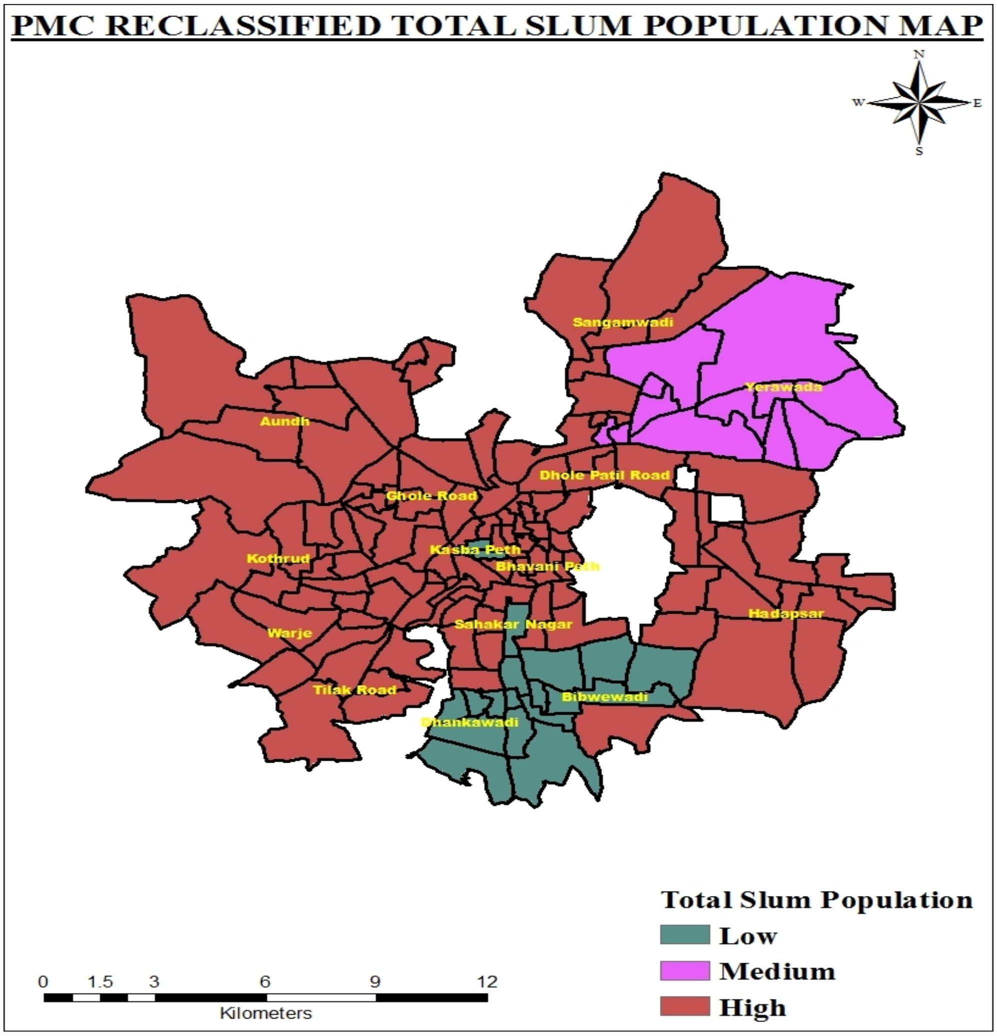


Figure-3.68: PMC Reclassified Total Slum Population Map

7. ***Reclassification of Slum Population Density:*** The Reclassify tool was used to classify the Slum Population Density layer into five classes as shown in figure-3.69. The variables in the Slum Population Density layer were classified: Slum population density variables from 51 to 64 as “Low” with pixel value as “1”,

Slum population density variables from 64 to 156 as “Medium” with pixel value as “2” and Slum population density variables from 156 to 989 as “High” with value as “3” as shown in figure-3.69. A low value means Slum population density variables from 51 to 64 have a low intensity influence; a medium value means Slum population density variables from 64 to 156 are equated to a greater risk influence to the dengue outbreak and a high value means Slum population density variables from 156 to 989 are equated to a very significant influence on the dengue outbreak pattern [Napier M, 2003]. The reclassified Slum Population Density layer is shown in figure-3.70.

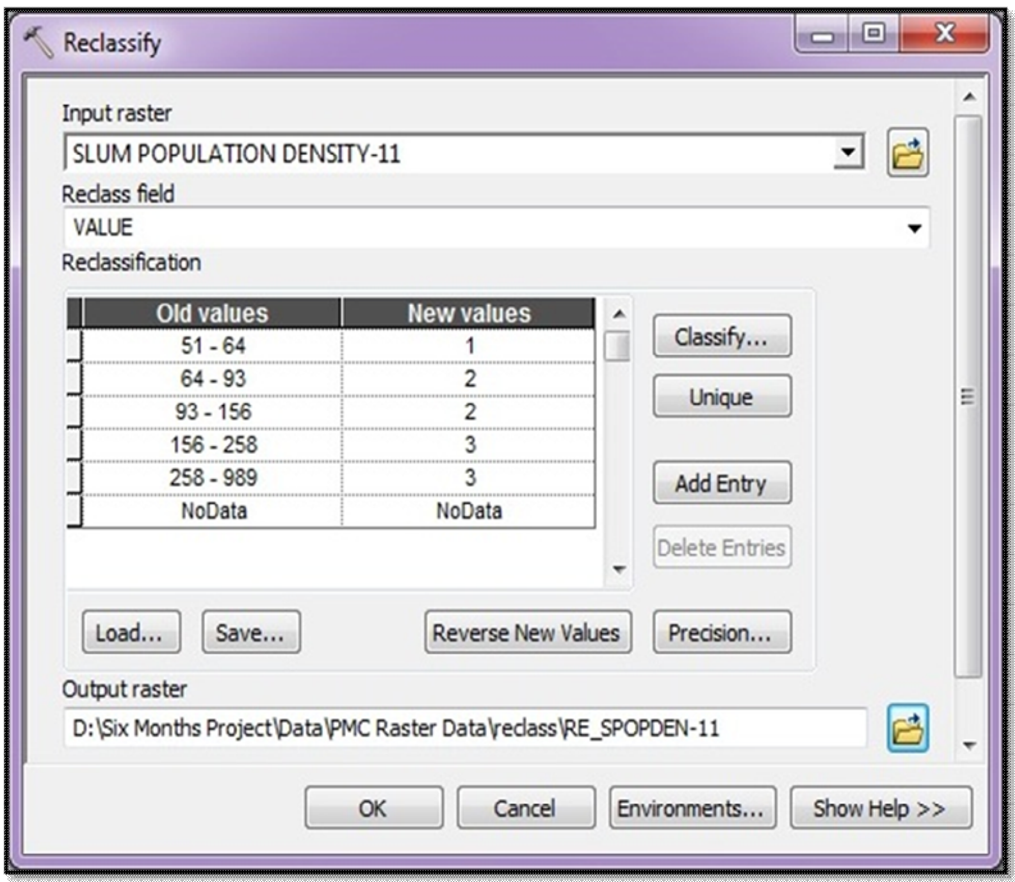


Figure-3.69: Reclassification of Slum Population Density Layer

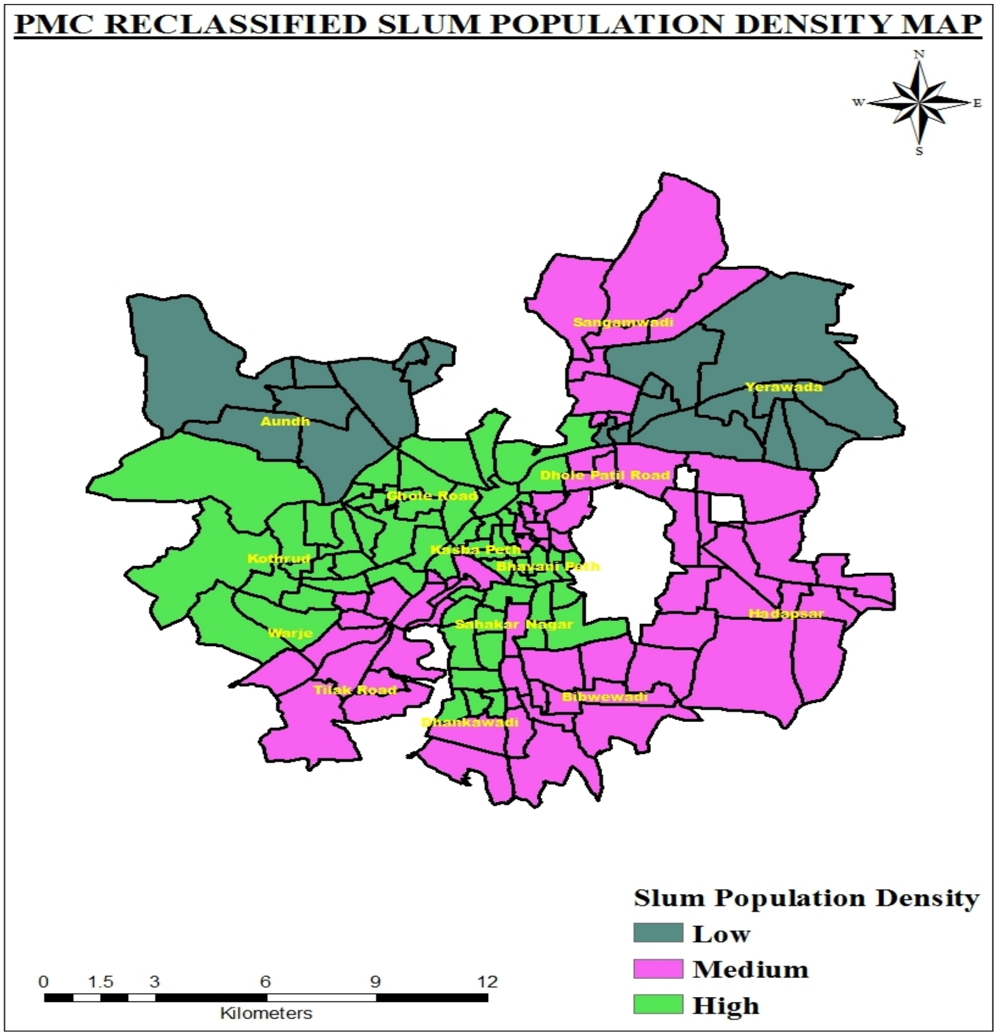


Figure-3.70: PMC Reclassified Slum Population Density Map

8. ***Development of Dengue Risk Map Using Weighted Overlay Analysis:*** Weighted Overlay technique overlays several raster datasets using a common measurement scale and weights each according to its importance. Here, all the reclassified environmental layers such as socio-economic factors such as Total Population-

2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, Dengue Cases-2012, Total Slums-2012, Total Gardens-2012, etc. were tested.

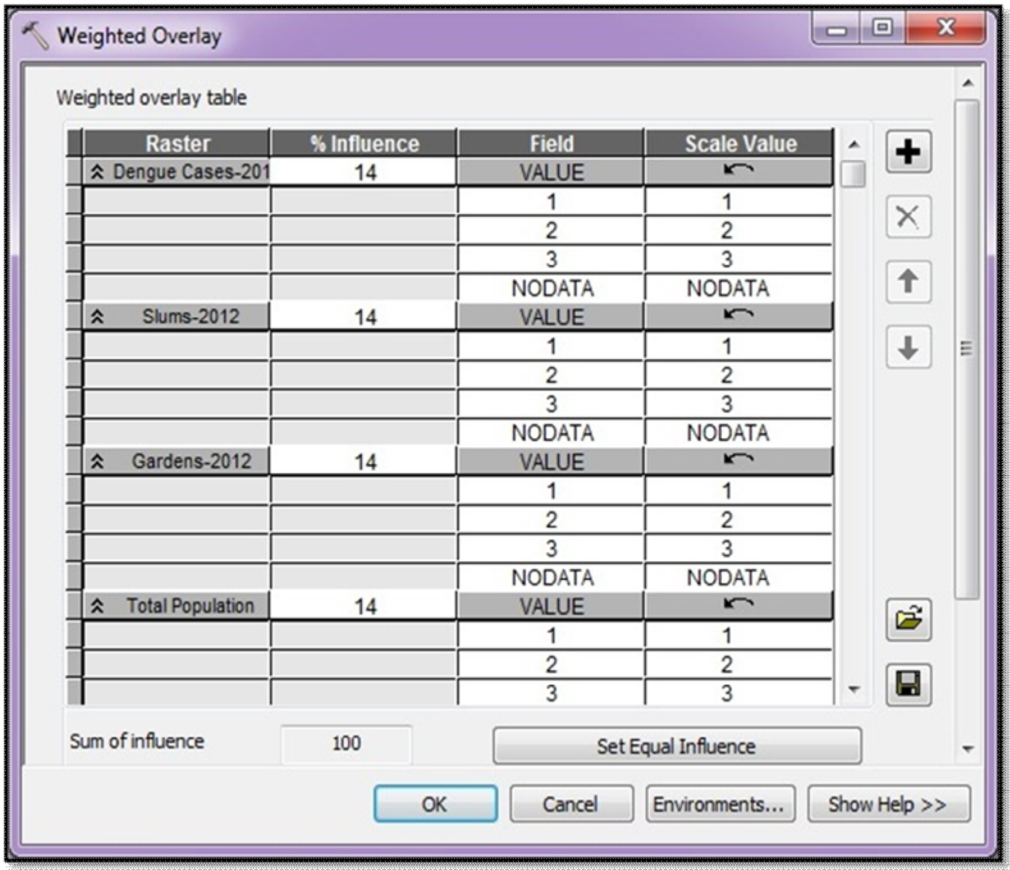


Figure-3.71: Weighted Overlay Table

The Dengue Risk Map generated from environmental factors that were obtained from remote sensing data was classified as “Low”, “Medium” and “High” risk potential areas of having the dengue outbreak. For the information obtained, the following algorithm was used to develop the dengue risk map from each environmental indicator as shown below.

