ASSESSMENT OF CULEX MOSQUITO PRONE ZONES USING REMOTE SENSING AND GIS

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

The metropolitan city of Chennai faces a major problem of mosquitoes. The three main breeds of mosquitoes found in Chennai are Culex, Aedes and Anopheles. Out of these, Culex mosquitoes that breed in polluted waters cause menace to city dwellers. In Chennai, Cooum river is prone to Culex mosquito breeding. The study area chosen for this work is a stretch of Cooum river from Maduravoyal to Chennai port trust. The larval count has been measured at 24 well-distributed sample locations for four consecutive weeks.

The various factors that influence Culex mosquito breeding have been identified to be temperature, vegetation, moisture/water, land use land cover and slope of terrain. The spatial distribution of these factors have been mapped and weightages for each factors have been obtained using Analytic Hierarchy Process (AHP). These layers have been overlaid to generate the mosquito prone area zonation map. The resultant map has been validated using the larval count measured at sample locations. Relationship between each of the factors and the larval count has been established in the form of scatter plots.

Results showed that breeding of Culex mosquitoes was found to be higher in areas having high moisture, high water content, high vegetation, low temperature and low rate of change of slope

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVI	Advanced Vegetation Index
COC	Corporation of Chennai
DEM	Digital Elevation Model
DN	Digital Number
ENVI	Environment for Visualizing Images
ERDAS	Earth Resource Data Analysis System
ETM	Enhanced Thematic Mapper
GIS	Geographic Information System
GLMM	Generalized Linear Mixed Effects Model
GPS	Global Positioning System
LU/LC	Land Use Land Cover
MSI	Multispectral Imaging
NDMI	Normalised Difference Moisture Index
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NIR	Near Infrared

OLI	Operational Land Imaging
PAN	Panchromatic
SWIR	Short Wave Infrared
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
USGS	United States Geological Survey
WNV	West Nile Virus

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Mosquitoes have a greater importance in terms of major public health problems. Infectious diseases continue to be a threat to populations around the world. Vector-borne diseases such as those transmitted by mosquitoes, contribute significantly to the total disease burden in developing countries. Approximately 1 million people died because of mosquito borne diseases and about 247 million people became ill in tropical and subtropical areas of the world in 2006, as reported by World Health Organization (WHO, 2008).

Different mosquito genera are Coquillettidia, Anopheles, Culex, Culiseta, Mansonia, Ochlerotatus, Aedes, Psorophora, Uranotaenia, Toxorhynchites. *Culex, Aedes* and *Anopheles* serve as significant vectors of several serious diseases (Weaver and Reisen, 2010; Kilpatrick, 2011). This has arisen as a result of their abundance, their ability to carry disease causing pathogens and their diversity (Njabo et al., 2013). Moreover, mosquito bites may cause a significant nuisance for mammals and humans which have adverse economic consequences. The three major genera of mosquitoes, their life cycle and their habitat conditions are explained in detail.

1.1.1 Anopheles

Anopheles is a genus of mosquito that is best known for transmitting the dangerous malaria. This genus contains over 420 known species of mosquitoes. Human malaria is transmitted by female Anopheles mosquitoes but only about 30-40 Anopheles species transmit malaria disease.

Anopheles mosquitoes consist of three main parts – head, thorax and abdomen (Fig 1.1). For detecting different odours from hosts such as those from a human skin and to find breeding sites these mosquitoes have specific antennae on their body. For feeding these mosquitoes have a proboscis and to detect carbon dioxide, which is one of the strongest mosquito attractants these species have two maxillary palps. Anopheles mosquitoes also have a pair of wings and three pairs of legs.

Fig 1.1- Anopheles

Anopheles mosquitoes can be easily differed from other mosquito genus by their resting position. The stomach of a mosquito is pointed upwards when they are in a resting position and not in parallel to the surface they are resting on. Most of species are active during dusk to down time of day or during the night and hides in dark areas during the day hours. The female Anopheles mosquito, which is the transmitter of malaria disease usually lives two weeks but can sometimes live up to a month depending on the weather conditions, climate, blood meals available and other factors, however male mosquitoes live only about a week. The main purpose of female mosquitoes is to breed and lay eggs and for male mosquitoes only to breed. Anopheles male and female mosquitoes feed on nectar from plants and take energy from sugars of nectars. Female mosquitoes also need blood to develop their eggs. Adult female Anopheles mosquito can lay up to 200 eggs at one time.

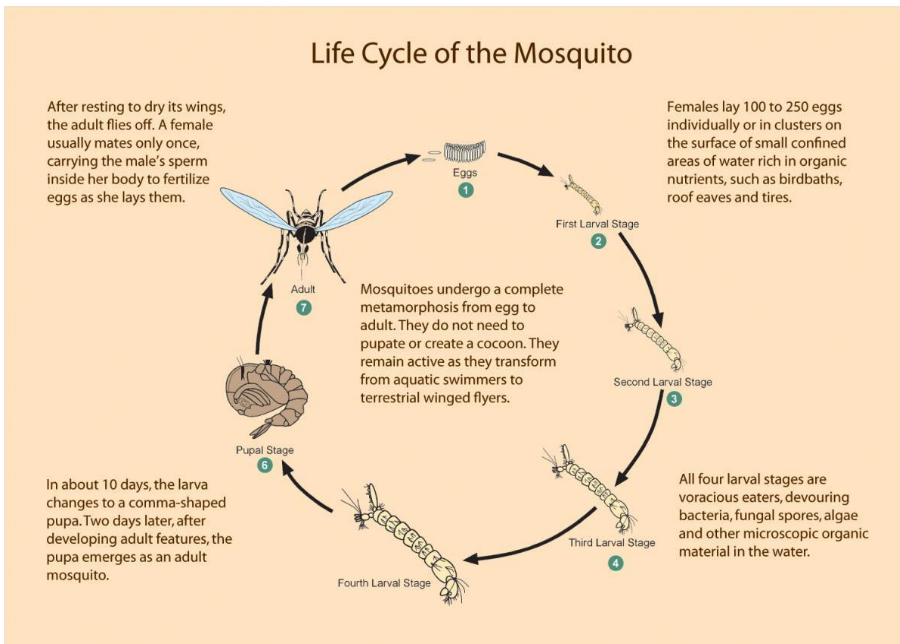

Fig 1.2- Life Cycle of Anopheles

There are four development stages of Anopheles mosquito life cycle: egg, larva, pupa and imago or adult mosquito (Fig 1.2). The breeding ares of these mosquitoes are any means of fresh or salt water. An adult female mosquito in a single time can lay up to 200 eggs. To develop eggs a female mosquito needs to have a blood meal and after few days it is ready to lay eggs. When eggs have been laid into water the female mosquito can go and seek for another blood meal to develop next batch of eggs. The duration for eggs to hatch can differ from the specie of mosquito and from the temperature and climate around. Anopheles mosquito can develop from egg to adult mosquito usually in about 5-14 days.

1.1.2 Aedes

Aedes aegypti, the yellow fever mosquito, is a mosquito that can spread dengue fever, chikungunya, Zika fever, Mayaro and yellow fever viruses, and other diseases. The mosquito can be recognized by white markings on its legs (Fig 1.3) and a marking in the form of a lyre on the upper surface of its thorax. This mosquito originated in Africa, but is now found in tropical and subtropical regions throughout the world.

Aedes aegypti is a vector for transmitting several tropical fevers. Only the female bites for blood, which she needs to mature her eggs. To find a host, these mosquitoes are attracted to chemical compounds emitted by mammals, including ammonia, carbon dioxide, lactic acid, and octenol.

Fig 1.3- Aedes

Aedes mosquitoes are visually distinctive because they have noticeable black and white markings on their body and legs. Unlike most other mosquitoes, they are active and bite only during the daytime. The peak biting periods are early in the morning and in the evening before dusk.

Aedes aegypti is a so-called holometabolous insect. This means that the insects goes through a complete metamorphosis with an egg, larvae, pupae, and adult stage (Fig 1.4). The adult life span can range from two weeks to a month depending on environmental conditions. The life cycle of Aedes aegypti can be completed within one-and-a-half to three weeks.

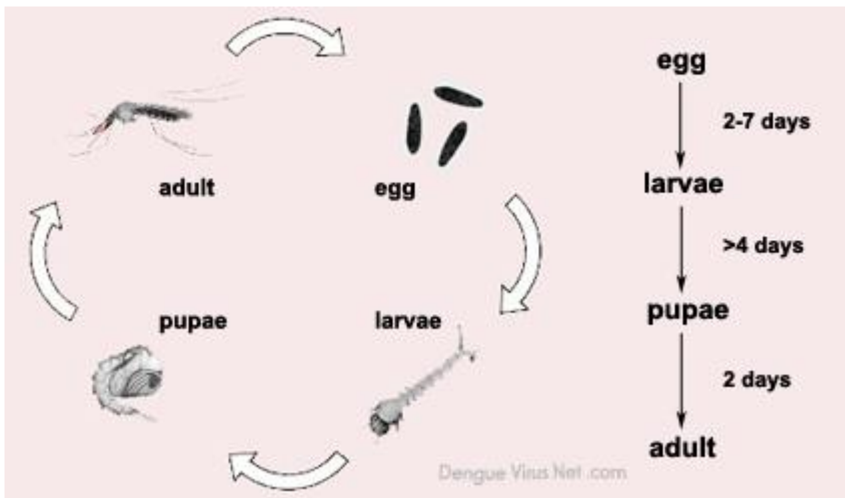

Fig 1.4- Life Cycle of Aedes

Members of the Aedes genus are known vectors for numerous viral infections. The two most prominent species that transmit viruses are Aedes aegypti and Aedes albopictus which transmit the viruses that cause dengue fever, yellow fever, West Nile fever, chikungunya, eastern equine encephalitis, and Zika virus, along with many other, less notable diseases. Infections with these viruses are typically accompanied by a fever, and, in some cases, encephalitis, which can lead to death.

Aedes aegypti is a day biting mosquito. That means that the mosquito is most active during daylight, for approximately two hours after sunrise and several hours before sunset. The mosquito rests indoors, in closets and other dark places. Outside, they rest where it is cool and shaded.

The males of all species of mosquitoes do not bite humans or animals of any species, they live on fruit. The female of Aedes aegypti feed not only on fruit, but also on blood. When viewed under a microscope, male mouthparts are modified for nectar feeding, and female mouthparts are modified for blood feeding. The female needs blood to mature her eggs. Feeding on humans generally occurs at one to two hour intervals. The mosquito attacks generally from below or behind, usually from underneath desks or chairs and mainly at the feet and ankles. Aedes aegypti is adapted to breed around human dwellings and prefers to lay its eggs in clean water which contains no other living species. These eggs become adult in about one-and-a-half to two weeks.

In dengue virus infected mosquito's, the virus is present in the salivary glands of the mosquito. When a female Aedes aegypti bites a human for food, she injects saliva into the wound where the anti-coagulants contained in her saliva facilitate feeding. Without knowing, the mosquito also injects the dengue virus into the host. Since the virus can be passed from adult to egg, the dengue virus is guaranteed to survive until the next summer and heavy rains.

1.1.3 Culex

The Culex mosquito, known as the common house mosquito, is one of the three major types of mosquito inhabiting the planet. Since it typically obtains its blood meal from birds instead of humans, it is not considered as much of a threat to our health as the Anopheles and Aedes mosquitoes. Nevertheless, the Culex remains a vector for an assortment of diseases that can be potentially fatal to humans.

The mosquito goes through four separate and distinct stages of its life cycle: Egg, Larva, Pupa, and Adult. Each of these stages can be easily recognized by its special appearance. There are 3 main habitats for insect's terrestrial, semi-aquatic and aquatic. Mosquitoes spend part of their lifecycle in the water so they are semi-aquatic insects. All mosquitoes have four stages of development – egg, larva, pupa and adult (Fig 1.5). Eggs can be laid directly onto the water or in areas that will be flooded with water. Larval and pupal stages are spent in water and the adult stage is spent out of water. Each of these stages can be easily recognized by its special appearance.

The egg, larval, and pupal stages, female ovarian development, and adult life span all depend on temperature, food supply, and species characteristics. Optimum temperature range for mosquito development is 75 – 85 degrees Fahrenheit. Under this range, eggs take 2 days to hatch, larvae take 5-7 days to become pupae, pupae take 2 days to emerge. Male adults survive for 2-3 weeks. Female adults take 3-4 days to develop eggs after a blood meal and survive for 4-5 weeks. They may suck blood and lay eggs 2-3 times. An entire life cycle takes about 10-14 days.

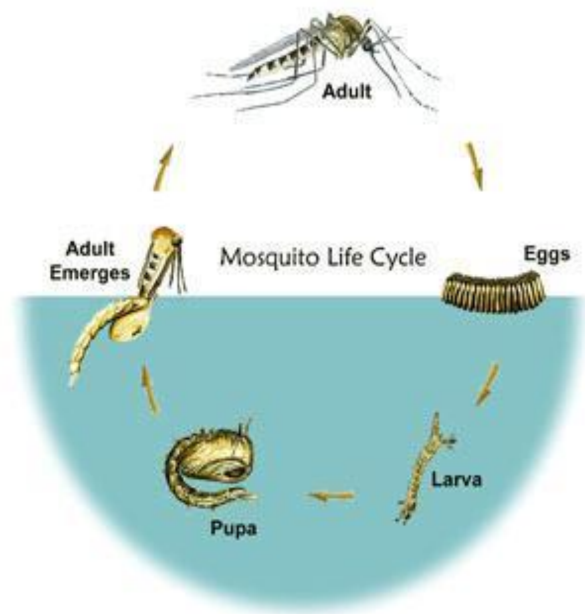

Fig 1.5- Life Cycle of CULEX

Eggs are laid by gravid females, one at a time or attached together to form "rafts" on the surface of the water (Fig 1.6). The female of some mosquito species deposit eggs on moist surfaces, such as mud or fallen leaves, that hold water but dry. Later, rain or high tides re-flood these surfaces and stimulate the eggs to hatch into larvae, for example, the salt marsh mosquitoes. The females of other species deposit their eggs directly on the surface of still water in such places as catch basins, tire tracks, ditches, streams, and pools, for example, Anopheles and Culex mosquitoes.

Fig 1.6- Eggs

The larvae live in the water and come to the surface to breathe. Larvae molt their skins four times, growing larger after each molt. Based on the molt time and size, larvae are divided into 4 stages or instars (from 1st instar to 4th instar). Larvae of Culex, Aedes, and Ochlerotatus mosquitoes have siphon tubes for breathing and hang upside down from the water surface (Fig 1.7). Anopheles larvae do not have a siphon (air tube) and lie parallel to the water surface to get oxygen supply through a spiracular opening. Some species, such as Coquillettidia and Mansonia larvae attach to plants to obtain their air supply. The larvae feed on microorganisms and organic matter in the water.

Fig 1.7- Larva

Pupae are mobile, responding to light changes and move with a flip of their tails towards the bottom or protective areas (Fig 1.8). A pupa is a resting, non-feeding development stage. This is the time the pupa changes into an adult (Fig 1.9). When development is complete (usually 2 days), the pupal skin splits and the adult mosquito emerges.

Fig 1.8- Pupa

The newly emerged adult mosquitoes include male and female, usually, 1:1 rate of male and female mosquitoes. The new adults rest on the surface of water for a couple of hours to dry and harden its exoskeleton (hard, outer protective shell). The wings spread and dry before it can fly. They fly to nearby vegetation and plants to rest and /or suck plant juice / nectar. After a couple of days, males and females begin to mate and after females are mated they will take a blood meal from animals and humans for their egg development. However, some species can develop their eggs without a blood meal. After a blood meal (3-4 days), gravid females start to lay eggs.

Fig 1.9- Adult

Although the Culex mosquito is not a primary vector for prevalent mosquito-borne diseases such as malaria, dengue and yellow fever, it can transmit a number of other illnesses that can present serious health problems to human beings. It is known to contribute to the spreading of the West Nile Virus, filariasis, and encephalitis.

Environmental conditions and climatic factors can lead to an increase in mosquito populations, commonly referred to as “blooms”. In order to prevent the spread of disease, it is advantageous to first assess human risk of disease transmission, both spatially and temporally. Knowing where risk is highest can improve preparedness and response efforts to the disease (World Health Organization, 2004).

