Geospatial Mapping of Wetland Dynamics - A Case study of Kanchipuram District, Tamil Nadu, India

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***Abstract*—In semi-arid regions, which are characterized by seasonal rainfall, wetlands play vital roles such as ground water recharge, improvement of water quality, reduction of seasonal flood impacts. However due to several natural and anthropogenic activities such as urbanization, agricultural activities, wetlands are facing drastic changes. The present study deals with the monitoring of wetlands changes using multi-temporal Landsat data. The study area is Kanchipuram district, Tamil Nadu, India, which is a semi-arid region that is characterized by rapid urbanization over last decade, is facing a decline in the areal extent of wetlands. The study has been done from the year 1991 to 2014 for the changes in wetlands in which wetland mapping is performed by geospatial technique and their corresponding changes have been observed. The decade wise and then the changes for 23 years has been shown in the different thematic. Thus decreases in the areal extent of wetlands have been observed which is due to decline in the annual rainfall and rapid urbanization over decades. From the change detection, the conversion of wetlands to different other land use covers have been identified and the severity of this results in severe flooding and rapid depletion of ground water.**

IndexTerms—Wetland Mapping, Multitemporal Images, Land use and Land Cover.

I. INTRODUCTION

A wetland is a land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem [4]. According to the Ramsar Convention on Wetlands; “Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters”. Wetlands are considered to be one of the world’s most important environmental assets such that they support large number of plant and animal species compared to other areas of the world. Wetlands are distributed around the world and cover an area that is 33% larger than the USA [6] and occur naturally on every continent except Antarctica [5]. They are quite essential to human survival and development. The continuous presence of water in wetlands creates a condition that favor the growth of hydrophytes and it also supports the development of hydric soils. Wetlands are among the most productive ecosystems in the world and play a vital role in improving the quality of water. Wetlands reduces the impact of flooding by absorbing heavy rain and releasing it gradually. Wetlands at the margins of lakes, rivers, bays and the ocean protect shorelines and stream prevent erosion. Wetlands also prevent the releasing of carbon dioxide into the atmosphere by storing carbon within their plant communities and soil. Thus wetlands help to moderate global climate conditions [5]. Due to the regional and local differences in soil, hydrology, climate, topography, vegetation, human disturbances and other factors, there occur vast variations in wetlands. These variations or disturbances to wetlands in turn leads to ecological imbalance as wetlands provide several environmental benefits. Thus the mapping and monitoring of wetlands are highly essential as it is used to analyze changes in wetlands over years.

Globally, the areal extent of wetland ecosystems ranges from 917 million hectares (m ha) [8] to more than 1275 m ha [3]. India, with its varying topography and climatic regimes, supports diverse and unique wetland habitats [11]. National Wetland Atlas 2011, prepared by Space Application Centre (SAC), is the latest inventory on Indian wetlands. As per the estimates, India has about 757.06 thousand wetlands with a total wetland area of 15.3 m ha, accounting for nearly 4.7% of the total geographical area of the country. Out of this, area under inland wetlands covers 69%, coastal wetlands 27%, and other wetlands (smaller than 2.25 ha) 4% [15]. The water spread area of wetlands varies greatly in the pre monsoon and post monsoon season. Overall, inland wetlands have a water spread area of 7.4 m ha in post monsoon and 4.8 m ha in pre-monsoon; and coastal wetlands have 1.2 m ha and 1 m ha in post monsoon and pre monsoon, respectively [15]. Tamil Nadu, a wetland-rich State have6.92% of geographic area under wetlands [15]. In terms of total wetland area, Kanchipuram is the leading district with 80,445 hectares (8.91%) and Chennai has the smallest area, 917 ha (0.10%).Lake/pond and tank/pond are the dominant wetland types found in all the districts in Tamil Nadu that accounts for 61%.

Techniques for wetland mapping and monitoring includes on-site evaluations, air photo interpretations, and satellite remote sensing. However due to high cost of equipment and time limitation, on-site evaluations and air photo interpretations are not quite feasible for wetland mapping and monitoring respectively. Satellite remote sensing play a major role in wetland studies as it can provide frequently wetland maps and also yields information on surrounding land uses and their changes over time, information that could potentially be used to understand the wetland changes.