Dengue Risk Map= Dengue Cases-2012 (A)+ Slums-2012 (B)+ Gardens-2012 (C)+ Total Population (D) + Population Density (E) + Total Slum Population (F) + Slum Population Density (G)

The Dengue Risk Map that was generated based on socio-economic factors shows a strong connection with the reported (real) dengue incidence case locations or recorded outbreak areas for the year 2012. Figure-3.72 shows the Dengue Risk Map with the point location of the dengue incidence cases-2012 as a verification of the dengue risk map areas. The results shows that most of the dengue incidences had occurred in the high risk areas categorize in the dengue risk map generated from the socio-economic factors. This means that the Dengue Risk Map can be used as a tool to identify the potential areas of a dengue outbreak occurrence. All major reported dengue outbreak areas were found to fall within areas identified in the Dengue Risk Map as being “High”, and in some cases “Medium”. This finding is very encouraging as it validates the accuracy of the generated Dengue Risk Map when compared with the reported dengue cases-2012 within the municipality area of PMC.

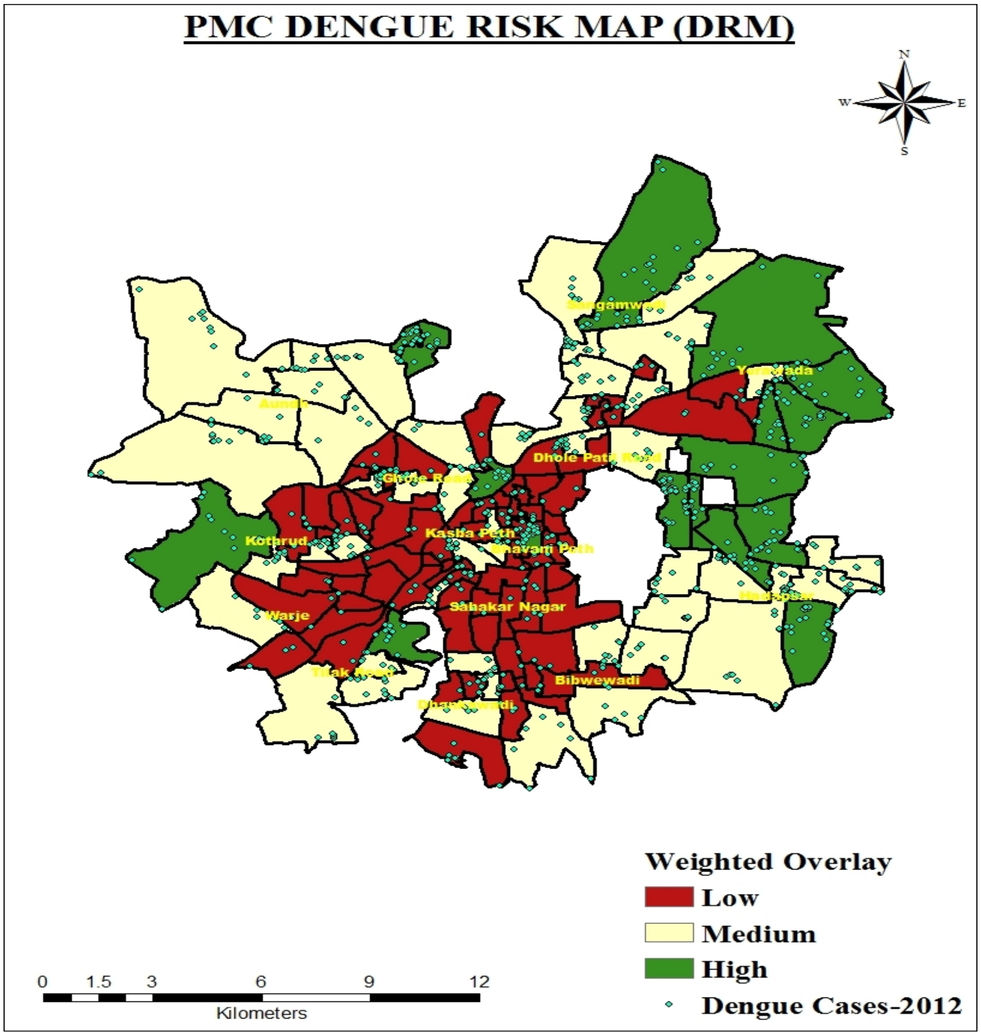


Figure-3.72: PMC Dengue Risk Map (DRM)

g) **SPATIAL ANALYSIS FOR DEVELOPING DENGUE RISK MAP (DRM) FOR THE YEAR 2013 BASED ON ENVIRONMENTAL & SOCIO-ECONOMIC FACTORS-** The Dengue Risk Map generated from environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. that were obtained from LANSAT 7 (ETM+) satellite data and Socio-economic factors such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum

Population Density-2011, Buffer (500) Dengue Cases-2012, Buffer (500) Total Slums-2012, Buffer (500) Total Gardens-2012, Settlements-2012, etc. that were obtained from PMC ‘s Census, Health, Slum, Garden, Housing, etc. Departments was classified as “Low”, “Medium” and “High” risk potential areas of having the dengue outbreak.

For this, firstly all the four environmental factors and all the four socio-economic layers Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011 as mentioned above were reclassified using Reclassify tool in order to classify each of the above mentioned layers as “Low” having value as “1”, “Medium” having value as “2” and “High” having value as “3” risk potential areas of having dengue outbreak. The Multiple Ring Buffer tool was used to create multiple buffers around features such as Dengue Cases-2012, Slums-2012, Gardens-2012, etc.

Aedes aegypti has maximum flight range of 32-50m per day and hence its flight ranges for its entire life-time ranges from 500-700 m. Hence, the distance used for to carry out multiple ring buffers was 500 m respectively. Then, these buffered features were converted to raster datasets by using Polygon to Raster conversion tool. Settlements-2012 layer was also converted to raster dataset using Polygon to Raster conversion tool.

Finally, all the four environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. and all the four socio-economic layers such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, etc. and all the three buffered features such as Dengue Cases-2012, Slums-2012, Gardens-2012, etc. along with the Settlements-2012 were tested using Fuzzy Overlay technique in the ArcGIS 10 software. The Fuzzy Overlay tool allows the analysis of the possibility of a phenomenon belonging to multiple sets in a multicriteria overlay analysis. Not only does Fuzzy Overlay determine what sets the phenomenon is possibly a member of, it also analyzes the relationships between the memberships of the multiple sets. Overlay type lists the methods available to combine the data based on set theory analysis. Each method allows the exploration of the membership of each cell belonging to various input criteria. The available methods are Fuzzy "And", Fuzzy "Or", Fuzzy "Product", Fuzzy "Sum", and Fuzzy "Gamma". Here Fuzzy "And" overlay type was used to return the minimum value of the sets the cell location belongs to. This technique was to identify the least common denominator for the membership of all the input criteria. Each approach provides a different aspect of each cell's membership to the multiple input criteria [Napier M, 2003]. Then the output feature Fuzzy Overlay was converted to polygon feature dataset using Raster to Polygon conversion tool. The result of the Fuzzy Overlay analysis is shown in the figure-3.73.

Dengue Risk Map= LULC (A) + NDVI (B) + LST (C) + SLOPE (D) + POP-11 (E) + POP DENSITY-11 (F) + SLUM POP-11 (G) + SLUM POP DENSITY-11 (H) + (Buff 500) DENGUE CASES-2012 (I) + (Buff 500) + SLUMS-2012 (J) + GARDENS-2012 (K) + SETTLEMENTS-2012 (L)

The Dengue Risk Map for the year 2013 that was generated based on all the four environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. and all the four socio-economic layers such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, etc. and all the three buffered features such as Dengue Cases-2012, Slums-2012, Gardens-2012, etc. along with the Settlements-2012 shows a strong connection with the reported (real) dengue incidence case locations or recorded outbreak areas for the year 2013 till date. Figure-3.73 shows the Dengue Risk Map with the point location of the dengue incidence cases-2013 and satellite imagery base-map as a verification of the dengue risk map areas. This means that the Dengue Risk Map can be used as a tool to identify the potential areas of a dengue outbreak occurrence in future. This finding is very encouraging as it validates the accuracy of the generated Dengue Risk Map when compared with the reported dengue cases-2013 till date within the municipality area of PMC.

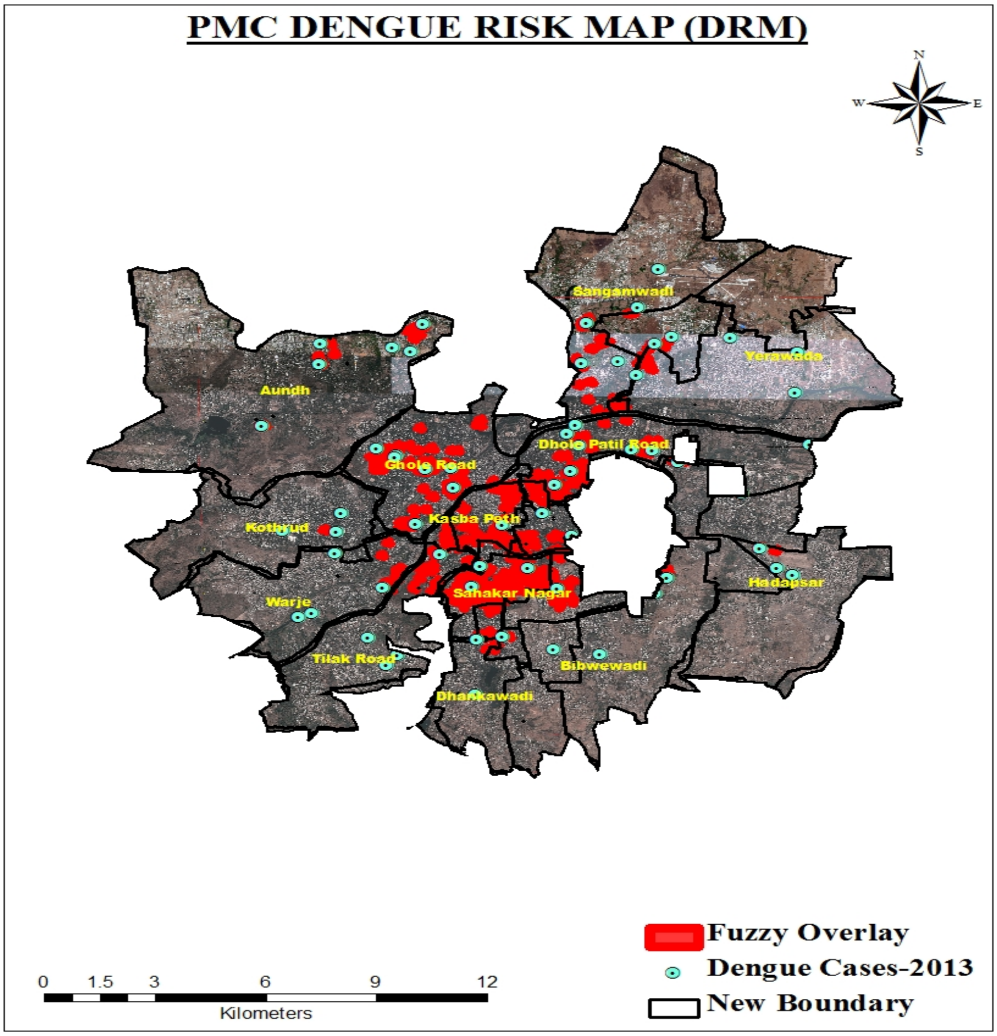


Figure-3.73: PMC Dengue Risk Map (DRM) for 2013

The generated Dengue Risk Map (on all the four environmental factors such as Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Slope (High Land and Low Land areas), etc. and all the four socio-economic layers such as Total Population-2011, Population Density-2011, Total Slum Population-2011, Slum Population Density-2011, etc. and all the three buffered features such as Dengue Cases-2012, Slums-2012, Gardens-2012, etc.) shows a very promising potential in identifying areas of having a high risk for a dengue outbreak in 2013.

