Study Of Urbanization Impact On Potential Groundwater Rechargeable Zones Of Hyderabad City

[1]P.Yaswitha, [2]K. Ravikumar, [3]T.VinayTeja, [4]P. Swathi, [5]K.Prem Kumarm, [6]K.Swetha
[1,3,4,5,6]Former UG student, Department of Civil Engineering, [2]Associate Professor,
[1,2,3,4,5,6]Department of Civil Engineering, [1,2,3,4,5,6]VNR VignanaJyothi Institute of Engineering and Technology, Hyderabad, India

Abstract: Hyderabad is the Metro Politian city in Southern India with an area of 650 sq.Km and having population of over 60 Lakhs (GHMC, 2017). It has undergone through rapid economic development, population growth and in turn multifold increase of water demand during the last 24 years (from 1988 to 2012). This fast urbanization growth has a great effect on the surface as well as hydrogeological characteristics of the urbanized area. The present study is an attempt to estimate the changes in Land Use and Land Cover (LULC) using ERDAS and obtained results were correlated with average rainfall (ARF) and groundwater levels (GWL) of the Greater Hyderabad Municipal Corporation (GHMC) administrative boundary. Landsat images were classified to get the changes in LULC patterns over the study period by using supervised classification technique. Followed by multiple regression analysis of multiple parameters such as Built Up Land (BUL), Open Land (OL), ARF and Groundwater Levels (GWL) is done to obtain the relationship among them. The study points out that the GHMC has undergone through remarkable increase of BUL by 253% from 1988 to 2012. Upon performing the multiple regression analysis from 2005 to 2012, the equation is obtained as "GWL=-7.34343+0.021213*BUL+0.020857*OL+0.003708*ARF" with the coefficient of regression (R^2) of 0.933.

IndexTerms- Groundwater Recharge, Open Areas, ERDAS, RS Images, GHMC and Regression Analysis.

1. Introduction:

Groundwater is present beneath the earth surface. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. It constitutes to about 30% of world's fresh water resources (K. Subramanya, 1997). Groundwater is naturally get recharged through soil layers when precipitation occurs on surface, through the river beds, etc. The amount of recharge is limited by the nature of soil profiles, nature of top surface of the ground, especially, the recharge will be nil when rock or impermeable surface is found in the vicinity though the rainfall is occurring. In the present urbanization scenario, the groundwater levels are going down since the groundwater recharge is decreasing as the ground surface is covered by various impervious layers like roads, buildings, sheds and parking lots in addition to the existing natural rocky topography (P. Yaswitha, et a., 2017).

In the recent past, some of the works reported to identify the potential groundwater occurrence zones by L.Yeshodha, et al., (2010) and Sheetal Sharma et al., (2013) as very high potential zone, high potential zone, moderate potential zone, low potential zone and very low potential zone. The authors have used the basic thematic layers and applied the weightage and rankings to derive the results.

On the other, several works have been reported on Remote Sensing and GIS applications in identifying the impact of land use on groundwater recharge and groundwater levels over the particular period of time. For example, O.S. Olokeoguna et al., (2014) have used the Landsat satellite imageries (of 30m resolution) covering the area of Shasha Forest Reserve at two epochs. The results of the comparison of the two classified images showed that vegetation (degraded forest) has increased by 30.96%, farmland cover increased by 22.82% and built up area by 3.09%. Forest reserve however, has decreased significantly by 46.12% during the period. Nitin Mishra and S. Kumar (2015) have used the supervised classification techniques to derive urban land use classification in the Haridwar District, Uttarakhand. With the help of GIS tools groundwater contour maps developed to identify the impact of the urbanization on groundwater storages for five different years from 1972 to 2011.A case study was presented through geo statistical methods and remote sensing data to analyse the spatiotemporal variability of land use, as well as its effect on groundwater depth change in the middle reaches of Heihe River basin. Reduction of groundwater recharge and increase of groundwater exploitation during 1985 and 2010 led to the decrease of groundwater depth in Linze County (Jinfeng Wang et al., 2016).