1.2 NEED FOR STUDY

The metropolitan city of Chennai faces a major problem of mosquitoes. Out of the 3 main breeds of mosquitoes- namely Culex, Aedes and Anopheles- Culex mosquitoes are found in large numbers and they breed in polluted waters. They rarely spread filariasis and mainly cause nuisance to city dwellers. In Chennai, the long stretch of Cooum River provides a very favorable habitat for their breeding. Using techniques of remote sensing and GIS, these habitats can be mapped by taking into consideration the various favorable factors. This saves time and workforce when compared to the conventional methods. The priority of the Corporation of Chennai (COC) is to first get rid of Culex mosquitoes before attending to other mosquito problems and hence this study is required. Collaborating with COC, this project aims to provide an easier means of identifying Culex prone zones so that their breeding can be controlled.

1.3 SCOPE OF STUDY

The goal of this work is to identify the risk prone zones of *Culex* mosquitoes in the study area. The results of this work can be used by the Corporation of Chennai to take the necessary precautionary measures to reduce the menace caused by *Culex* mosquitoes.

1.4 OBJECTIVES

The main objectives of this study are:

i. To assess the favorable factors for mosquito breeding.
ii. To prepare and integrate map layers such as land use/land cover, slope, vegetation, moisture, water content and temperature in order to identify prone zones in a part of Cooum River.
iii. To validate the prone areas using reference data collected from the field.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter encompasses various articles and book citations, which were of major inspiration in taking up this project. The articles also gave valuable ideas for proceeding with the project and obtaining the results.

2.2 ENVIRONMENTAL MODELLING

Ahmed El-Zeiny, et al., *(“Geospatial techniques for environmental modeling of mosquito breeding habitats at Suez Canal Zone, Egypt”, The Egyptian Journal of Remote Sensing and Space Sciences, November 2016*) carried out the detection of mosquito breeding habitats in Suez Canal zone using integrated Remote Sensing and GIS techniques and field surveys. In this study, the breeding sites of mosquitoes were identified and the larval densities of those places were found. Normalized Difference Vegetation Index, Normalized Difference Moisture Index and the Land Surface Temperature were calculated from the Landsat 8 OLI image at the breeding sites and then GIS model was developed using weighted overlay of these layers and overlay analysis was carried out to obtain the output. The results revealed that *Culex pipiens* is the most abundant species in Suez Canal recording a total of 362 larvae. It is predicted that Ismailia is the most subjected Suez Canal Governorate mosquito borne disease.

2.3 REGRESSION MODELLING

Yasin Jemal, et al., *("Combining GIS application and climatic factors for mosquito control in Eastern Province, Saudi Arabia", Saudi Journal of Biological Sciences, 2006*) has carried out a study to determine the effects of climatic factors on mosquito abundance and map the breeding sites using GIS techniques. The area included in this study was Eastern Province of Saudi Arabia bordered by Kuwait in the north & Oman in the south. In this study, initially the effect of climate factors such as temperature, relative humidity and rainfall on mosquito abundance was determined then the mosquito larva breeding sites was mapped using GIS application in Eastern province of Saudi Arabia. A linear regression model was developed between mosquito abundance and climate factors. The result shows strong negative correlation between temperature and mosquito abundance and it shows strong positive correlation with relative humidity.

Haley Cleckner, et al., ("*Remote Sensing and Modeling of Mosquito Abundance and habitats in Coastal Virginia, USA", Journal of Remote Sensing: Volume 3, 2663-268, December 2011)* predicted the mosquito abundance across the city of Chesapeake. The goal of the study was to produce an abundance model that could guide risk assessment, surveillance and potential disease transmission. In this study remote sensing techniques were used to quantify environmental variables for a potential habitat suitability index for the mosquito species and abundance model. Independent variables used for the regression model were behaviour cap index, hydrology, drain potential, runoff potential, water table depth and available water storage. Linear regression models were used to quantify the effect of certain climate variables on mosquito trap counts for each month. The risk assessment, surveillance and potential disease transmission were studied. The results highlighted the utility of integrating field surveillance, remote sensing and dynamic environmental data for predicting mosquito vector abundance.

2.4 HYBRID TECHNIQUES OF MAPPING POTENTIAL BREEDING HABITATS

Palaniyandi, et al., ("*The Integrated Remote Sensing and GIS for Mapping of Potential Vector Breeding Habitats, and the Internet GIS Surveillance for Epidemic Transmission Control, and Management", Journal of Entomology and Zoology Studies Vol: 4(2), pg: 310-318, February 2016*) used integrated hybrid techniques of remote sensing, GPS, and GIS to map the spatial variation of the vector biodiversity, vector abundance, and vector borne disease transmission. The study was carried out in Visakhapatnam. In this study the Indian IRS satellite data was used to map the use/ land cover of study area. The mosquito potential breeding habitats of malaria, dengue, chikungunya, JE and filariasis were calculated for each ward and were mapped with graduated colors. The Arc View 3.2, Arc View Spatial analysis and Arc View image analyst, GIS software were used to create a systematic grid sampling method for conducting the reconnaissance survey. The total potential breeding surfaces of malaria, filariasis and JE were measured (in sq.km). The results prove that remote sensing, GPS, and GIS are effectively useful to identify, delineate and map vector mosquito potential breeding surface areas and study the mosquitogenic conditions in the urban agglomeration.

Li Zou, et al., (*"Mosquito Larval Habitat Mapping Using Remote Sensing and GIS: Implications of Coalbed Methane Development and West Nile Virus", Entomological Society of America: Volume 43(5): 1034-1041, 2006)* identified potential larval habitats of the mosquito *Culex tarsalis* (implicated as a primary vector of West Nile virus in Wyoming) using integrated remote sensing and geographic information system (GIS) analyses. The area focussed in this study was Powder River Basin of North Central Wyoming. The condition suitability and increase in count of Culex were studied. The results showed a 75% increase in potential larval habitats from 1999 to 2004 in the study area, primarily because of the large increase in small coalbed methane water discharge ponds.

2.5 MALARIA EARLY WARNING SYSTEM

Yaniv Kazansky, et al., *(The Current and Potential Role of Satellite Remote Sensing in the Campaign against Malaria", Vol: 121, pg: 292–305, September 2015)* explored the use of environmental data generated via satellite remote sensing as an ingredient to Malaria Early Warning System. The study was carried out in Sub Saharan Africa. In this study, a model was developed to estimate geographic regions that have high risk for malaria transmission using environmental data weather, terrain, altitude that predict the behaviour of mosquitoes, and other environmental characteristics such as temperature, moisture etc., that affect the mosquito populations. The demographic data was used to develop vulnerability model. Information from these two models were combined to develop a risk model. Results revealed that environmental data from satellites can be effectively used to predict malaria risk and implement a Malaria Early Warning System.

2.6 SURVEY OF MOSUITO VECTOR ABUNDANCE

Suganthi et al (“*Survey of mosquito vector abundance in and around tribal residential areas”, Journal Entomology and Zoology, Vol: 2(6), pg: 233-239; December 2014)* estimated the mosquito larval density, diversity and preference of breeding sites for Aedes, Culex and Anopheles mosquito species. The region of study was Sithera hills, Dharmapuri district, Tamil Nadu. In this study the larval densities of different breeds of mosquito were estimated from the samples collected at different sites in the study area. It is observed in the result that the major breeding sources are mud pot, grinding stones, metal vessels, tree hole and stagnant water lock area. It concludes that species Aedes aeygpti was most predominant container breeding mosquito.

2.7 SPATIO - TEMPORAL MAPPING OF MOSQUITO VECTORS

John Wilson, et al., (“*Spatial and temporal distribution of mosquitoes (Culicidae) in Virudhunagar district, Tamil Nadu, South India”, International Journal of Mosquito Research; Vol: 1 (3), pg: 04-09, July 2014)* found out the distribution of dengue and chikungunya vectors in different villages of Virudhunagar district, South India. In this study the different breeds of mosquitoes were found and spatial distribution of mosquitoes were mapped for the study area. The results showed that 9 species of mosquito belonged to 5 genera namely Aedes, Anopheles, Armigeres, Culex, Mansonia.

Donal Bisanzio, et al., (“ *Spatio-temporal patterns of distribution of West Nile virus vectors in eastern Piedmont Region, Italy”, Journal of Parasites and Vector, Vol: 4-230, July 2011***)** quantified the abundance and distribution of West Nile Virus (WNV) Vector in space and time and to generate prediction maps outlining the areas with the highest vector productivity and potential for WNV. In this study by applying spatial statistical analysis (spatial point pattern analysis) and models (Bayesian GLMM models) to a longitudinal dataset on the abundance of the three putative WNV vectors in eastern Piedmont, their abundance and distribution in space and time was quantified and prediction maps were generated. The result indicates highest abundance and significant spatial clusters of Oc. Caspius and Cx. Modestus were in proximity to rice fields, and for Cx. Pipiens, in proximity to highly populated urban areas. It was found that distance from the preferential breeding sites and elevation were negatively associated with the number of collected mosquitoes.

2.8 MOSQUITO ABUNDANCE MODELLING

Scott Bellows, et al., ("*Spatial habitat detection of mosquitoes in a fragmented landscape on the southern coastal plain of Virginia using remote-sensing techniques and a GIS", Dept. of biological sciences, Nov 2015*) created a predictive, spatially explicit classification model capable of identifying, categorizing, and ranking suitable mosquito habitat in heterogeneous landscapes. The City of Chesapeake, Virginia, was selected for study. The local mosquito abundance was predicted from measurable landscape factors which include land cover, wetland characteristics and soil and vegetation characteristics. The spatial composition and configuration of vegetation were closely linked with species diversity and abundance. Results of Vegetation Indices were derived by incorporating mathematical operations between spectral bands. Collectively, these layers were used to statistically arrive at relationships between mosquito abundance and landscape factor.

2.9 CONCLUSION FROM LITERATURE REVIEW

Ahmed El-Zeiny et al concluded that remote sensing and GIS techniques offer the necessary requirements for studying the environmental variables associated with mosquito breeding habitats, thus mapping risk areas. GIS modeling proved strong success in identifying the relationships between occurrence of mosquito (presence/absence) and environmental data.

Yasin Jemal et al concluded that a strong negative correlation exists between mosquito abundance and temperature, while there is a strong and moderate positive correlation between relative humidity and rainfall, respectively.

Palaniyandi et al suggested the potential breeding habitats of various disease causing mosquitoes. The breeding grounds of Culex, which is a carrier of Filariasis were also studied in detail.

Yaniv Kazansky et al suggested the methodology to develop a risk model by combining the vulnerability model which used demographic data and geographic model which used environmental data.

Suganthi et al concluded the water storage containers are acting as breeding habitats of mosquitoes, which are vectors for the mosquito-borne diseases.

John Wilson et al concluded that seasonal fluctuations of mosquito communities are variable across years, affecting both the abundance of individual species and the community composition, and their subsequent response to meteorological variables.

Donal Bisanzio et al found that the number of collected mosquitoes is negatively correlated with distance from the preferential breeding sites and elevation.

Haley Cleckner et al used linear regression models to quantify the effect of certain climate variables on mosquito trap counts for each month.

Li Zou et al concluded that the abundance of mosquitoes increased with the increase in level of pollution in the discharge ponds.

Scott Bellows et al derived vegetation indices in order to establish a relationship between mosquito abundance and measurable landscape factors.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

The study area for this work is a stretch of Cooum river from Maduravoyal to Chennai port trust. The larval count has been measured at 24 well-distributed sample locations for four consecutive weeks. Satellite data used in this study are Sentinel 2A, Landsat 8 OLI data and Aster data.

The various factors that influence Culex mosquito breeding are identified to be temperature, vegetation, moisture/water, land use land cover and slope of terrain. The spatial distribution of these factors are mapped and weightages for each factors are obtained using Analytic Hierarchy Process (AHP). These layers are overlaid to generate the mosquito prone area zonation map. The resultant map is validated using the larval count measured at sample locations. Relationship between each of the factors and the larval count is established in the form of scatter plots.

3.2 FLOWCHART

The methodology of this work is represented in the form of a flowchart as shown in Fig. 3.1.

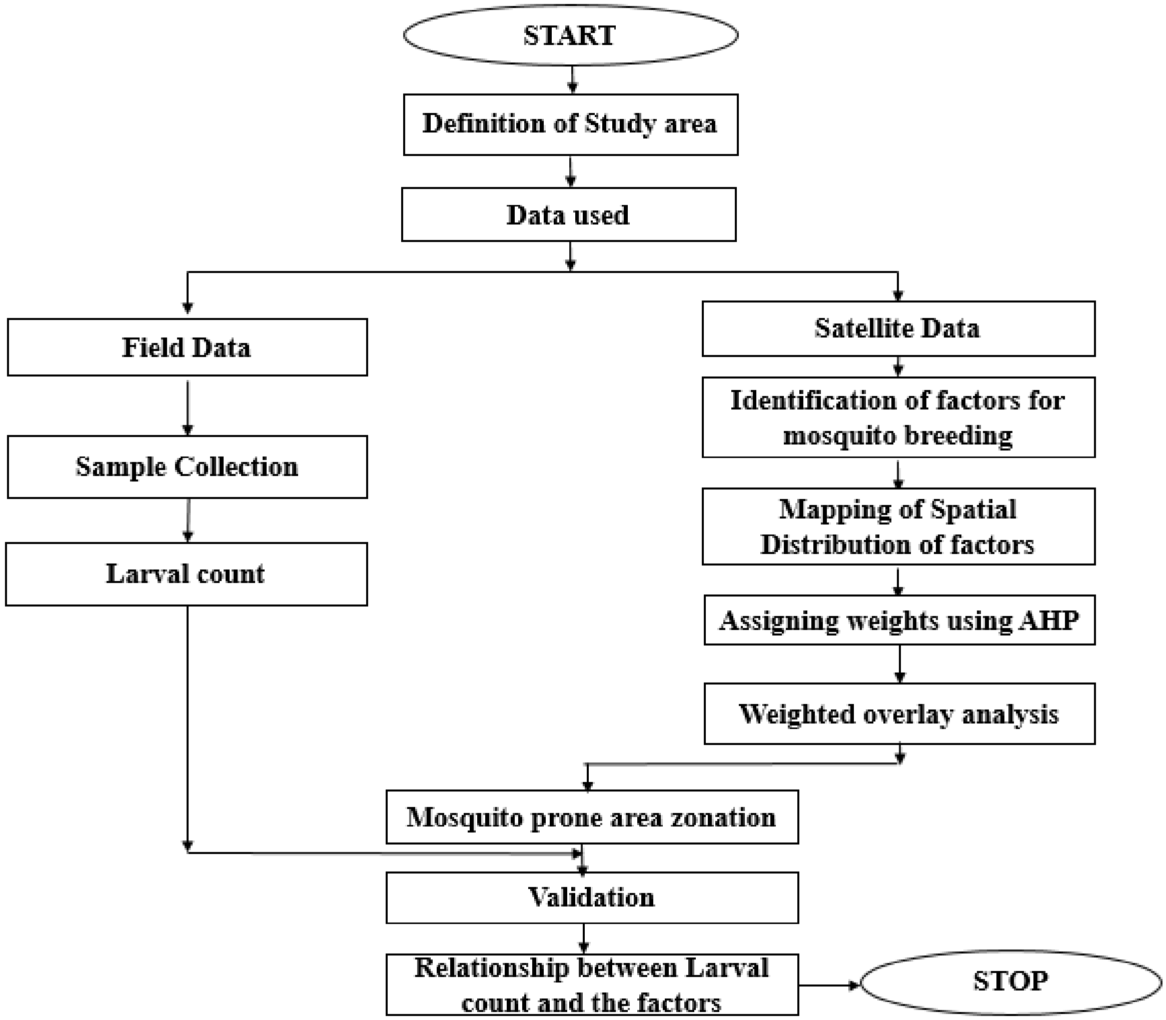

Fig 3.1- Methodology flow diagram

3.3 DEFINITION OF STUDY AREA

The Cooum River originates from the surplus course of Cooum tank in Tiruvallur District. It runs east for a distance of about 65 kilometers and confluences with the Bay of Bengal downstream of Napier Bridge, traversing a distance of 20 kilometers within Chennai city limits.

Cooum River Sub-Basin is a narrow drainage basin of about 505.88 Sq.km situated between the Kosasthalaiyar sub-basin on the northern side and Palar basin and Adyar basin on the southern side. Cooum River is fed by Kosasthalaiyar river surplus from Kesavaram Anicut through old Bangaru channel and Palar river surplus from Palar anicut through Govindavadi Channel, Kambakkal Channel and the chain of surplus courses of groups of tanks. Cooum River also supplies water to Chembarambakkam Lake in the Adyar Sub-basin from Korattur Anicut through New Bangaru Channel. Cooum River is connected to its adjoining basins through the Buckingham Canal.

