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Urban Sprawl Analysis of Madurai City using Remote Sensing and GIS

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Abstract

Urbanization can be both planned and unplanned where unplanned one causes urban sprawl. It makes an impact on environment like affecting the natural resources like vegetation, agriculture, water bodies etc. The rapid urbanization tends to result in lots of changes in the current use of infrastructure facilities and increase in the growth of population results in urban congestion, transportation problems, landuse/landcover changes. Therefore, in order to overcome these problems, proper understanding of the rapid changes should be made and to find the suitable sites for the future urban expansion of the area. In this study, Madurai city is taken as the study area. Landuse/landcover (LULC) map were prepared by processing Landsat 8 satellite imageries using ArcGIS. Then the changes in landuse/ landcover for four different years are found out. The urban sprawl pattern of the city is identified using GIS.The criteria for the site suitability analysis are evaluated and the weightages for the different parameters are calculated using AHP. Then the weightages are implemented in the maps to get the final suitability map which shows various categories as not suitable , low, moderate, highly suitable.

Keywords — Urban Sprawl , Urban Development , Madurai , Remote Sensing and GIS.

I. INTRODUCTION

Well organised planning is needed in order to avoid the impacts on environment due to rapid urbanization. The various factors which governs urbanization are environmental and socio economic factors like population, economic development. It is known that urbanization is the migration of people from rural areas to the urban areas for better employment opportunities, education, and to develop the standard of living. The transformation of green cover into urban build-ups is in alarming rate which is sure to cause adverse impacts on the environment and natural resources. Urban development which includes the suitable sites is totally based on various factors or parameters like social, economic and the geographical features of the location. These parameters help in determining the site suitability for the respective purposes of the land. It is possible by analysing the land use, landcover classification, population density, water quality, surface temperature, land guideline value, normalized difference vegetation index, road proximities etc.

Ibrahim Rizk Hegazy and Mosbeh Rashed Kaloop., [1] used GIS in Mansoura and Talkha from 1985 to 2010 for the land use detection. The study indicated an increase in built up area of 30% (28 sq.km to 255 sq.km) and a reduction in agricultural land by 33% and also inferred that these information on land use/landcover change and urban growth will be useful for urban planners and local government for the future urban development of the city. Abdelkader El Garouani et al., [2] analyzed the urban growth and sprawl for Fez, Morocco using remote sensing data and studied the relationship between urbanization and land use changes to analyze their impact on the increase in impervious surface area. To identify the land use changes and growth between the period of 1984-2013, satellite images and census data were used. Then image classification was performed using Erdas imagine and ArcGIS software and concluded that there was an increase in landcover by about 21% whereas decrease in agriculture and forest area by 11% and 3% respectively.

Vivek Garg, Alok Sharma., [3] studied the different activities in Jabalpur city and its surrounding to find the land cover changes. Most importantly, nine types of land use data were derived from the images. Then, buffer analysis was done to find the urban growth. The mean relative and distributed entropy for both the buffer types are calculated using this method. Conclusions from entropy method indicate that the urban development in the study area (Jabalpur city) is growing randomly in an unplanned manner. This research can be used by planners and administrators to make an efficient urban planning. Mukesh Singh Boori et al., (2015) [5] studied the monitoring and modelling of Urban sprawl for Kuala Lumpur, Malaysia using Landsat images for the year 1989, 2001 and 2014 to classify four types of landcovers like urban/built area, agriculture, forest and water by maximum likelihood classification. All the area coverage for different points in time were identified and overlaid with the distance from city center. Then calculated the urbanization densities from city center to buffer area of 1 km and was inferred that population, traffic conditions, industrialization and policy plays a major role in urban expansion.

