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ASSESSING SPATIAL URBAN GROWTH USING MIXED METHOD APPROACH: THE CASE OF LAHORE, PAKISTAN

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ABSTRACT

Urban sprawl is a multidimensional process involves multiple factors of socio economic and population dynamics in which urban areas are expanding un-monitored leads to haphazard & uncontrolled development. This urban sprawl is usually managed through urban growth strategies & master plans. Lahore has experienced many of master plans for the future urban growth but their fully implementation remained unanswered and there seems lot of haphazardness and unplanned development in the city. In this research, spatio temporal urban growth of Lahore is examined using Landsat Imageries for the years 1996, 2001, 2008, 2015. Regression analysis is also performed using the dependent and independent variables (built up areas & population) to predict the future expansion of growth areas. It is revealed that land use growth is relatively low which is 21.6% during year 1996 to 2001, but in the last 15 years from 2001-2015 it is exponentially increased to 94.5% due to weak enforcement and implementation of master plan. The results depicts that urbanization rate of Lahore is alarming and is expanding unidirectional in southwards and growth will become double in the next 15-20 years. The results of this mixed method approach proved to be effective in demonstrating urban growth studies.

1. Introduction

Rapid increase in urbanization rate, pressure of land development, provision of housing along with other socio economic factors leads to urban sprawl phenomenon which is confronting by most of the metropolitan cities of developing countries like Pakistan. Dramatic urban areas growth & population explosion resulted in enervation of social amenities (Jarah et al., 2019). Literature reveals that there is no consensus exist among

the scholars regarding the definition and impact of urban sprawl (Johnson, 2001). Urban sprawl is referred as unplanned, uncontrolled and haphazard development on the suburban lands at the periphery of a city (Farooq & Muslim, 2014; Lambin et al., 2001). The Characterization of urban sprawl is generally associated with poor planning and lack of implementation of provision of Master Plan and weak enforcement (Ahmad & Dinye, 2011; Pendall, 1999).

Managing urban growth is usually done through various policy instruments such as master plans, development plans, spatial growth strategies and building control and zoning regulations, infrastructure investment etc (Alnsour, 2016). Master Plan of a city provides broad guidelines and policies for urban development which is generally in the form of reports and land use proposals maps. Lahore had a rich experience of master planning. Most of the master plans were prepared but could not be fully implemented due to host of reasons and Lahore is no exception (Hameed & Nadeem, 2006).

Master Plan for Greater Lahore (MPGL), 1966 was prepared by Housing and Physical Planning Department, which focused on controlling haphazard development in the city (Hameed & Nadeem, 2006) for the 20 years. Thereafter, Lahore Urban Development and Traffic Study (LUDTS) was prepared by the Lahore Development Authority (LDA) in collaboration with the World Bank in the year 1980, which served as a guiding document and called the Structure Plan for Lahore. In the year 2001, Integrated Master Plan for Lahore 2021 (IMPL) was developed for the planning period of 20 years uptill 2021 that aimed at managing the growing Lahore metropolitan area (LDA & NESPAK, 2004). Every time the strategy for preparation of master plan was different in scale and dimensions for urban growth & development which created more complexities and resulted in haphazard development (Rana and Bhatti, 2018).

Usually, rapid population growth, employment shifts, commuting cost and commercial development and accessibility in the form of highways are considered as major socio economic factors contributing increase in urban sprawl (Kearney, 2003; Weng, 2001; Jaret et al., 2009; Ji et al., 2001). This approach of characterization of urban sprawl cannot effectively identify the causes and impacts on spatial scale of city. In order to fulfill this gap, GIS and Remote sensing techniques clubbed with statistical models can be used to predict the land use and land cover changes in the area (Allan, 1996; Ward et al., 2000). Most frequent approaches used by the researchers to observe the transformation of spatial expansion is by using the data of population dynamics, such as population density and population per unit built-up area (Cai et al., 2003; Fonseca and Wong, 2000; Wang and Zhou, 1999).