Cooum River supports a substantial portion of irrigation and additional rain fed agriculture in its upper part and also provides water supply to Chennai city and its adjoining areas. Cooum River also acts as the major flood carrier for Chennai city with its arms viz., Otteri Nallah in the north (10.8 km) and Virugambakkam to Arumbakkam drain in the south (6.4 km).

The upper catchment of Cooum River is primarily rural and as it enters the peri-urban areas and Chennai City, the river is constrained in channels before draining into the Bay of Bengal. The Cooum River in its upstream rural areas shows issues of catchment degradation and tank siltation. There is also no minimum flow maintained in the river during the lean season. As the river flows through peri-urban areas and municipalities, there are increasing problems of water quality. The highly polluted reputation of the river also leads to public apathy and disposal of solid waste on the river bed that impacts downstream water quality and oxygen levels in the water. When it enters the city, the river is basically an urban sewer receiving municipal and industrial wastewater and solid waste (especially near bridges) and refuse from slums. This results in the direct impact of polluted anoxic stretches, as well as raises public health (including from mosquito breeding in stagnant waters) and odour concerns and secondary groundwater pollution. The river mouth is subject to blockage by sand bars resulting from littoral drift creating a lack of tidal exchange in the river.

Polluted Part of Coovum includes Paruthipattu Anaikat to the River Mouth in Bay of Bengal and the Unpolluted Part of Coovum includes the Origin in the Cooum Village to Paruthipattu Anaikat. In Chennai district, the river flows through five corporation zones of Valasaravakkam (Zone-11), Royapuram (Zone-5), Teynampet (Zone-9), Ambattur (Zone-7), Anna Nagar (Zone-8) for a total length of 19 kilometres.

A buffer of 1km was generated for a stretch of Cooum River between Maduravoyal and Chennai Port trust using ArcGIS software (Fig 3.2). The buffer distance was decided based on the maximum flying distance of Culex species as suggested by Expert.

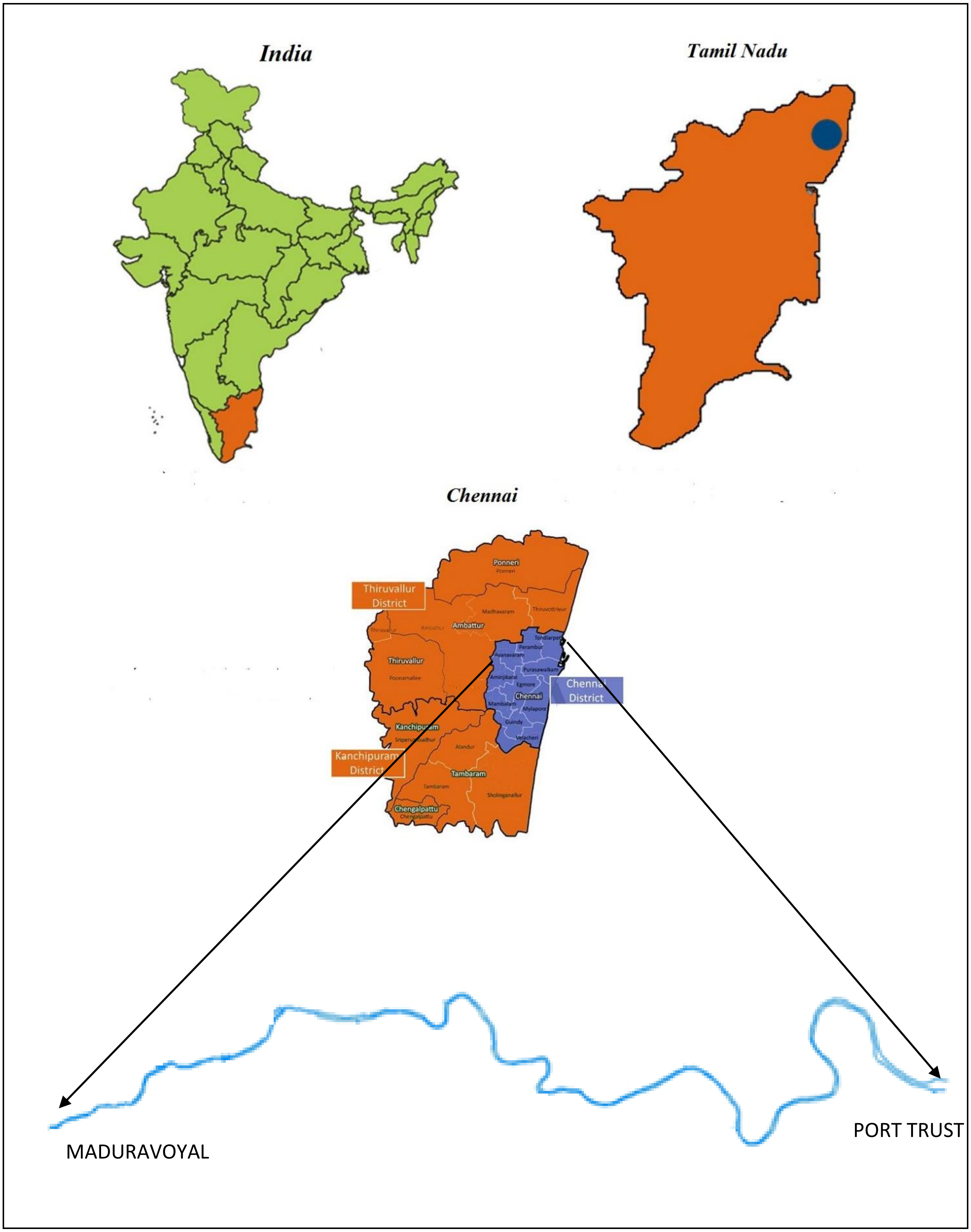

Fig 3.2- Study Area

3.4 DATA USED

Satellite data as well as field data are used for the study. Satellite data used in this study are Sentinel 2A data, Landsat 8 OLI data and ASTER data. The larval count at 24 sample locations has been collected from the field.

3.4.1 Satellite Data

The satellite data used for this study are explained in detail below:

3.4.1.1 Sentinel-2A Data

The 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 meters on the ground, takes global land monitoring to an unprecedented level (Table 3.1). MSI covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edge and shortwave infrared bands) and 60 m (three atmospheric correction bands). The sentinel imagery for the date 3rd October 2016, was downloaded from the Remote Pixel website.

Table 3.1- Sentinel 2A bands

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

3.4.1.2 Landsat Data

The Landsat imagery for the date 21st February 2017, was downloaded from USGS website. Band 11 data of this imagery was used to obtain the temperature at 24 sample locations by converting DN values to radiance and then to temperature using appropriate formulae. Table 3.2 shows the characteristics of Landsat 8 sensor.

Table 3.2- Landsat Bands

Landsat-7 ETM+ Bands (μm)			Landsat-8 OLI and *TIRS* Bands (μm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

3.4.1.3 Aster Data

Aster DEM data was downloaded from USGS website. This data was used to obtain 5 classes of slope in the study area, ranging from very high to very low slope.

3.4.2 Field Data

The larvae are found in foul water and water containing vegetable wastes from food-processing plants often provides favourable conditions for larval development. Mosquito larvae and pupae can be collected with dippers, nets, aquatic light traps, suction devices (turkey baster for bromeliad and container collections), and container evacuation methods. The most commonly used apparatus is the dipper. The term “standard pint dipper” is used in the scientific literature, but, in practice, there is no standard dipper or standardized dipping techniques (Service 1993). The dipper consists of a white plastic cup, 400ml in volume, with a two to five-foot handle to allow for an extended reach. The dipper can be used as a survey tool simply to determine the presence or absence of larvae.

Such a method usually involves taking several dipper samples from designated areas in the habitat of interest and then counting the larvae captured in each dip (Fig 3.4). The dipping method will vary with water depth, presence of aquatic vegetation or other debris, and water clarity. Collectors must take into account certain factors of importance, e.g., mosquito species difference in submerging behaviour, and stage differences (first and second instar stay under longer). Training, practice, and experience are important when control programs use larval density as a basis for larval control measures: Larvae densities measures = Number of larvae per dip.

Resting boxes are used for the collection of Culiseta and Anopheles spp. By programs interested in monitoring vector populations. Resting boxes are generally placed on the ground with the open end facing west to minimize the influence of direct sunlight during the early part of the day. A dark, forested habitat with high canopy yields the highest collections (Crans 1989). Mosquitoes utilizing resting boxes as diurnal resting sites enter the boxes during the morning hours, remain inactive during late morning and early afternoon, and then exit the boxes later in the day. The inside of the resting boxes is usually painted black or red, while the outside is painted flat black. The 12” x 12” x 12” plywood cubes have one open end and are usually positioned no closer than 10 feet from one another in either a line or grid design. Collection from these boxes is usually by aspirator and should be conducted in mid-morning to late afternoon.

The larval count was estimated at 24 locations (Fig 3.3) distributed throughout the study area. Table 3.3 and 3.4 shows the larval count for four weeks in the 24 sample locations.

Fig 3.3- 24 Sample Locations

Fig 3.4 Field Data collection

Table 3.3- Larval Count (1)

Point number	Latitude	Longitude	Week 1 (21/1/17)	Week 2 (28/1/17)	Week 3 (4/2/17)	Week 4 (11/2/17)
1	13°4'6.30"N	80°16'54.5"E	20	2	2	4
2	13°4'24.0"N	80°16'29.6"E	2	2	0	2
3	13°4'47.90"N	80°16'12.30"E	20	70	40	35
4	13°4'34.50"N	80°15'57.50"E	6	60	15	25
5	13° 4'1.80"N	80°16'3.60"E	32	8	5	7
6	13° 4'1.00"N	80°15'50.20"E	35	30	25	15
7	13°3'48.60"N	80°15'38.34"E	10	20	17	18
8	13° 4'3.15"N	80°15'14.26"E	50	13	10	5
9	13° 4'5.74"N	80°14'32.57"E	16	7	0	2
10	13° 3'58.75"N	80°14'16.85"E	200	27	16	18
11	13° 4'3.75"N	80°14'3.87"E	0	16	7	20
12	13° 4'4.84"N	80°13'44.09"E	200	70	37	15

Table 3.4- Larval Count (2)

Point number	Latitude	Longitude	Week1 (21/1/17)	Week2 (28/1/17)	Week3 (4/2/17)	Week4 (11/2/17)
13	13° 4'18.56"N	80°13'46.18"E	10	7	5	6
14	13° 4'19.20"N	80°13'38.2"E	4	5	5	3
15	13° 4'50.48"N	80°13'6.20"E	8	7	9	6
16	13° 4'45.63"N	80°12'56.49"E	6	3	4	4
17	13° 4'40.91"N	80°12'42.92"E	9	6	7	9
18	13° 4'38.72"N	80°12'13.06"E	8	10	6	10
19	13° 4'16.77"N	80°10'51.28"E	3	2	3	2
20	13° 4'16.50"N	80°10'48.24"E	150	10	5	7
21	13° 4'3.83"N	80°10'26.21"E	100	20	10	15
22	13° 4'1.95"N	80°10'23.92"E	2	0	2	3
23	13° 3'47.47"N	80° 9'44.35"E	5	100	50	35
24	13° 3'47.80"N	80° 9'40.42"E	10	10	8	6

3.5 IDENTIFICATION OF FACTORS FOR MOSQUITO BREEDING

The breeding of mosquitoes is affected by the environmental and climatic factors of the breeding area. The environmental variables including temperature, precipitation and soil moisture will affect the breeding of Culex mosquitoes. The presence of low temperature increases the breeding of mosquitoes while a high temperature is not favourable for Culex breeding. Also a frequently varying temperature will not increase the breeding.

Higher breeding of Culex mosquitoes is observed in the areas of high moisture content. This may include rivers, swamps, lakes or any other polluted stagnant water body. However, the water bodies that have more salinity content are not favourable for breeding.

The polluted water serves as favourable breeding ground for Culex mosquitoes. There are various types of water pollutants which includes chemical pollutants discharged from chemical, fertilizer and tannery industries; sludge discharge from the oil industries; Garbage pollutants consisting of plastics, household and sewage wastes discharged from the settlement area accounts for the major pollution of the river. The garbage pollutants act as a breeding ground for Culex mosquitoes. On the other hand, the chemical pollutants might either increase or decrease the Culex breeding. The effect of the chemical pollutants on the breeding depends upon the composition and concentration of chemicals released into the water body.

The presence of vegetation in or near the river banks triggers further growth of mosquitoes. The growth of water Hyacinth in polluted or contaminated water helps in increasing the larval density. The mosquito larvae receive the required oxygen and nutrients from these water plants and multiplies in number. The shrubs and bushes along the river side acts as breeding grounds for Culex mosquitoes. The moisture content present in the roots and soil is favourable for breeding.

The breeding of the mosquitos' increases aftermath the heavy rains as more stagnant water in forms of puddles will be formed. However, the continuous and heavy downpour will lead to flooding which in turn will wash away the mosquito larvae and pupae, hence resulting in decrease in its population.

Seasonal variation plays a major role in deciding the life span of the mosquitoes. During summer the life span of the Culex mosquitoes is reduced because of the sudden and continuous changes in the temperature. Also the continuously varying water temperature throughout the day will not behave as a suitable condition for breeding and hence the number for adult mosquitoes emerging will also decrease. So the overall number of mosquitoes will be less in summer. During winter, the temperature of the water will be ambient for breeding and the lifespan of the mosquitoes is also increased.

Apart from environmental and seasonal factors, the breeding is influenced by locational variables such as slope of terrain, the river course and the velocity of water and wind. The stagnant water bodies are prone to mosquito breeding unlike moving waters which deter the mosquito population growth. Breeding of mosquitoes is not possible in water bodies with higher velocity. When the rate of change of slope is higher, then the water velocity increases and the breeding also decreases and vice versa.

In this study, the influence of temperature, moisture content, presence of vegetation and its density and rate of change of slope on mosquito breeding is studied in detail.

3.6 MAPPING SPATIAL DISTRIBUTION OF FACTORS

The spatial distribution maps of the factors including moisture, temperature, water content, vegetation, rate of change of slope and land use land cover features has been prepared.

3.6.1 Spatial Distribution Map of Moisture

The Normalized Difference Moisture Index (NDMI) is a numerical indicator, that is used in combination with other vegetation indexes (NDVI and/or AVI), which is associated with vegetation moisture. NDMI uses the near infrared and short wave infrared spectral bands to capture the variations of moisture in vegetated areas.

The Normalised Difference Moisture Index for the study area has been prepared using ENVI Band Math. The NDMI for the Sentinel 2A is calculated as follows:

NDMI = (Band 8 – Band 11) / (Band 8 + Band 11) ………. Eq. 3.1

Where,

Band 8 is the NIR band, Band11 is the SWIR band.

The features having high moisture content have high DN values. The features may include vegetation, water bodies, soil or any other feature having moisture content. The output from NDMI has been reclassified into 5 classes ranging from very high moisture to very low moisture areas.

3.6.2 Spatial Distribution Map of Water Content

The Normalized Difference Water Index (NDWI) is a numerical indicator, derived from optical satellite images, using the near-infrared and short wave infrared spectral bands. The latter spectral band is highly associated with changes in vegetation water content and spongy mesophyll structure in the vegetation canopies. The near infrared spectral band response is correlated with the leaf internal structure and the leaf dry matter content, excluding water content. NDWI is useful in many remote sensing applications. Crop health monitoring, land/water boarding mapping, inland water discrimination from open sea water bodies, are just a few applications where NDWI is used.

The Normalised Difference Water Index for the study area has been prepared using the following formula in ENVI Band Math:

NDWI = (Band 3 – Band 8) / (Band 3 + Band 8) ………. Eq. 3.2

Where,

Band3 is the green band, Band8 is the NIR band.

The NDWI highlights all the water bodies including the river and ocean. The output from NDWI has been reclassified into 5 classes ranging from very high water content regions to very low water content regions.

3.6.3 Spatial Distribution Map of Vegetation

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the red and near-infrared spectral bands. NDVI is highly associated with vegetation content. High NDVI values correspond to areas that reflect more in the near-infrared spectrum. Higher reflectance in the near-infrared correspond to denser and healthier vegetation.