Landsat TM [13], [14], and ETM+ [1], data are ideal for wetland mapping, because these data have a middle-infrared (IR) band that is sensitive to wetness (band 5), and red (band 3) and near-IR (band 4) bands, which are sensitive to vegetation and many studies have been successful in utilizing Landsat TM and ETM+ data for wetland mapping [14], [9].

II. STUDY AREA

The study area is Kanchipuram district, Tamil Nadu, India which has a total geographical area of 4,534 km^2 (1,711 sq. mi) and coastline of 57 km (35 mi). It lies between 11° 00‘ N to 12° 00‘ N latitudes and 77° 28' E to 78° 50' E longitudes. It possess wetlands of area of about 80,445 hectares. Palar is the major river in the district, which is not perennial. This is the only river that flows thorough the district, originating from NandhiDurg in Karnataka. The north east monsoon contributes more rainfall than the south west monsoon. Generally flood occurs during north east monsoon as there is heavy precipitation with cyclonic storm formed in Bay of Bengal. Kanchipuram has wetland area of 80,445 hectares (8.91%), which is the highest in terms of area in Tamil Nadu. The proportion of urban population to total population has increased over the decades in the district. Acceleration in density of population is felt heavily in urban areas. The decadal growth rate indicates that the urban centers have increased in the district adding enormously on the urban population. This in turn has led to the decrease in wetlands in Kanchipuram. The decline in the rate of precipitation over years in kanchipuram have also resulted in reduction in wetlands and thus precipitation plays a vital role in determining the areal extent of wetlands.

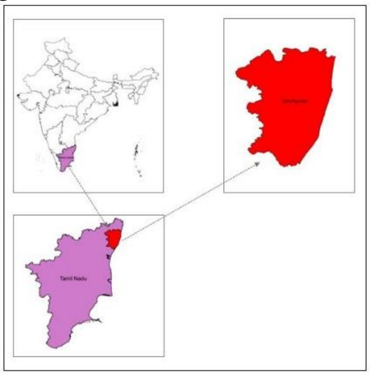


Fig 1. Location map of the study area

A. Rainfall and Climate

The pre-monsoon rainfall is almost uniform throughout the district. The coastal taluks get more rains rather than the interior regions. This district is mainly depending on the seasonal rains. Northeast and southwest monsoons contribute respectively to the total annual rainfall. The normal rainfall of the district has been 1213.3 mm and actual rainfall has been 1133 mm. The months between April and June are generally hot with temperatures going up to an average maximum of 36.6ºC. In winter (December - January) the average minimum temperature is 19.8ºC. High relative humidity between 58 and 84% prevail throughout the year. Relative humidity is maximum in the morning and minimum in the evening. Higher rates of relative humidity are observed between November and January i.e., 83 to 84%. In the months of June, the humidity is lower i.e., around 58%. Average relative humidity in the morning and evening are 74 and 64% respectively.

III. MATERIALS AND METHODS

A. Remote Sensing Data

Landsat data have been widely used in wetland studies due to its spatial resolution. In this study, a total of 5 Landsat series images (TM, OLI/TIRS) acquired for the post monsoon months of different years from 1991 to 2014 were used. Series remote sensing images include 4 Thematic Mapper (TM) images of 1991, 1997, 2006, 2009 and 1 Operational Land Imager (OLI) image of 2014. Detail information of remote sensing image is listed in Table 1. All images were projected using the Universal Transverse Mercator system in the world reference system (WGS84) datum.

TABLE 1. IMAGE ACQUISITION DETAILS

Year	Landsat missions	Sensor types	Acquisition
1991	5	TM	February
1997	5	TM	February
2006	5	TM	February
2009	5	TM	February
2014	8	OLI	March

B. Image Classification

In this study, the acquired remote sensing images were classified in order to investigate the changes in wetlands from 1991 to 2014. The classification included 5 land use land cover types namely water bodies and wetlands, agricultural land and forest, fallow land, barren land, built-up area. A supervised classification method, the support vector machine was used to classify the images into land use land cover types. SVM is a supervised machine learning method that performs classification based on the statistical learning theory [16]. SVM is based on fitting a separating hyperplane that provides the best separation between two classes in a multidimensional feature space. This hyperplane is the decision surface on which the optimal class separation takes place. The optimal hyperplane is the one that maximizes the distance between the hyperplane and the nearest positive and negative training example, called the margin. Thus, in general, the larger the margin, the lower the generalization error of the classifier. From a given set of training data, the optimization problem is solved to find the hyperplane that leads to a sparse solution. Hence, only a subset of the training samples, the support vectors, is used to build the hyperplane.