3.8 STATISTICAL ANALYSIS

a) **PMC ENTOMOLOGY INDEX, DENGUE CASES, TEMPERATURE & RAINFALL DISTRIBUTION FOR 2010, 2011, & 2012-** Total Dengue Cases reported for the year 2010 is 52, 2011 is 56 and 2012 is 783 as shown in figure-3.74. Temperature and Rainfall both these factors are taken into consideration to carry out statistical analysis. The dengue incidence cases in PMC area are significantly influenced by the Temperature and Rainfall. Temperature and rainfall have positive and significant influence towards the incidence dengue incidence cases. The increasing temperatures could also increase dengue incidences by extending the season in which transmission occurs [Patz & Reisen, 2001]. Lengthy drought conditions in endemic areas without a stable drinking water supply may encourage the storage of drinking water, thereby increasing the number of breeding sites for the mosquito vector Aedes aegypti [Beebe et al., 2009]. Conversely, high rainfall will ensure that small artificial containers used as larval mosquito habitat would remain flooded, thereby expanding adult mosquito population [Patz et al., 1998]. Moreover, climate change associated with PMC may trigger outbreak of dengue in populated areas where the disease is endemic [Hales et al., 1999; Johansson et al., 2009]. As climate change may have a significant impact on the dengue transmission and incidence cases, it is essential to examine the association between climatic variables i.e. Temperature and Rainfall and dengue epidemic. Thus, climate change i.e. global warming's effects on temperature and rainfall patterns can affect the risks of dengue outbreak in PMC area. Most of the reported dengue cases occurred in the areas with a temperature range from between 20.0ºC to 30.0ºC. This temperature range is very conducive to the mosquito breeding cycle as an increase in the number of times that the mosquito breeds will also increase the likelihood of the emergence of the dengue outbreak. Development increases in warmer temperature, raising the odds of disease transmission, while the reproduction rates and replication of diseases are slower in cooler temperatures. In general, high amounts of precipitation lead to increases in the number of breeding sites, and humidity is often overlooked as a factor in the life cycle of mosquitoes and in disease replication and transmission. Relative humidity is increased by rainfall particularly following drought. Relative humidity strongly impacts flight and the subsequent host seeking behaviour of mosquitoes [Githeko, A. K., Lindsay, S. W., Confalonieri, U. E. and Patz, J. A., 2000]. The number of cases gradually increases in Monsoon period i.e. June – September, and then in the Post- Monsoon period i.e. October to January the number of cases shows a significant rise especially in the year 2012, this is mainly because of the warmer temperatures i.e. 24° C to 29° C and this temperature range is very favorable for mosquito breeding and finally in the Pre-Monsoon period the number of cases gradually decreases as the temperature increases from 30°C to 40°C and this temperature range is not at all favorable for mosquito breeding as the humidity decreases and the climate becomes more dry as shown in figure-3.75, figure-3.76 and figure-3.78. Also, it was observed that the age group from 15-24 and 24-35 of both male and female incidence cases was the most affected in the year 2012 as shown in figure-3.78. Here, wardwise distribution of Entomology Index i.e. Aedes Aegypti mosquito rate was observed to have significant influence over wardwise distribution Dengue Cases-2012 as shown in figure-3.79.

