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Modelling Land use Patterns of Lahore (Pakistan) using Remote Sensing and GIS

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Abstract- In this research, an attempt was made to reveal the land use patterns of Lahore, the 2nd largest city of Pakistan, using remote sensing and GIS techniques. Results revealed that at present more than 1200 hectares of agricultural and forest land is acquired for urban uses every year. From 1972 to 2009, the urban area of Lahore expanded 68 percent while a loss of 32500 hectares in agricultural land is recorded. Around 5000 hectares of forest land had vanished from the landscape of the city. More than 200 rural localities have been merged into the city since 1972. Around 100 new housing schemes are approved to accommodate the ever increasing population at the expense of loss in agricultural land. Most of the expansion took place in south and southwest direction along major roads and highways.

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I. Introduction

The present research is focused on the land use patterns of Lahore, the 2nd largest city of Pakistan. The term land use is often applied to the urban centers where cities are expanding at the expense of loss in agricultural or forest land. In the realm of urban studies, urban sprawl is a matter of great interest and is seen as having harmful effects on people as a whole. The uncontrolled and haphazard urban sprawl over rural landscape is a matter of great concern; these urban expansions are swallowing rural land and green fields at a rate twice than the actual growth of population (Sultana and Weber, 2007). Urban expansion can lead to problems, such as transportation, ecological imbalance, income and ethnic segregation of neighborhoods, the differences among jobs and shelter, local economic disparities, alteration of agricultural land to urban uses, and civic isolation, among other maladies (Galster et al., 2001).

Sullivan (2007) states that land is a common good, meaning that an increase in the amount of wealth of a person, leads to a desire to obtain more land. In addition, he further states that the low cost travelling allows people of fair income to purchase larger housing units of comparatively less expensive land surrounding the city and commute daily to work and social functions, creating an urban land use of low-density. One method used to analyze the spatial aspects of the expansion of urban development is remote sensing. Since the launch of Landsat 1, the first "land sensing satellite," in the summer of 1972 the Landsat Program has archived imagery nearly twice per month for public use at a moderate spatial resolution. The USGS (United States Geological Survey) currently maintains and collects data from Landsat 5 and Landsat 7. These data are collected frequently and are cost-effective (Ryznar and Wagner, 2001). However, one disadvantage of these images is cloud cover. This cover can limit the number of useful scenes required for analyses in any given year, especially in the tropical, humid and sub humid climates. Remotely sensed data incorporated with a geographic information system (GIS) has made it easy to monitor urban growth patterns in different ways and manners that was not possible by using conventional methods of using census data (Sultana and Marzen, 2004).

II. Study Area

Lahore District lies on the left bank of river Ravi. It lies between 74°1′1″E to 74°38′10″E longitude and from 31°15′ to 31°44′2″ N latitude. It is the 2nd largest city of Pakistan after Karachi both in terms of population and urban hierarchy. The total area of Lahore is 1772 square km (177200 hectares). Total population of Lahore was 6.319 million in 1998 with a population density of 3,566 persons per square kilometer (GOP, 2000). The latest studies argue that the population of Lahore has increased to 9 million inhabitants (Riaz, 2011). The urban population of Lahore increased steadily since independence in 1947. Physiographically, the land of Lahore is made of alluvial soil deposited by Ravi through ages. Lahore is plain alluvial land with a gentle slope towards south east. Its height above sea level ranges from 700 feet in north east to 680 feet in south west with a slope gradient of 1 feet per 5-10 kilometers. The first underground water table is found at depth of 35 to 40 meters. But this water is not drinkable. Drinkable water is available at a depth of 125 to 150 meters. Lahore district is a part of Indo-Gangetic plain formed in front of the Himalayas (Bender & Raza, 1995). Lahore has fertile soil suitable for vegetation and plantation. Its soil and climatic conditions support all types of crops. Major crops of Lahore are wheat, rice, sugarcane, cotton, and vegetables. The cropping pattern of Lahore also shifted from cash crops to food grain crops and vegetables to fulfill the needs of the city. Now the major cash crops like cotton and sugarcane

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are not seen on the city profile. In 1998, the land area under wheat was 50,000 hectares; rice, 32,000 hectares; and vegetable, 6,317 hectares. The major vegetable was potatoes, which accounted for 70% of the area under vegetables (GOP, 2000).