NDVI can be used in numerous remote sensing applications, like crop phenology determination, crop type identification, crop health, forest monitoring etc. The Normalised Difference Vegetation Index for the study area has been prepared using the following formula in ENVI Band Math:

NDVI = (Band 8 – Band 4) / (Band 8 + Band 4) ………. Eq. 3.3

Where,

Band 8 is the NIR band, Band 4 is the Red band

The NDVI which is highly associated with vegetation, highlights all types of vegetation present in study region. The output from NDVI has been reclassified into 5 classes ranging from very high distribution of vegetation content to very low distribution of vegetation content.

3.6.4 Spatial Distribution Map of Slope

The ASTER DEM data has been downloaded from USGS website and the required study area has been extracted from it. This data has been further reclassified into 5 classes ranging from very high slope to very low slope.

3.6.5 Land use and Land Cover Map

The Land use/ Land cover map has been prepared from Sentinel 2A imagery by supervised classification. Representative training sites for each class such as river, ocean, settlements, sandy area, road, vegetation within the Sentinel 2A image have been selected. These training sites has been used for the supervised classification using Maximum likelihood algorithm in the ERDAS IMAGINE software.

3.6.6 Spatial Distribution Map of Temperature

Band 11 imagery of Landsat data has been used to obtain the temperature at 24 sample locations. The DN values of the image have been converted into radiance and then to temperature (in kelvin), using the following formulae:

From DN to Radiance:

$$CV_{R1} = ((LMAX-LMIN)/ (QCALMAX-QCALMIN))* (QCAL-QCALMIN) +LMIN \quad \text{………. Eq. 3.4}$$

Where

CV_{RI} is the cell value as radiance

QCAL is digital number

LMIN is spectral radiance scaled to QCALMIN

LMAX is spectral radiance scaled to QCALMAX

QCALMIN is the minimum quantized calibrated pixel value (typically 1)

QCALMAX is the maximum quantized calibrated pixel value (typically 255)

From Radiance to Kelvin:

$$T = \frac{K_2}{\ln\left(\frac{K_1 * \varepsilon}{CV_{R1}} + 1\right)} \qquad \text{………. Eq. 3.5}$$

Where

T in kelvin, CV_{R1} is cell value as radiance, ε is emissivity (typically 0.95)

For Band 10:

K_1= 774.8853, K_2= 1321.0789

For Band 11:

K_1= 480.8883, K_2= 1201.1442

3.7 ASSIGNING WEIGHTS USING AHP

The analytic hierarchy process is a structured technique (Fig 3.5) for organising and analysing complex decisions based on mathematics and psychology. It was developed by Thomas L. Saaty. It provides measures of judgement consistency and derives priority among criteria. It simplifies preference ratings among decision criteria using pair wise comparisons. The AHP is done using the following steps:

1. Decompose the decision problem into a hierarchy.
2. Make pair wise comparison and establish priorities among the elements in the hierarchy.
3. Synthesise judgements to obtain the set of overall or weights for achieving the goals.

4. Evaluate and check the consistency of judgements.

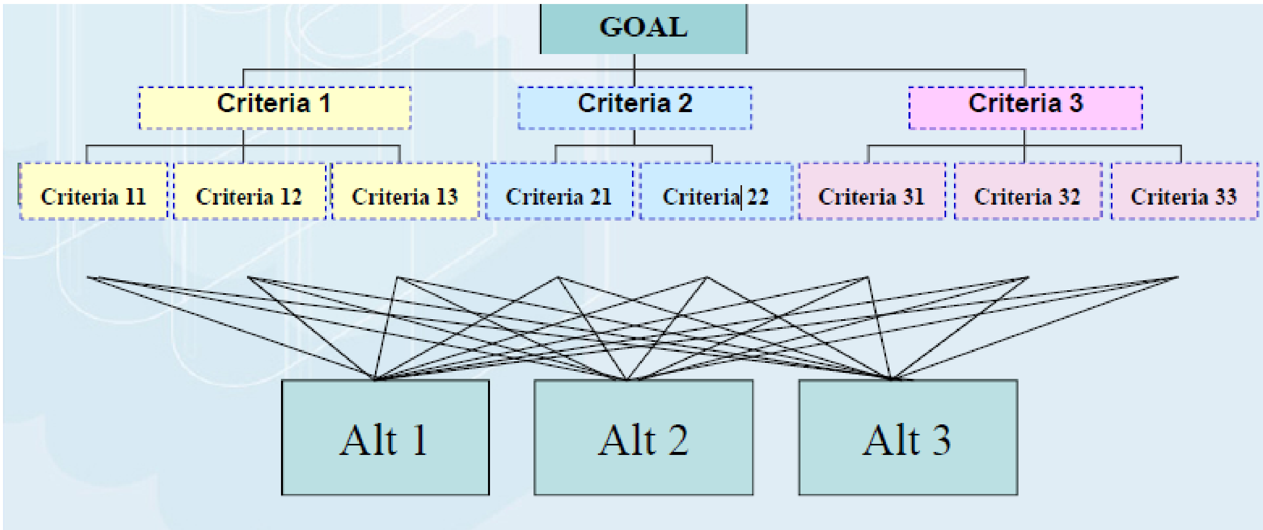

Fig 3.5- Structural hierarchy of AHP

3.7.1 Goal

To find the weightage of factors influencing mosquito breeding.

3.7.2 Criteria

Here all the factors are taken as criteria in order to arrive upon their weights for further analysis (Table 3.5).

Table 3.5– Criteria for AHP

LU/LC	SLOPE	VEGETATION	MOISTURE	WATER CONTENT	TEMPERATURE
Settlement and Road	Very less slope	Very less vegetation	Very low moisture	Very low water content	Very low temperature
Vegetation	Less slope	Less vegetation	Low moisture	Low water content	Low temperature
Sandy areas	Moderate slope	Moderate vegetation	Moderate moisture	Moderate water content	Moderate temperature
Ocean	High slope	High vegetation	High moisture	High water content	High temperature
River	Very high slope	Very high vegetation	Very high moisture	Very high water content	Very high temperature

3.7.3 Degree of Preference

In AHP, the pairwise comparison is made between each criteria. The degree of preference is a more than 1 when the criteria in the row is preferred over the criteria in the column. The degree of preference is less than 1 when the column criteria is preferred to the row criteria.

The degrees of preference (Table 3.6) have been assigned according to the following scale for comparison (Saaty & Vargas, 1991):

Table 3.6 –Degree of preference scale

Scale	Degree of preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Values for inverse comparison

3.7.4 Pair Wise Comparison Matrix

The pairwise comparison matrix is then created by fixing the degree of preference in MS Excel.

3.7.5 Normalized Matrix

The normalized matrix is formed by totalling each entry in the column and then dividing each entry by that column total. The matrix thus formed is known as the normalized matrix (Fig 3.6).

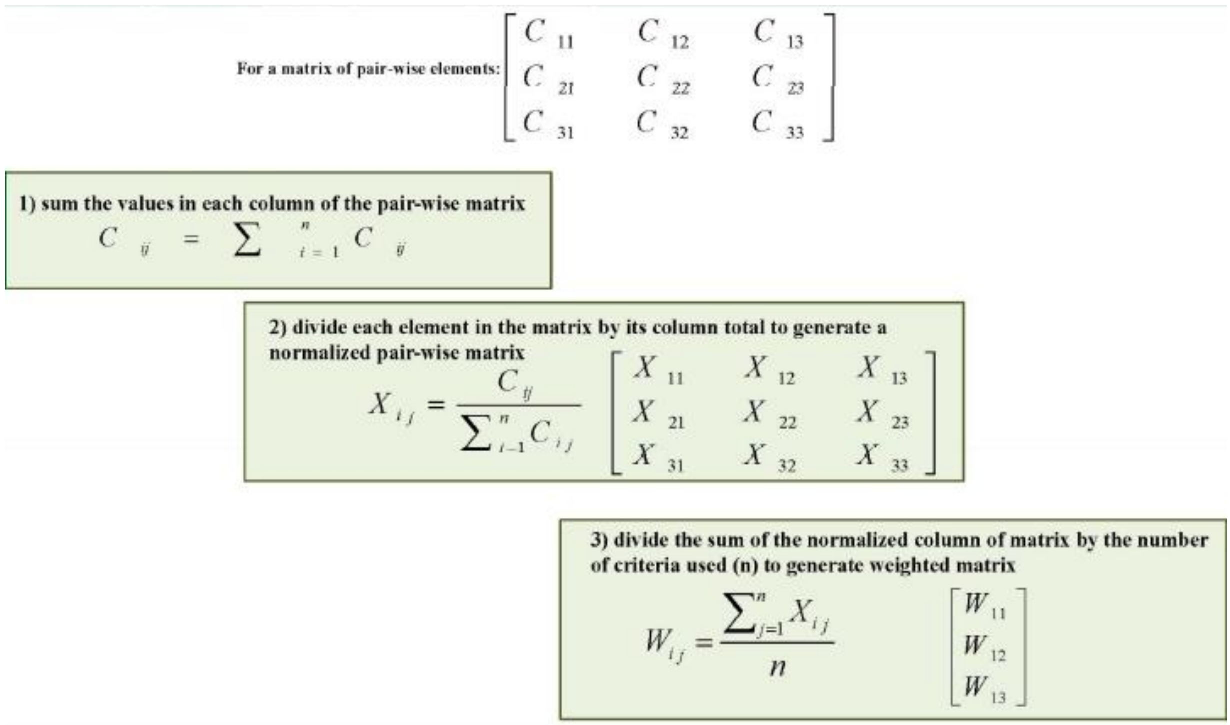

Fig 3.6- Mathematics behind normalization

The row total for each row of normalised matrix is found out. Then the row average for respective rows is calculated by dividing the sum by number of rows (here n=31). These row averages are the weightages for respective criteria.

3.7.6 Consistency Analysis

The purpose of performing this analysis is to make sure that the original preference ratings are consistent (Fig 3.7). There are 3 steps to arrive at the consistency ratio:

1. Calculate the consistency measure.
2. Calculate the consistency index (CI).

   $CI = (\lambda_{max} - n)/(n-1)$ ………. Eq. 3.6

3. Calculate the consistency ratio (CI/RI where RI is a random index).

CR= CI/RI ……… Eq. 3.7

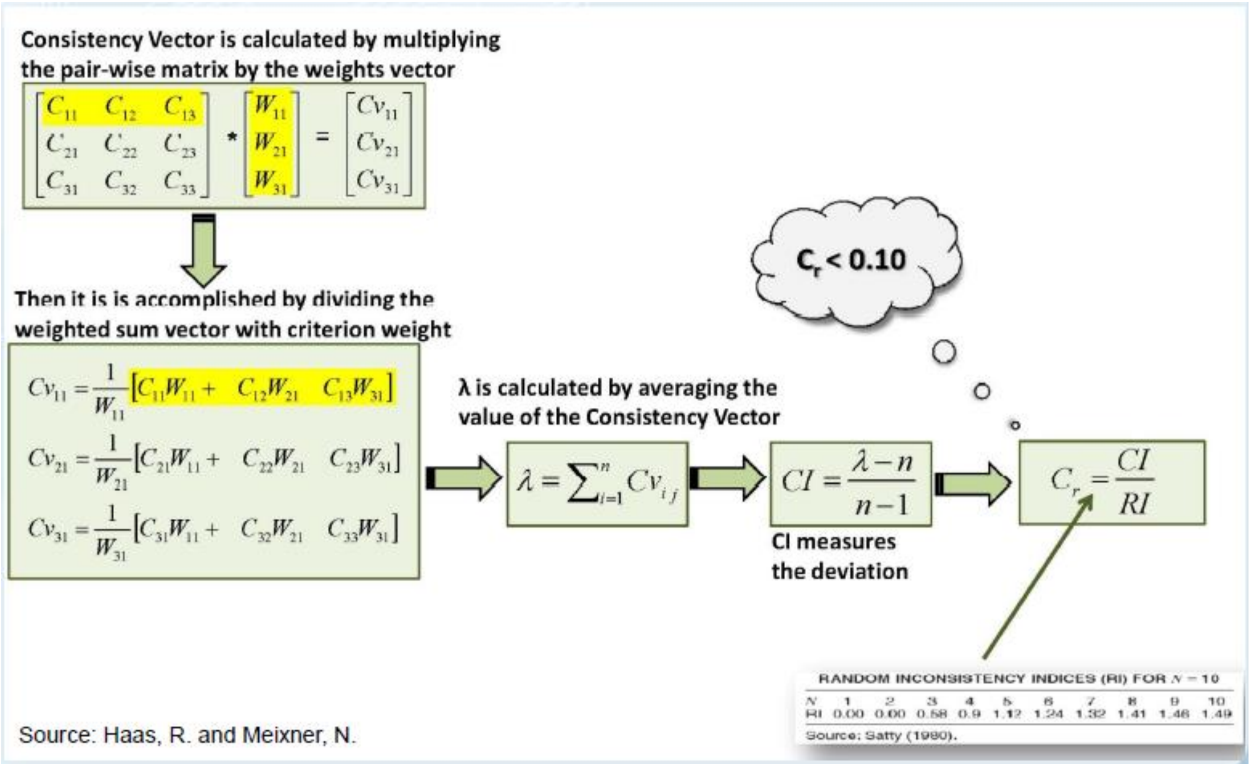

Fig 3.7- Consistency analysis

The Random Index (RI) for n=31 is 1.6839 as suggested by Jose Antonio Alonso.

The consistency ratio (CR) of 0.1 or less means that the weightage is consistent.

3.8 WEIGHTED OVERLAY ANALYSIS

Weighted Overlay can be performed in ArcGIS using the weighted overlay analysis tool. This tool allows the calculation of multiple- criteria analysis between several rasters.

The tool requires the following inputs:

Raster: The input criteria raster being weighted.

% Influence: The influence of the raster compared to the criteria as a percentage of 100. Values are rounded to the nearest integer. The sum of influences must equal 100.

Field: The field of the criteria raster to use for weighting.

Scale Value**:** The scaled value for the criterion, as specified by the Evaluation scale setting. Changing these values will alter the values in the input rasters used in the overlay analysis. In addition to numerical values, the following options are available:

- Restricted: Assigns the restricted value (the minimum value of the evaluation scale set, minus one) to cells in the output, regardless of whether other input rasters have a different scale value set for that cell.
- NoData: Assigns NoData to cells in the output, regardless of whether other input rasters have a different scale value set for that cell.
- Evaluation Scale: It can be chosen from a list of predefined evaluation scales or can also be defined using From, to and by options
- Set Equal Influence: Balances the percent influence of the input rasters equally and sums them to 100.

The weights obtained as a result of AHP are decimal numbers. These have to be rounded off to the nearest whole number such that the sum of weights is 100. For the various thematic layers such as slope, temperature, NDVI, NDMI, NDWI, LU/LC, the classes under them will be ranked based on AHP weights. The percentage of influence for each layer is calculated as the sum of weights of all classes of the layer such that the sum of influence percentage of all layers is 100.

3.9 RELATIONSHIP BETWEEN LARVAL COUNT AND THE FACTORS

The relationship between each of the factors influencing mosquito breeding namely- temperature, NDVI, NDMI and NDWI against the larval count is established in Microsoft Excel. A scatter plot is created for each factor versus larval count. A trend line is drawn in order to observe the relationship between the two components. For each of the relationship, a polynomial equation of degree 2 is developed and the correlation factor is also computed in MS Excel.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 GENERAL

The spatial distribution maps of slope, temperature, moisture content, water content, vegetation and land use land cover maps were prepared for the study area. The Landsat data was used for preparing the spatial distribution map of temperature. Weighted overlay analysis was performed to map the mosquito prone zones by using the weightages generated from AHP.

4.2 LAND USE LAND COVER MAP

The land use land cover map for the study area was prepared using ERDAS image processing software. Initially unsupervised classification was performed to identify the different features available. But the classification resulted in formation of mixed pixels due to which supervised classification was performed. The training sites for each feature was given in signature editor and Maximum likelihood algorithm was used for performing supervised classification. Accuracy assessment was performed by using both software and ground truth verification. The results of accuracy assessment performed using ERDAS Imagine software is shown in the table 4.1 and 4.2.

Table 4.1 Overall accuracy

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
ocean	5	5	5	100.00%	100.00%
sandy area	3	3	3	100.00%	100.00%
river	4	5	4	100.00%	80.00%
settlement	5	5	5	100.00%	100.00%
vegetation	6	5	5	83.33%	100.00%
road network	5	5	4	80.00%	80.00%
Totals	28	28	26		

Overall Classification Accuracy = 92.86%

----- End of Accuracy Totals -----

Table 4.2 Kappa statistics

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.9138

Conditional Kappa for each Category.