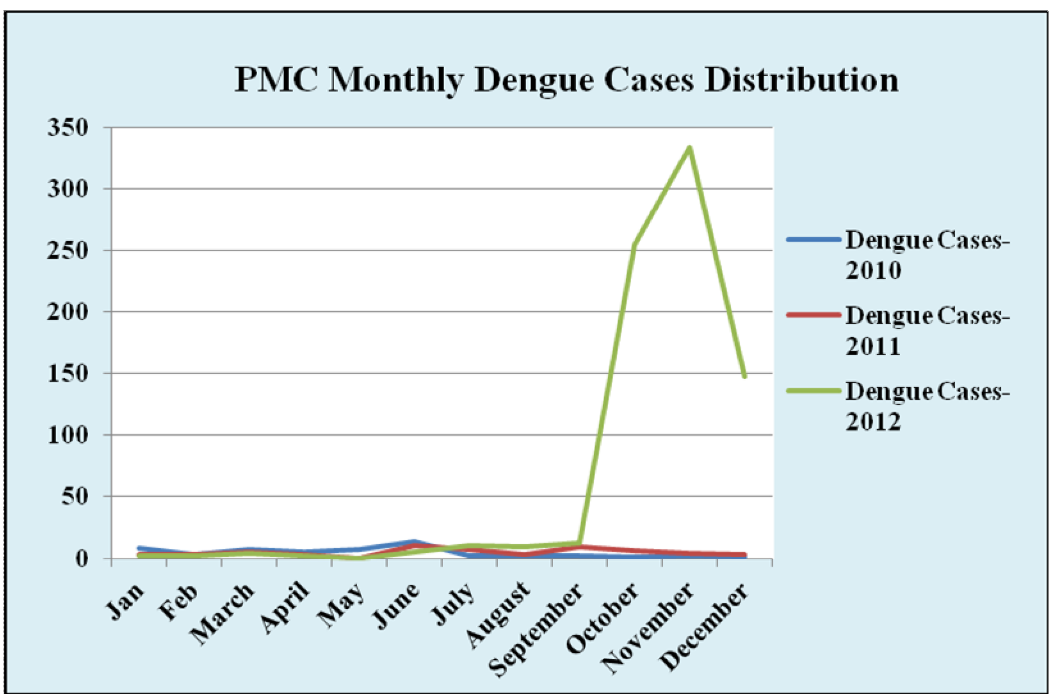


Figure-3.74: PMC Monthly Dengue Cases Distribution for 2010, 2011 & 2012

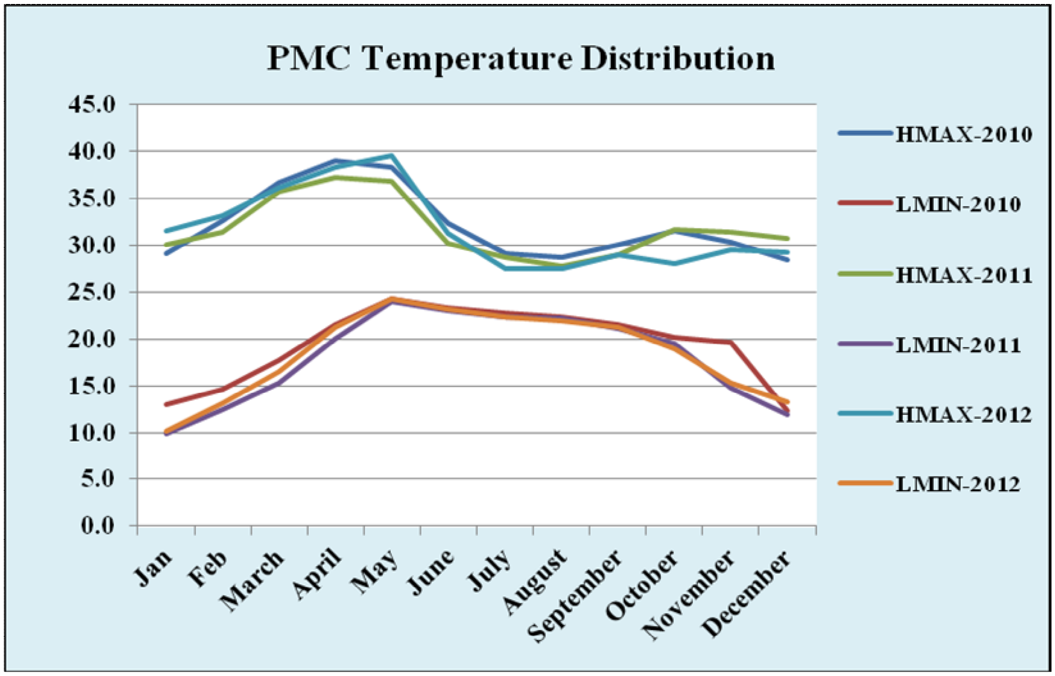


Figure-3.75: PMC Temperature Distribution for 2010, 2011 & 2012

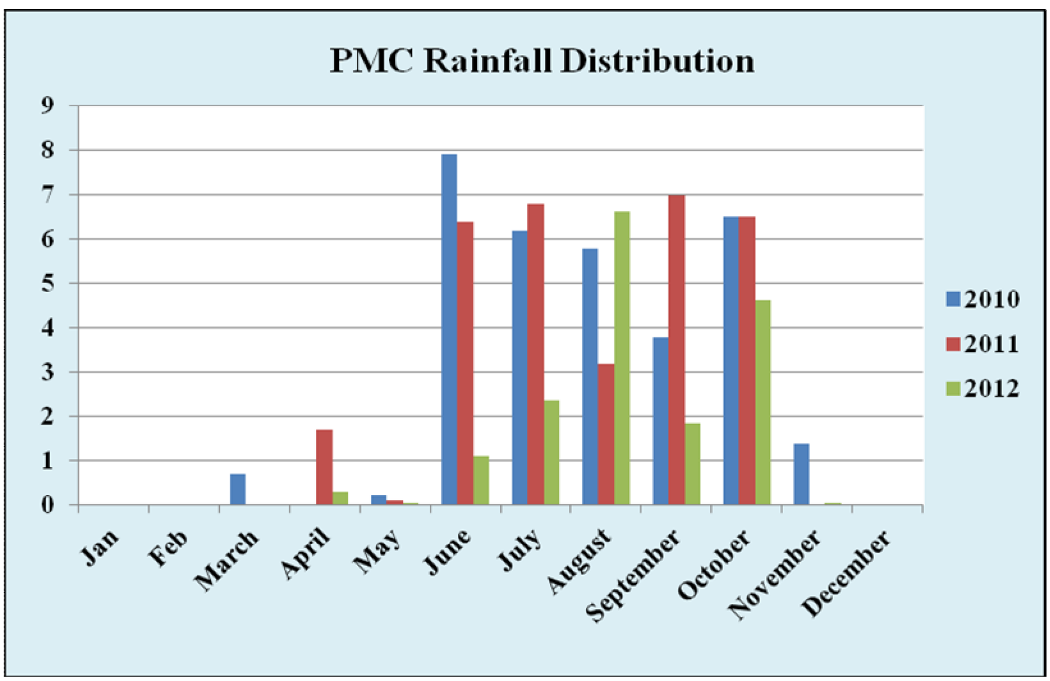


Figure-3.76: PMC Rainfall Distribution for 2010, 2011 & 2012

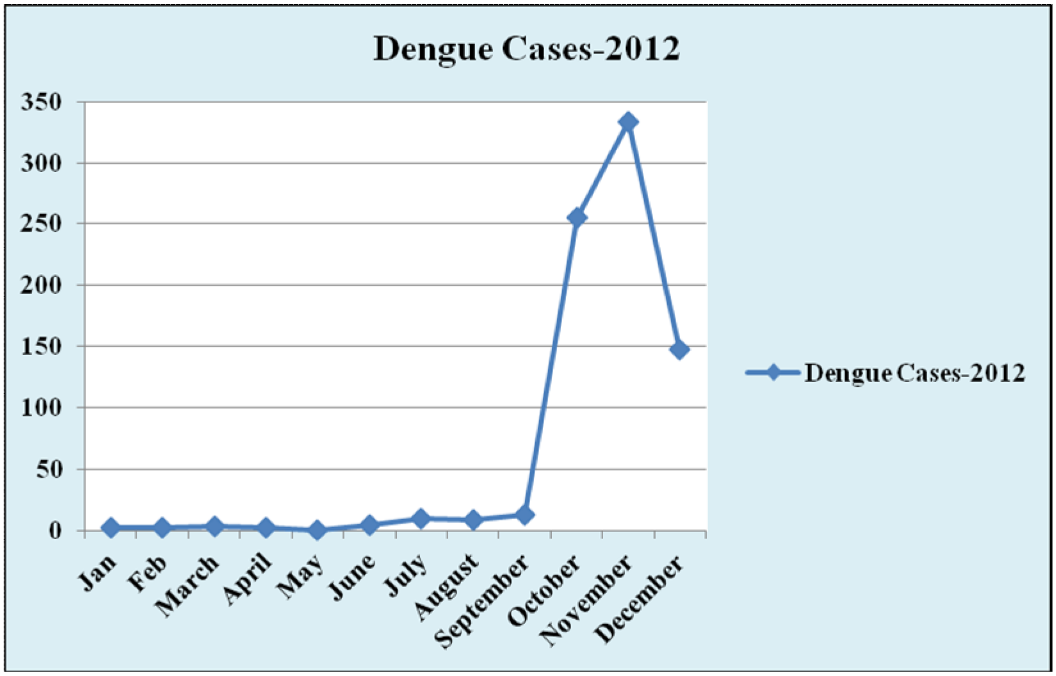


Figure-3.77: PMC Dengue Cases-2012

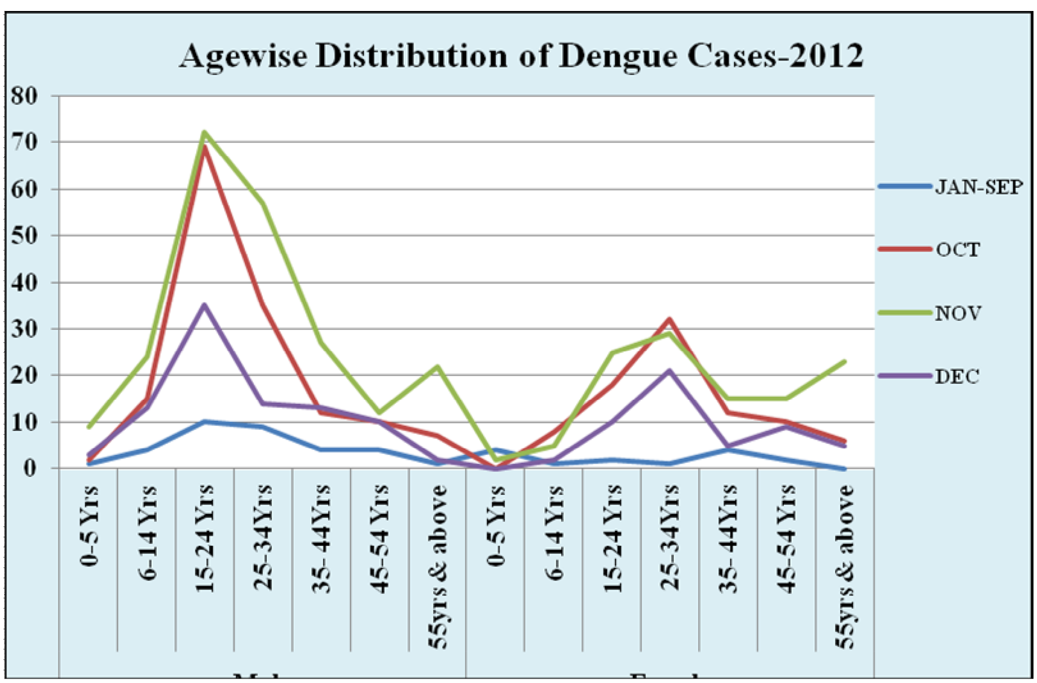


Figure-3.78: Agewise Distribution of Dengue Cases-2012

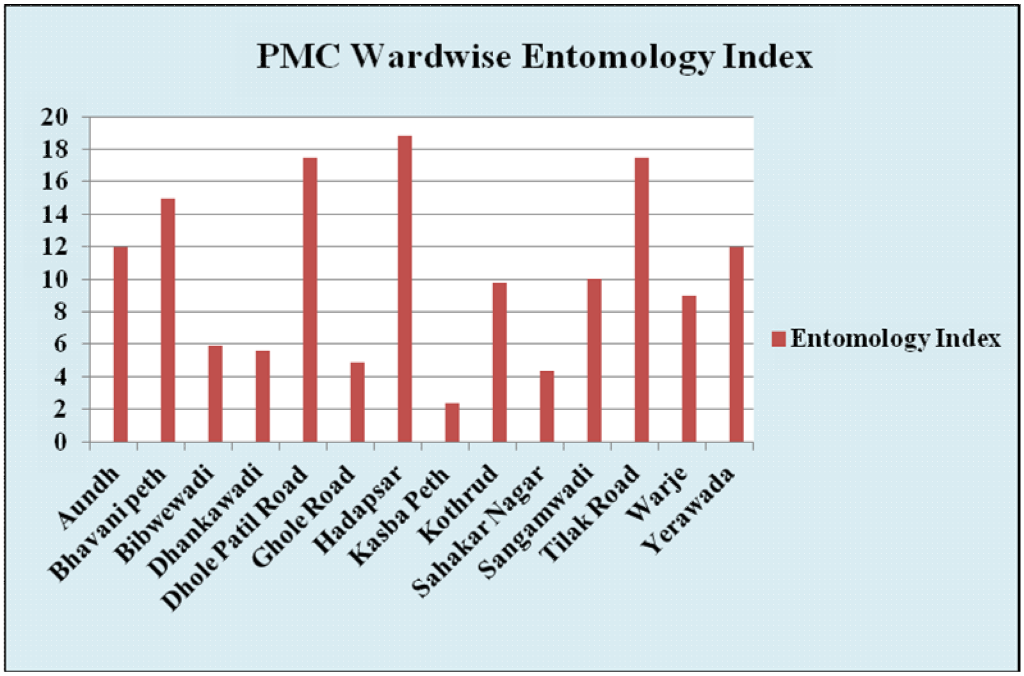


Figure-3.79: PMC Wardwise Entomology Index

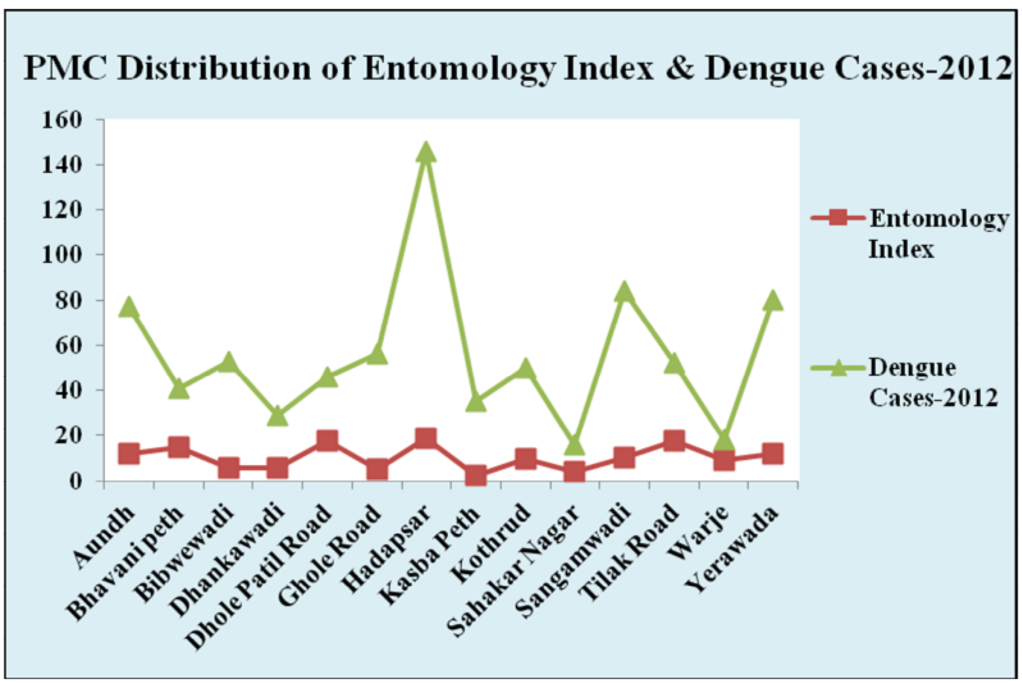


Figure-3.80: PMC Wardwise Distribution of Entomology Index & Dengue Cases-2012

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 FOREWORD

The results as briefly narrated below are emerged from the spatial analysis. The discussions accompanying the results illustrate the utility and usefulness of the work done. The results of Dengue Risk Maps (DRM) for the year 2013 through GIS analysis considering various thematic layers are validated from a virtual tour of Google Earth and from the Field Survey of the area. The following description depicts the results of the study.

4.2 RESULTS

The Dengue Incidence Risk Areas for the year 2013 are depicted in figure-4.1 respectively. This has three clusters of locations and is grouped under:

1. Low
2. Medium
3. High

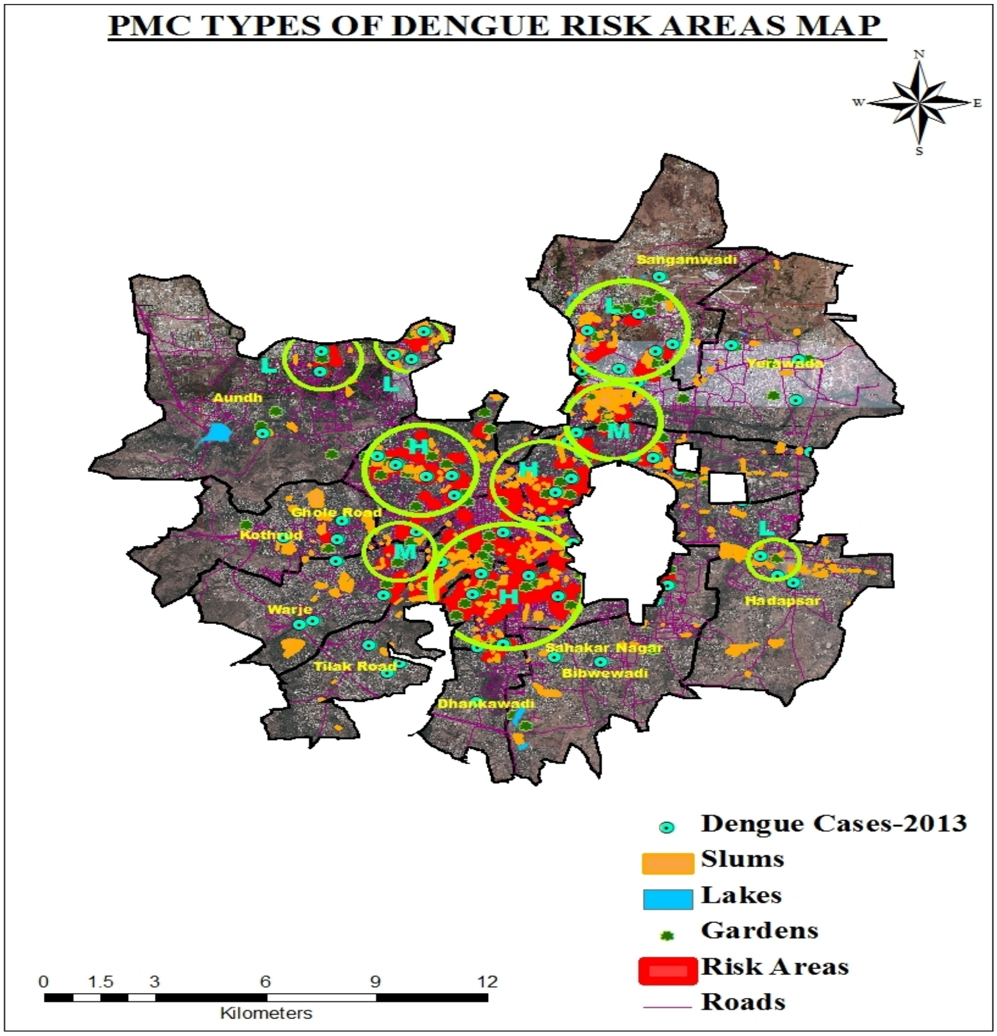


Figure-4.1: Types of Dengue Incidence Risk Areas Map

DISCUSSIONS- The results as accrued from the analysis as depicted in the figure-4.1 explains that the Dengue Incidence Risk Areas are of three types within the domain of PMC. The cluster area of each group is considered and in order of decreasing sizes catches the nomenclature of **"high"**, **"medium"** and **"low"** risk areas. The details of theory behind the analysis are vividly outlined in the methodology chapter.

4.3 GROUND TRUTH

A Field Survey of PMC area was carried out to collect and gather information at the local level. Basically, field visits to each of the dengue risk areas as per the analysis were carried out in order to make the study more realistic. To record the present scenario at each location, photos were taken of all types of dengue risk areas including using a digital camera. Also, hyperlink tool was used to provide additional information about the features to the users. Here, View Risk Areas attribute of Dengue Risk Areas feature has been hyperlinked to the documents showing the present scenario of the risk areas. On clicking a feature with a hyperlink tool, a document or file is launched using the application with which that file was currently associated.

1. **HIGH DENGUE RISK AREAS OF PMC**

The “high” dengue incidence risk areas of Pune Municipal Corporation (PMC) are mainly concentrated in the central areas i.e. urban areas of the municipality. It was observed from the areas visited as shown in figures 4.2, 4.3 and 4.4 that the high dengue incidence risk areas were found mainly in and around slums, commercial areas, construction sites and in the areas with higher population density, respectively. Here, chances for the spread of the dengue disease are high and therefore, these areas can be the highest contributors to the dengue incidence distribution in the year 2013.