Onur Satir et al., (2016) [6] mapped the land use suitability for urban sprawl for Van city considering factors like distance from roads, distance from urban boundary, hill shade, slope, elevation, land-use cover, and land-use ability between the period of 2002-2015. Weightages for various input factors were calculated which indicated that they had a greater potential in the change in dynamics of Van city. Since agriculture and animal production were the major income in Van city, there was a new strategy developed to maintain a sustainable balance between agriculture and urbanization. Rajchandar Padmanaban et al. (2017) [8] studied the Landsat images from 1991, 2003 and 2016 and found the landscape metrics to find the extent of urban area within a buffer zone of 19km of Chennai which was then quantified with Renyi's entropy. This study was useful to address the socio-ecological consequences of urban sprawl and to protect ecosystem services.

Satty (2008) [11] proposed an effective tool for dealing with complex decision making process under different fields. This method is useful for reducing complex decisions to a series of pair-wise comparisons and then synthesizing the results. Additionally, the AHP tool is a suitable technique for evaluating the consistency of the result.

The objective of the study is to reduce the urban sprawl, the planners require suitable data for the effective urban planning of the area. In such cases GIS and remote sensing helps the planners to plan efficiently and effectively. Proper identification of reasons of urban sprawl is needed to make a well proper Infrastructure planning of the areas.

II. Study Area

The study area is Madurai City. It is the fourth largest corporation by area and third largest city by population in Tamil Nadu. The study area extends from 78° 00' to 78° 13' E longitude and 9° 48' to 10° 01' N latitude. The city covers an area of 150.71 km^2 and had a population of 1470755 in 2011. In 2011, the jurisdiction of the Madurai Corporation was expanded from 72 wards to 100 wards, dividing into four regions – Zone I, II, III and IV. The digitized and georeferenced image of Madurai city as shown in Figure 1.

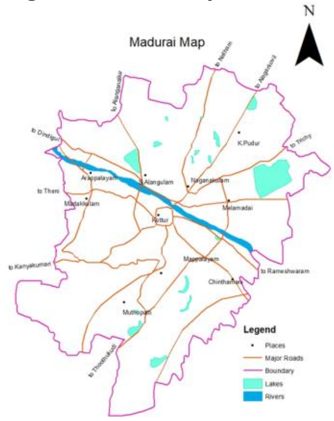

Fig. 1 Digitized and Georeferenced Image of Madurai City

III. Methodology

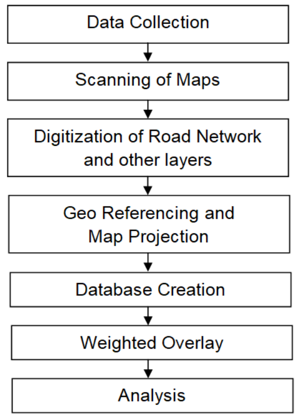

Fig. 2 Methodology for site suitability of Urban Development

The above Fig. 2 explains the methodology carried out in the study. Data collection includes Base map, Population data, Landsat 8 imageries, Groundwater table data, Pollution data, Road proximities data, public amenities data, and Industrial development data. Scanning of maps converts images into digital format. The image classification of satellite images are done through with ArcGIS software. The digitization and georeferencing process was done by using ArcGIS software. The weightages were calculated by using Analytical Hierarchy Process (AHP) for the overlay process based on their significance. The weightages obtained is used to carried out weighted overlay maps.

The parameters influencing the selection of suitable sites for future expansions of urban development are as follows.

1. Population Density
2. Landuse and Landcover
3. Normalised Difference Vegetation Index (NDVI)
4. Surface Temperature
5. Ground Water Quality
6. Land Guideline Value
7. Road Proximities.

*A. **Population Density***

Population data of each ward is taken from the ward population data from Madurai city Ward Delimitation Report 2011. The ward no. 81 has the highest population density. There are 100 wards in Madurai city. The population density is calculated by using the formula.

Population density = Population / Area (km^2)

The population density map is shown in Figure. 3.