In this study, the SVM classifier was applied to the Landsat imagery for mapping the wetlands of the study area using the training data. Selection of the training sites was done by photo interpretation. Further the SVM algorithm was implemented using the training sites that were collected. SVM was implemented using the radial basis function (RBF) kernel for performing the classification. RBF kernel was chosen as it generally requires defining a small number of parameters and is also known to generally produce good results [7]. The input parameters required for running SVMs in ENVI include the ‘‘gamma (g)’’ in the kernel function, the penalty parameter, the number of pyramid levels to use, and the classification probability threshold value. The penalty parameter was set to its maximum value (i.e., 100), so that no misclassification occurred during the training process. The pyramid parameter was set to a value of zero so that the Landsat image was processed at full resolution, whereas a classification probability threshold of zero was used. Thus classifications were done using SVM algorithm and the wetlands were extracted for satellite images of post monsoon season. Further the areal extent of wetlands were calculated and accuracy assessment have been performed. Further the dynamic nature of wetlands and their impacts were analyzed.

IV. RESULTS AND DISSCUSSION

Thus in this study wetlands were extracted by Support Vector Machine (SVM) and a significant fluctuation in the areal extent of wetlands were observed from year 1991 to 2014. These fluctuations were the result of rapid urbanization over decades in addition to the reduction of rainfall over the district. It was observed that the annual precipitation of 1115.34 mm was recorded in the year 1990, but over years there was a significant reduction in the precipitation i.e, in 2013 only 805.3 mm of annual precipitation was recorded. On the other hand there occurred a drastic increase of built up area i.e, in 1991 the areal extent of built up region was just 58.13 sq.km while in 2014 it was 584.47 sq.km. The areal extent of different land use land cover types are shown in table 2 as they influence changes in wetlands by activities such as agricultural conversion, direct deforestation in wetlands, hydrologic alteration such as the removal of water from wetlands or raising the land-surface elevation and urbanization.

As the urbanization increased in the late 1990’s, it resulted in vast extent of built up areas and in 2014 the areal extent increased to 584.47 since the population size increased by 38.69 % from 2001 to 2011. Further a dynamic nature was observed in agricultural land, forest and fallow lands. The dynamic nature of several land use land cover types are shown in figure 2.

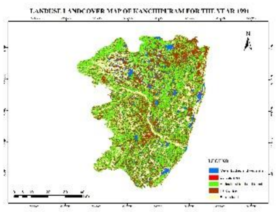
TABLE 2.AREA OF LAND USE LAND COVER TYPES

Land use land cover type	Area (in Sq. km)				
	1991	1997	2006	2009	2014
Water bodies/wetlands	259.65	367.98	380.22	254.36	137.80
Built up area	58.13	92.88	249.81	304.56	584.47
Agricultural land and forest	1743.84	1783.14	1496.51	1537.29	959.34
Fallow land	14444.05	919.83	1406.62	1267.45	1680.56
Barren land	1028.53	1370.38	1001.05	1170.55	1172.01

The table 3 shows the changes in wetlands in post monsoon months and it was seen that during the year interval 1991 to 1997, variation of 108.33 sq.km was observed while during the year interval 1997 to 2006, variation of 12.24 sq.km was observed. Due to the abnormal monsoonal rainfall in the year 1996 and 2005, increase in the areal extent of wetlands were observed. Further due to rapid urbanization over the last decade accompanied by decrease in rainfall, a vast reduction in wetlands of 125.68 sq.km and 116.56 were observed during the year interval 2006 to 2009 and 2009 to 2014 respectively.