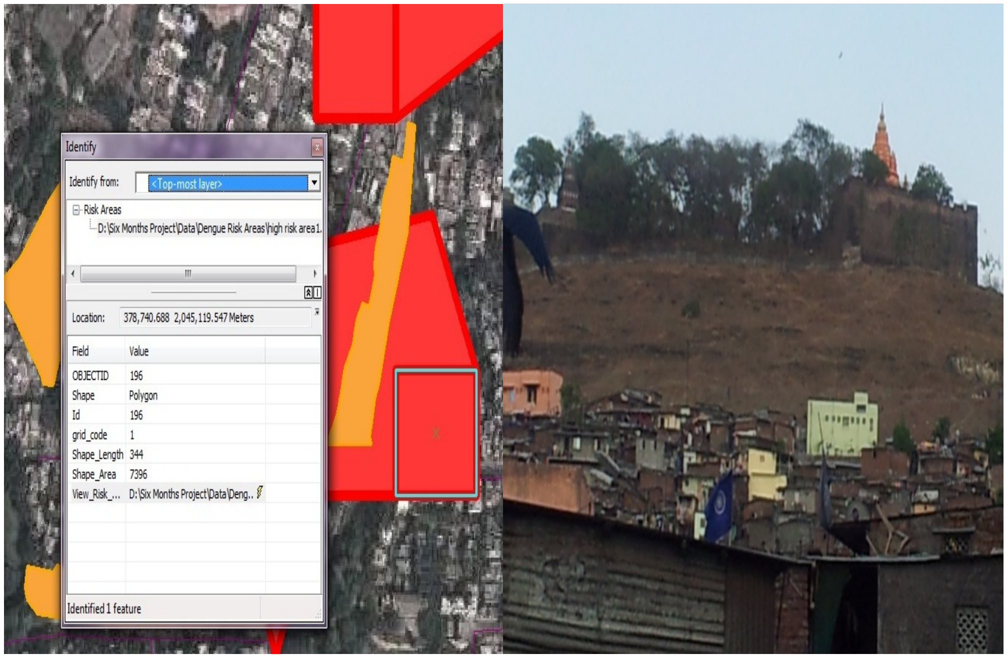


Figure-4.2: Janata Vasahat-Parvati Gaon

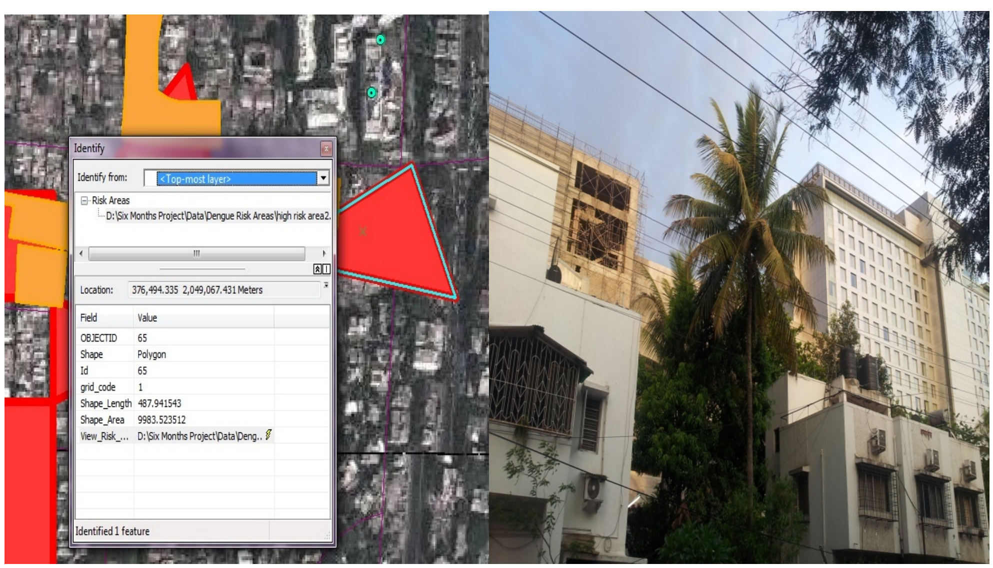


Figure-4.3: Kapila Society-Gokhale Nagar

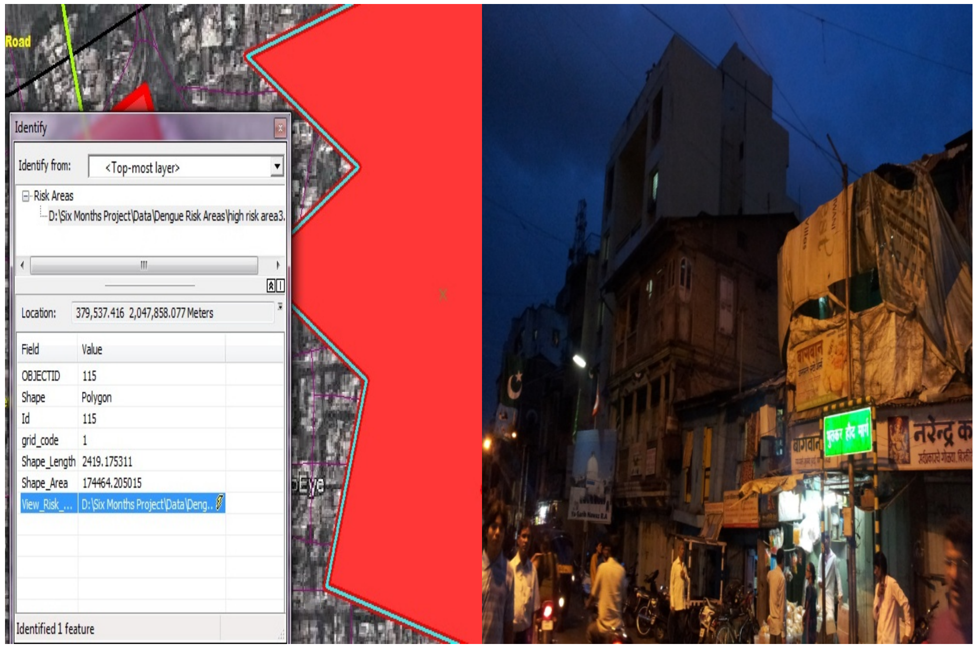


Figure-4.4: Manish Market-Raviwar Peth

2. MEDIUM DENGUE RISK AREAS OF PMC

The “medium” dengue incidence risk areas of Pune Municipal Corporation (PMC) are mainly co-areas i.e. sub-urban areas of the municipality. It was observed from the areas visited as shown in figures 4.5, 4.6 and 4.7 that the medium dengue incidence risk areas were found mainly around slums, in the residential areas, construction sites, in the areas with higher population, respectively. Here, the chances for the spread of dengue disease are medium and therefore, these areas can be the medium or moderate contributors to the dengue incidence distribution in the year 2013.

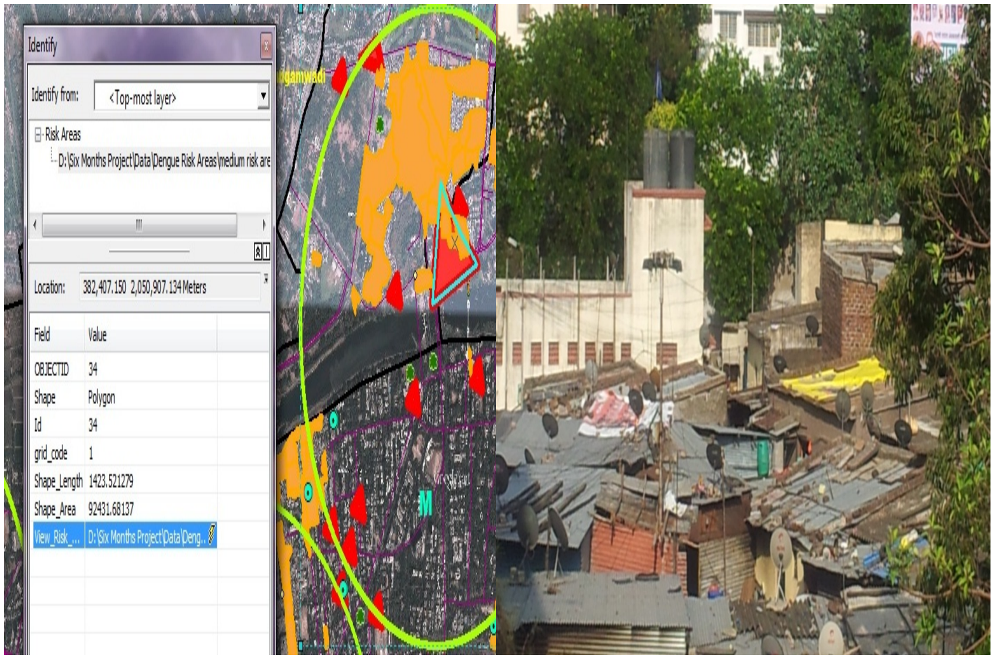


Figure 4.5: Laxmi Nagar-Yerawada

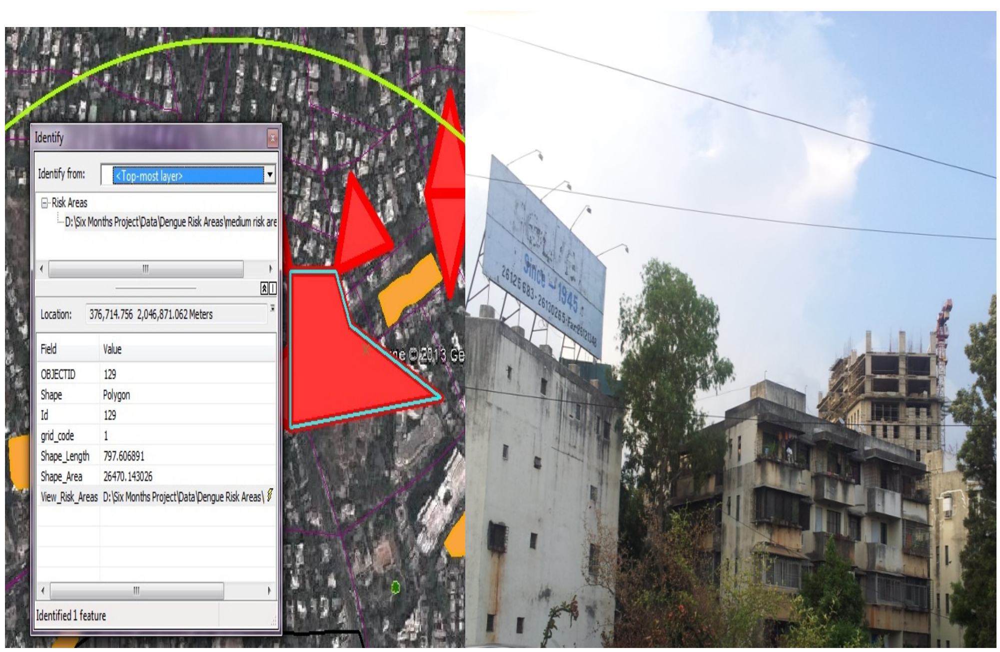


Figure-4.6: Udyog Housing Society-Kothrud

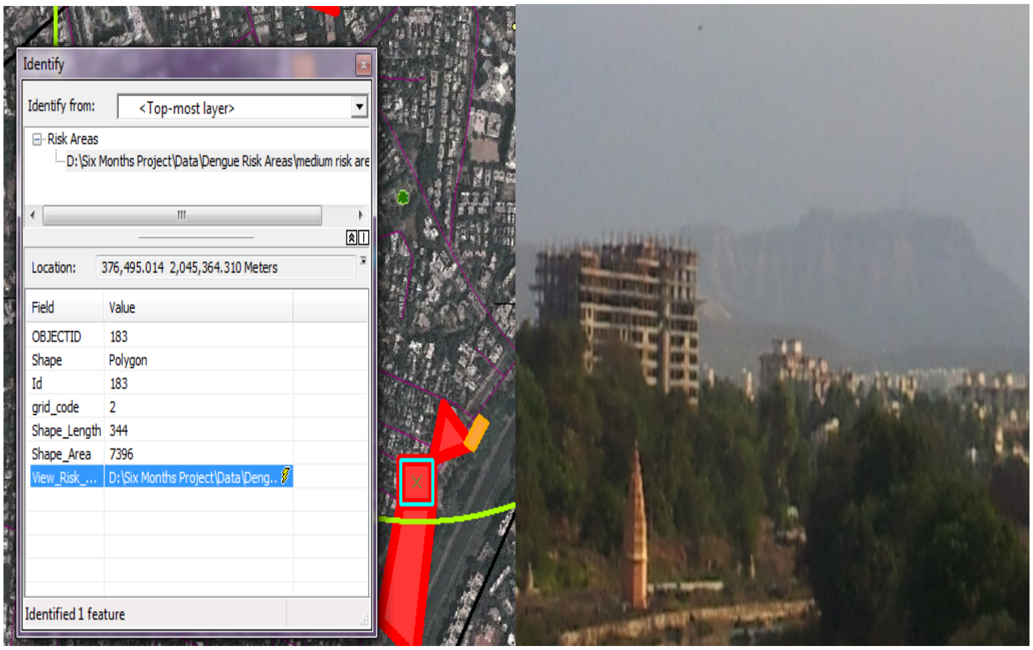


Figure-4.7: Anand Nagar-Sinhgad Road

3. **LOW DENGUE RISK AREAS OF PMC-**

The "low" dengue incidence risk areas of Pune Municipal Corporation (PMC) are mainly the peripheral areas i.e. sub-urban areas of the municipality. It was observed from the areas visited as shown in figures 4.8, 4.9 and 4.10 that the low dengue incidence risk areas were found mainly away from the slums, in and around construction sites and residential areas, in the areas with higher population, respectively. Here, the chances for the spread of dengue disease are low and therefore, these areas can be the lowest or least contributors to the dengue incidence distribution in the year 2013.