Spatio temporal growth analysis using Landsat data with the help of GIS tools and Statistical models results can be integrated for the future predictions of urban growth changes. This analysis will be helpful to identify the Landuse and land cover changes over the years and calculation of urban extents (Herold et al., 2003; Masek et al., 2000). This paper aims to assess the urban growth of Lahore using spatial and attribute data of the past and present, to predict future urban growth patterns and spatial restructuring, for the balanced growth of city & development control by highlighting useful insights to the policy makers and regulating authorities.

2. Materials And Methods

2.1 Case Study

The case study area for this research is one of the largest metropolitan area of Lahore, which the capital city of the Punjab province of Pakistan (Fig 1). Total area of Lahore District is about 1770 sq kms and is located at 31°32’59”N 74°20’37”E. The Population of Lahore is 11.1 Million and urbanizing at rapid pace. Administratively, Lahore city is further divided into 9 towns and a cantonment. Towns are further sub-divided

into 150 union councils (UCs) where 122 are characterized as urban and the rest are peri-urban/rural (Punjab Bureau of Statistics, 2015).

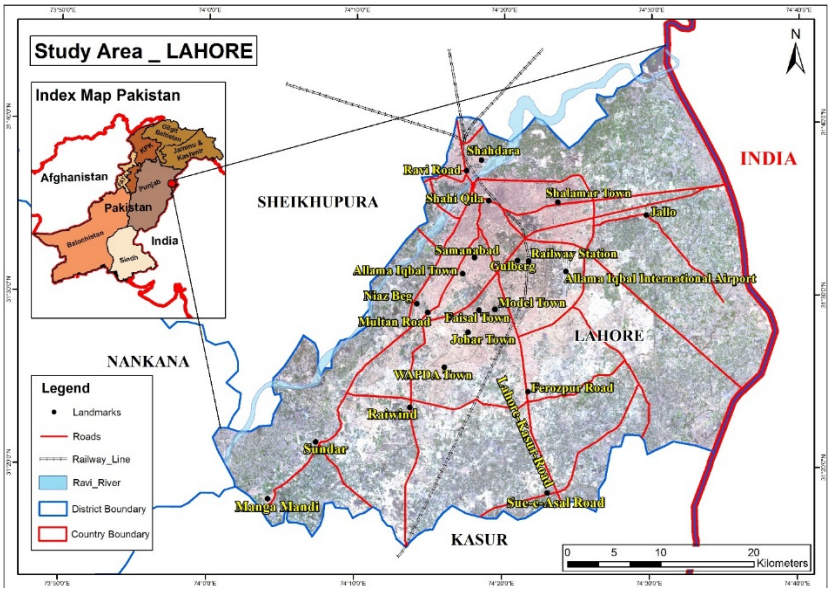

Fig. 1: Location map of study area: the Lahore.

2.2 Data used

The data was collected from the secondary data sources include Master Plans of Lahore i.e. Master Plan for Greater Lahore 1966, Lahore Urban Development and Traffic Study Plan (Lahore Structure Plan) 1980 and Integrated Master Plan of Lahore (IMPL) 2021 from Lahore Development Authority. The detail of the Multispectral Landsat Images acquired form USGS Earth Explorer are given in below Table:

Table 1: Dataset Used for Classification of Map

Year	Sensor type	Spatial Resolution	Spectral Resolution	Acquisition Date
1996	LANDSAT 5 TM	30*30	7 band	10-Oct-1996
2001	LANDSAT 5 TM	30*30	7 band	22-Sep-2001
2008	LANDSAT 5 TM	30*30	7 band	28-Nov-2008
2015	LANDSAT8 OLI	30*30	11 band	16-Nov-2015

Methodology

This paper is an attempt to explore the spatio temporal dynamics of Lahore particularly with respect of its Landuse Land cover and Landuse Proposal of Master. Various Layers of administrative boundaries, transportation including roads and railways, water channels were digitize using the Toposheet and other relevant maps of the areas. All the GIS maps are generated with the Arc GIS and Erdas image tools. To quantify the dimensions of spatio-temporal urban growth, multiple models can be run using GIS environment and results in the form of maps and attribute data can be produced (Calvo-iglesias et al., 2006).

