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Impact of Urban Growth on Air Quality of Developing Country–A Case of Kota, India

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Abstract—*Urban growth and accelerated industrialization had been rapidly affecting the environmental quality of urban centers. Increase in population also have adverse impact on environment. Developing country like India is facing rapid urbanization and population growth. These effects are also visible in new urban centers like Kota, Which is known as an education hub of India. Therefore it is become necessary to evaluate, monitor environment quality and restore the environment for better living. In this work remote sensing and GIS were applied together to evaluate the impact of urban growth on air quality of Kota city. For this purpose different spatial variables are incorporated such as impervious area, land consumption rate and air pollutants concentration within an urban context of Kota city. Remotely sensed images are used to create impervious layer and thereafter Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC) were quantified to evaluate the impervious area growth in different wards of the Kota city. The variations in gaseous and particulate pollutants with time were also computed to determine the degree of association between air pollutants and impervious area. It has been detected that there is enormous increase in impervious area during study period. The spatial distribution of LCR and LAC reveals very high rate in outskirts of the city. The urban air quality results indicate that PM_{10} has the highest effects on the environment in comparison to gaseous pollutants (SO_2 and NO_x). These results would be valuable for future urban planning and monitoring of current urban growth to reduce the adverse effect on environment.*

Keywords*: Geographic Information systems, Remote Sensing, Urban Growth, Air Pollution.*

1. INTRODUCTION

Air pollution has become an issue of severe concern in many parts of the world particularly in developing urban centers like India. Air quality of a city is affected by several human influenced activities, such as urban growth, vehicle growth etc. Human induced activities are increasing by huge population growth especially in developing countries. Population in urban centre is growing rapidly as compare to rural. Migration from villages and towns to urban centers for livelihood and to avail good quality basic amenities is increasing in developing cities like Jaipur [1]. Therefore, population density is also increasing and spreading rapidly from core city to suburban areas. Urban growth accompanied with population growth are leading to unplanned and haphazard development putting more pressure on available resources, infrastructures and basic amenities planned for the city. This is creating more demand for basic resources to be provided for growing population. Due to this demand for transportation is also increasing and in absence of good public transit system, there will be huge increasing in private vehicles. In India, the number of motor vehicles has grown from 72.7 million in 2004 to approximately 210.1 million in 2015. This vehicles growth will also have more effects on air quality.

The changes in air quality associated with urban growth were significant during the last two decades and are projected to continue through the next decades, which increases regional temperature, degrades air and water quality [2], [3]. Urban growth is also believed a vital reason for agriculture land loss [4], traffic congestion and air pollution; and permanent damage to land caused by haphazard and unplanned fragmented urban development [5]. Highly dense populated areas and their activities in urban areas produce more air pollutants with higher rate as compared to less-developed areas and natural environment. The Kota city is also facing rapid industrialization, high migration rate, land transformation, transportation and infrastructure development activities due to that environmental quality is deteriorating day by day.

Therefore, this research aims to find out the urban change dynamics in terms of impervious area during 2008 to 2013 and its impact on ambient air quality of Kota's urban area. Remote Sensing, with its multidate coverage together with multiband capabilities is a powerful tool [6] for mapping and monitoring the urban growth over years [7]. The geospatial techniques provide a flexible approach for creating digital data from various primary and secondary sources and also a potential means for analyzing their association [8], [9].

2. MATERIAL AND METHODS

2.1 Study Area

Kota is located in south East of the Rajasthan state and geographical location between 24°32’ & 25°50 N Latitude and 75°37’ & 76°34’ E Longitude. Kota, popularly known as an education hub of India is rapidly growing city and also famous for medical and engineering preparation. The urban population of Kota city was 11, 76,604 in 2011 as per census India. Kota has been selected as the research area because of the rapid urban growth rate and not much research has been done on this city. Kota city is facing unprecedented population growth, which is coupled with unplanned developmental activities have led to haphazard urban development [10]. This unplanned development is bringing various inverse effects such as uncontrolled, unplanned, scattered urban growth in sub-urban areas of the city. Due to absence of planning these urban areas are devoid of the basic amenities or infrastructure. This unplanned development accompanied with population growth affecting the environment of city.