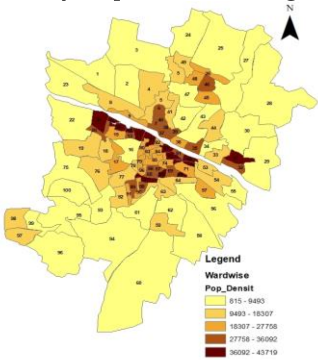

Fig. 3 Madurai City Population Density Map

*B. **Landuse / Land Cover***

Landuse/ Landcover (LULC) imagery is obtained from analysing the Landsat 7 and Landsat 8 imageries which have a temporal resolution of 16 days and provides recent imageries up-to-date. The imageries are obtained for four different years 1990, 2000, 2010, and 2020 to detect the changes in the areas of Landuse/ Landcover. It facilitates OLI – TIRS (Operational Land Imager & Thermal Infrared Sensor) sensor which has a high resolution of 30m. Landsat 8 imagery contains 11 bands of which Band 2, Band3, Band 4 and Band 5 are composited and true colour imagery is obtained as shown in Fig. 4. False Colour Composite (FCC) which is required for LULC classification is obtained through band swapping Red, Green and Blue to Band 5, Band 4 and Band 3 respectively. The FCC is shown in Fig. 5.

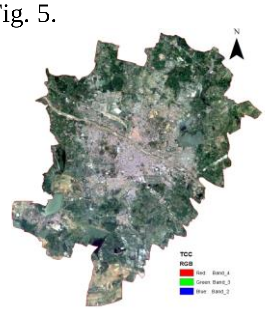

Fig. 4 True Colour Composite

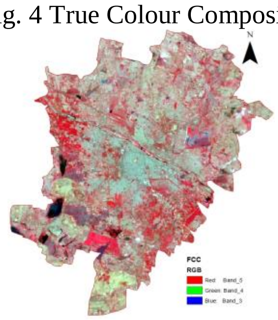

Fig. 5 False Colour Composite

The FCC imagery helps in the distinct identification of features and helps in LULC classification. Red colour indicates vegetation, blue indicates water bodies, and yellow indicates fallow lands and grey indicates built-up areas like buildings and roads. For Supervised Classification through manual identification, training sites are plotted which is compared and the whole map is analysed and the LULC imagery is obtained as shown in Fig. 6 (a), Fig. 6 (b), Fig. 6(c) and Fig. 6 (d) for four different periods. Water bodies, built-up area, agriculture, high vegetation and fallow land are distinctly marked in the LULC classified imagery.

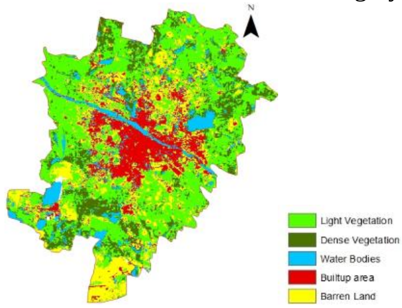

Fig. 6 (a) LULC Supervised imagery (1990)

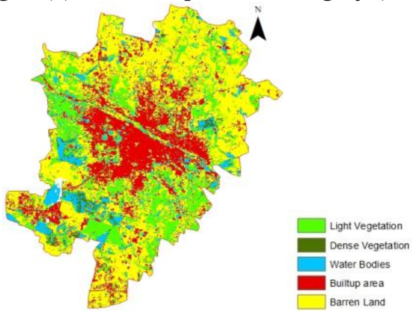

Fig. 6 (b) LULC Supervised imagery (2000)

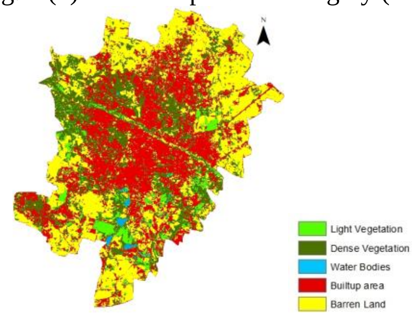

Fig. 6 (c) LULC Supervised imagery (2010)