The standardize techniques of Image processing and interpretation were utilized for image extraction, corrections, staking and mosaicing. Amin et al. (2018), also implied the same method for classification of

Landsat Images. Supervise and Unsupervised Image classification was performed on the Landsat images for the year 1996, 2001, 2008 and 2015. This classification used by the researcher (Mahboob and Atif, 2015) which produced more effective results than any other methods. To bring spectral characteristics of all the satellite images at common reference, atmospheric correction was applied (Ryznar, 2001). Subtracting of images were executed using the administrative boundary of Lahore to the area of interest i.e. Lahore District. Supervised and Unsupervised classes were developed by analyzing the spectral response of different pixel bands (Dawelbait and Morari, 2012). Land cover classes consist of urban areas, vegetation, water and barren land were identified. Thereafter, Normalized Difference Built Index NDBI was applied, to extract built areas from the satellite images. To calculate the built up areas, the formula developed by Zha et al. (2003) with following equation was used:

NDBI= (TM Band5-TM Band4/TM Band 5+TM Band4)

The NDBI result present the clearer and correct representation as compared to supervised and unsupervised image classification. Therefore, NDBI results were retained to extract the land cover and map the urban extent in Lahore over the period of more than twenty years. Overlay Analysis were also performed to check the conformance of urban growth of Lahore with proposed land uses of Master Plan.

Finally, the correlation analysis and regression analysis were implied on the built up area calculated with the aforementioned techniques and population density over different period. After also utilized to quantify/estimate urban patterns trends through space and time with respect to the demography change.

3. Results And Discussion

3.1 Spatio Temporal Growth using Normalize Difference Built up Index (NDBI)

The land cover classification maps were prepared using the Normalize Difference Built up Index (NDBI) for the four temporal years which depicts the built up and non-built up areas of Lahore. (See Fig 2,3,4 and 5)