2.2 Data Used

Remote sensing satellite data have been downloaded from USGS Earth Explorer for 2016 satellite image and National remote sensing Centre (NRSC) for 2011 satellite image. Resourcesat 2 LISS-III satellite image was acquired for 2 December 2011 with spatial resolution of 24 meter from NRSC Bhuvan web portal. Satellite image of Landsat 8 of 9 June 2016 downloaded from USGS website. Landsat satellite image are enhanced to spatial resolution of 15 meter through the pan merge tool.

ERDAS Imagine software is used for image processing and image interpretation for the creation of land use/land cover maps of Kota city. The accuracy was assessed for classified outputs and analyzed to ascertain the change in urban growth. The Kota city boundary was created in GIS environment using Arc GIS software and urban sprawl pattern assessed using GIS tools.

2.3 Image Processing for Land use/cover Data

The satellite images were geo-corrected and geo-referenced in Earth Resource Data Analysis System (ERDAS) Imagine software and all data were projected into Universal Transverse Mercator (UTM) coordinate system, zone 43 North, with World Geodatic System (UTM WGS 84) projection parameters. Bands of satellite images are stacked in to a single layer to make false color composite and the area of interest (i.e. study area) is extracted from stacked layer. Satellite images are enhanced using histogram equalization tool to bring both image on common enhancement level for better interpretation.

The processed satellite images were classified using hybrid classification approach, which is a combination of supervised and unsupervised classification process. ISODATA clustering algorithm was adopted in un-supervised classification method, whereas maximum likelihood algorithm was used in the supervised classification technique to classify the image using the training sets (signatures). The satellite images were classified into various classes viz. built-up, agriculture land, scattered vegetation, barren and water body to made land use/land cover map.

The classified outputs obtained from classification approach are re-assessed with ground data and other secondary data to find out wrongly classified or missing pixel and these pixels were modified adequately. The overall accuracy was used to ascertain the classification accuracy by evaluating the classified output with the ground survey locations using Erdas Imagine. The urban change detection was carried out by comparing the areas under each LULC class for both periods.

The classification results obtained from supervised classification are re-checked with ground data and other secondary data to find out wrongly classified or missing pixel and these pixels were updated adequately. The overall accuracy was used to determine the classification accuracy by comparing the classified output with the ground truth locations using Erdas Imagine. The change detection was then carried out by comparing the areas under each LULC class of the respective years.

2.4 Estimation of Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC)

Land consumption rate is used to find out the compactness of urban structures and also indicates the spatial expansion patterns of a city. The increase in LCR indicates denseness while low value indicates more open spaces. The land absorption coefficient is used to measure new development in the form urban on land by each unit increase in urban population [11], [12], [13], [14]. It indicates the way the new developments and sprawl are taking place on city land for built-up purposes. The ward wise population data of Kota city was collected from Census data of 2001 and 2011 to estimate the LCR and LAC. Population growth rate was used to predict the population for 2013 for each ward using compounded exponential growth model. The population projection equation is expressed as:

$$p_n = p_o(e^{m}) \tag{1}$$

where Pn = estimated population (2016), P0 = initial population (i.e. year 2011), r= annual rate of growth, e = base