Class Name	Kappa
Unclassified	0.0000
ocean	1.0000
sandy area	1.0000
river	0.7667
settlement	1.0000
vegetation	1.0000
road network	0.7565

----- End of Kappa Statistics -----

The land use land cover map is shown in fig. 4.1

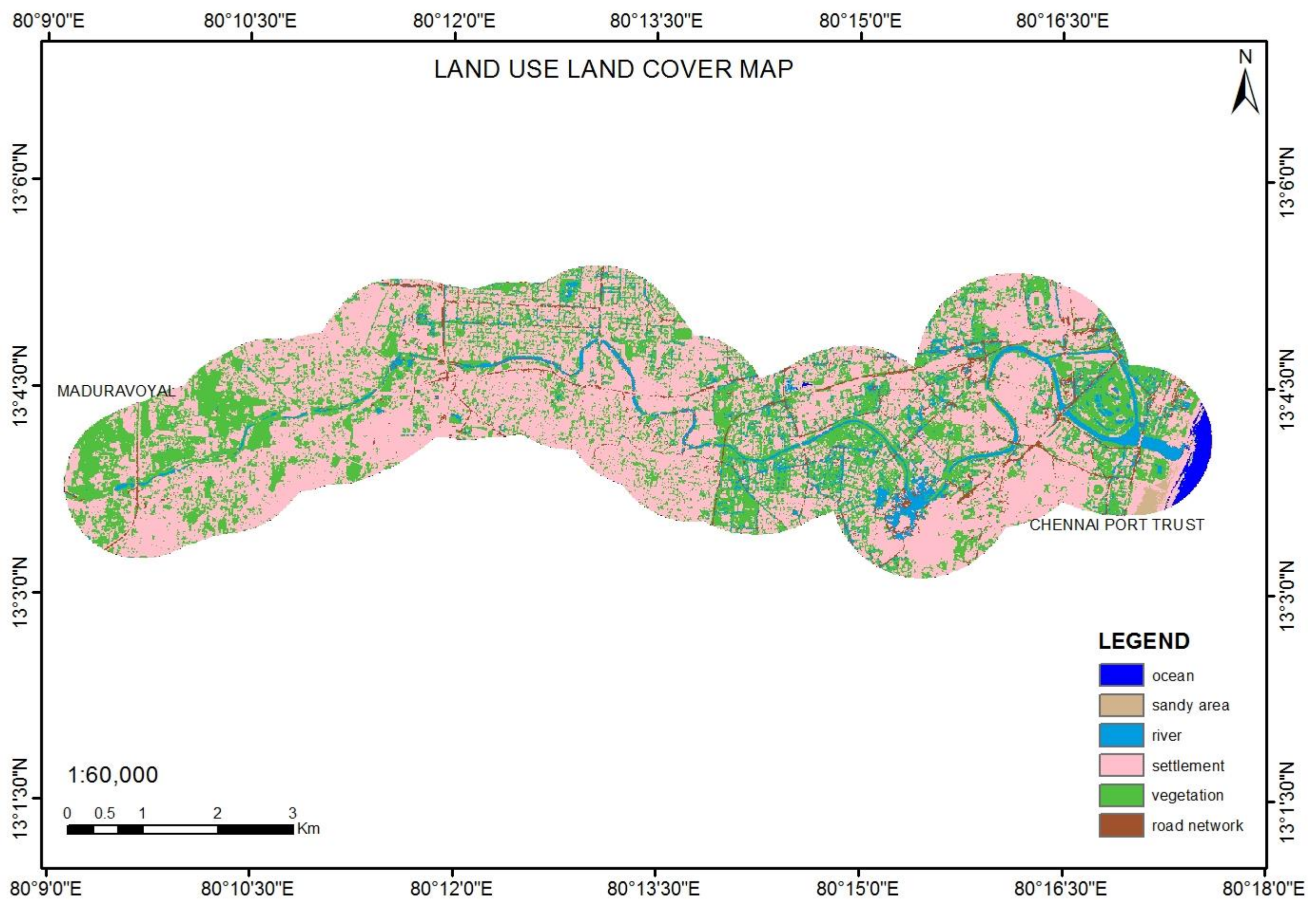

Fig. 4.1 Land Use Land Cover Map

The land use land cover classes available in the study area are ocean, river, road, vegetation, sandy area and settlement. From the map it is observed that the area (shown in Table 4.3) occupied by settlement is higher than the other classes and the area occupied by sandy area is very less.

Table 4.3 Area of land use classes

S. No	CLASS	AREA (sq.m)
1	Settlement	2,17,46,000
2	Ocean	2,75,700
3	Sandy area	1,35,000
4	River	23,40,000
5	Vegetation	1,15,93,200
6	Road	13,76,000

4.3 SPATIAL DISTRIBUTION MAP OF MOISTURE

The moisture content of the study area ranges between -0.312141 and 0.470660. The highest moisture content is observed in the water bodies and vegetation while the lowest moisture content is found to be in settlements and sandy area. The moisture index is different from water content as the NDMI highlights all the regions having moisture including vegetation and soil, whereas the NDWI highlights only the water bodies. The spatial distribution map of moisture content is shown in Fig. 4.2. The classes in the map are as follows:

- Very low moisture (-0.312141 to -0.1556)
- Low moisture (-0.1556 to 0.0010)
- Moderate moisture (0.0010 to 0.1575)

- High moisture (0.1575 to 0.3141)
- Very high moisture (0.3141 to 0.470660)

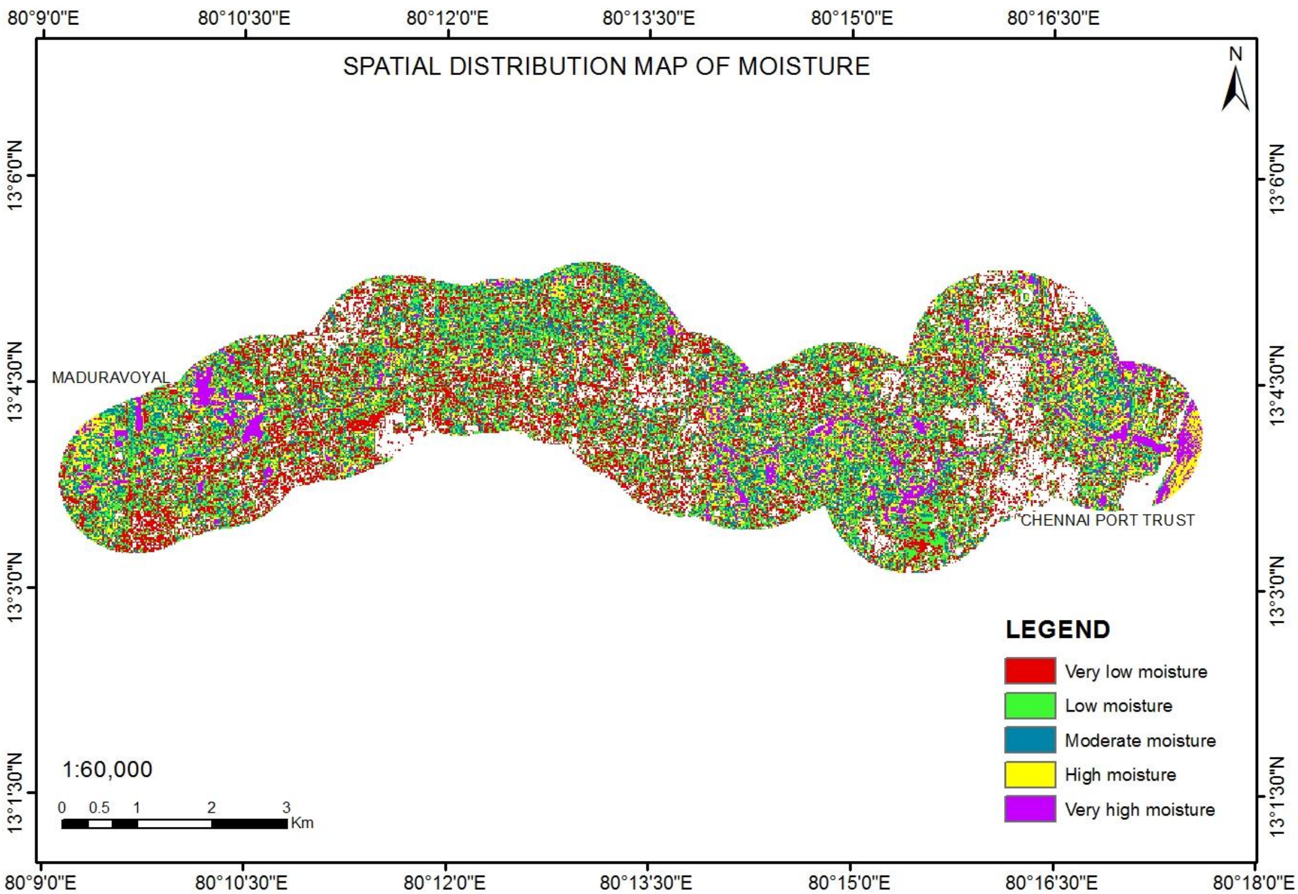

Fig 4.2 Spatial Distribution map of Moisture

4.4 SPATIAL DISTRIBUTION MAP OF WATER CONTENT

The NDWI values in the study area ranges between -0.566366 and 0.396518. A high water content is observed in ocean, river and other water bodies. Vegetation has less water content. The water content in the settlements and sandy areas is the least almost no water content. The spatial distribution map of water content is given in Fig 4.3. The classes in the map are as follows:

- Very less water content (-0.566366 to -0.3738)
- Less water content (-0.3738 to -0.1812)
- Moderate water content (-0.1812 to 0.0114)
- High water content (0.0114 to 0.2039)
- Very high water content (0.2039 to 0.396518)

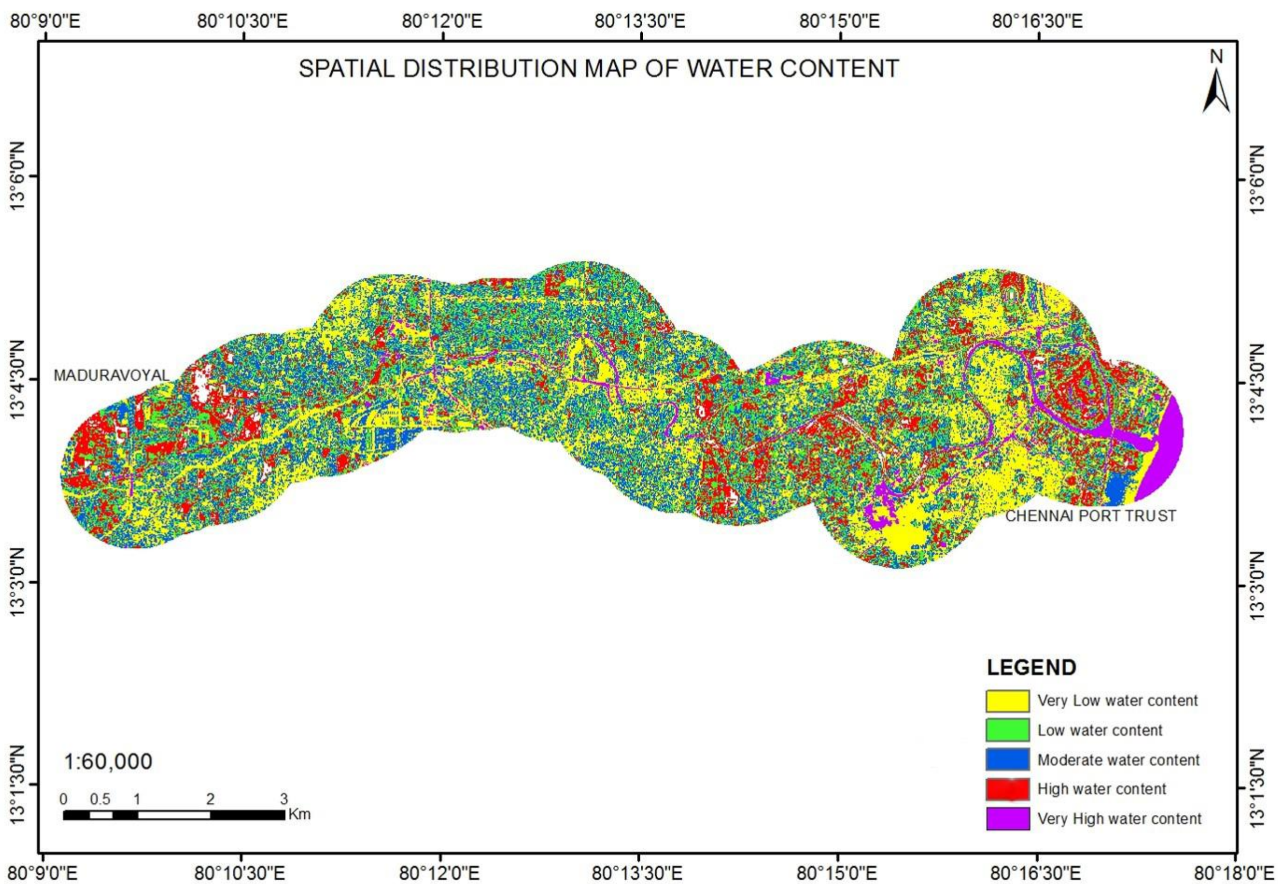

Fig. 4.3 Spatial distribution map of water content

4.5 SPATIAL DISTRIBUTION MAP OF VEGETATION

The NDVI values of the study area ranges between -0.304938 and 0.706714. The spatial distribution map of vegetation given in Fig.4.4 shows that higher vegetation is observed along the river banks and near the coast. Moderate vegetation is observed in the city side while water bodies and settlements have very low or no vegetation, i.e. the NDVI values are the least here. The vegetation towards the sea is more and decrease as moved towards the city. The classes in the map are as follows:

- Very less vegetation (-0.304938 to -0.035975)
- Less vegetation (-0.035975 to 0.143144)
- Moderate vegetation (0.143144 to 0.278576)
- High vegetation (0.278576 to 0.435851)
- Very high vegetation (0.435851 to 0.706714)

4.6 SPATIAL DISTRIBUTION MAP OF SLOPE

The slope map was generated by using the DEM data. The DEM for the study area was extracted and then it was reclassified into 5 classes. The slope map given in Fig 4.5 shows that the rate of change of slope decreases towards the ocean. The slope increases when moved away from the sea. The breeding decreases in the areas where the rate of change of slope is higher. This is because the water velocity will be high and hence it is not prone to mosquito breeding. This may lead to a conclusion that the breeding will be higher in the river portion with less rate of change of slope, i.e., towards the ocean. Though the rate of change of slope in this portion is less, the salinity in the river caused by the tidal actions will affect the mosquito breeding. The classes in the map are as follows:

- Very low rate of change of slope (1.5 to 2.5°)
- Low rate of change of slope (2.5 to 3.5°)
- Moderate rate of change of slope (3.5 to 4.5°)
- High rate of change of slope (4.5 to 5.5°)
- Very high rate of change of slope (5.5 to 6.5°)