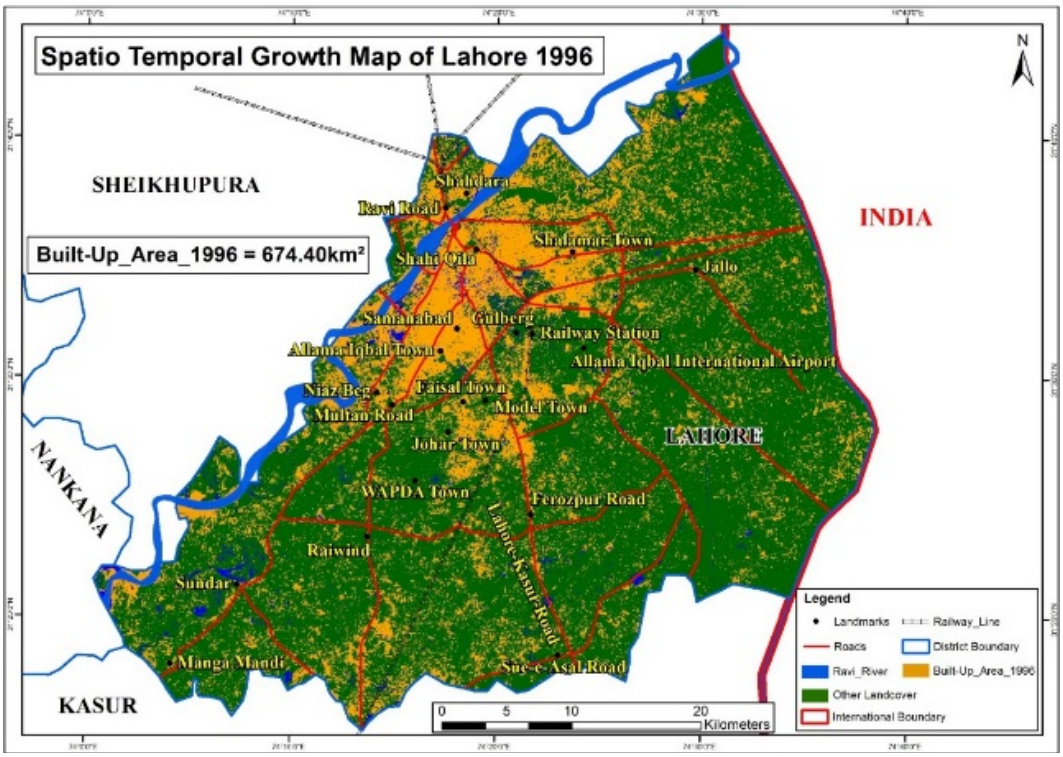

Fig. 2: Classified Map of Lahore 1966

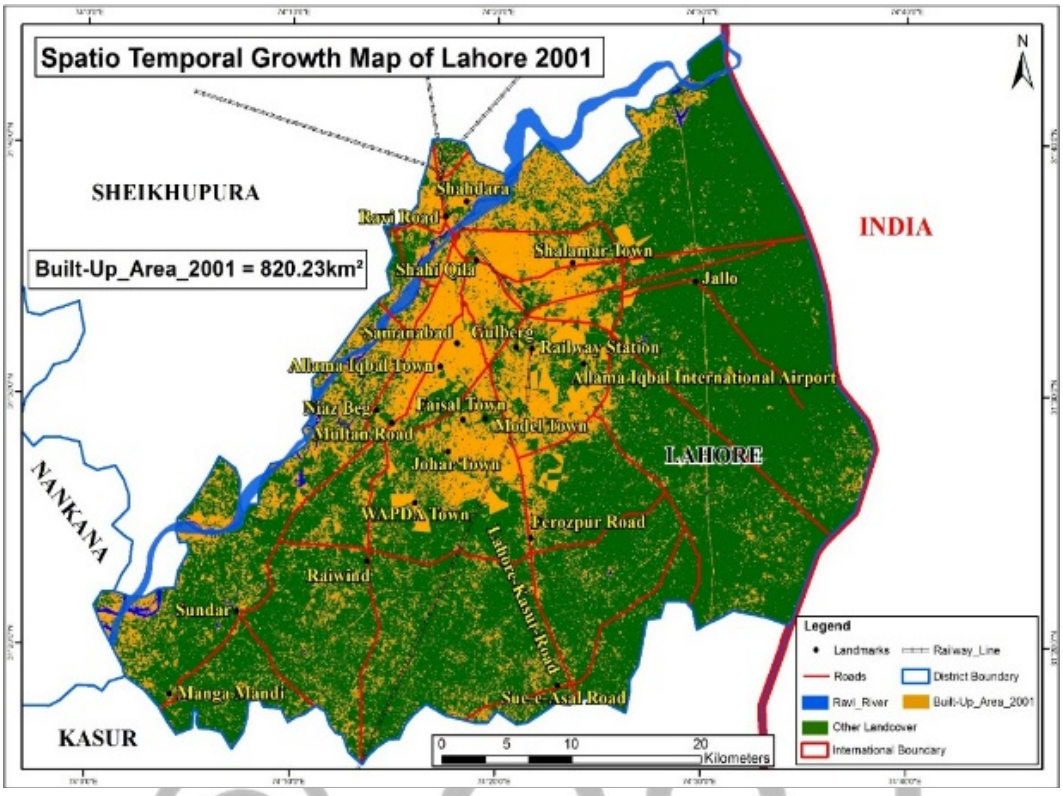

Fig. 3: Classified Map of Lahore 2001

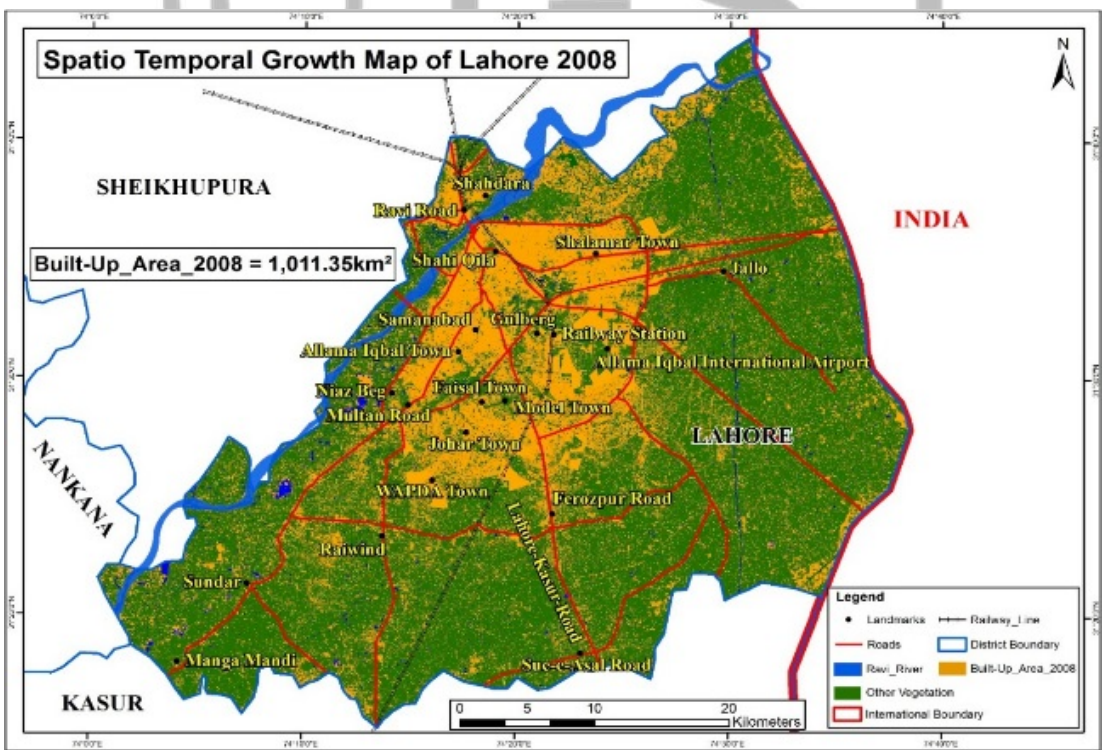

Fig. 4: Classified Map of Lahore 2015

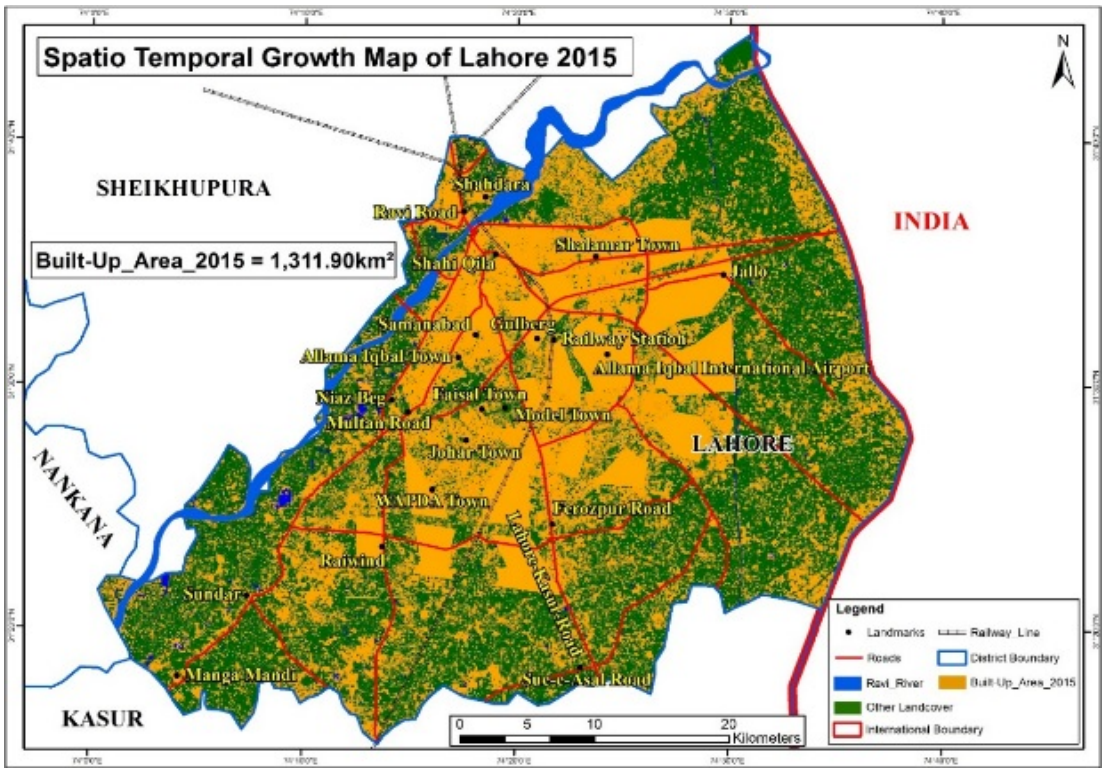

Fig. 5: Classified Map of Lahore 2008

The results in the below table depicts that land cover classes were categories into two i.e. built-up and non-built-up areas. Over the period of time the built-up area was continuously increasing and the non-built-up area was decreasing rapidly. It can also be observed that barren land and vegetation was decreased, whereas the urban area (built-up) was increased significantly.

Table 2: NDBI results of Built up area

Year	Built-Up Area (km^2)	Other Land Cover (Non-Built-up) Area (km^2)	Percentage Increase in Built Up Area
1996	674.41	1,021.31	Base Value
2001	820.23	880.25	21.6%
2008	1,101.35	601.18	63.3%
2015	1,311.90	390.19	94.5%

3.2 Overlay Analysis

To identify how much of the land use proposals of Master Plans period time to time for the Lahore conform with the urban growth, the overlay methods was implied. The planning period of Lahore Urban Development Traffic Study Plan which usually called as Structure Plan of Lahore 1980 was for 20 years till 2000, The built up areas extracted used NDBI methods was overlaid on this map for see the extent of proposed land uses. The Integrated Master Plan of Lahore 2021 proposed land uses for Lahore till 2021, the built up areas calculated for the years 2015 were also overlaid (See Fig 6 & 7).