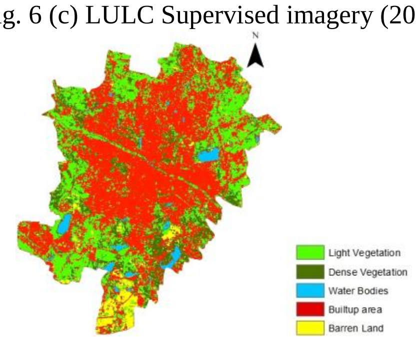

Fig. 6 (d) LULC Supervised imagery (2020)

*C. **NDVI***

Normalized Difference Vegetation Index (NDVI) indicates the intensity of vegetation. NDVI value ranges from -1 to +1 where negative values indicate water bodies and higher positive values indicate denser vegetation while lower values indicate low vegetation. The NDVI imagery is derived from Band 4 and Band 5 of Landsat imagery i.e., red band and near infrared band and shown in Fig. 7(a), Fig. 7(b), Fig. (c) and Fig. 7(d).

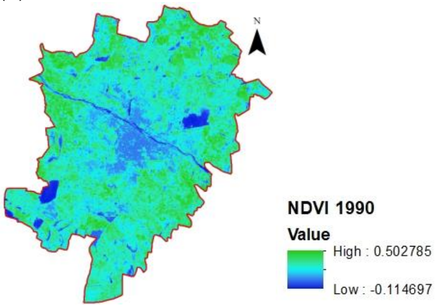

Fig. 7 (a) NDVI Imagery (1990)

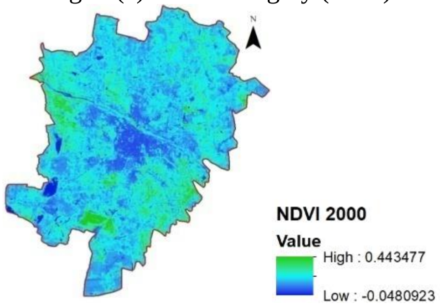

Fig. 7 (b) NDVI Imagery (2000)

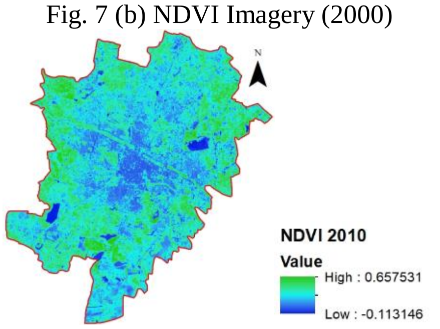

Fig. 7 (c) NDVI Imagery (2010)

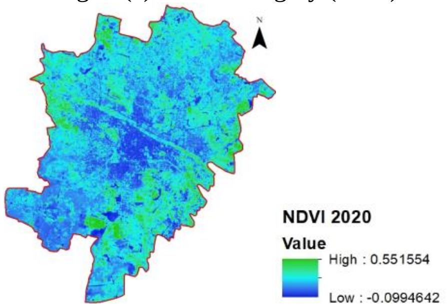

Fig. 7 (d) NDVI Imagery (2020)

*D. **Surface Temperature***

Surface Temperature data is obtained from the various pre-processing procedures which include determination of radiance values and satellite temperatures for Band 10 and Band 11 followed by determining emissivity and Surface temperature for both bands which is then averaged to obtain the mean surface temperature as shown in Fig. 8 (a), Fig. 8 (b), Fig. 8 (c) and Fig. 8 (d).

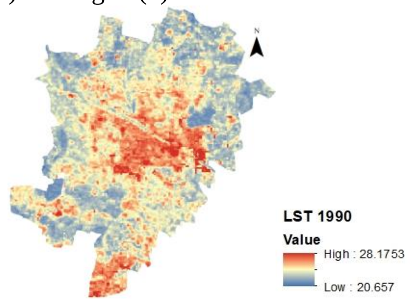

Fig. 8 (a) Surface Temperature Imagery (1990)