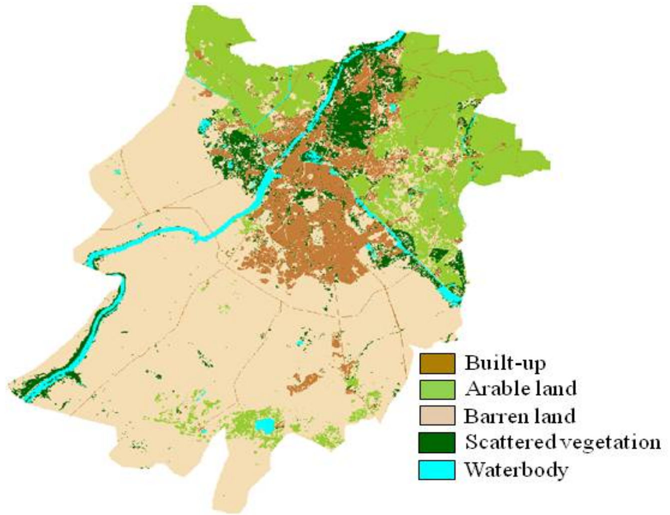

Fig. 1: Land use / Cover Map-2011

of the natural logarithm, n= number of years. The projected total population

The Land consumption rate (LCR) and land absorption coefficient (LAC) have been quantified by using the following equations[11]:

$$LCR = \frac{A_i}{P_i} \quad (2)$$

where, Ai = Impervious area (in hectares), and Pi = Population

$$LAC = \frac{(A2_i - A1_i)}{(P2_i - P1_i)} \quad (3)$$

where, A1i and A2i = Impervious area (in hectares) for the early and later years, and P1i and P2i = Population figure for the early and later years, respectively.

2.5 Evaluation of Air Quality

The air quality data of air pollutants in gaseous form viz. nitrogen oxides (NO_X), sulfur dioxide (SO_2); and particulate air pollutants viz. respirable suspended particulate matter (RSPM) or PM10 were collected from Rajasthan State Pollution Control Board. These air pollutants concentration data was collected from three fixed air quality monitoring stations of Kota city namely, Municipal Corporation building; Regional Office Anantpura, and Samcore Glass Ltd. for the study periods. All these three locations of air quality monitoring stations were plotted in GIS and interpolation method was used to generate the interpolated maps of air quality parameters. Air quality data was used to create annual average interpolated maps of SO_2, NOx and PM_{10} for air quality evaluation of Kota city during study period.

3. RESULTS AND DISCUSSIONS

As it is understood that human activities have profoundly changed land use/land cover of any city, same has been found in Kota city during the last 5 years (2011-2016). Urban change detection analyses quantified the differences between maps of the same area at different times [9]. The classified landuse map of different period viz. 2011 and 2016 were used to estimate the area of different land use/land covers and find the changes that are took place during study period. Classification accuracy of satellite images were assessed for the years 2011and 2016 and it is found that accuracy level is satisfactory to publish results. Classification accuracy was 89.26% and 91.71% for 2011 and 2016 respectively.

The Kota city has been classified into five categories depending up to prevalent type of land uses (Figure 1). In 2011, barren land was a dominant land use i.e. 59.5% of the total study area followed by agriculture land (19.74%) and built-up area (10.6%). The dominance of barren land in Kota city reflects the rocky, parched landscape of Hadoti region. The built-up area has been recorded 9.4% in 2011, which include all built categories viz. residential, industrial, commercial and road.

Figure 2 shows the land use/land cover map of Kota city in 2016. Results indicate that built-up area increased by 18.3% in 2016. Excessive increase was observed in built-up (93.5%) whereas cropland decreased by 17.6% and barren land decreased by 5.6% during 2011 to 2016. It can be understood by Table 2 that there is substantial increase in built-up area of Kota city i.e. the annual change during 2011-2016 was 862.4 hectare. These result shows that rapid urban development was occurred in last 6 years (Figure 3). Population pressure, migration and economic development in the city impacted the continuous rise in built-up area. The interpretation demonstrates the huge growth in sub urban areas of city and most of the new development is near and along the roads and highways.