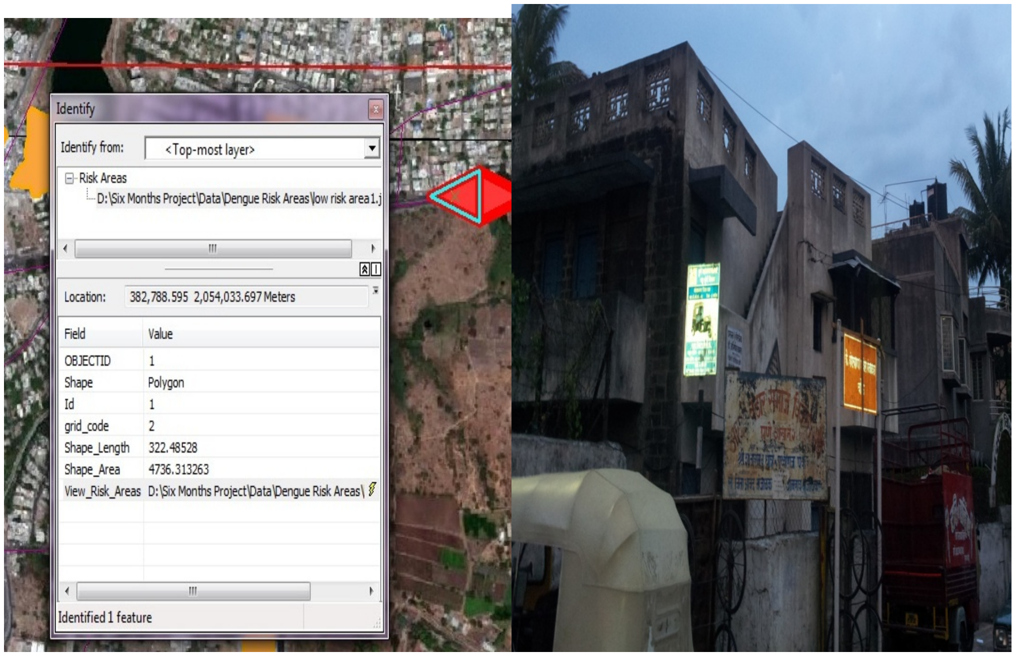


Figure-4.8: Laxmi Nagar-Dhanorie

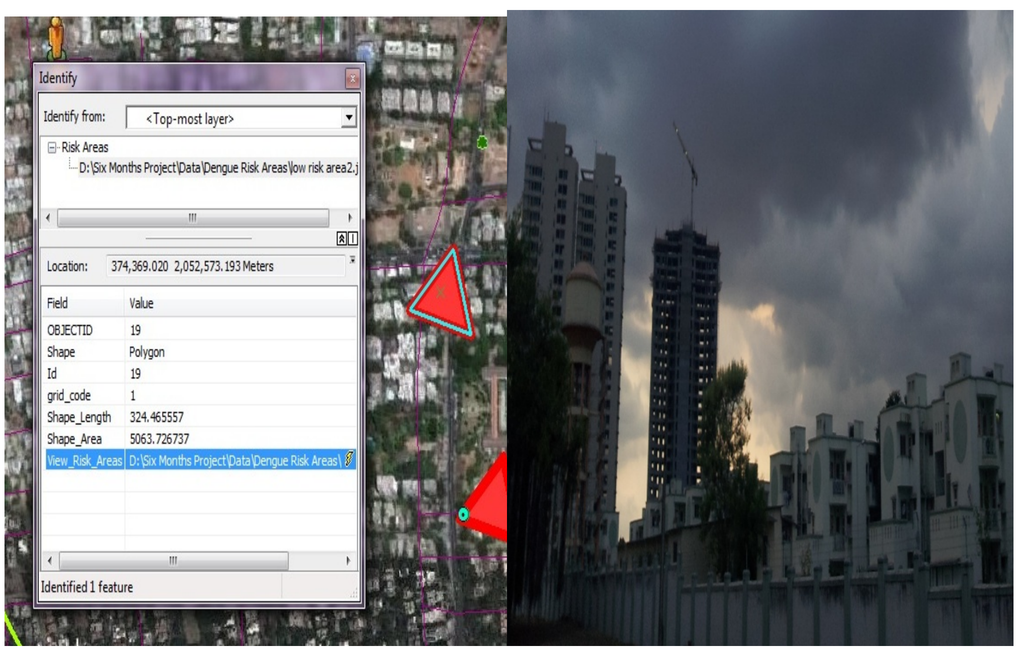


Figure-4.9: Behind University of Pune-Ganeshkhind

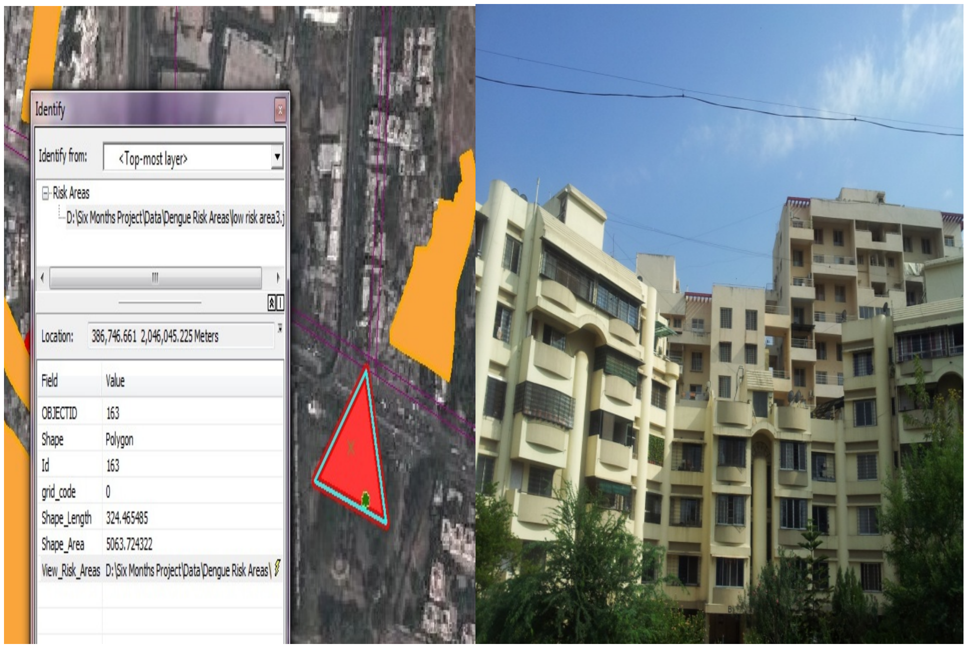


Figure-4.10: Nirmal Township-Sasane Nagar

DISCUSSIONS- The purpose of ground investigations is to give the operational user the realistic portrait of the target. The ground truth observations are done for calibration, correction, interpretation of properties, locational validation of dengue risk areas and accuracy evolution for appropriate mitigations.

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

5.1 FOREWORD

This study used GIS integrated standard methodology for the development of dengue risk areas, which are and can be affected by the dengue disease. This methodology incorporates a large number of weather, environmental and socio-economic factors which are essential to identify the dengue incidence risk areas which have no or minimum adverse impact on the dengue disease outbreak. In fact, many other parameters are required for this study, but the most important parameters have been taken into consideration. The study illustrates the importance of GIS technology in the present days. GIS technology, as an information tool, has helped in the acquisition of recent land use information studies aimed at solving environmental problems. Information on different aspects for this study like land use/land cover, slope etc., has been derived using this technique. Further integrating this data using GIS has helped in the analysis of the study, which would have otherwise been difficult to do manually using the conventional method. The involvement of such factors or criteria requires adequate database of different dimensions. So, adequate attention is required for data management to ensure the perfection of the decision based on the methodology.

Though GIS based methodology is highly sophisticated or developed or standard one but its success depends on the proper and careful application of it. Thus, with the use of these technologies Ministry of Health in PMC can take proper precautions and mitigations.

5.2 ENUMERATED CONCLUSIONS

The following conclusions were emerged from the study. Three i.e. “High”, Medium” and “Low” categories of Dengue Incidence Risk areas were revealed after using spatial techniques.

1. From Spatial Statistical Analysis, it is clear that the dengue incidence distribution in PMC is of clustered type and there can be various environmental and socio-economic factors contributing to this type of pattern. Further, with Kernel Density technique it is easy to identify the hot spots locations of Dengue Incidence Cases in PMC. Finally by using directional distribution, the geographic distribution of dengue incidences is obtained which helps in determining the seasonal path and trend of dengue outbreak.

2. From Spatial Analysis to find whether there is any correlation between dengue incidence cases and the environmental factors, it is clear that there is a positive correlation between Land Use/Land Cover (LULC), Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI) and Slope. However, Dengue Incidence Cases are observed in non-vegetated areas and low land areas.

3. From Spatial Analysis to develop Dengue Risk Maps (DRMs), first Environmental factors are analyzed using Weighted Overlay technique and then Socio-Economic factors are analyzed using the same technique. With this, two Dengue Risk Maps (DRMs) are developed one based on Environmental factors and other based on Socio-Economic factors. Finally, both the Environmental and Socio-Economic factors are together processed and overlaid with buffered features of Dengue Incidence Cases, Slums, Gardens, Settlements, etc. Here, Fuzzy Overlay technique with “AND” overlay type is used to develop Dengue Risk Map (DRM) for the year 2013.

4. From non-spatial Statistical Analysis, it is clear that Dengue Incidences are influenced by Temperature and Rainfall variations. It is observed that the number of cases gradually increases in Monsoon period i.e. June – September, and then in the

Post- Monsoon period i.e. October to January the number of cases shows a significant rise especially in the year 2012, this is mainly because of the warmer temperatures i.e. 24° C to 29° C and this temperature range is very favorable for mosquito breeding and finally in the Pre-Monsoon period the number of cases gradually decreases as the temperature increases from 30°C to 40°C and this temperature range is not at all favorable for mosquito breeding as the humidity decreases and the climate becomes more dry

5. Ground truth verification was done using a Digital Camera. Hence, Dengue Incidence Risk areas validation was confirmed. Based on these "High", Medium" and "Low" Dengue Incidence Risk areas respectively.

5.3 FUTURE ENHANCEMENTS

It is proposed that a better resolution DEM be used for future analysis work. A good candidate would be a DEM generated from the SPOT-5 (2.5 meter resolution) data in order to give a better representation of the DEM in urban areas. This is important due to rapid changes in the ground elevation within the study area that is caused by rapid development activities. Therefore a higher resolution DEM data is required in order to obtain more accurate results. More analysis on spatial and temporal aspects in landuse changes is further required to improve the results of this study. By having yearly results with yearly analysis, it may be possible to perform prediction on where next high threat area for a dengue outbreak will be. Developing and refining the Dengue Risk Map by performing multiple or longer temporal time analysis (example: a 5 year period sampling datasets) in order to create a better model for the Dengue Risk Map could produce better and more accurate results. This study has found that the usage of LST data plays a major part towards the development of the Dengue Risk Map. It is proposed that the ASTER satellite data be used to generate all future LST data in order to ensure a guaranteed continuity of this highly required data. For a more accurate result, monthly collection

of LST data would be required as inputs to the dengue risk model in order to build a better averaging representative reading of the studied year's LST through multi temporal analysis.
Spatial analysis has shown proof that construction and industrial sites contribute indirectly towards the spread of the disease. It is therefore suggested that in future, it would be important for local authorities to create specific industrial zones that do not mix with or are not located adjacent to dwelling areas. Frequent and detailed checks performed by the authorities need to be enforced further and continuously at all construction sites during the construction phase in order to counter the high occurrences of Aedes breeding sites found in these areas.

Also, Internet based technique provides a viable alternative to the traditional method of flow of information and the information is instantly available across the globe. Health data can be stored in a central server that can be accessed from various terminals connected to the server through Internet or Intranet. It is proposed to develop a Web GIS based application for Dengue Surveillance.