In another study, Hasan Mohammed Hameed et al., (2015) have used the supervised classification (maximum likelihood logarithm) and regression analysis to identify the relationship between urbanization and groundwater level. The study points out that Erbil urban areas have increased by 278% between 2004 and 2014 and in contrast, the level of groundwater has declined by more than 54%. The authors ,Hsin-Fu Yeh, et al., (2016) have grouped the groundwater recharge areas as excellent, good, moderate, lower and poor potential in the basin of Hualian river of Taiwan. They have used the integration of input factors such as lithology, land cover/land use, lineaments, drainage, and slope in GIS.

Hyderabad, the capital of Telangana state is experiencing the crisis of groundwater every year as urbanization is rapidly increasing. Unless the authorities take strategy for groundwater recharge works to increase the groundwater levels to meet the integrated water demand of the city, the crisis will continue rather it may become worse in future (The Hindu (2012), The Times of India (2012) and The New Indian Express (2015)). The objective of present work is to identify the loss of open land areas (which absorbs the rainwater) due to expanding city with immigrating population from surrounding areas as well as industrialization and relate it with the decreasing groundwater levels in the Hyderabad city. GHMC administrative boundary has been considered for study of the urbanization growth over 22 years from 1988 to 2012, its impact on reducing the open land areas and subsequently reducing the groundwater recharge areas which in turn influence the groundwater levels in the aquifers of GHMC area. In this regard, Landsat satellite images (30mx30m) were used for classification of LULC purpose and the obtained images were analyzed on

GIS platform to count the areas such as BUL and OL. These results were correlated with the average rainfall and groundwater levels to recognize the direct impact of urbanization to decrease the groundwater levels with available rainfall. In addition, using the multiple correlation, this study seeks to estimate the future groundwater levels for the unrestricted urbanization growth.The outcomes of the present study can be useful to the groundwater resource managers and land use policy-makers when composing suitable strategies for sustainable water resources management of GHMC.

2. Study Area:

GHMC is occupying about 650 Sq.km along the banks of Musi River and the Hyderabad Urban Agglomeration (HUA) is the sixth largest in India. Hyderabad lies on predominantly sloping terrain of grey and pink granite, dotted with small hills. As of 1996, the city had 140 lakes and 834 water tanks (ponds). The latitude and the longitude of the city are 17° 22′ 12″ N and 78° 28′ 48″ E.The area under the municipality increased from 170 square kilometresto 650 square kilometres in 2007 when the GHMC was created. As a consequence, the total population leaped from 3,637,483 in 2001 census to 6,809,970 in 2014 census, an increase of over 87% ((Census (2011) and Wikipedia (2017)). The study area of GHMC is depicted in figure 1.In Deccan Plateau, Hyderabad is centrally located. The topographic elevation ranges from 460 to 560 m above mean sea level. The main identified geomorphic units includes residual hills, valley fills, pediment inselbergs and pediplains. Hyderabad forms part of the Pre-Cambrian peninsular shield and is underlain by the Archaean crystalline complex, comprising of granites intruded by dolerite dykes. A thin veneer of alluvium of recent age occurs along the Musi River. Granites exhibit structural features such as fractures, joints, faults and fissures (Narshimha Ch. and U. V. B. Reddy, 2014).

According to CGWB (2013), the groundwater occurs under phreatic conditions in weathered zone and under semi-confined to confined conditions in the fractured zones. Until 1970, shallow wells and large diameter dug wells were utilized for exploiting groundwater to meet domestic and irrigation requirements. Presently,shallow and deep bore wells are being in operation with depth ranging from 100-300 m to exploit groundwater.

3. Data Collection:

The images required for processing and analyzing to identify the change in land use and land cover are acquired from earth explorer. In the present study, the images used are of Landsat 5 TM, Landsat 7 ETM+ and Landsat 8. In this work, satellite images for the years of 1988, 1992, 1997, 2002, 2005, 2007, 2008, 2010 and 2012 were downloaded and utilized for image processing work. In between years data were not utilized because the quality of those years are not good. Hence, only the said 9 years satellite data has been utilized. Spectral Signatures for image classification have been taken from Google Earth view in respective years. The rainfall data required for regression analysis have been downloaded from the free source Global weather (2017) and also the groundwater table levels were downloaded from CGWB (2017) for the periods from 1992-2012 at free of cost for various locations within the city.