TABLE 3.CHANGES IN WETLANDS IN POST MONSOON MONTHS

Year	Area of wetlands (in Sq.km)		Changes in wetlands (in Sq.km)
1991-1997	259.65	367.98	108.33
1997-2006	367.98	380.22	12.24
2006-2009	380.22	254.36	125.68
2009-2014	254.36	137.80	116.56



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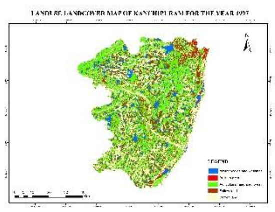

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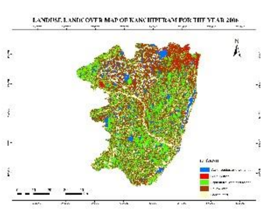

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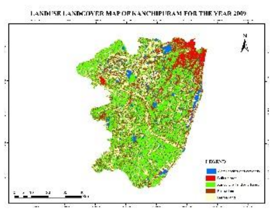

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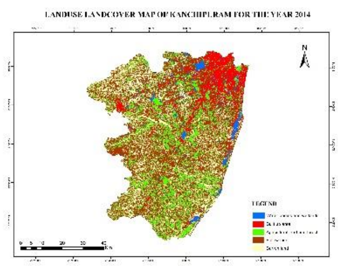
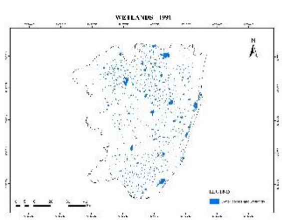


(e)

Fig 2. Land useland cover map for the year (a)1991, (b)1997, (c)2006, (d)2009, (e)2014



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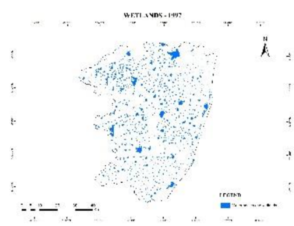

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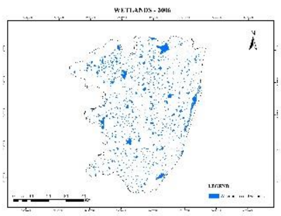
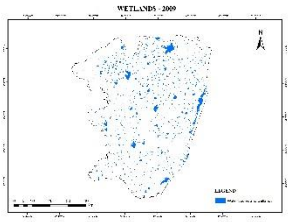
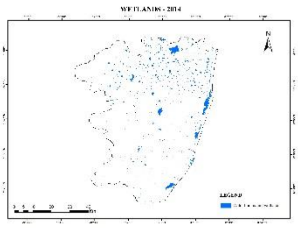




(c) (d)



(e)

Fig 3. Wetland extent map for the year (a)1991, (b)1997, (c)2006, (d)2009, (e)2014

The figures 3 (a), (b), (c), (d), (e) shows the extracted wetlands for the year 1991, 1997, 2006, 2009, 2014 respectively and changes in wetlands were observed. The average north east monsoon rainfall for Kanchipuram district is 899.8 mm and in the year 1990 the monsoonal rainfall was about 640.14 mm which is less than the average monsoonal rainfall. However in the year 1996, the monsoonal rainfall was about 883.71 which is normal. Thus an increase in the areal extent of wetlands were observed between the years 1991 and 1997. Similarly in the year 2005, an abnormal monsoonal rainfall of about 1487.1 mm was recorded which in turn resulted in the increase in the areal extent of wetlands in 2006 when compared with the wetlands extent in 1997. Further in 2013, a below average rainfall of 315.4 mm of rainfall was recorded and this in turn resulted in decrease in the areal extent of wetlands. These variations in wetlands resulted in the depletion of ground water level which is accompanied by increase in population growth. To validate the classification, the accuracy assessment was done using ENVI. The classification accuracy achieved were 75.3519 %, 78.0201 %, 76.0489 %, 78.7559 %, and 75.3763% for the classified images for the year 1991, 1997, 2006, 2009, and 2014 respectively.

V. CONCLUSION

In this study land use land cover of multi temporal Landsat data and their impacts on wetlands changes were analyzed. Decrease in the areal extent of wetlands have been observed which is due to decline in the annual rainfall and rapid urbanization over decades This decline in wetlands leads to depletion of ground water and further it could increase the severity of flood as wetlands play a vital role in trapping of water during flood. Thus conservation and monitoring of wetlands are highly essential such that they provide balance to the ecosystem.

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