ASSESSMENT OF URBAN SPRAWL OF LAHORE, PUNJAB, PAKISTAN USING MULTI-STAGE REMOTE SENSING DATA

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ABSTRACT:*Over the past 30 years, Land development and consumption have been out of control and expanding out of order, especially in marginal areas of some metropolises in Pakistan. In this research the dynamic change of urban sprawl and its spatial and temporal characteristics was analyzed for Lahore division, Pakistan. To achieve the goal two satellite image classification techniques were applied, i.e. (i) supervised, (ii) unsupervised. Also the greenness of the Lahore was calculated using Normalized Difference Vegetation Index on Landsat imageries for the years 1991, 2000, 2014. Unsupervised classification technique was proved to be more effective with an overall agreement of 81%. The study was concluded that from 1991 to 2000, the urbanization in Lahore was increased from 2279.7 km^2 to 5214.9 km^2; whereas from 2000 to 2013 the urbanization was almost double i.e. 6451.6 km^2. There is an overall decrease in barren land and increase I the vegetation/ greenness in the region. Apart from the derived results, this study also proved the potentials of remote sensing data and the effectiveness of demonstrated/proposed techniques in urban geographic studies*.

INTRODUCTION

Urban sprawl, a consequence of socioeconomic development under certain circumstances, has increasingly become a major issue facing many metropolitan areas. Although a general consensus regarding the definition and impact of urban sprawl has not been achieved [1], urban sprawl is often referred to as uncontrolled, scattered suburban development that increases traffic problems, reduces local resources, and destroys open space [2]. It is critically important to properly characterize urban sprawl in order to develop a comprehensive understanding of the causes and effects of urbanization processes. However, due to its association with poorly planned urban land use and economic activity[3], urban sprawl is often evaluated and characterized exclusively based on major socioeconomic indicators such as population growth, commuting costs, employment shifts, city revenue change, and a number of commercial establishments [4-7]. This approach cannot effectively identify the impacts of urban sprawl in a spatial context. To fill this gap, remote sensing has been used to detect urban land cover changes in relation to urbanization [e.g., 8-11]. Remote sensing techniques have advantages in characterizing the spatiotemporal trends of urban sprawl using multi-stage images, providing a basis for projecting future urbanization processes.

Also the use of satellite images will assist us in identifying the spatial and temporal patterns of urban land expansion from the urban core, and in detecting land-use change in urban fringes, especially in what concerns the relation between urban and agricultural land uses [12-13]. With this in mind, the aim of this current study was (i) to map the expansion of urbanization in Lahore both spatially and temporally (ii) to assess the impact of urbanization on greenness in the study area. To address these objectives, multi-stage remote sensing images, geographic information systems and some secondary data from urban organizations was deployed.

MATERIALS AND METHODS

Study Area

The study area for this research is Lahore, the capital city of the Pakistani province of Punjab and the second largest metropolitan area in the country (figure 1). According to the 1998 census, Lahore's population was 6,319,000. In July 2014, Index Mundi put the population of the city at 7,566,000. An estimate in January 2015 gave the population of the Lahore agglomeration as 10,052,000.It is ranked 34 in the most populated urban areas in the world and the 8th largest city within the Organization of Islamic Cooperation

Total Area of Lahore division is 1,772 km² and it is located at 31°32′59″N 74°20′37″E.

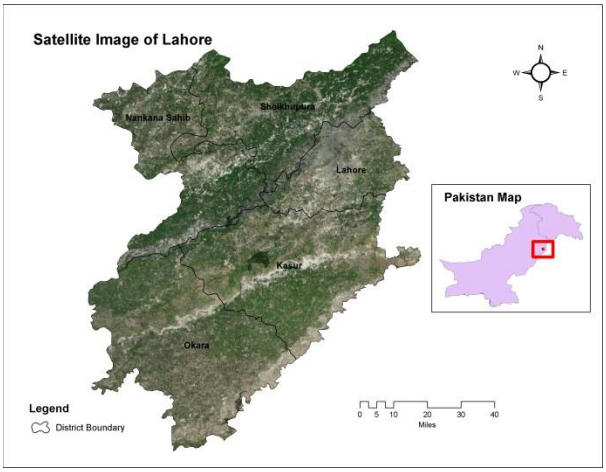


Figure 1: Location map of study area: the Lahore.

Data used

The data was collected from primary data source include Survey of Pakistan (SOP) topo-sheets of Lahore (scale, 1:50,000) and multi-spectral Landsat TM, ETM+ and OLI sensors. The data collected from secondary sources include the administrative boundary map. The details are given in table 1.