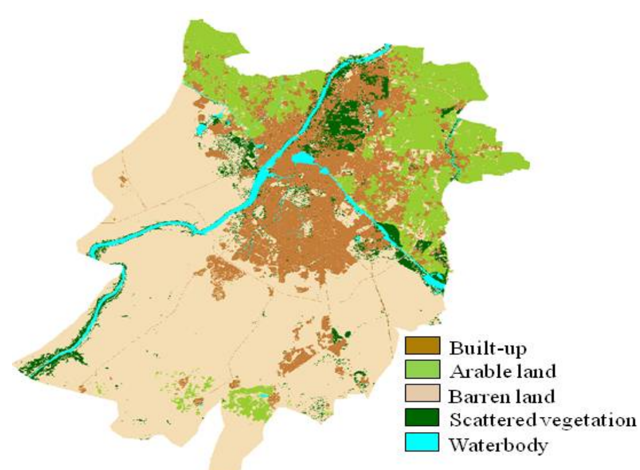

Fig. 2: Land use/cover Map - 2016

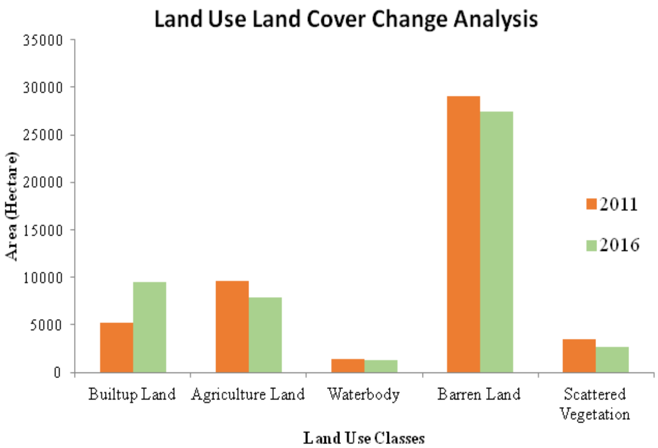

Fig. 3: Land Use/Cover Change Analysis

In 2011, the population of Kota city was 1001694; and reached to 1199246 (projected population) in 2016. The Land consumption rates were computed for Kota city for the year 2011 and 2016. The Land consumption rates were 0.00518 in 2011 and 0.00793 in 2016 in Kota city. There is a huge increase in impervious land during this study period, which is also indicated by increase in land consumption rate. Impervious land is increased by 83% during study period whereas land consumption rate increased by 53% from 201 to 2016. Land consumption rate indicates progressive spatial development of the city and it has shown an increasing trend from 2011 to 2016.

The land absorption coefficient (LAC) results suggest that the rate at which new lands are acquired for development is high. The LAC results have shown significant areal growth in the Kota city during the study period (2011-2016). Land absorption coefficient was 0.02188 of Kota city during 2011-2016. This urban development is taking place because of the fact that the central city area has become more congested and due to that planning policies and strategies have been adopted for developing education centers, government and private offices in the sub urban areas of the city.

From Table 1a and b it is revealed that annual average concentration of NO_X and SO_2 concentration did not cross the reference levels of 80/120 $\mu g/m^3$ during the study period, however, particulate matter (PM_{10}) concentration surpasses the standard value and shows rising trend from 2011 to 2016. The increase in the amount of PM_{10} may be due to the industrial development and multiplication of vehicles numbers; this is leading to emission of pollutant in ambient air.

Figure 4 and 5 reveals the spatial allocation of annual average NO_X concentration and annual average SO_2 concentration with respect to impervious area during the study period (2011-2016). NO_X and SO_2 clearly indicate the higher values in wards, which have more impervious area in the form of residential, and industries development as there is less NO_X and SO_2 in the Central and South Eastern part of Kota city that is clearly visible from Figure 5a and b.

Table 1a & 1b Concentration of Gaseous and Particulate pollutants during 2011 to 2016

Year	Concentration of gaseous pollutants in ambient air (µg/m3)							
	NO_X				SO_2			
	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.
2011	28.25	33.14	30.36	0.85	6.49	8.25	7.18	0.32
2016	33.04	35.92	34.34	0.48	6.52	7.45	6.88	0.17

Year	Concentration of particulate pollutants in ambient air (µg/m3)			
	PM10			
	Min	Max	Mean	S.D.
2011	125.21	164.37	140.04	7.31
2016	111.56	153.26	128.68	7.22

However lower concentration of NO_x and SO_2 in North Eastern part of Kota city due to less impervious area or more agriculture and open spaces. It is also observed from figure that the pollution level rises with land use density and tends to increase towards the city center. Annual trend of NO_X and SO_2 indicates that rise in the concentration of these pollutants during 2011 and 2016.