4. Methodology:

Landsat images are composed of several bands with varying wavelength. An RGB composite of three different bands must be created to prepare various maps. Available standard image bands are of: band 1 (0.45-0.52 µm, blue-green), band 2 (0.52-0.60 µm, green), band 3 (0.63-0.69 µm, red), band 4 (0.76-0.90 µm, near infrared), band 5 (1.55-1.75 µm, mid-infrared), band 6 (10.40-12.50 µm, thermal infrared) and band 7 (2.08-2.35 µm mid-infrared). From these available individual standard bands, the combination of bands possible were (3,2,1), (4,3,2), (4,5,3), (7,4,2) and (5,4,1). In this work, a layer stack is prepared by considering only the composite of bands 4, 3 and 2 for both Landsat 5 TM and Landsat 7 ETM+ images and finally a composite image is created. The layer stacked images is depicted in figure 2.

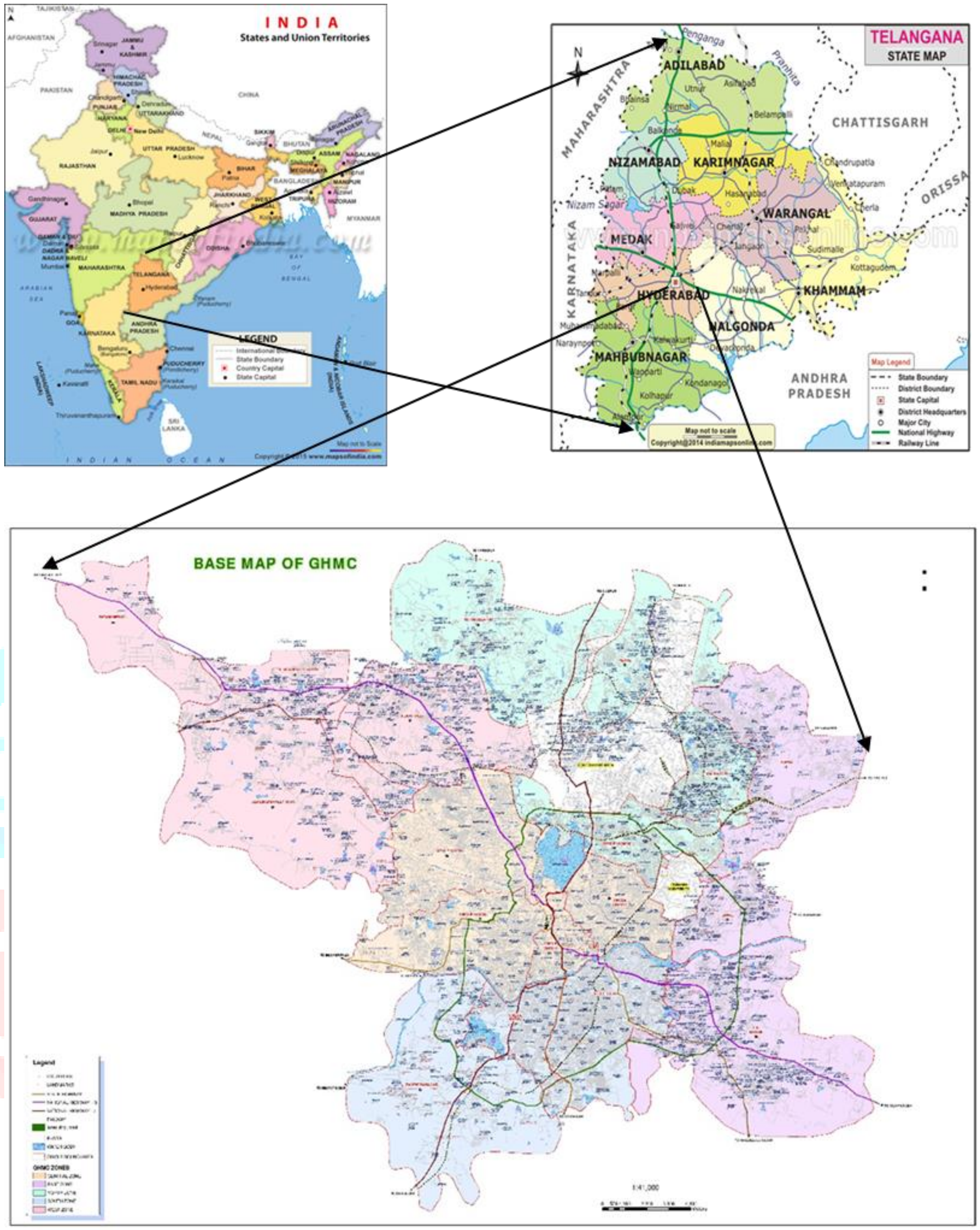