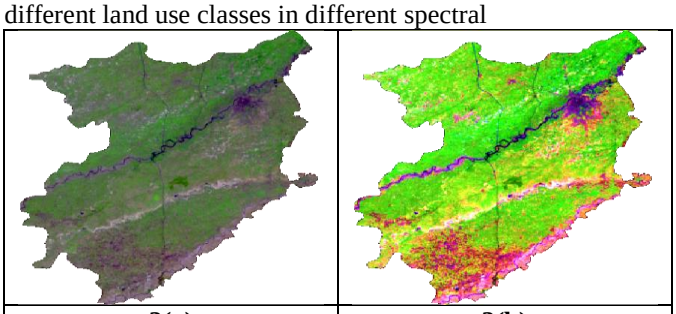
Table 1: Different type of data used

S. no	Type of data used	Scale/resolution	Years
1	Survey of Pakistan topo-sheets	1:50,000	1995-96
2	Landsat TM image	30 m	1991
3	Landsat ETM+ image	30 m	2000
4	Landsat OLI image	30 m	2014
5	Administrative boundary map	1:25,000	1990

METHODOLOGY

Understanding the dynamic phenomenon, such as urban sprawl/growth, requires land use change analyses, urban sprawl pattern identification. ERDAS (Leica) and ArcGIS software (ESRI) have been used to generate various thematic layers, like, Lahore administrative boundary map, roads, railway network and administrative boundary map using the topo-sheets and other available maps.

The standard image processing techniques, such as image extraction, rectification, restoration, and classification have been used for the analysis of three satellite images (1991, 2000 and 2014). ERDAS imagine software has been used for image analysis. First of all, atmospheric correction has been applied using improved dark object subtraction method to bring all the images at common reference spectral characteristics [14]. Water bodies available in the areas have been used as the dark object. Further, these subtracted images have been stretched to 8 bit digital number range. As an example the figure 2 shows the before 2(a) and after 2(b) satellite image correction. Further, the subset of each year has been developed by using the administrative boundary of Lahore division. Satellite images have been studied thoroughly to determine the probable land use classes. Spectral profiles have been drawn to determine the seperability and relative difference in pixel values of different land use classes in different spectral



3(a) 3(b)

Figure2: Effect of image enhancement and correction; before 2(a) and after 2(b) satellite image.

bands [15]. Four separable land cover classes have been identified, such as urban areas, vegetation, water and barren land. Initially, supervised classification using MLC algorithm has been performed for the classification of various images [16-17]. To enhance the classification accuracy, knowledge-based expert system was used for post-classification refinement of initially classified outputs [18].

Then the accuracy assessment of classified images is performed using ground truth data. More than 650 points for each year are collected and finally an error matrix is generated.

Also in parallel another technique, Normalized Difference Vegetation Index (NDVI) is applied, a popular image processing technique to get the vegetation cover from satellite and airborne sensors [19-21]. The principle underlying NDVI is that healthy green vegetation reflects more infrared radiation and absorbs more energy in the red wavelength when compared with unhealthy vegetation or to non-vegetated surfaces.

The NDVI was calculated according to the following algorithm;

$$NDVI = (NIR - RED) / (NIR + RED)$$

All these techniques, i.e. supervised, unsupervised image classification and NDVI, were applied to extract the landcover from satellite images and map the urbanization in Lahore over the period of more than twenty years.

RESULTS AND DISCUSSION

By using remote sensing and GIS techniques, the urban sprawl of Lahore were identified. Both supervised and unsupervised image classification techniques were applied. The results show that there is a significant increase in urbanization.

Detecting Urban Growth Using Supervised Classification:

The supervised classification of the satellite images into built-up and non-built-up areas for three temporal instants has resulted in the creation land cover of Lahore division (figure. 3a,3b,3c), which define the urban extents of specified times. The results show that over the period of time the barren land and vegetation decreased, whereas the urban area (built-up) had been increased significantly.

The square kilometer area of each land cover is given in the table 2. Also the square kilometer area graphical information is given in figure 4.

Table 2: Area in sq.km of landcover of Lahore Division.