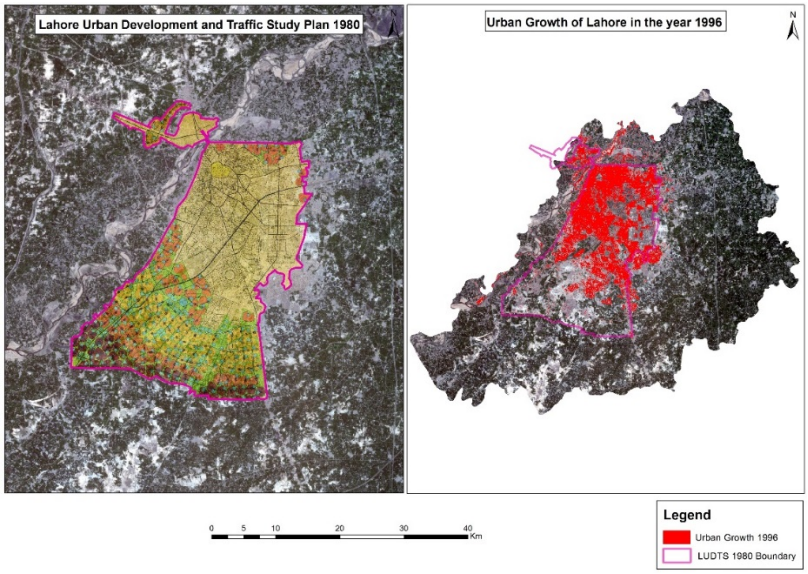

Fig. 6: Overlay Map of Master Plan 1980 with Urban Growth of Year 1996

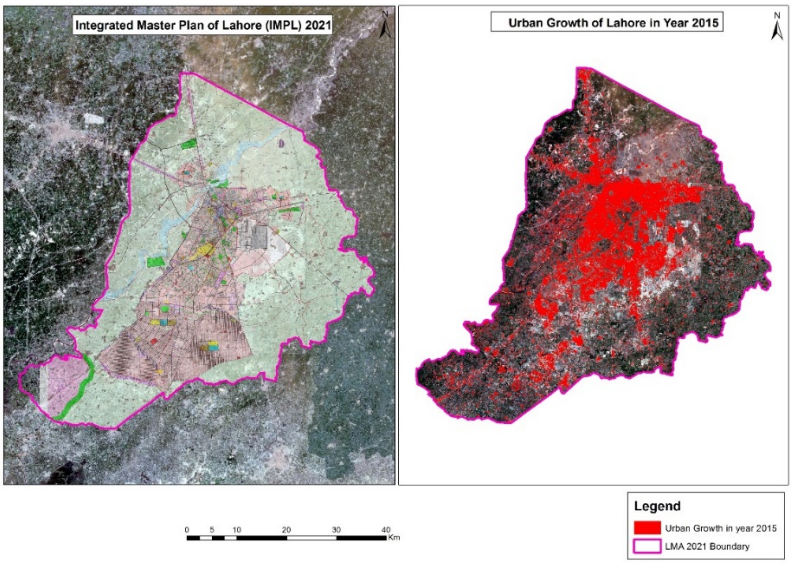

Fig. 7: Overlay Map of Master Plan 2021 with Urban Growth of Year 2015

The above maps clearly shows that the output comprises on urban growth potential which is gradually expanding toward southern side of Lahore District, following the same trend (of growth) that was proposed/described in the Master Plan of Lahore 1980 & Integrated Master Plan of Lahore 2021.

3.3 Regression Analysis

To perform the regression analysis, a hypotheses was developed that what and which rate amounts of built up areas varies with the different years of populations. For this very purpose The Co relation and Regression analysis were performed using SPSS software. The analysis for two main variables under consideration i.e. Population Statistics and Built up Area demands methods which could devise the form of relationship between the two. Rather, the analysis needs to go further beyond just the relationship to elaborate how increase in one variable would affect the other one.

To test the hypothesis, this study relies on unique datasets of land cover change derived from remotely sensed data for four key time periods: the period, 1996, 2001, 2008 and 2015. Therefore, it is justified to use

correlation analysis in first step while use regression analysis on next step so that the value of dependent variable could be calculated for future year 2035. The data presented in table below is used for this analysis.

Table 2: Built up Areas & Population Density

Year	Built up Area (Km^2)	Population (District Census Report 1998)	Population Density per Sq Km
1996	674.41	5,904,678	8,755
2001	820.23	6,997,586	8,531
2008	1,101.35	8,878,826	8,062
2015	1,311.90	11,265,822	8,587

The following is the model summary generated through SPSS :

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.993[a]	.985	.978	42.41170
Predictors: (Constant), Population of the Town Dependent Variable : Built Up area				

The R value represents the simple correlation and is 0.993 (the "R" Column), which indicates a high degree of correlation. The R2 value (the "R Square" column) indicates how much of the total variation in the dependent variable, can be explained by the independent variable. In this case, 98.5% can be explained, which is very large.

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	240,163.991	1	240,163.991	133.517	.007[a]
	Residual	3,597.505	2	1,798.753		
	Total	243,761.496	3			

a. Predictors: (Constant), Population of the Town

b. Dependent Variable: Built up Area

This table indicates that the regression model predicts the dependent variable significantly well. At the "Regression" row and the "Sig." column. This indicates the statistical significance of the regression model that was run. Here, $p < 0.007$, which is less than 0.05 (the standard benchmark for significance), and indicates that, overall, the regression model statistically significantly predicts the outcome variable (i.e., it is a good fit for the data).