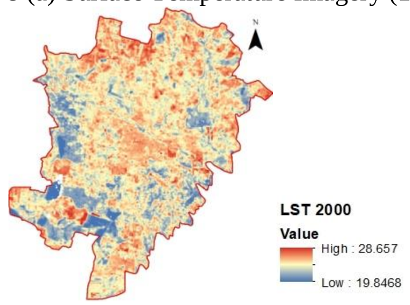

Fig. 8(b) Surface Temperature Imagery (2000)

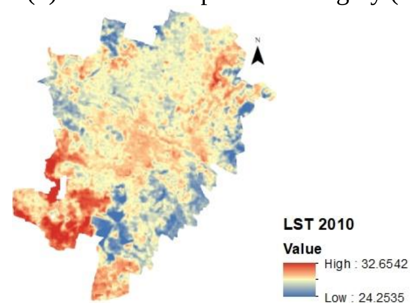

Fig. 8(c) Surface Temperature Imagery (2010)

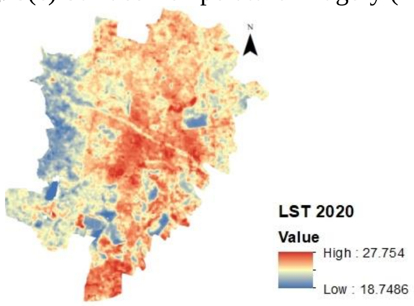

Fig. 8(d) Surface Temperature Imagery (2020)

*E. **Ground Water Quality***

Groundwater quality data for the city was obtained from "State Ground and Surface Water Resources Data Centre, Chennai" for the year 2019. From the data, Groundwater quality is analysed by Water Quality Index (WQI) method where Weighted Arithmetic process is used. From the data, the water quality index map is formed as shown in Figure 9.

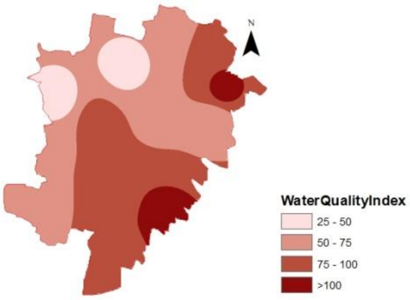

Fig. 9 Water Quality Index(WQI) map

F. *Land Guideline Value*

Land Guideline Value is the minimum principal value fixed by the government of Tamil Nadu for property registration. These guideline data is obtained from the department of registration (TNREGINET). From the data, the guideline value map is formed as shown in Figure 10.

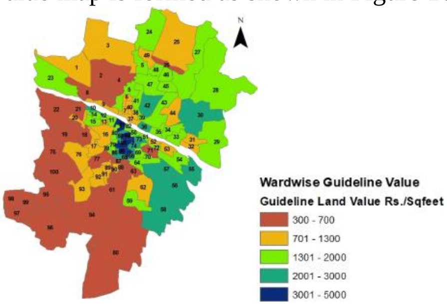

Fig. 10 Land Guideline Value map

G. *Road Proximity*

The urban areas faces issues of inadequate transport network which are unable to adjust with the increasing population. Here therefore roads proximity is taken as one of the criteria for selection of suitable sites where it is analysed by creating buffer zone around the road which lies between 0-500m where higher weightage is taken for proximity of 0-100m for easy access to the nearest area. The road proximity after assigning of buffers is shown in Figure 11.

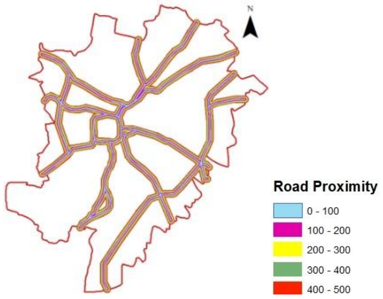

Fig. 11 Road proximity of buffer 0-500m

IV. SITE SUITABILITY

Using the above data, the AHP process is carried out to as per Saaty's method to find out the weightages for suitable sites for urban development as shown in Fig. 12. Normalized pairwise comparison matrix is shown in Table 1. Then the weightages obtained from AHP procedures are listed in Table. 2.