Year	Barren Land	Vegetation	Built-up Area	Water
1991	7043.3	6812.5	2109.9	163.3
2000	4925.7	6979.4	3659.9	564
2014	4005.5	6679.2	5251.2	193.1

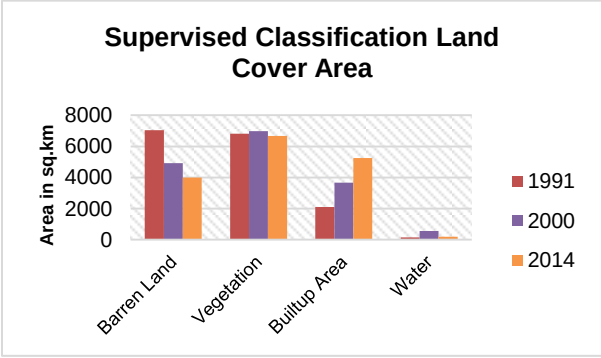
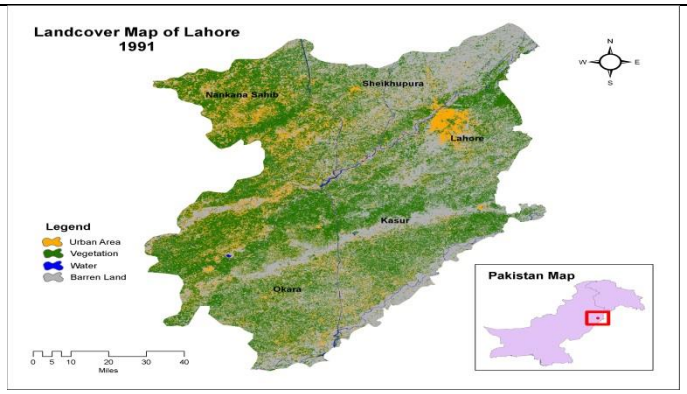


Figure 4: Area in sq.km of landcover of Lahore Division as per Supervised Classification Technique.



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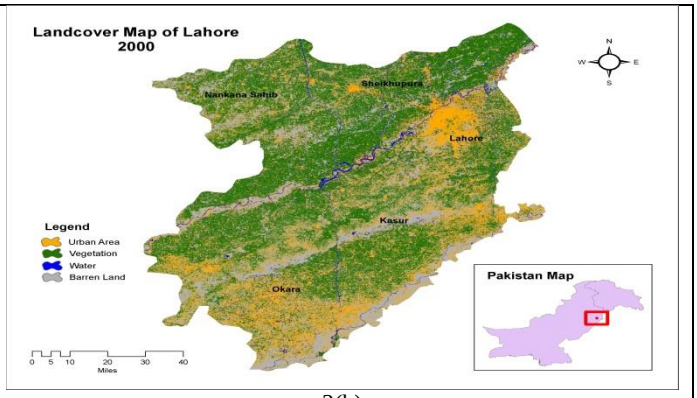

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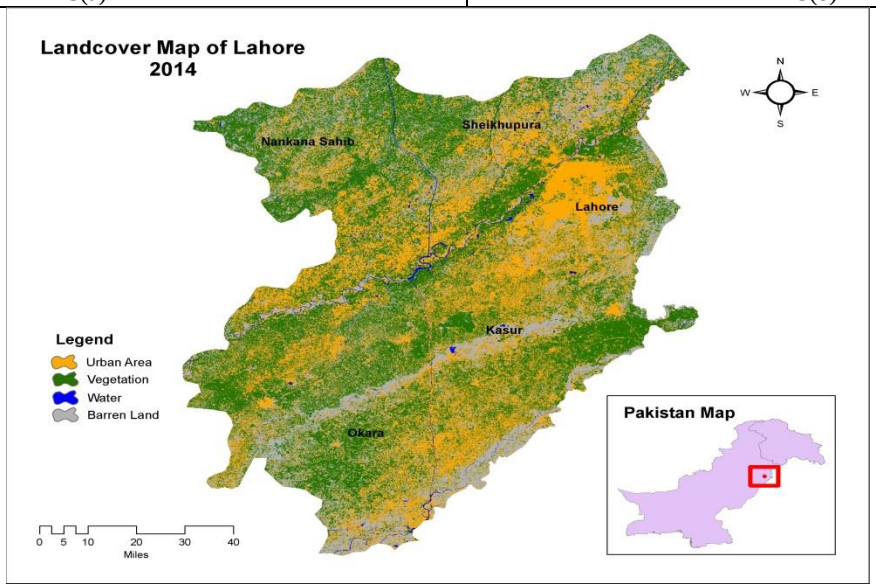
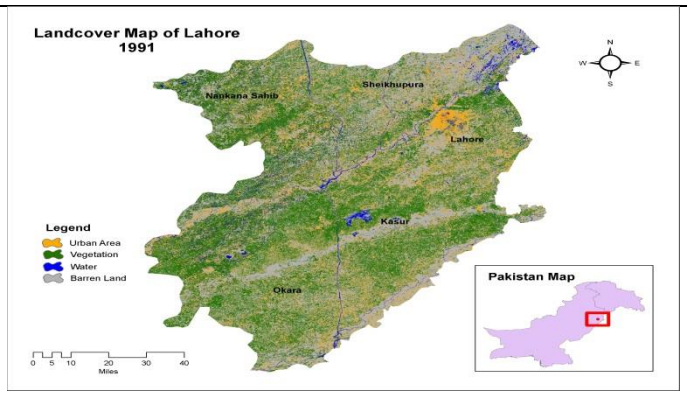