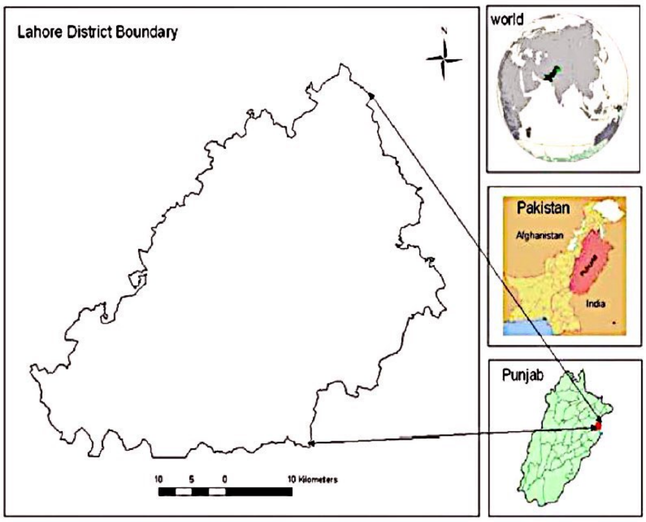

Figure 1 : Locational Map of the Study Area

III. Methodology

Research methodology is a critical part of any type of research. This is a systematic and scientific method to achieve goals. A number of steps involved to accomplish the present research. Figure 2 presents the whole picture of the presents study.

a) Image Processing

Satellite images for this research were acquired from the United States Geological Survey (USGS) website. Five satellite images were acquired for the years 1972, 1981, 1992, 2000, and 2009. This site provides images in different layers. Each layer represents a band. Every image has commonly seven layers except 1972 and 1981 images which have four layers.

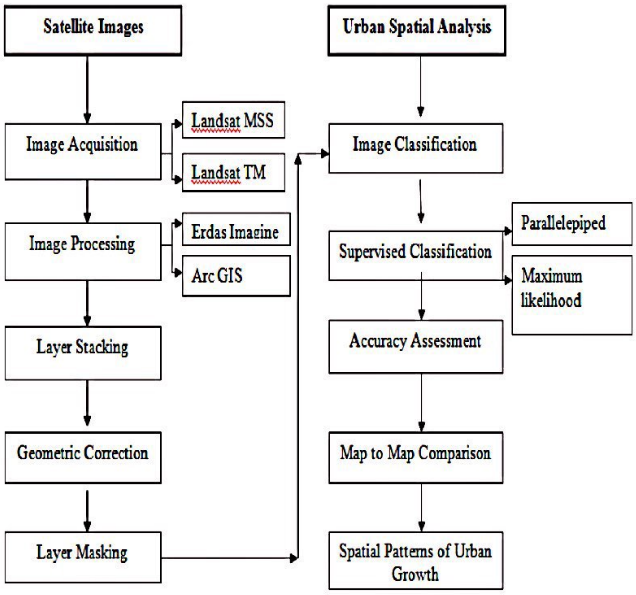

Figure 2 : A Flow diagram of the research methodology

These layers were than merged with each other through layer stacking process in Erdas Imagine software. The end product is an image file that is ready to be used. The images acquired from USGS have fair resolution. The scene size in these images was approximately 185 by 185 km. These images were rectified and georeferenced to a Universal Transverse Mercator Projection with WGS 84 datum and zone 43. Zone 43 is best suitable for the locations lie between 72˚E to 78˚E latitudes. Lahore lies at about 74˚E, so zone 43 was the best choice. Lahore district boundary was extracted from these images through masking of the image for analysis.

b) Image Classification

After the extraction of Lahore district boundary image, the next step was to classify the image according to its land use. But, before classifying an image, it is necessary to define a classification scheme (Yang, 2002). Keeping in view the scope of the present research and the resolution of images, following scheme was developed:

- *Urban Land use Area:* this land use area consists of 80 to 90 percent construction material including commercial and industrial.
- *Agricultural/cultivated land area:* this area includes land under different crops.
- *Forest land area:* consists of mixed forest with a concentration of 80 to 100 percent.
- *Water Bodies:* comprising of open water like river, lakes, and canals.
- *Others:* includes open spaces and undeveloped land.