Figure1: Greater Hyderabad Municipal Corporation (GHMC) Administrative boundary (Source: GHMC Website)

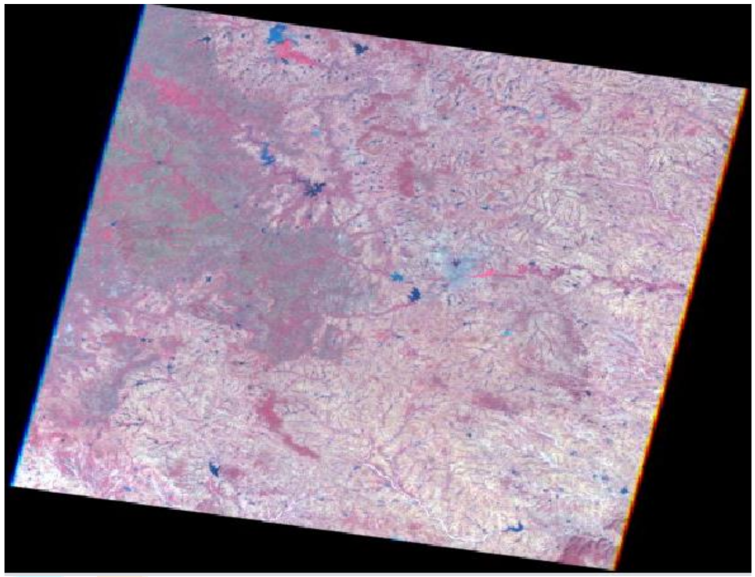
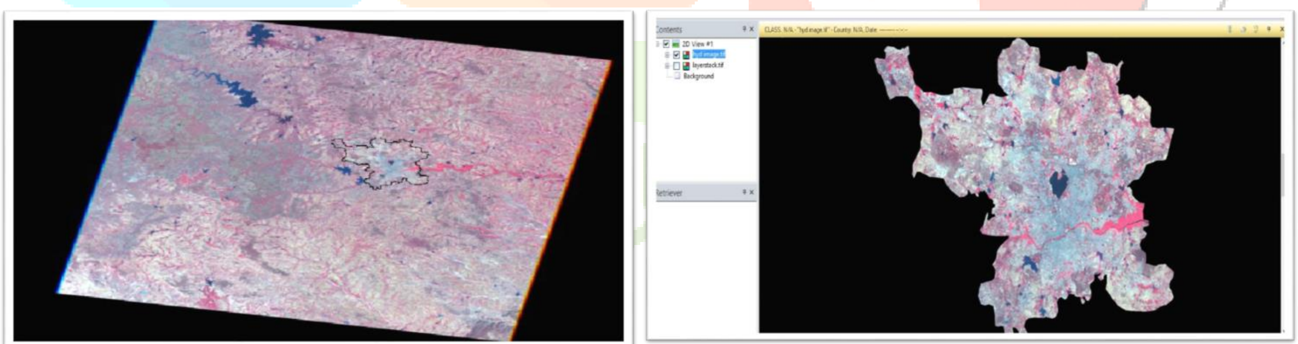


Figure 2: Layer stacked image of the study area and its surroundings.

The next step is to create the area of interest (AOI) file. It is used to extract the study area from the available layer stacked image. In ERDAS the image that is geo-referenced using Q-GIS is given as input. The image boundary is digitized carefully and saved in AOI file format. In the sub-setting operation, the extraction of only the study area from the whole image is done. In the present work, the study area of GHMC boundary is obtained by clipping the layer stacked image with the AOI file. Figure 3 shows the before and after the extraction of study area GHMC.