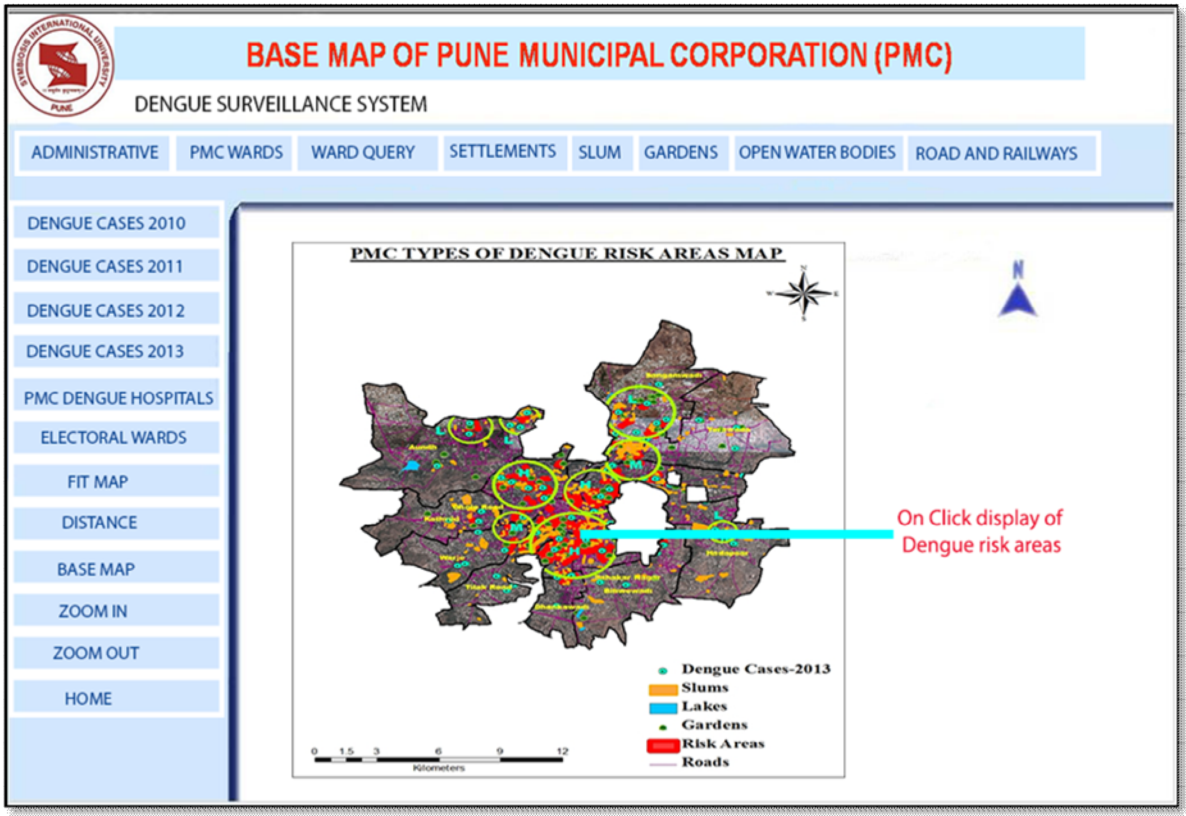


Figure-5.1: Web Enabled GIS based Dengue Surveillance System

APPENDIX

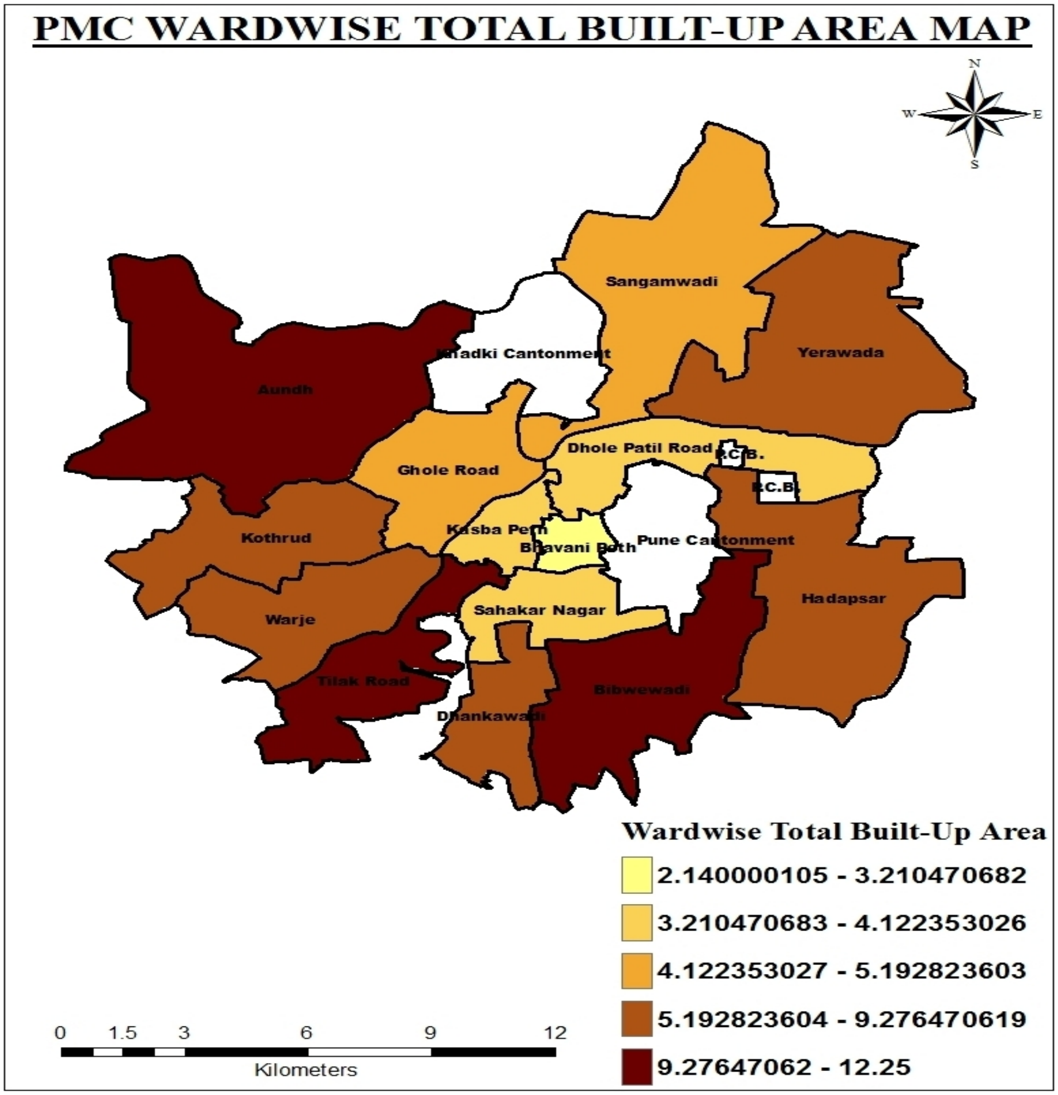


Figure-a: PMC Wardwise Total Built-Up Area Map

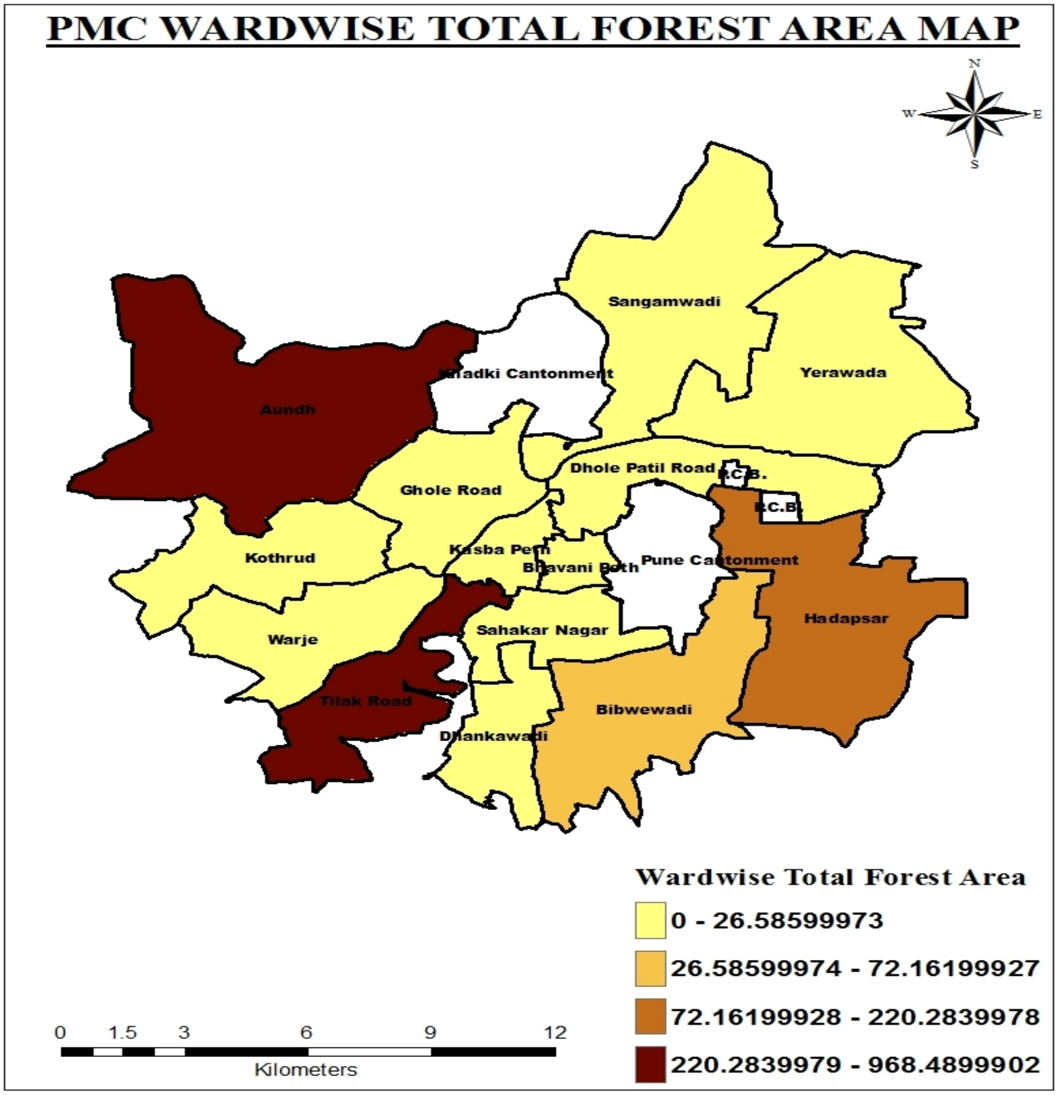


Figure-b: PMC Wardwise Total Forest Area Map

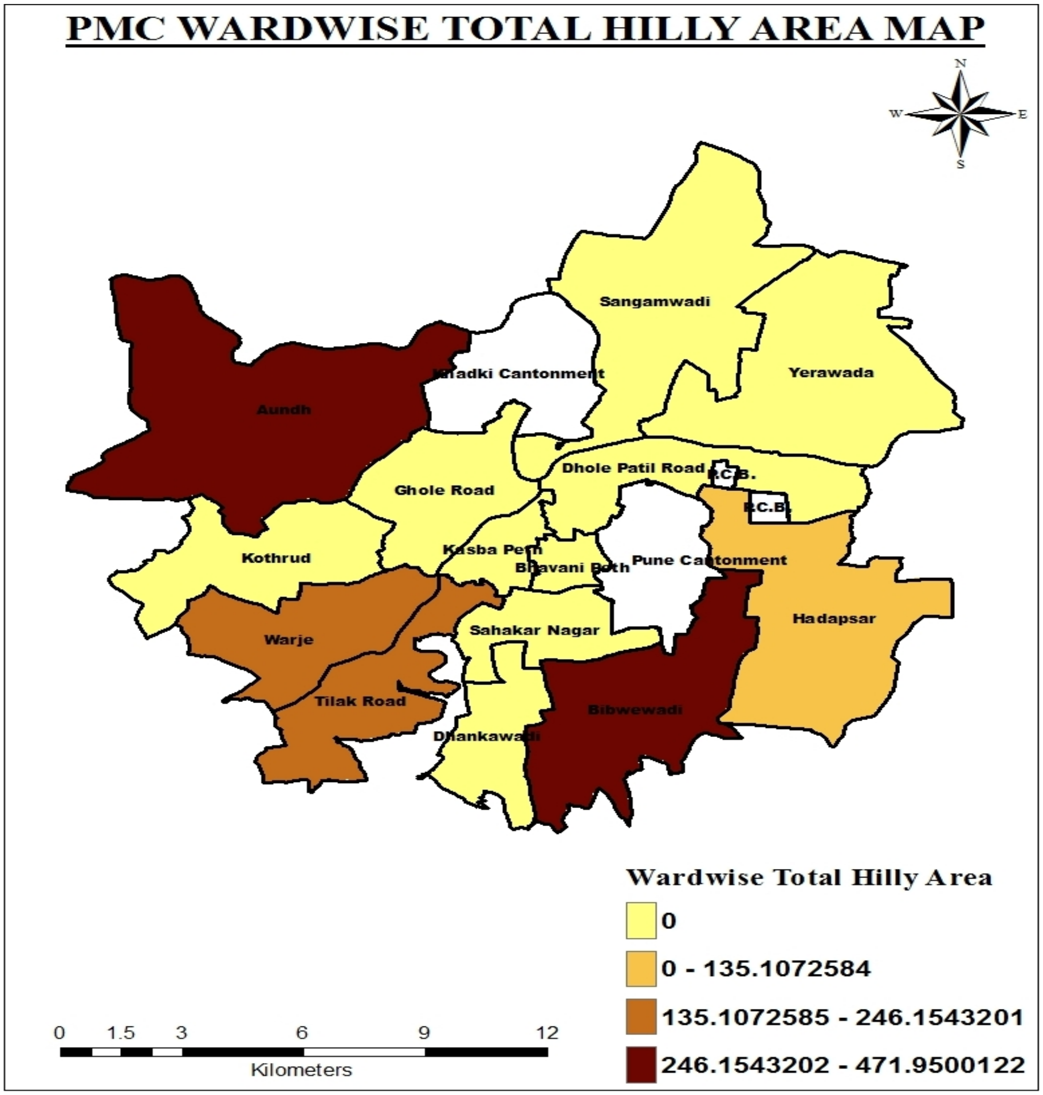


Figure-c: PMC Wardwise Total Hilly Area Map