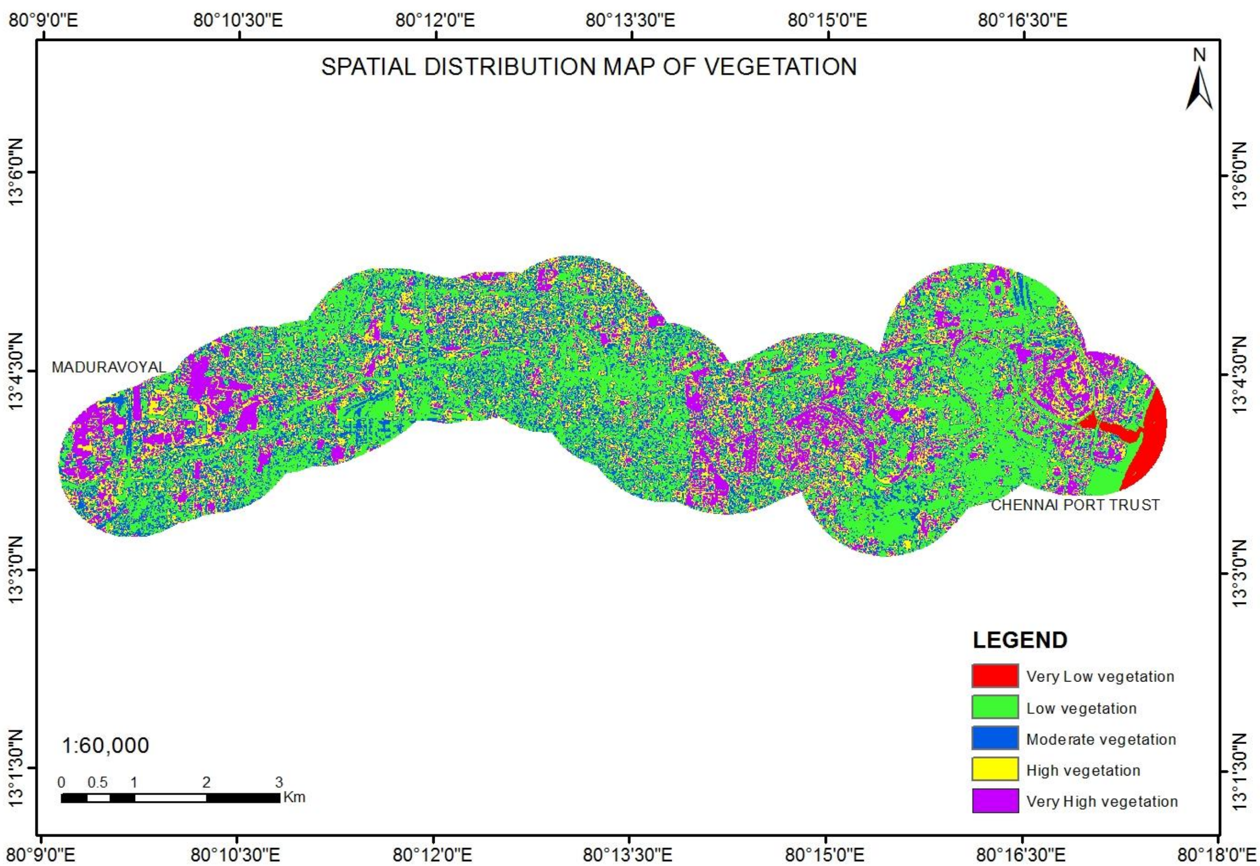

Fig 4.4 Spatial distribution map of vegetation

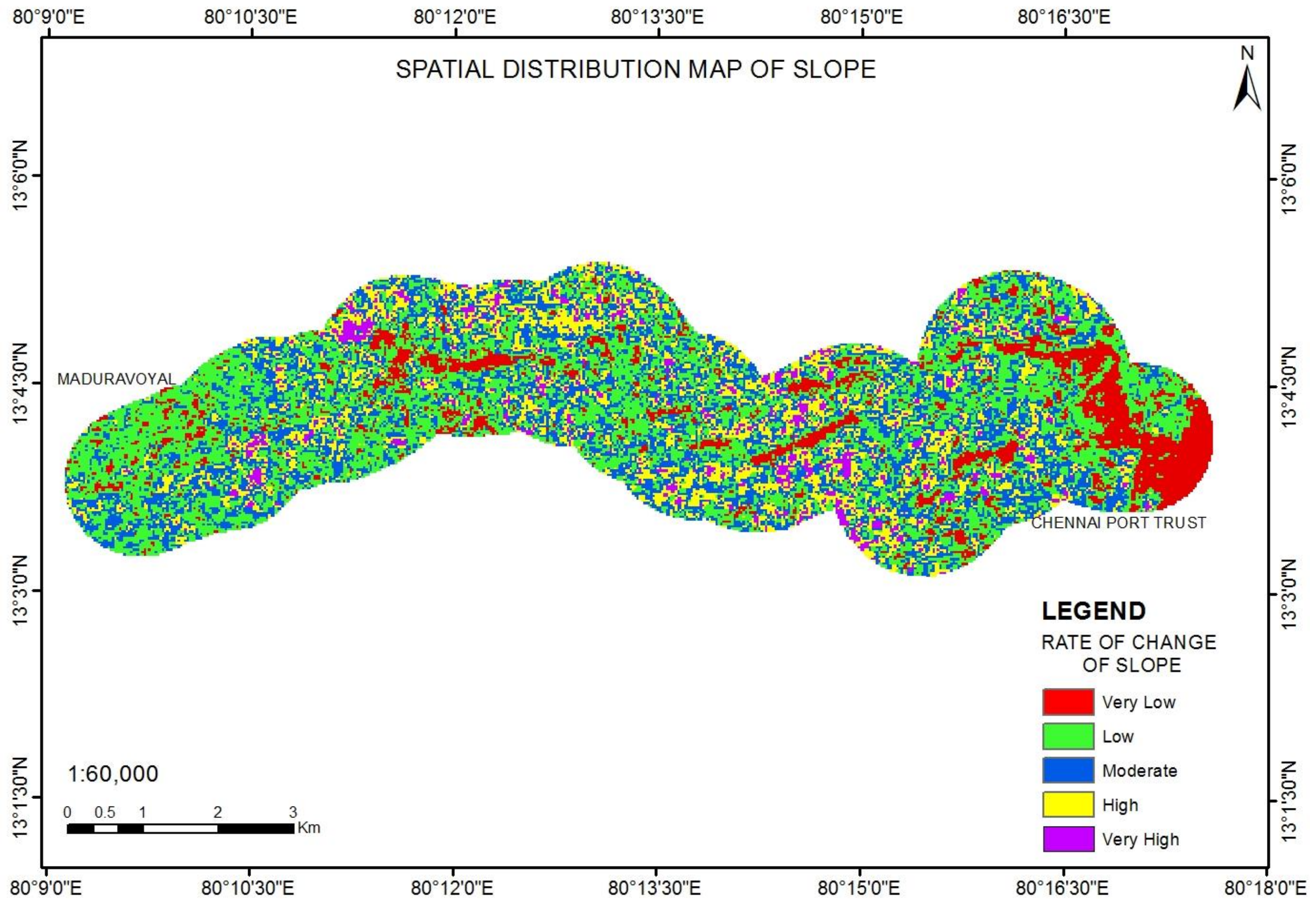

Fig 4.5 Spatial distribution map of Slope

4.7 SPATIAL DISTRIBUTION MAP OF TEMPERATURE

The spatial distribution map of temperature was generated by converting the DN values to kelvin by using formula. The temperature in the study area ranges between 294.137718 K and 297.811911 K. The temperature values at the 24 sample locations are given in Table 4.4. The spatial distribution map given in Fig 4.6 shows that the temperature is high at the places away from the ocean while the regions nearby the coast have less temperature. It is observed that the temperature at the vegetated areas is lower when compared to settlement regions. The classes in the map are as follows:

- Very low temperature (294.137718 to 294.853808)
- Low temperature (294.853808 to 295.150570)
- Moderate temperature (295.150570 to 296.152965)
- High temperature (296.152965 to 296.886527)
- Very high temperature (296.886527 to 297.811911)

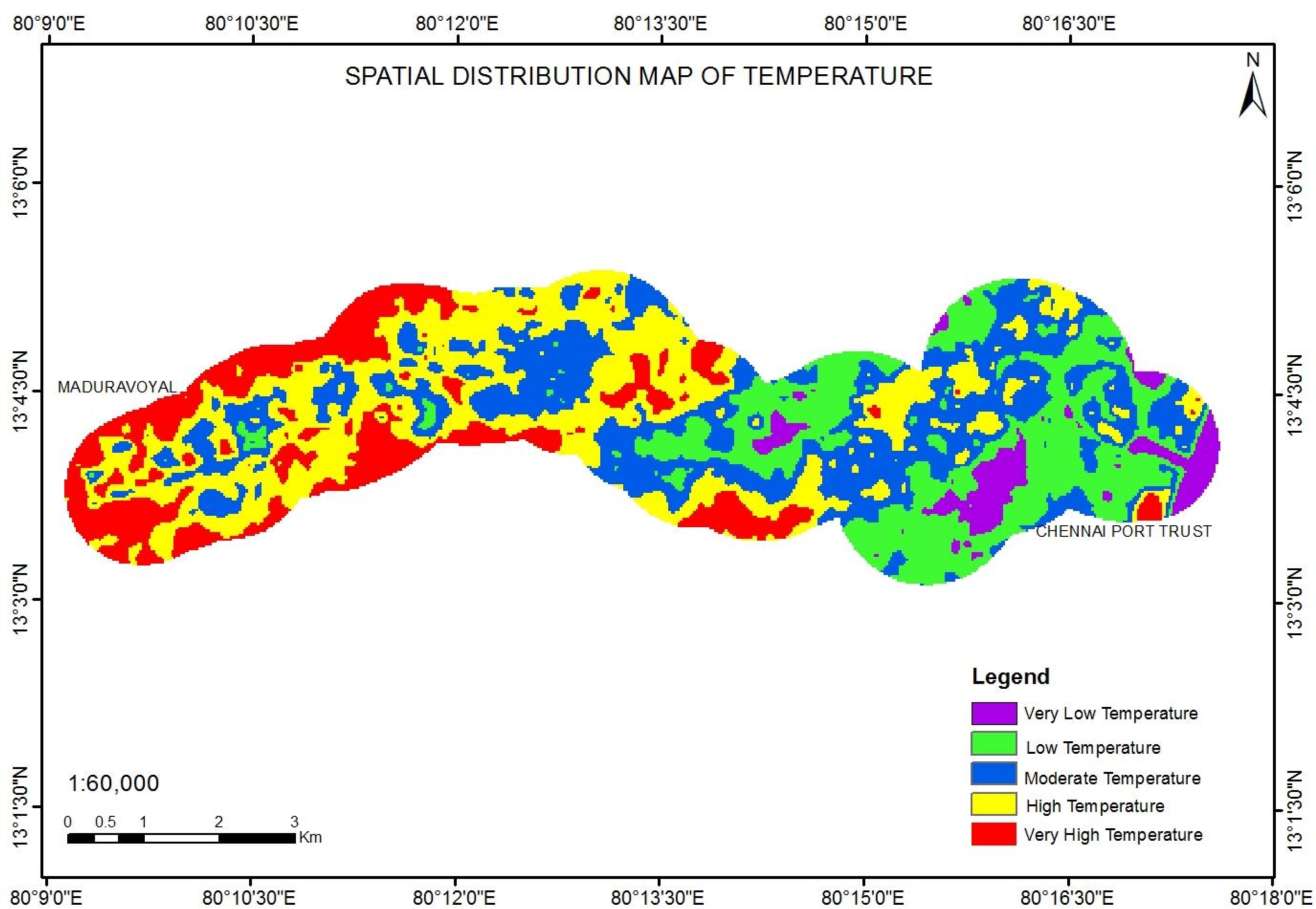

Fig 4.6 Spatial distribution map of temperature

Table 4.4 Temperature at Sample locations

Location number	Temperature (Kelvin)
1	295.495012
2	294.785231
3	295.889603
4	296.201051
5	294.137718
6	295.301550
7	294.853808
8	296.683785
9	296.328253
10	295.150570
11	295.321478
12	295.418230
13	295.940618
14	296.711273
15	296.886527
16	296.618956
17	296.427106

Table 4.4 Temperature at sample locations (Continued)	
18	296.604854
19	297.223759
20	297.811911
21	296.152965
22	297.032764
23	297.285494
24	297.655318

4.8 ANALYTIC HIERARCHY PROCESS

The preference between different factors was given based on the advice of expert, Mr. Selvakumar, Chief vector control officer, Corporation of Chennai. According to his advice the order of preference is given as

River > High moisture > High water content > Low temperature > High vegetation > low slope > Settlement.

The pairwise comparison matrix (Table 4.6) was generated by assigning the degree of preference as given in Table 4.5. The sum of the elements of each column in the pairwise matrix was found. The normalized matrix (Table 4.7) was then formed by dividing each entry by the respective column total. The row total was found and its average was generated which gives the weight for each row (Table 4.8). The consistency was checked for normalized matrix and the consistency ratio was found to be 0.0925.

Table 4.5 Degree of preference

CLASS	DEGREE OF PREFERENCE
Very low moisture	2
Low moisture	2
Moderate moisture	7
High moisture	7
Very high moisture	7
Very low water content	2
Low water content	2
Moderate water content	7
High water content	7
Very high water content	7
Very low slope	3
Low slope	3
Moderate slope	2
High slope	2

Very high slope	2
Very low temperature	5
Low temperature	5
Moderate temperature	2
High temperature	2
Very high temperature	2
Very low vegetation	2
Low vegetation	2
Moderate vegetation	5
High vegetation	5
Very high vegetation	5
Ocean	Not preferred
Road	Not preferred
Sandy areas	Not preferred
Vegetation	5
Settlement	3
River	9

Table 4.6 Pairwise comparison matrix

	VL Slope	L Slope	M Slope	H slope	VH slope	VL veg	L veg	M veg	H veg	VH veg	VL moist	L moist	M moist	H moist	VH moist	VL water	L water	M water	H water	Vh water	VL temp	Ltemp	M temp	H temp	VH temp	Ocean	sandy are	sett	veg	river	road
VL slope	1	3	3	3	3	3	3	0.2	0.2	0.2	3	3	0.14	0.14	0.14	3	3	0.14	0.14	0.14	0.2	0.2	3	3	3	3	3	0.33	0.2	0.11	3
L Slope	0.33	1	3	3	3	3	3	0.2	0.2	0.2	3	3	0.14	0.14	0.14	3	3	0.14	0.14	0.14	0.2	0.2	3	3	3	3	3	0.33	0.2	0.11	3
M Slope	0.33	0.33	1	2	2	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	2	0.33	0.2	0.11	2
H slope	0.33	0.33	0.5	1	2	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	2	0.33	0.2	0.11	2
VH slope	0.33	0.33	0.5	0.5	1	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	2	0.33	0.2	0.11	2
VL veg	0.33	0.33	2	2	2	1	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	2	0.33	0.2	0.11	2
L Veg	0.33	0.33	2	2	2	2	1	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	2	0.33	0.2	0.11	2
M Veg	5	5	5	5	5	5	5	1	0.2	0.2	5	5	0.14	0.14	0.14	5	5	0.14	0.14	0.14	0.2	0.2	5	5	5	5	5	5	5	0.11	5
H Veg	5	5	5	5	5	5	5	5	1	0.2	5	5	0.14	0.14	0.14	5	5	0.14	0.14	0.14	0.2	0.2	5	5	5	5	5	5	5	0.11	5
VH Veg	5	5	5	5	5	5	5	5	5	1	5	5	0.14	0.14	0.14	5	5	0.14	0.14	0.14	0.2	0.2	5	5	5	5	5	5	5	0.11	5
VL Moist	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	1	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	2	2	2	2	2	0.33	2	0.11	2
L moist	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	2	1	0.14	0.14	0.14	2	0.5	0.14	0.14	0.14	0.2	0.2	2	2	2	2	2	0.33	2	0.11	2
M Moist	7	7	7	7	7	7	7	7	7	7	7	7	1	0.14	0.14	7	7	0.14	0.14	0.14	7	7	7	7	7	7	7	7	7	0.11	7
H Moist	7	7	7	7	7	7	7	7	7	7	7	7	7	1	0.14	7	7	0.14	0.14	0.14	7	7	7	7	7	7	7	7	7	0.11	7
VH Moist	7	7	7	7	7	7	7	7	7	7	7	7	7	7	1	7	7	0.14	0.14	0.14	7	7	7	7	7	7	7	7	7	0.11	7
VL Water	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	2	0.5	0.14	0.14	0.14	1	0.5	0.14	0.14	0.14	0.2	0.2	2	2	2	2	2	0.33	2	0.11	2
L water	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	2	2	0.14	0.14	0.14	2	1	0.14	0.14	0.14	0.2	0.2	2	2	2	2	2	0.33	2	0.11	2
M Water	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	1	0.14	0.14	7	7	7	7	7	7	7	7	7	0.11	7
H water	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	1	0.14	7	7	7	7	7	7	7	7	7	0.11	7
VH Water	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	1	7	7	7	7	7	7	7	7	7	0.11	7
VL Temp	5	5	5	5	5	5	5	5	5	5	5	5	0.14	0.14	0.14	5	5	0.14	0.14	0.14	1	5	5	5	5	5	5	5	5	0.11	5
L Temp	5	5	5	5	5	5	5	5	5	5	5	5	0.14	0.14	0.14	5	5	0.14	0.14	0.14	0.2	1	5	5	5	5	5	5	5	0.11	5
M Temp	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	1	2	2	2	2	0.33	0.2	0.11	2
H temp	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	1	2	2	2	0.33	0.2	0.11	2
VH temp	0.33	0.33	2	2	2	2	2	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	1	2	2	0.33	0.2	0.11	2
Ocean	0.33	0.33	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	1	0.5	0.33	0.2	0.11	0.5
Sandy Area	0.33	0.33	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	1	0.33	0.2	0.11	2
Sett	3	3	3	3	3	3	3	0.2	0.2	0.2	3	3	0.14	0.14	0.14	3	3	0.14	0.14	0.14	0.2	0.2	3	3	3	3	3	1	0.2	0.11	3
Veg	5	5	5	5	5	5	5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	5	5	5	5	5	5	1	0.11	5
River	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	1	9
Road	0.33	0.33	0.5	0.5	0.5	0.5	0.5	0.2	0.2	0.2	0.5	0.5	0.14	0.14	0.14	0.5	0.5	0.14	0.14	0.14	0.2	0.2	0.5	0.5	0.5	2	0.5	0.33	0.2	0.11	1
Col Total	90.28	92.95	111.5	113	114.5	110	108.5	75.8	71	66.2	98	95	48.36	41.5	34.64	96.5	93.5	27.78	20.92	14.06	56.6	61.4	104	105.5	107	119	116	87.61	87.8	4.3	117.5