Figure 3: Study area (a) before extraction (b) after extraction from whole image



(a) (b)

In order to perform the supervised classification anuser must provide the training samples. This is created using signature, where the known samples are given as reference for further classification of the image. Image classification refers to the task of extracting information classes from a multiband raster image. Pixels are the smallest unit represented in an image. Image classification uses the reflectance statistics for individual pixels. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification techniques available: supervised and unsupervised.

4.1 Supervised classification process:

Supervised classification is a controlled classification where the user needs to assign the training samples for reference (Thomas Lillesand et al., 2012). Supervised classification uses the spectral signatures obtained from training samples to classify an image. From these training samples, signature file can be easily created, which is then used by the classification tools to classify the given image. With the assistance of the image classification toolbar from ERDAS, training samples were created to represent the classes that need to be extracted.

Finally after image classification LULC map is composed using map composition. In map composition map layout, legend, title of map, etc. be placed. Legend gives the details of the classified classes.

All the 9 years imageries were classified into following five classes: water bodies, vegetation, built up land, shrub land and barren land/open land.

4.2 Regression analysis:

Regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables are varied, while the other independent variables are fixed.

One of the most commonly used regression techniques in modeling is Linear Regression. It establishes a relationship between dependent variable (Y**)** and one or more independent variables (X**)** using a best fit straight line (also known as regression line). It is represented by an equation **Y=a+b*X + e**, where a is an intercept, b is slope of the line and e is error term. This equation can be used to predict the value of target variable based on given predictor variable.

When there are more than one independent variable to be considered, multiple regression analysis is adopted. It is an extension of simple linear regression. While performing multiple regression model it must be ensured that there is a relationship between the independent and dependent variables.

5. Results:

All the 9 images were classified according to the spectral signatures discussed in the previous section. Following table 1 provides the summary of the built up area and the open land areas obtained from image classification from 1988 to 2012. Since this work is aimed at finding the open land areas decreasing as built up land increasing, here only the built up land and open land areas are given.

Table 1: Summary of the Built Up Land and Open Land areas

Year	Built Up Land in sq.km	Open Land in sq.km
1988	126.17	292.92
1992	138.83	256.26
1997	146.15	227.67
2002	213.35	236.00
2005	261.19	192.07
2007	281.45	118.50
2008	295.76	126.99
2010	334.64	124.53
2012	446.15	98.23

From the above table it is clearly observed that there is huge increase in the built up land area from 126.1737 sq.km (19.41%) to 446.1534 sq.km (68.63%) between 1988 to2012 and consequently there is huge decrease of open land areas from 292.92 sq.km (44.95%) to 98.23 sq.km (15.11%) between 1988 to 2012. This rapid urbanization has resulted in the decrease in open areas which are mainly potential areas for the recharge of groundwater. Figure 4, 5 and 6 depicts all the classified image-LULCs with the index of classifications.