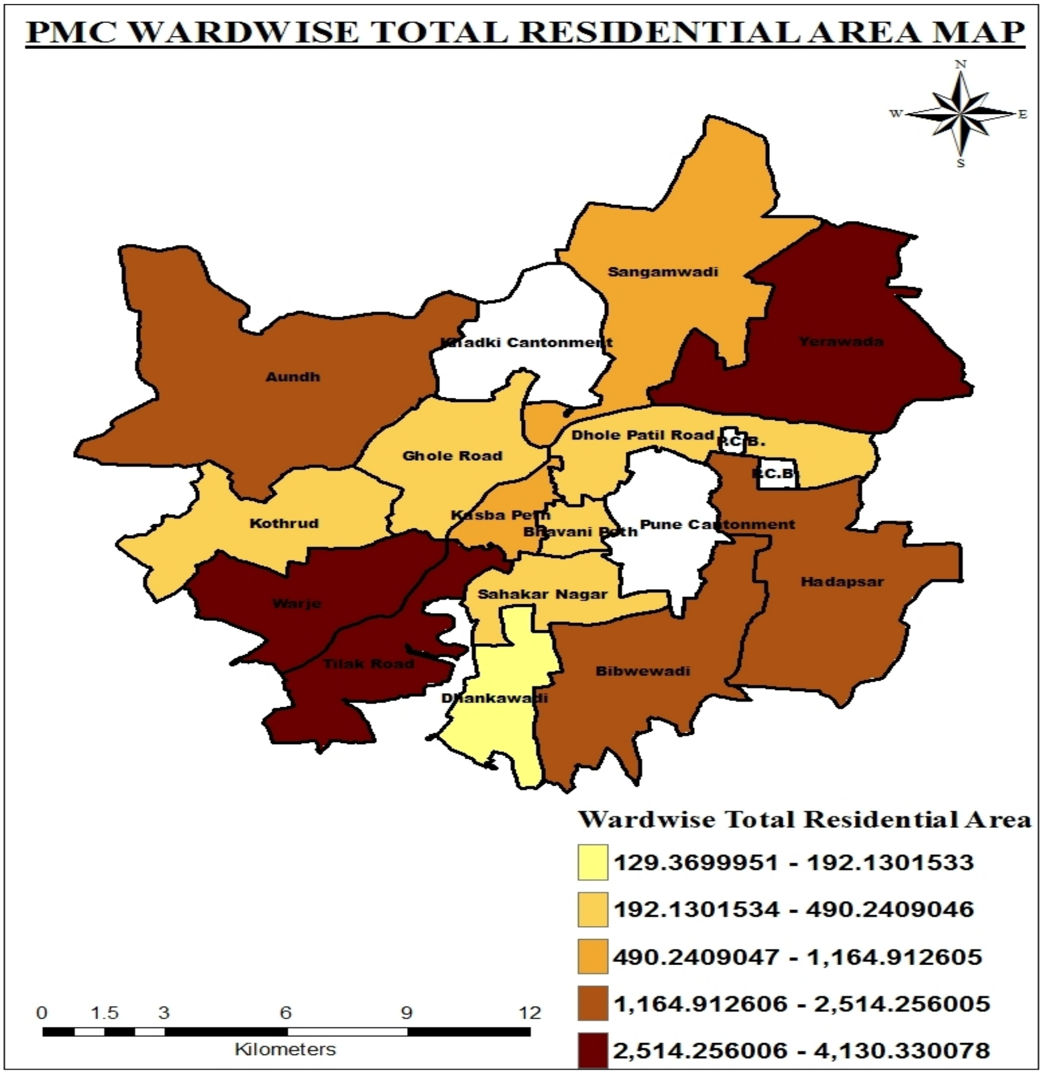


Figure-d: PMC Wardwise Total Residential Area Map

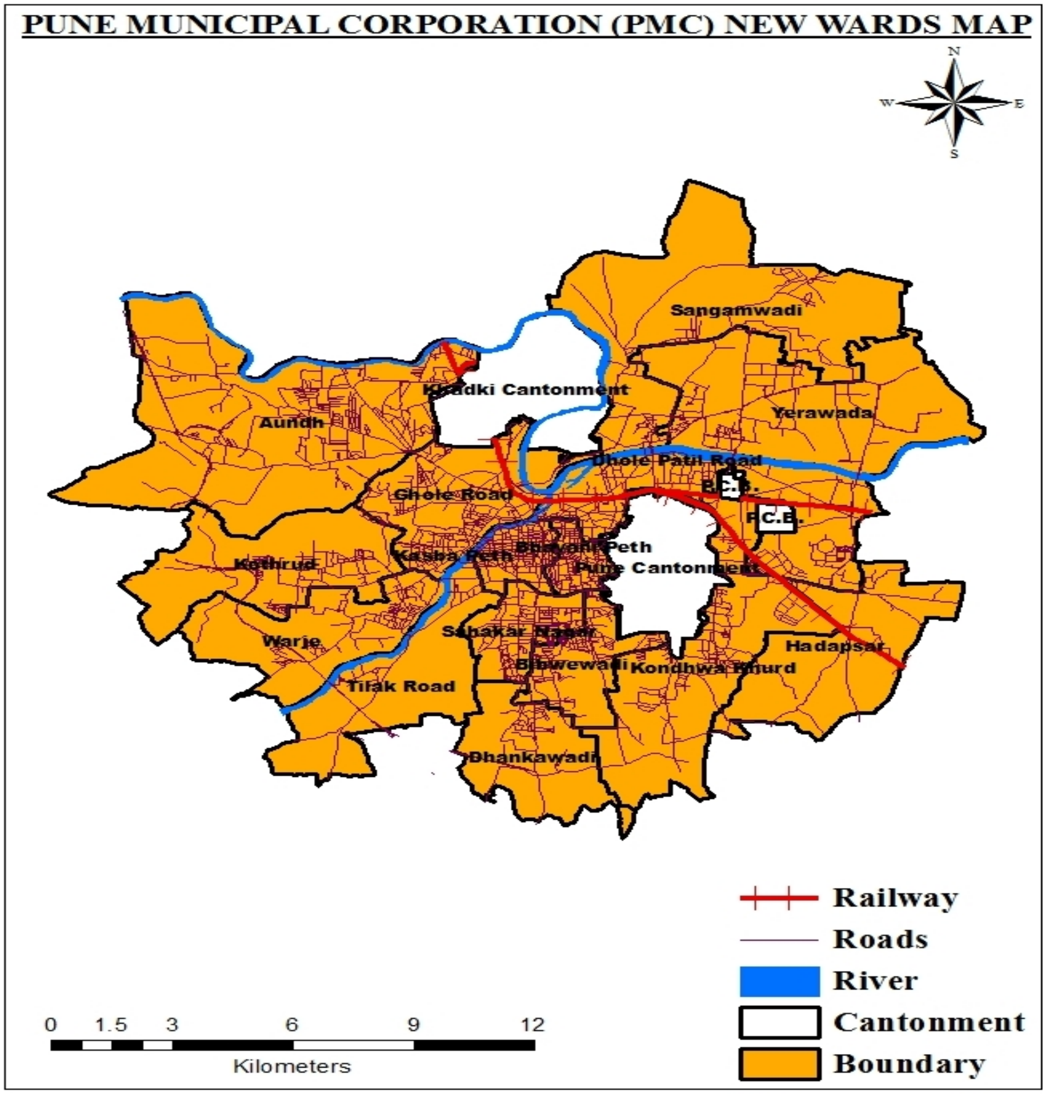


Figure-e: Pune Municipal Corporation (PMC) New Wards Map

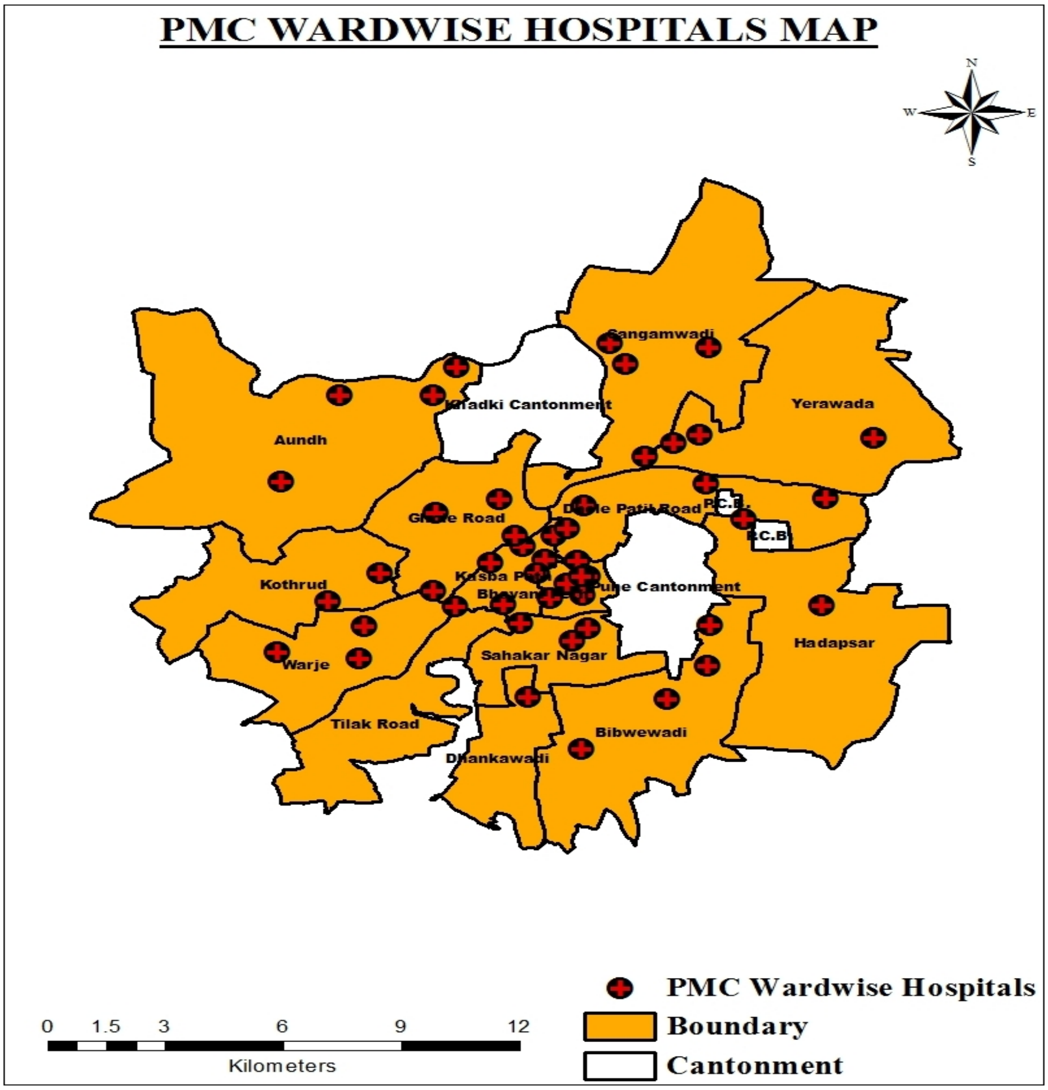


Figure-f: PMC Hospitals Map

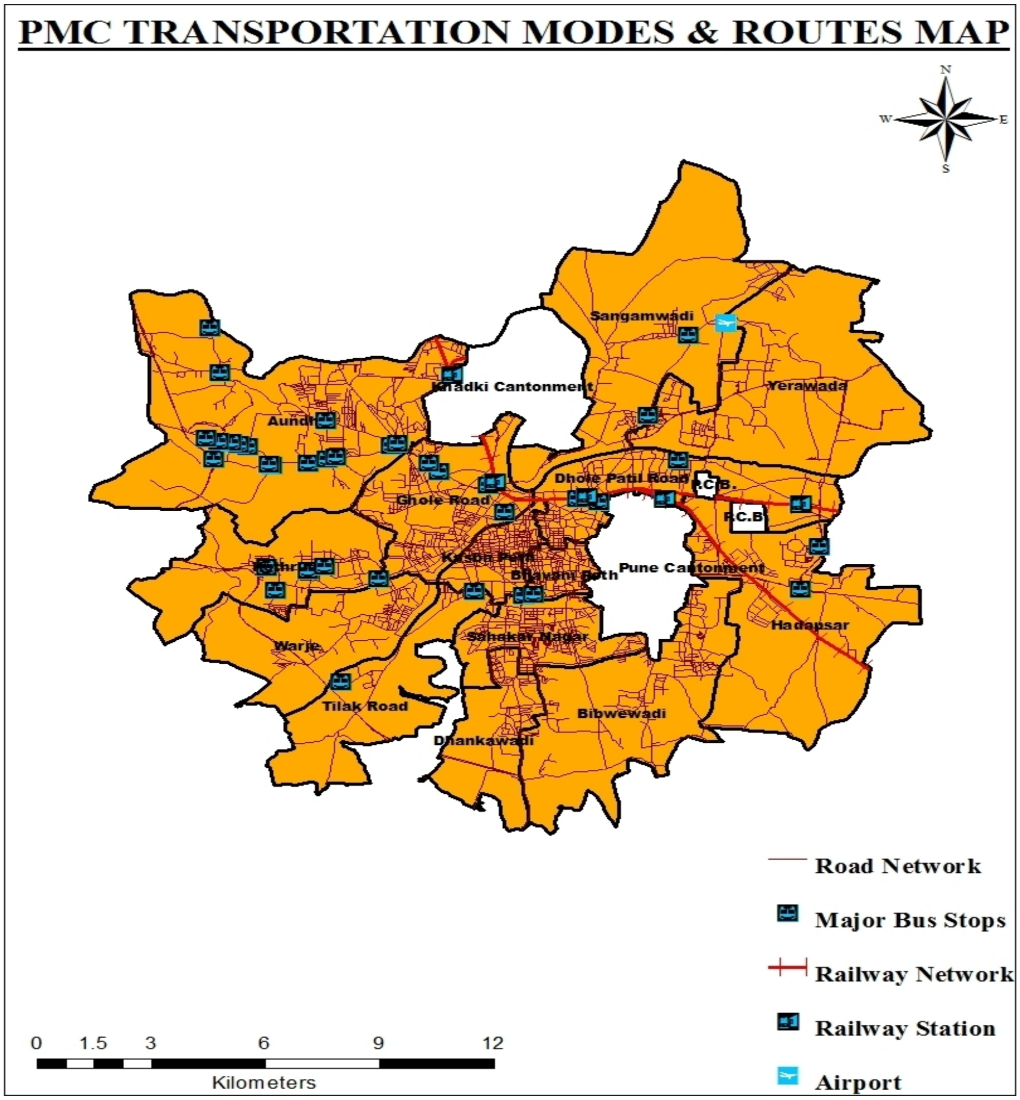


Figure-g: PMC Modes & Routes of Transportation Map

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