Figure 6 indicates the spatial distribution of annual average SPM concentration and annual average PM10 concentration during the study period (2011-2016). The particulate matter

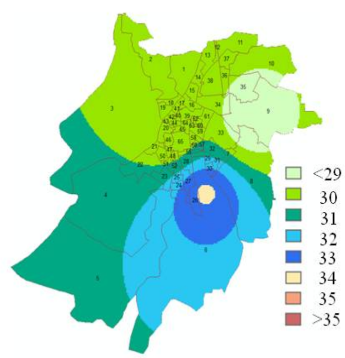

Fig 4a. Spatial distribution of Annual Average NO_X 2011

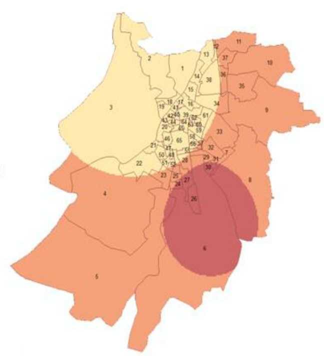

Fig 4b. Spatial distribution of Annual Average NO_X 2016

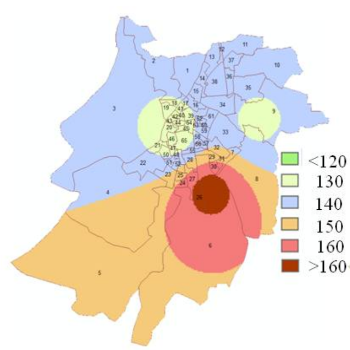

Fig 5a. Spatial distribution of Annual Average RSPM or PM10 2011

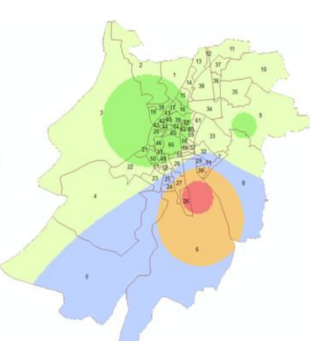

Fig 5b. Spatial distribution of Annual Average RSPM or PM10 2016

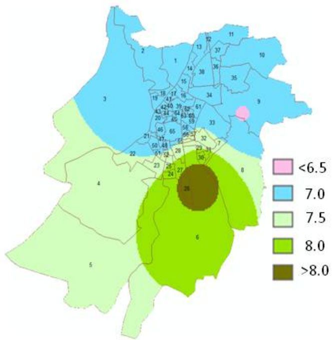

Fig 6a. Spatial distribution of Annual Average SO_2 2011

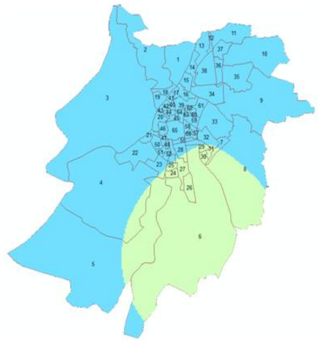

Fig 6b. Spatial distribution of Annual Average SO_2 2016

(PM_{10}) infer the increasing trend with rise in impervious area during 2011-2016. Although particulate pollutants concentration is high in most of the wards of the Kota city but highest concentration was observed in south-eastern part of Kota city.

It is due to major industrial area of Kota is located in this part of city. While lowest concentration was in areas with more open spaces and agriculture land (north-eastern part of Kota city). This implies that air dispersion rate is more in low land use density areas in comparison to congested city areas.