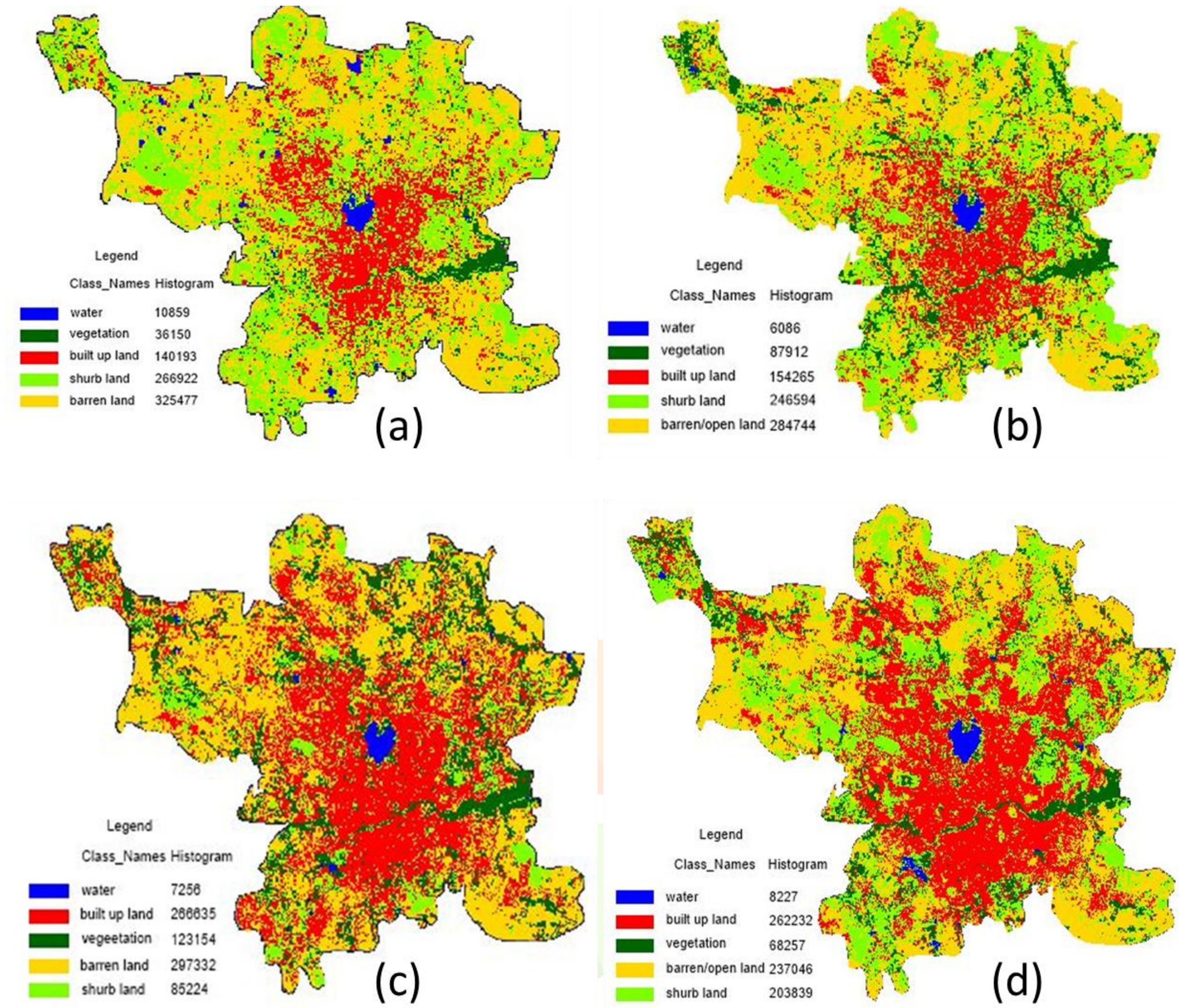


Figure 4: (a) LULC of 1988 (b) LULC of 1992 (c) LULC of 1997 (d) LULC of 2002

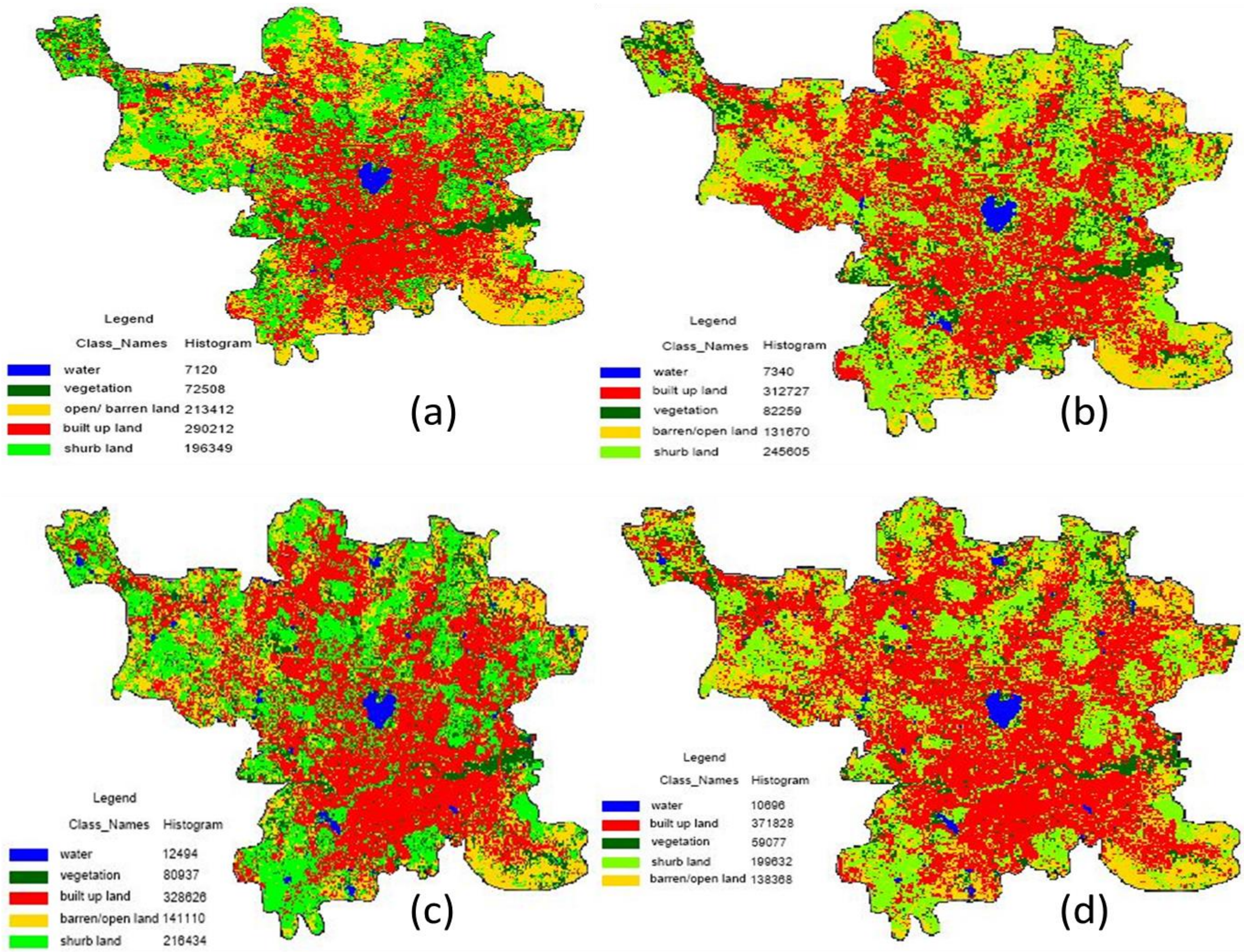


Figure 5: (a) LULC of 2005 (b) LULC of 2007 (c) LULC of 2008 (d) LULC of 2010

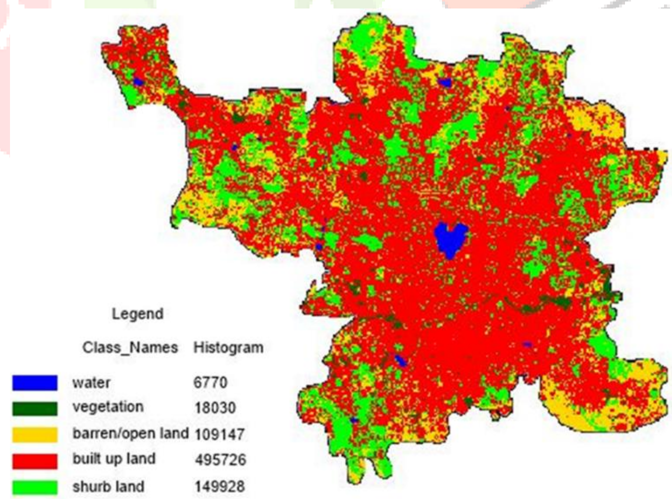


Figure 6: LULC of 2012

In order to relate the impact of urbanization in terms of decreasing the open land areas and thereby decreasing the recharge of groundwater with the groundwater levels of GHMC, a multiple regression analysis is proposed.

5.2: Multiple Regression Analysis:

In this study the fluctuations in ground water levels due to the increase in urbanization is analyzed by regression and correlation studies. In regression analysis, the results obtained from image classification i.e. built up land area and open land area are usedas two input variables. Average rainfall is the other third input variable is used. A multiple regression analysis is done to find the relation among the (i) Built Up Land (ii) Open Land (iii) Average Rain fall and the (iv) Groundwater Table Levels of the respective years.