Table 4.7 Normalized matrix

VL SLOPE	0.011077	0.032275	0.026906	0.026549	0.026201	0.027273	0.02765	0.002639	0.002817	0.003021	0.030612	0.031579	0.002895	0.003373	0.004042	0.031088	0.032086	0.00504	0.006692	0.009957	0.003534	0.003257	0.028846	0.028436	0.028037	0.02521	0.025862	0.003767	0.002278	0.025581	0.025532		0.544111	0.017552	1.755197
L SLOPE	0.003655	0.010758	0.026906	0.026549	0.026201	0.027273	0.02765	0.002639	0.002817	0.003021	0.030612	0.031579	0.002895	0.003373	0.004042	0.031088	0.032086	0.00504	0.006692	0.009957	0.003534	0.003257	0.028846	0.028436	0.028037	0.02521	0.025862	0.003767	0.002278	0.025581	0.025532		0.515173	0.016618	1.661847
M SLOPE	0.003655	0.00355	0.008969	0.017699	0.017467	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.22557	0.007276	0.727646
H SLOPE	0.003655	0.00355	0.004484	0.00885	0.017467	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.212236	0.006846	0.684634
VH SLOPE	0.003655	0.00355	0.004484	0.004425	0.008734	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.199078	0.006422	0.642187
VL VEG	0.003655	0.00355	0.017937	0.017699	0.017467	0.009091	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.239084	0.007712	0.77124
L VEG	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.009217	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.252784	0.008154	0.815431
M VEG	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.013193	0.002817	0.003021	0.05102	0.052632	0.002895	0.003373	0.004042	0.051813	0.053476	0.00504	0.006692	0.009957	0.003534	0.003257	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.056948	0.025581	0.042553		1.009707	0.032571	3.257119
H VEG	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.065963	0.014085	0.003021	0.05102	0.052632	0.002895	0.003373	0.004042	0.051813	0.053476	0.00504	0.006692	0.009957	0.003534	0.003257	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.056948	0.025581	0.042553		1.073745	0.034637	3.463694
VH VEG	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.065963	0.070423	0.015106	0.05102	0.052632	0.002895	0.003373	0.004042	0.051813	0.053476	0.00504	0.006692	0.009957	0.003534	0.003257	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.056948	0.025581	0.042553		1.142168	0.036844	3.684412
VL MOIST	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.010204	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.019231	0.018957	0.018692	0.016807	0.017241	0.003767	0.022779	0.025581	0.017021		0.330263	0.010654	1.065365
L MOIST	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.020408	0.010526	0.002895	0.003373	0.004042	0.020725	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.019231	0.018957	0.018692	0.016807	0.017241	0.003767	0.022779	0.025581	0.017021		0.361274	0.011654	1.165401
M MOIST	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.020678	0.003373	0.004042	0.072539	0.074866	0.00504	0.006692	0.009957	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		1.906552	0.061502	6.150168
H MOIST	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.144748	0.024096	0.004042	0.072539	0.074866	0.00504	0.006692	0.009957	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		2.051344	0.066172	6.61724
VH MOIST	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.144748	0.168675	0.028868	0.072539	0.074866	0.00504	0.006692	0.009957	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		2.22075	0.071637	7.163708
VL WATER	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.020408	0.005263	0.002895	0.003373	0.004042	0.010363	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.019231	0.018957	0.018692	0.016807	0.017241	0.003767	0.022779	0.025581	0.017021		0.345649	0.01115	1.114995
L WATER	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.020408	0.021053	0.002895	0.003373	0.004042	0.020725	0.010695	0.00504	0.006692	0.009957	0.003534	0.003257	0.019231	0.018957	0.018692	0.016807	0.017241	0.003767	0.022779	0.025581	0.017021		0.377148	0.012166	1.216608
M WATER	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.144748	0.168675	0.202079	0.072539	0.074866	0.035997	0.006692	0.009957	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		2.424917	0.078223	7.822314
H WATER	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.144748	0.168675	0.202079	0.072539	0.074866	0.25198	0.047801	0.009957	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		2.682009	0.086516	8.651642
VH WATER	0.077537	0.075309	0.06278	0.061947	0.061135	0.063636	0.064516	0.092348	0.098592	0.10574	0.071429	0.073684	0.144748	0.168675	0.202079	0.072539	0.074866	0.25198	0.334608	0.071124	0.123675	0.114007	0.067308	0.066351	0.065421	0.058824	0.060345	0.0799	0.079727	0.025581	0.059574		3.029982	0.097741	9.774136
VL TEMP	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.065963	0.070423	0.075529	0.05102	0.052632	0.002895	0.003373	0.004042	0.051813	0.053476	0.00504	0.006692	0.009957	0.017668	0.081433	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.056948	0.025581	0.042553		1.294901	0.041771	4.177099
L TEMP	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.065963	0.070423	0.075529	0.05102	0.052632	0.002895	0.003373	0.004042	0.051813	0.053476	0.00504	0.006692	0.009957	0.003534	0.016287	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.056948	0.025581	0.042553		1.21562	0.039214	3.921355
M TEMP	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.009615	0.018957	0.018692	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.295045	0.009518	0.951757
H TEMP	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.009479	0.018692	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.280758	0.009057	0.905672
VH TEMP	0.003655	0.00355	0.017937	0.017699	0.017467	0.018182	0.018433	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.009346	0.016807	0.017241	0.003767	0.002278	0.025581	0.017021		0.266673	0.008602	0.860236
OCEAN	0.003655	0.00355	0.004484	0.004425	0.004367	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.008403	0.00431	0.003767	0.002278	0.025581	0.004255		0.160611	0.005181	0.5181
SANDY	0.003655	0.00355	0.004484	0.004425	0.004367	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.008621	0.003767	0.002278	0.025581	0.017021		0.186091	0.006003	0.600292
SETT	0.03323	0.032275	0.026906	0.026549	0.026201	0.027273	0.02765	0.002639	0.002817	0.003021	0.030612	0.031579	0.002895	0.003373	0.004042	0.031088	0.032086	0.00504	0.006692	0.009957	0.003534	0.003257	0.028846	0.028436	0.028037	0.02521	0.025862	0.011414	0.002278	0.025581	0.025532		0.573912	0.018513	1.851328
VEG	0.055383	0.053792	0.044843	0.044248	0.043668	0.045455	0.046083	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.048077	0.047393	0.046729	0.042017	0.043103	0.057071	0.01139	0.025581	0.042553		0.765548	0.024695	2.469508
RIVER	0.09969	0.096826	0.080717	0.079646	0.078603	0.081818	0.082949	0.118734	0.126761	0.135952	0.091837	0.094737	0.186104	0.216867	0.259815	0.093264	0.096257	0.323974	0.43021	0.640114	0.159011	0.14658	0.086538	0.085308	0.084112	0.07563	0.077586	0.102728	0.102506	0.232558	0.076596		4.644028	0.149807	14.98074
ROAD	0.003655	0.00355	0.004484	0.004425	0.004367	0.004545	0.004608	0.002639	0.002817	0.003021	0.005102	0.005263	0.002895	0.003373	0.004042	0.005181	0.005348	0.00504	0.006692	0.009957	0.003534	0.003257	0.004808	0.004739	0.004673	0.016807	0.00431	0.003767	0.002278	0.025581	0.008511		0.17327	0.005589	0.558934
																																		sum of wt	100
TOT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				

Table 4.8 Weights obtained from AHP

SLOPE	
VERY LESS SLOPE	1.755197
LESS SLOPE	1.661847
MODERATE SLOPE	0.727646
HIGH SLOPE	0.684634
VERY HIGH SLOPE	0.642187
VEGETATION	
VERY LESS VEGETATION	0.77124
LESS VEGETATION	0.815431
MODERATE VEGETATION	3.257119
HIGH VEGETATION	3.463694
VERY HIGH VEGETATION	3.684412
MOISTURE	
VERY LOW MOISTURE	1.065365
LOW MOISTURE	1.165401
MODERATE MOISTURE	6.150168
HIGH MOISTURE	6.61724
VERY HIGH MOISTURE	7.163708
WATER CONTENT	
VERY LOW WATER CONTENT	1.114995
LOW WATER CONTENT	1.216608
MODERATE WATER CONTENT	7.822314
HIGH WATER CONTENT	8.651642
VERY HIGH WATER CONTENT	9.774136
TEMPERATURE	
VERY LOW TEMPERATURE	4.177099
LOW TEMPERATURE	3.921355
MODERATE TEMPERATURE	0.951757
HIGH TEMPERATURE	0.905672
VERY HIGH TEMPERATURE	0.860236
LAND USE LAND COVER	
OCEAN	0.5181
SANDY AREA	0.600292
SETTLEMENT	1.851328
VEGETATION	2.469508
RIVER	14.98074
ROAD	0.558934

4.9 WEIGHTED OVERLAY ANALYSIS

The weighted overlay analysis resulted in five classes namely, very less prone, less prone, moderately prone, high prone and very high prone regions. The mosquito prone zonation map is shown below in fig 4.7

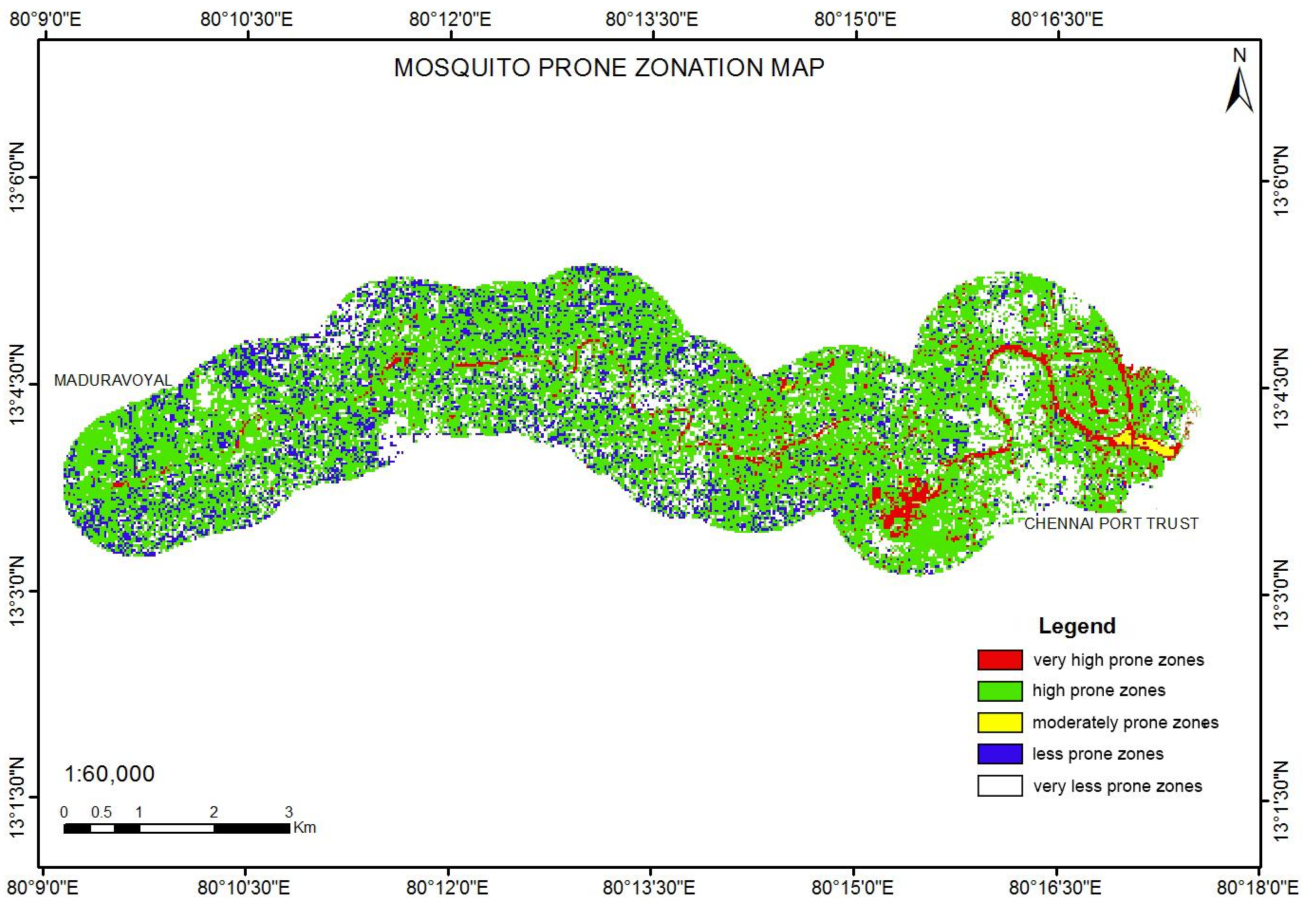

Fig 4.7 Mosquito Prone Zonation Map

From the map it is clearly seen that breeding of mosquitoes is highest along the river course and hence the regions closer to the river are highly prone to Culex mosquitoes. However, the portion of river closer to the ocean is moderately prone to mosquito breeding though it has less rate of change of slope, high moisture content and high vegetation because of the salinity caused by the tidal actions. The areas away from the coast, towards the interior of the city are less prone to mosquito breeding since vegetation is low.

4.10 VALIDATION OF WEIGHTED OVERLAY

The mosquito prone zonation map was validated using field samples. The results are discussed below:

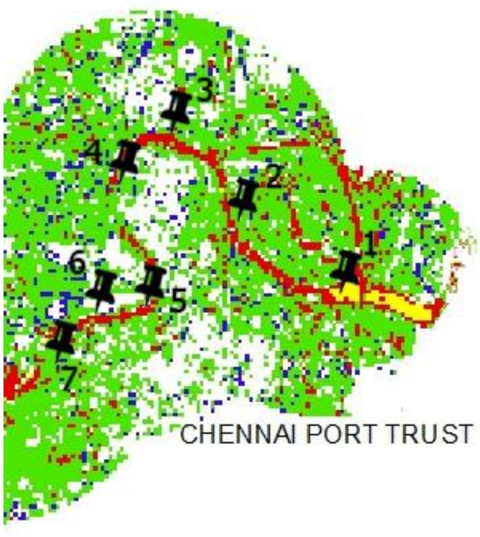

Fig 4.8 Validation points (a)

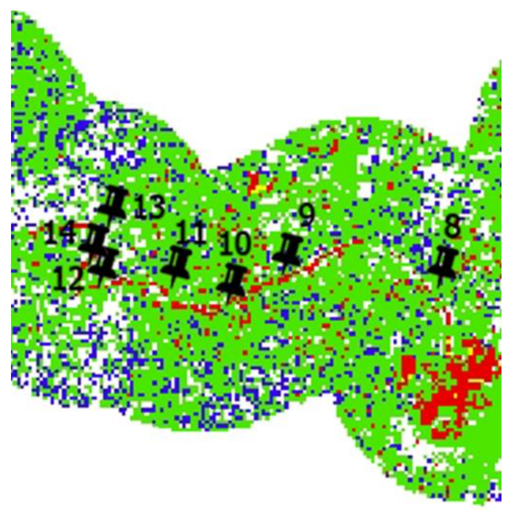

Fig 4.8 Validation points (b)

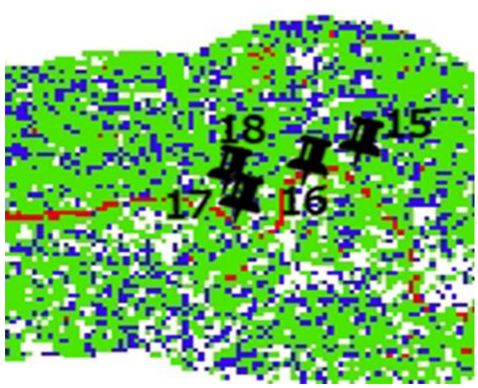

Fig 4.8 Validation points(c)

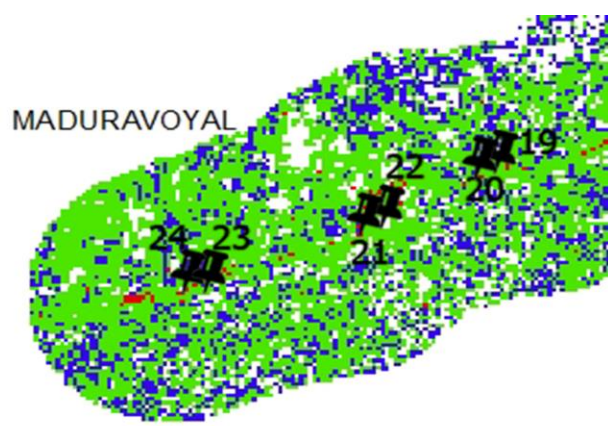

Fig 4.8 Validation points (d)

The Fig.4.8 a, b, c, d shows the category of prone zones on which each sample location belongs to. The range of larval count corresponding to each class of prone zones as suggested by the expert is shown in Table 4.9.