After establishing the classification scheme, the land use data from different images was reclassified from more than fifteen classes into five classes (table 1). These five Landsat images were classified through parallelepiped algorithm with maximum likelihood classification method. The parallelepiped classification algorithm is widely used digital image classification decision. This algorithm is computationally efficient method for classification that involves spectral bands to perform classification (Gibson and Power, 2000). The maximum likelihood algorithm is based on probability. It calculates the predefined set of classes and then the pixel is assigned to the class for which the probability is highest (Jensen, 2005). Yet, it is one of the most commonly used algorithms for supervised classification (Wu and Shao, 2002; Mclever and Friedl, 2002). With the help of Signature Editor Toolbar in Erdas Imagine, different signatures were allocated to the different land uses according to the already established classification scheme.

c) Accuracy assessment

Accuracy assessment is difficult rather important procedure for remote sensing analysis. Random sample strategy was adapted for unbiased assessment (Jensen, 2005). More than 50 ground control points (GCPs) for each class are used. A fieldwork was conducted and GPS is used to collect and compare the sampled pixels and their corresponding land cover on the ground. These results are accurate and efficient for the Landsat image of 2009 because the fieldwork was done in early half of 2010. To assess the accuracy of historical images of 1972, 1981, 1990, and 2000, following technique was adopted. Firstly, the randomly collected GCPs were verified through field observations for the areas that had almost no change over the period of study, such as water bodies, forests, and historical buildings. Secondly, additional verifications of these localities were employed through already published census reports of population and agriculture.

Table 1 : Classification Scheme of Land Use

Sr No	Reclassification patch type	Actual land use type (Satellite images)
1	Urban Land Use	All built up areas (Residential, commercial, industrial, and educational) and new housing schemes
2	Agricultural Land	Cultivated and non cultivated farm land
3	Forest Land	Mixed forest
4	Water Bodies	Water
5	Others	Sand, barren land, recreational parks etc.

The accuracy results are shown in table 2, indicating the producer accuracy, user accuracy, overall image accuracy and Kappa statistics of agreement for all five images. The producer accuracy and user accuracy for each is calculated separately for all images. To assess the accuracy of all five images, error matrix was drawn. The landsat thematic images of 1990, 2000, and 2009 show the overall accuracy of 90.64%, 86.7%, and 88.7% respectively. The landsat MSS images of 1972 and 1981 have an accuracy of 83.2% and 83.9% respectively. The three thematic images of 1990, 2000, and 2009 show slightly higher accuracy than the MSS images of 1973 and 1981. This might be the result of comparatively higher spatial, spectral and radiometric resolution. However, all the images show acceptable overall accuracy. The Kappa index of agreement for each image is displayed in table 2. The images of 1973, 1981, 1990, 2000, and 2009 displayed the kappa index of agreement of 0.791, 0.80, 0.882, 0.883, and 0.859 respectively. The error matrix for the image of 1972 is shown in the table 3. The procedure adopted for the calculation of accuracy and kappa index for 1972 is displayed on the next page. The error matrix for other four images to assess accuracy is also drawn and only the results are shown here in table 2.

Table 2 : Accuracy Assessment of the Classified Images

	Urban		Agriculture		Forest		Water		Others		Overall Accuracy	Kappa indexes
	P(%)	U(%)	P(%)	U(%)	P(%)	U(%)	P(%)	U(%)	P(%)	U(%)		
1972	81.36	84.2	81.8	83.3	88.0	84.6	83.3	94.0	81.8	72.5	83.2%	0.791
1981	84.85	78.8	82.6	83.8	84.7	93.8	82.8	88.3	84.8	76.7	83.9%	0.80
1990	95.95	92.2	92.3	91.1	88.4	95.8	88.4	90.2	86.6	82.5	90.64%	0.882
2000	87.76	93.4	88.4	77.9	85.7	91.3	83.3	89.7	87.5	84.4	86.7%	0.833
2009	88.06	93.6	86.9	90.9	91.2	88.1	91.6	91.6	86.6	81.2	88.7%	0.859
P stands for producer's accuracy and **U** stands for user's accuracy.												

Table 3 : Error matrix of the Classification Map Derived from the 1972 Image of Lahore.