4. CONCLUSIONS

Kota an educational hub has been characterized by rapid urbanization and it is affecting on urban air quality. Therefore, it is important to investigate the coupling relationship between urban growth and the air environment from the perspective of urban expansion in Kota city. As it is understood that coordinated development of urban and the air environment is a dynamic process, therefore this paper displayed that geospatial tools are very efficient in analyzing the spatial and temporal changes of air contaminants and their involvement with urban pattern. The rapid impervious area growth has been observed during the 2011-2016. The LCR and LAC results reveal that city is expanding mostly in south-east direction. Air quality results infer that two indicators of ambient air quality, NOx, SO_2, and PM10 concentration have the greatest effects on the air environment. The Impact of impervious area on particulate pollution indicates strong harmonic relation south eastern part of Kota city during study period. To mitigate inverse effect on environment, sustainable policies need to plan and execute by local authorities.

REFERENCES

[1] A. Mitra, “Migration, Livelihood and Well-being: Evidence from Indian City Slums,” Urban Studies, vol. 47, no. 7, pp. 1371-1390, 2010.

[2] M. Alberti and J.M. Marzluff, “Ecological resilience in urban ecosystems: Linking urban patterns to human and ecological functions,” Urban Ecosystems, vol. 7, pp. 241-265, 2004.

[3] J. Tratalos, R. A. Fuller, P. H. Warren, R. G. Davies and K. J. Gaston, “Urban form, biodiversity potential and ecosystem services,” Landscape and Urban Planning, vol. 83, pp. 308-317, 2007.

[4] G. C. S. Lin and S. P. S. Ho, “China’s land resources and land-use change: insights from the 1996 land survey,” Land Use Policy, vol. 20, pp. 87–107, 2003.

[5] A. Frenkel and M. Ashkenazi, “Measuring Urban Sprawl - how Can we Deal with It?,” 45th Congress of the European Regional Science Association: "Land Use and Water Management in a Sustainable Network Society", Amsterdam, The Netherlands, August 23-27, 2005.

[6] A. Rahman and M. Netzband, “An assessment of urban environmental issues using remote sensing and GIS techniques an integrated approach: A case study: Delhi, India,” Paper presented in PRIPODE workshop on Urban Population, Development and Environment Dynamics in Developing Countries, Nairobi, Kenya. June 11-13, 2007.

[7] P.N. Dadhich and S. Hanaoka, “Remote sensing, GIS and Markov’s method for land use change detection and prediction of Jaipur District,” J. Geomatics, vol. 4, no. 1, pp. 9-15, 2010.

[8] M. Herold, H. Couclelis and K. C. Clarke, “The role of spatial metrics in the analysis and modeling of urban land use change,” Comput. Environ. Urban Syst., vol. 29, pp. 369–399, 2005.

[9] A.P. Dadhich and K. Nadaoka, “Modeling Hydrologic response to land use change in Watersheds of Viti Levu Island, Fiji,’ Journal of Environmental Research and Development, vol. 8, no. 3, pp. 492-503, 2013.

[10] A.P. Dadhich, R. Goyal, P.N. Dadhich, “Impact of Urbanization on arable land in Kota - a geospatial analysis,” Engineering Sciences International Research Journal, vol. 5 Spl issue, pp.1-4, 2017.

[11] M.Yeates and B. Garner, “The North American City,” Harper and Row Publishers, New York, 1976.

[12] Z. A. Opeyemi, “Monitoring the Growth of Settlements in Ilorin, Nigeria,” The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII. Part B6b. Beijing; pp 225-232, 2008.

[13] B. M. Oladele and B. H. Oladimeji, “Dynamics of urban land use changes with remote sensing: Case of Ibadan, Nigeria,” J. Geography and Regional Planning, vol. 4, no. 11, pp. 632-643, 2011.

[14] L. Sharma, P. C. Pandey and M. S. Nathawat, “Assessment of land consumption rate with urban dynamics change using geospatial techniques,” J. Land Use Sci., vol. 7, no. 2, pp. 135–148, 2012.