Firstly, since the Groundwater Table (GWT) data was available only from 1996 onwards from open source, the other values of GWT for the 1988 and 1992 years were estimated by doing the regression of the available values from the 1996 to 2013.So, there are total 9 years of all above four parameters were available for doing the regression to find the impact of the urbanization on open land decreasing and in turn depleting the rechargeable capacity of the land in GHMC.

Following table 2 gives the values of all above four parameters and the estimated GWT values based on the regression using some years of the data as explained below:

Table 2: Results of Multiple Regression Analysis

Sl. No	Year	BUL (Km^2)	OL (Km^2)	RF (mm)	GWT (m from GL)	Estimation of GWT			
						1	2	3	4
						R^2=0.33	R^2=0.29	R^2=0.32	R^2=0.93
1	1988	126.17	292.92	982.26	5.602	8.927	5.555	5.552	5.084
2	1992	138.83	256.26	524.40	6.243	6.472	6.684	6.674	2.891
3	1997	146.15	227.67	462.16	7.001	5.243	7.068	7.064	2.219
4	2002	213.35	236.00	360.87	7.858	6.675	6.487	6.478	3.442
5	2005	261.19	192.07	645.47	4.597	6.460	6.045	6.062	4.596
6	2007	281.45	126.99	1225.90	6.135	5.536	5.605	5.666	5.821
7	2008	295.76	124.53	1204.10	5.670	5.660	5.533	5.594	5.992
8	2010	334.64	118.50	570.67	4.313	4.591	6.345	6.384	4.343
9	2012	446.15	98.232	537.41	6.199	5.851	5.554	5.601	6.162

Estimation 1 – GWT: Groundwater Table levels were estimated using the regression equation developed by doing the multiple regression of the parameters of the years from 2002 to 2012. The R^2 obtained in this regression is only 0.3367.The obtained regression is:

GWT=-8.50576+0.01979*BUL+0.04262*OL+0.002496*RF

Estimation 2 – GWT: Groundwater Table levels were estimated using the regression equation developed by doing the multiple regression of the parameters of the years from 1988 to 2007.The R^2 obtained in this regression is only 0.294. The obtained regression is:

GWT=12.07475-0.00982*BUL-0.01209*OL-0.00177*RF

Estimation 3 – GWT: Groundwater Table levels were estimated using the regression equation developed by doing the multiple regression of the parameters of the years from 1988 to 2008.The R^2 obtained in this regression is only 0.32.The obtained regression is:

GWT=12.11611-0.00979*BUL-0.01239*OL-0.00173*RF

Estimation 4 – GWT: Groundwater Table levels were estimated using the regression equation developed by doing the multiple regression of the parameters of the years from 2005 to 2012.The R^2 obtained in this regression is only 0.933.The obtained regression is:

GWT=-7.34343+0.021213*BUL+0.020857*OL+0.003708*RF

Among all the regression attempts, the 'Estimation 4' could give the best R^2 value of 0.933 compare to all other R^2 values. The regression based on this fourth attempt was seems to be better as the R^2 was highest.

6. Conclusions:

An integrated approach is used to evaluate the effect of urban growth on the groundwater level of the Hyderabad city (GHMC area). The growth of the built up land has been assessed from classification of satellite imagery for9 different years. Multiple Regression analysis was performed to find the relationship between urban growth, open land decrease and groundwater levels fluctuation.

(1) Urban growth has leaped from 19.41% (126.17 sq.km) to 68.63% (446.15 sq.km) between 1988 to 2012. Contrastingly, the open land areas were decreased rapidly from 44.95% (292.22 sq.km) to 15.11% (98.23 sq.km).

(2) The multiple regression (to findthe relation among the various parameters) was successfully performed on the four important parameters [(i) Built Up Land (ii) Open Land (iii) Average Rain fall (iv) Groundwater Table Levels]. The first three parameters were used as input variables and the fourth parameter used as an output variable.

(3) From 1997 onwards there is huge development of Built Up Land observed in the GHMC area and consequently Open Land decreased accordingly. This could be observed from the obtained R^2 value of 0.933 from multiple regression analysis performed between 2005 to 2012 years.

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