TABLE 2 CRITICAL WEIGHTAGES FROM A.H.P.

Parameters	**Weightages (%)**
Population Density	35
Landuse/Landcover	19
N.D.V.I	24
Surface Temperature	9
Water Quality	4
Land Guideline Value	2
Road Proximities	7

TABLE 1 NORMALIZED PAIRWISE COMPARISON MATRIX

Factors	**Population Density**	**LULC**	**NDVI**	**Surface Temperature**	**Water Quality**	**Guideline Value**	**Road Proximity**	**Criteria weight**
Population Density	0.418	0.443	0.576	0.336	0.212	0.231	0.228	0.349
LULC	0.139	0.148	0.096	0.269	0.212	0.231	0.228	0.189
NDVI	0.139	0.295	0.192	0.269	0.247	0.231	0.285	0.237
Surface Temperature	0.084	0.037	0.048	0.067	0.106	0.128	0.171	0.09
Water Quality	0.070	0.025	0.027	0.022	0.035	0.077	0.011	0.038
Guideline Value	0.046	0.016	0.021	0.013	0.012	0.026	0.019	0.022
Road Proximity	0.104	0.037	0.038	0.022	0.176	0.077	0.057	0.071

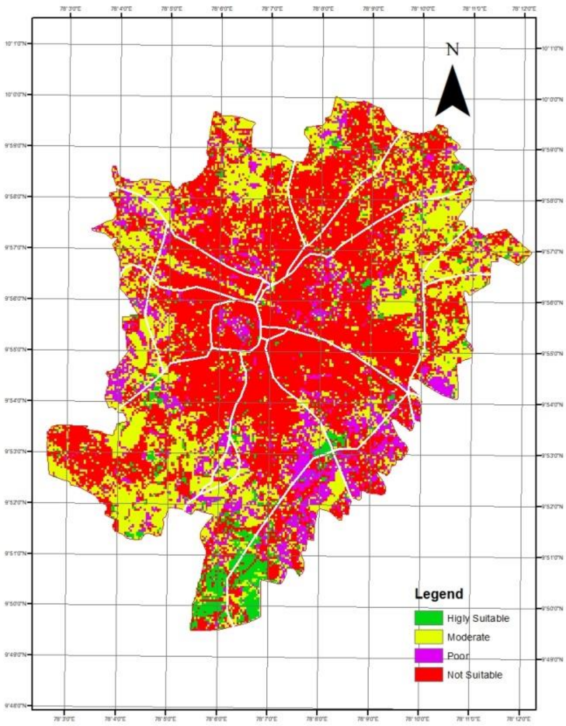

Fig. 12 Suitable Areas for future development

V. RESULT AND DISCUSSION

The area distribution of classified suitable sites for urban development are made by using pixel count as shown in Table 3. It shows that 30% of the total area are moderately suitable, 6% are highly suitable, 51% are not suitable and 13% are poorly suitable.

TABLE 3 CATEGORIES OF SUITABILITY AREA DISTRIBUTION

Suitability	Area (Sq.Km)	Area (%)
High	8	6%
Moderate	45	30%
Poor	20	13%
Not Suitable	76	51%

V CONCLUSION

This study is made to understand the different techniques and methods used for detecting sprawl pattern and urban development. Using Analytical Hierarchy Process (AHP), the site suitability model for Madurai city is developed for the suggestion of future development of the city. It shows that 30% of the total area are moderately suitable, 6% are highly suitable, 50% are not suitable and 13% are poorly suitable. Urban sprawl analysis is carried out over a period of 1990 to 2020 and change in land pattern from barren, vegetation to built up area is observed. The result of this study indicates that integrated evaluation of urban development could be conducted better using study of maps, satellite data, GIS, and AHP weightage method. Several other technologies could be adopted as Geographic information systems by application of artificial intelligence in modelling for solving various decision-making problems. The integration of soft computing techniques with geographic information systems could be proposed in future study to include various types of spatial variables in the optimization.

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