The Coefficients table provides us with the necessary information to predict built up area from population, as well as determine whether population contributes statistically significantly to the model (by looking at the "Sig." column). Furthermore, we can use the values in the "B" column under the "Unstandardized Coefficients" column, as shown below:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-17.990	88.680		-.203	.858
	Population of the Town	.00012	.000	.993	11.555	.007

a. Dependent Variable: Built up Area

To represent the regression equation as:

y=a+bx

where

y=Dependent Variable

x=Independent Variable

a=x-Intercept

b=y-Intercept

So, equation for subject analysis will become as under

Regress Equation: Built up Area = -17.990 + 0.00012(Population)

Equation developed through regression analysis needs to be verified through cross checking of the values obtained by the equation. The procedure to check the equation is to calculate the built up area through equation and then relate it with the value found by the map; find the difference between the both and then find the percentage variation value in built up area. This way the accuracy of the equation can be verified and average variation in the calculations through the equation can be estimated as shown in the table below:

Table 4: Comparison of Built-up Areas calculated through Regression Analysis & Classified Image

Year(s)	Population	Built-up Area (km^2)			
		Calculated by Classification Map	Estimated by Equation	Difference	Percentage Variation
1996	5,904,678	674.41	690.57	16.16	2.40%
2001	6,997,586	820.23	821.72	1.49	0.18%
2008	8,878,826	1,101.35	1,047.47	53.88	4.89%
2015	11,26,5822	1,311.9	1,333.91	22.00	1.68%

Average of the percentage values in the last column of the table above shows that average variation in the values of built up area through equation estimation is 2% from the value calculated by the Map. Thus in order to devise a value for the built up area in year 2035, this variation factor must be accommodated.

Output of regression analysis in the form of equation above is a predictive tool for dependent variable. Thus dependent variable, in this case the built up area, can be predicted for the year 2035 through input of forecasted independent variable, population, in subject equation.

Population for year 2035 = 22,234,974
Thus,
Built up Areayear2035 = -17.990 + 0.00012 (Population year2035)
Built up Area year2035= -17.990 + 0.00012(22,234,974)
Built up Area year2035 = 2,650.206 km2
This value needs to be adjusted through the variation factor (2%) calculated above.
Therefore,
2% of Built up Area year2035 = (2/100) x 2,650.206 km2
2% of Built up Area year2035 = 53.00
Range: [2,650.206 – 53.00] to [2,650.206 + 53.00]

The built up area for year 2035 is estimated to be within the range of 2,597.206 km2 to 2,703.206 km2. The results of the above statistics analysis show that there is strong relationship between the Population and Built up Area of Lahore District. The urban growth in Lahore district correspond the built up areas. It is quite evident from that built up area was increased alongwith increase of population. Prediction shows that in year 2035, Built up area will be around 2,600 km2 expand beyond the district boundary of the Lahore.

Overall results of spatio temporal growth, overlay and regression analysis depict that pace of urban growth of Lahore varies with different time period. It has been revealed that Lahore is expended at southwards direction and agriculture landscape of Lahore are engulfing within the urban areas of Lahore. The adjoining areas/villages are becoming part of Lahore because of increasing population growth rate, pressure for development, construction of highways with great mobility and real estate investment opportunity in terms of development of housing schemes. The spatial direction mostly follows the intended land use proposals of development plans, whereas some deviation is also notable at some points. It can be say that Lahore has gone through different transition of spatial growth from 1960 to 2015, initially it had compact development within the radius of 5km, then from 1980 to 2000 it has followed contiguous growth pattern within the radius of 15-20km. In the last decade the growth pattern is shifted from the compact, contiguous to linear then transformed into scattered at periphery to attain the form of multiple nuclei with the emergence of Gulberg, DHA, Johar Town, Iqbal Town, Bahria Town, Wapda Town and Raiwind as nucleus and the city limit are not restricted and mostly followed the southern western directions within the radius of 35-40 km.

4. Conclusion

Urban Sprawl is potential threat for the large cities which can be cater for with the help of urban planning, resource optimization and controlled land use development. The paper aimed to explore the spatial urban extent for Lahore using the satellite imagery and statistically techniques which proved to be to be more effective and accurate as compare to supervised classification. It concludes that overall urban built-up growth potential of Lahore has been increased with the decrease in prime agriculture land from 1996 to 2015 and the trend of urban sprawl is increasing tremendously from the center of the city toward the southern side of Lahore. This study is an effort to pay attention to conserve the productive agricultural land cover against rapid sprawl of urbanization. This study also recommends to limit the city expansion to manage the sustainable urban growth of Lahore.

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