	Urban	Agriculture	Forest	Water	Others	Row total
Urban	**48**	3	0	3	3	57
Agriculture	2	**45**	4	0	3	54
Forest	2	2	**44**	0	4	52
Water	3	0	0	**47**	0	50
Others	4	5	2	6	**45**	62
Column Total	59	55	50	56	55	**275**

Overall accuracy = 229/275=83.2%

Table 4 : Producer and User Accuracy of the Image 1972

Producer's Accuracy		User's Accuracy	
Urban	48/59=81.36%	Urban	48/57=84.21%
Agriculture	45/55=81.82%	Agriculture	45/54=83.33%
Forest	44/50=88%	Forest	44/52=84.62%
Water	47/56=88.93%	Water	47/50=94%
Others	45/55=81.82%	Others	45/62=72.58%

Kappa Index of Agreement Calculation

$$K = \frac{N \Sigma_{i=1}^{k} x_{ii} - \Sigma_{i=1}^{k} (x_{i+} \times x_{+i})}{N^2 - \Sigma_{i=1}^{k} (x_{i+} \times x_{+i})}$$

(Jensen, 2005).

Where N = 275

$$\sum_{i=1}^{k} x_{ii} = 48 + 45 + 44 + 47 + 45 = 229$$

$$\sum_{i=1}^{k} (x_{i+} \times x_{+i}) = 57 \times 59 + 54 \times 55 + 52 \times 50 + 50 \times 56 + 62 \times 55 = 15143$$

Therefore

$$K = \frac{275(229) - 15143}{275^2 - 15143} = \frac{62975 - 15143}{75620 - 15143} = \frac{47832}{60482} = 0.791$$

IV. Results and Discussion

Figure 3 displays the total land use change occurred during 1972 to 2009 for different time periods. The urban land use has increased from 58,977 hectares in 1972 to 99,173 hectares in 2009 (table 5). The share of urban land was 33.28% in 1972 which increased to 55.97% in 2009. It added 40,196 hectares in urban land use giving an addition of 68.16% in total urban area (table 6). While there is a loss of 32,500 hectares in agricultural land during this period. The percentage share of agricultural land decreased from 54.08% in 1972 to 35.74% in 2009. Area under forest cover decreased from 5,706 hectares in 1972 to 856 hectares in 2009. This means 85% land under forest vanished from the study area. It is necessary to reveal the fact that the total loss of agricultural and forest land was acquired by urban land use. The population of Lahore increased from 2.6 million in 1972 to 9.3 million in 2009. The population increased three times during this period. This speedy population growth is the chief factor of rapid urban expansion in Lahore. It is also found that no major change occurred in the area consisted of water bodies during this period. The water bodies lost only 457 hectares of area. It is also evident that the area under other land uses like bare soil, barren land etc also recorded little change. From the table 6 and figure 3 is noted that the major and dramatic change in urban land use occurred during the period 1990-2000.

Table 5 : Land Use Statistics of Lahore: 1972-2009

Sr. No	Land Use	1972 Area (hectares)	1981 Area (hectares)	1990 Area (hectares)	2000 Area (hectares)	2009 Area (hectares)
1	Urban	58977	71361	76406	96697	99173
2	Agriculture	95838	85627	82720	65324	63338
3	Forest land	5706	4298	2637	1056	856
4	Water	8129	7724	7685	7646	7672
5	Others	8550	8190	7752	6477	6161
6	Total	177200	177200	177200	177200	177200

Table 6 : Land Use Change During Different Time Periods 1972-2009.

Periods		Urban	Agriculture	Forest	Water	Others
1972-1981	Hectares	12384	-10211	-1408	-405	-360
	%	21	-10.65	-24.68	-4.98	-4.21
1981-1990	Hectares	5044	-2907	-1661	-39	-438
	%	7.07	-3.39	-38.65	-0.50	-5.35
1990-2000	Hectares	20291	-17396	-1581	-39	-1275
	%	26.56	-21.03	-59.95	-0.51	-16.45
2000-2009	Hectares	2476	-1986	-200	26	-316
	%	2.56	-3.04	-18.94	0.34	-4.88
1972-2009	Hectares	40196	-32500	-4850	-457	-2389
	%	68.16	-33.91	-85	-5.62	-27.94