Table 4.9 Range of Larval count

LARVAL COUNT RANGE	PRONE ZONES
0-5	Very less
6-16	Less
16-20	Moderate
20-100	High
100-200	Very high

The location details, larval count and the category of prone zones of each sample location is shown in Table 4.10 a, b.

Table 4.10(a) Validation table

POINT	LAT	LONG	LARVAL COUNT	PRONE ZONES
1	13°4'6.30"N	80°16'54.5"E	20	Moderate
2	13°4'24.0"N	80°16'29.6"E	2	Very less
3	13°4'47.90"N	80°16'12.30"E	20	High
4	13°4'34.50"N	80°15'57.50"E	6	Less
5	13° 4'1.80"N	80°16'3.60"E	32	High
6	13° 4'1.00"N	80°15'50.20"E	35	High
7	13°3'48.60"N	80°15'38.34"E	10	Less
8	13° 4'3.15"N	80°15'14.26"E	50	High
9	13° 4'5.74"N	80°14'32.57"E	16	Less
10	13° 3'58.75"N	80°14'16.85"E	200	Very high

Table 4.10(b) Validation Table

POINT	LAT	LONG	LARVAL COUNT	PRONE AREAS
12	13° 4'4.84"N	80°13'44.09"E	200	Very high
13	13° 4'18.56"N	80°13'46.18"E	10	Less
14	13° 4'19.20"N	80°13‘38.2"E	4	Very less
15	13° 4'50.48"N	80°13'6.20"E	8	Less
16	13° 4'45.63"N	80°12'56.49"E	6	Less
20	13° 4'16.50"N	80°10'48.24"E	150	Very high
21	13° 4'3.83"N	80°10'26.21"E	100	Very high
22	13° 4'1.95"N	80°10'23.92"E	2	Very less
23	13° 3'47.47"N	80° 9'44.35"E	5	Less
24	13° 3'47.80"N	80° 9'40.42"E	10	Less

Out of the 24 sample points collected, the larval count at 20 locations matched accurately with the prone zonation map. The accuracy of prone zonation map according to the validation is 83.3%.

4.11 RELATIONSHIP BETWEEN LARVAL COUNT AND THE FACTORS

The relationship between larval count and other factors namely- NDVI, NDMI, NDWI and Temperature is established by generating scatter plot and trend line in MS Excel.

The Fig 4.9 shows the relationship between NDVI and larval count. It is observed that the larval count increases with increase in vegetation. The relationship is expressed in the form of Polynomial equation of order 2. The correlation factor (R^2) for the relationship is 0.6265.

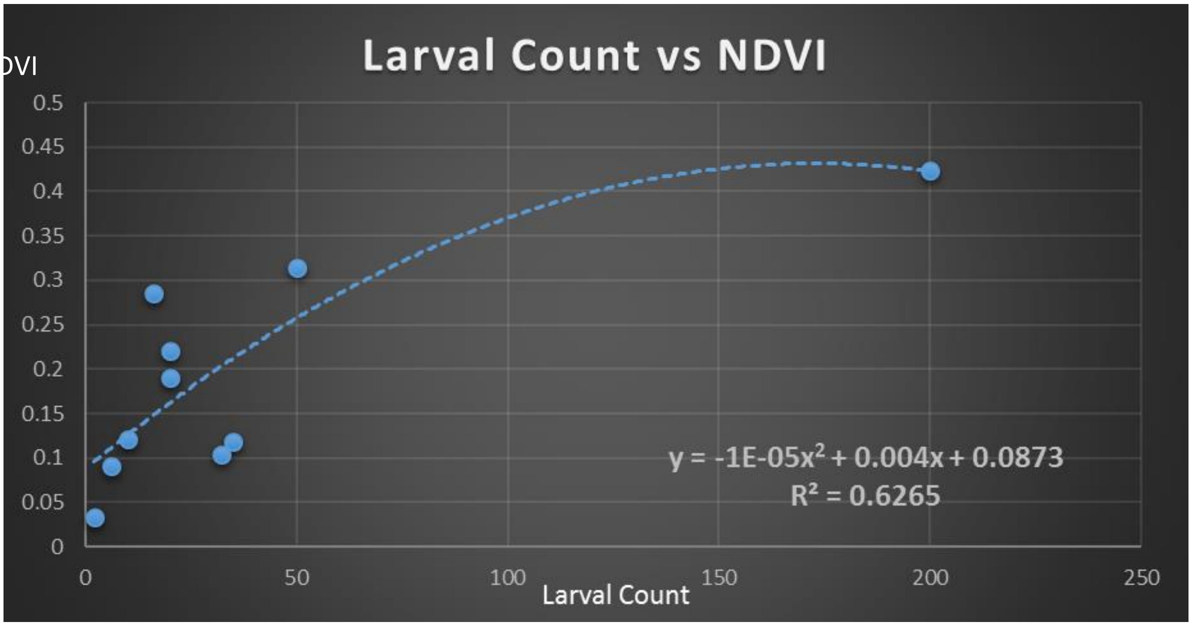

Fig 4.9 NDVI vs Larval Count plot

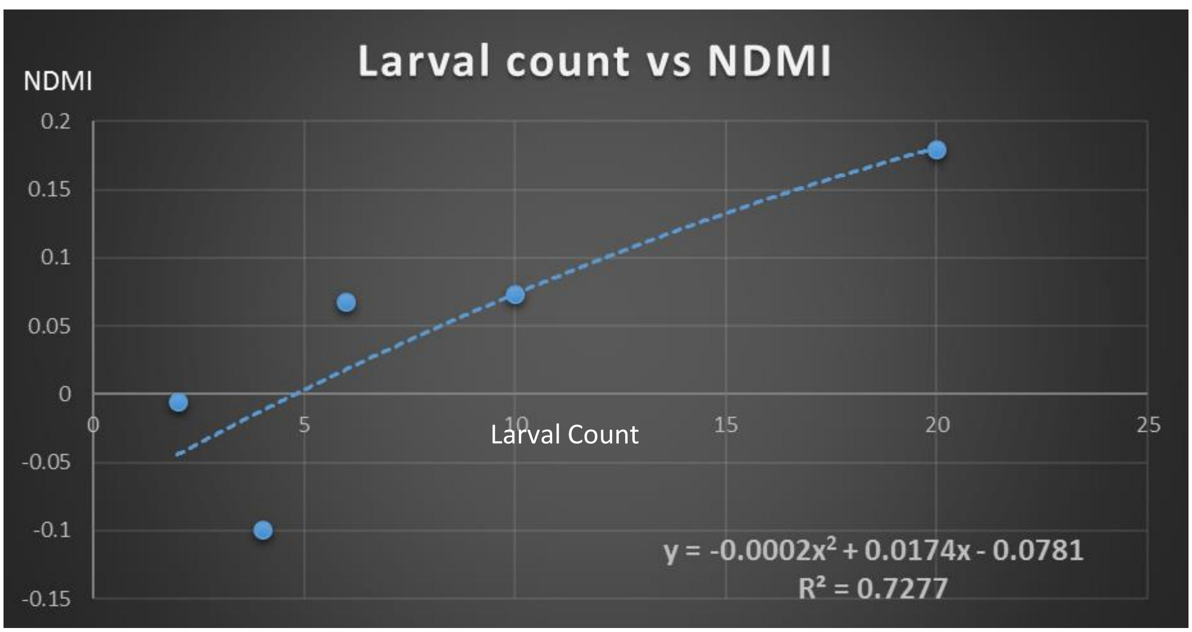

Fig 4.10 NDMI vs Larval count plot

The Fig 4.10 shows the relationship between NDMI and larval count. It is observed that the larval count increases with increase in moisture and this trend continues for higher values of moisture as well. The relationship is expressed in the form of Polynomial equation of order 2. The correlation factor (R^2) for this relationship is 0.7277.

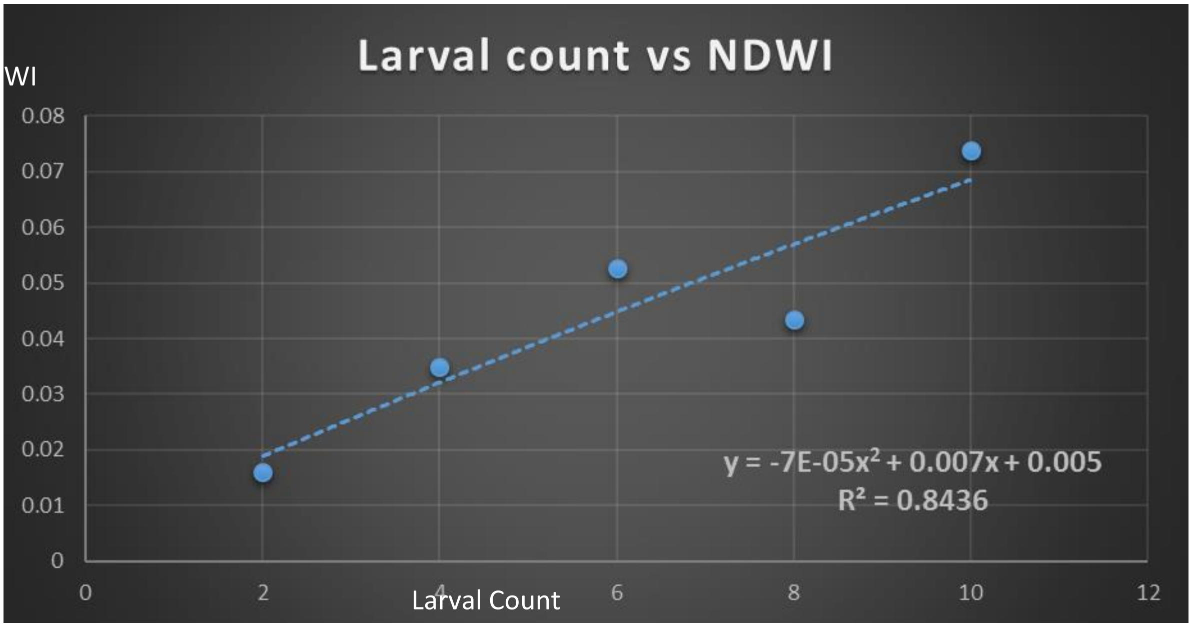

Fig 4.11 NDWI vs Larval Count plot

From Fig.4.11 it is observed that the breeding increases with increase in water content. The relationship between the two is in the form of polynomial equation of degree two and the trend of plot continues for higher values of water content as well. That is the breeding increases as the water content keeps increasing. The correlation factor(R^2) for this plot is 0.8436.

From Fig 4.12, it is observed that the breeding is less in areas with higher temperatures. The areas with temperature more than 30°C are not prone to mosquito breeding. The relationship between temperature and larval count is given as a polynomial equation of degree 2 with correlation factor of 0.6136.

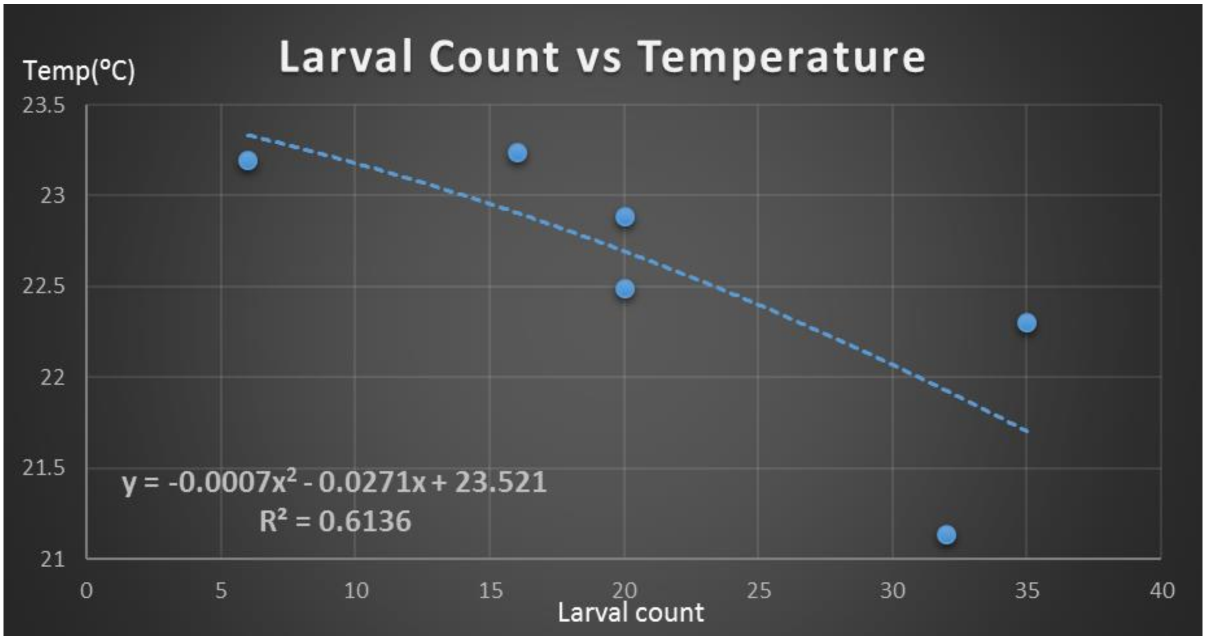

Fig 4.12 Temperature vs Larval Count plot

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

The various factors influencing the Culex mosquito breeding were identified and were mapped spatially. Analytic Hierarchy Process was performed in order to assign weights to the various layers by prioritizing the layers based on expert's advice. Weighted overlay analysis was carried out in order to identify the Culex mosquito prone areas. The mosquito prone zonation map consisted of five classes namely very high prone, high prone, moderately prone, less prone and very less prone zones. This map was validated using data collected from field and the accuracy obtained was 83.3%. Further, the relationship between larval count and the various factors were established as scatter plots using polynomial equations of degree 2.

5.2 CONCLUSION

From this study it can be concluded that remote sensing and GIS can be effectively used to identify the habitats prone to Culex mosquito breeding by mapping the spatial distribution of each of the factors namely vegetation, moisture, water, temperature, slope and land use/ land cover.

Using the techniques of remote sensing and GIS in this field, the areas prone to Culex mosquito breeding can be identified through a less time consuming process that provides accurate results. The Analytic Hierarchy Process proved to be an effective tool in arriving at the weightages for each factor and the rankings for each classes within. The mosquito prone zonation map obtained from weighted overlay analysis can be used to identify the risk prone areas and take precautionary measures to combat the surge in Culex mosquito population.

5.3 SCOPE FOR FUTURE WORK

- This study can be extended for the other major polluted waters like Buckingham canal and Adyar River.
- A comparison study on the favorable breeding conditions of *Culex* and other breeds of mosquitoes can be done.
- The continuously varying factors like temperature, salinity, humidity etc., can be mapped in real time and correlated with the breeding of *Culex* mosquitoes.
- A multivariable regression equation can be developed by including various other factors that influence *Culex* mosquito breeding.

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