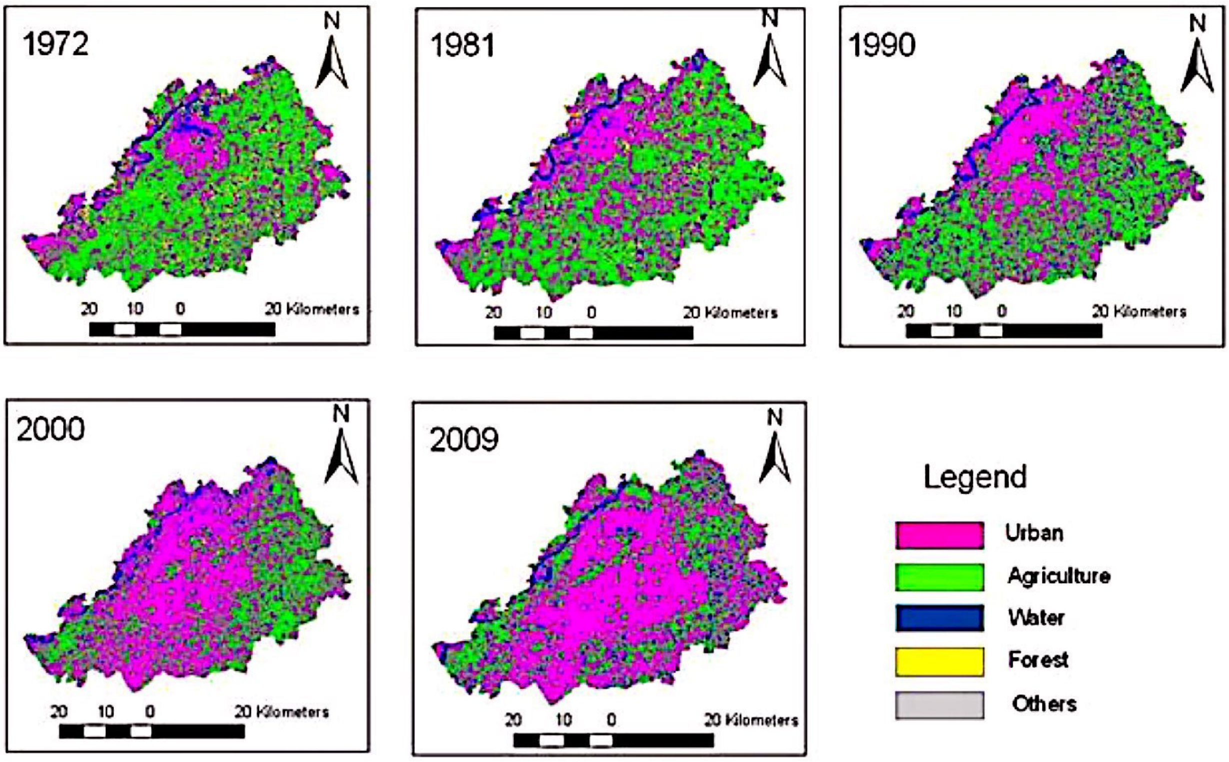

Figure 3 : Land Use Change maps of Lahore from 1972 to 2009

V. Conclusion

The results revealed that the urban area of Lahore recorded 68% increase since 1972. In 1972 the share of urban land was just 33.2% of the total land area which increased to 55.97% in 2009. The total built up area of Lahore was 58,977 hectares in 1972 that has increased to 99,173 hectares in 2009. In order to cater for the demand of the land more than half of the agricultural land of the study area was acquired for urban land use. The area under agriculture has decreased from 95,838 hectares in 1972 to 63,338 hectares in 2009. The share of agricultural land decreased from 54% in 1972 to 35.7% in 2009. The expanding urban housing replaced the natural vegetation cover with the urban infrastructure .The same time duration recorded a loss of 85% forest land in the study area. Lahore is bounded by river Ravi in North and India in the east. The river channel and territorial demarcation of India have been hindering the urban expansion towards the areas. Resultantly the major urban expansion took place in the south and south western part of the district. It is also observed that most of the urban expansion took place along the highways and major roads. The urban expansion history reveals that more than 200 housing schemes were approved to accommodate the residential demands of increasing population in the city. This expansion reached the boundaries of villages and it is estimated that this urban population specter has swallowed around 250 villages since 1972 to onwards. This rapid urban expansion has changed the land use profile of the district from agriculture to urban. Over the past few decades, urban expansion of Lahore has significantly modified the land use patterns of the area. The built up area has increased remarkably at the expanse of agricultural as well as forest land. This rapid expansion has resulted as haphazard growth, high density population, air, water and noise pollution and unplanned expansion along canal road, Ferozpur road and Raiwind road. This situation has been further aggravated by the lack of an integrated urban development approach and absence of proper integrated urban planning and zoning. It is, therefore, strongly recommended that further research must be carried on the aspects such as disorganized development, traffic congestion, loss of agricultural land and other environmental issues.

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