3(c)

Figure 3: Landcover maps of Karachi Division as per Supervised Classification Technique.



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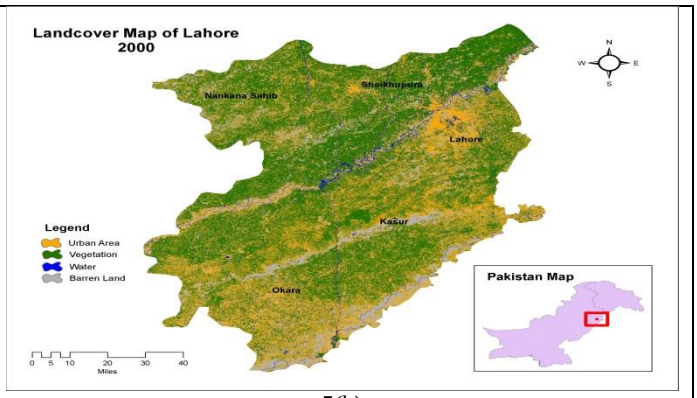

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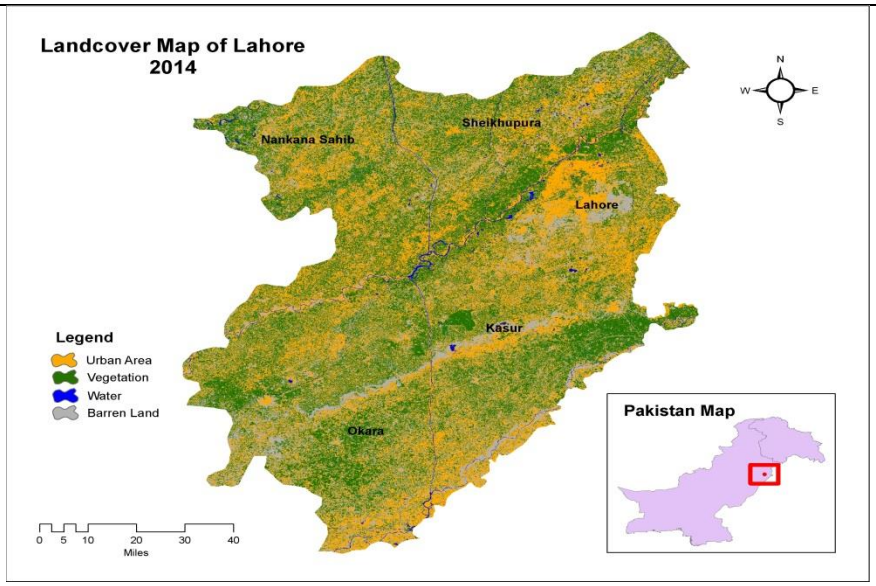

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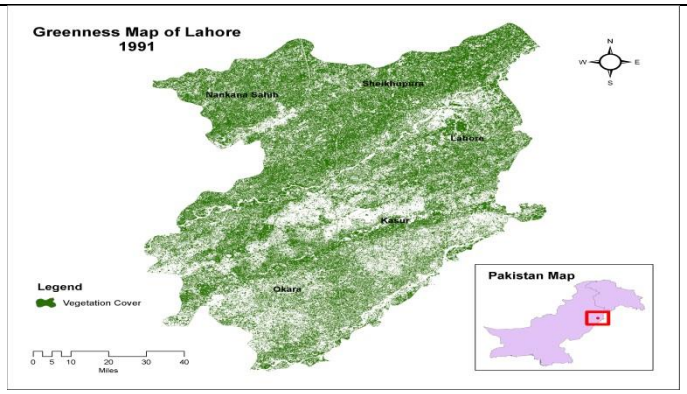
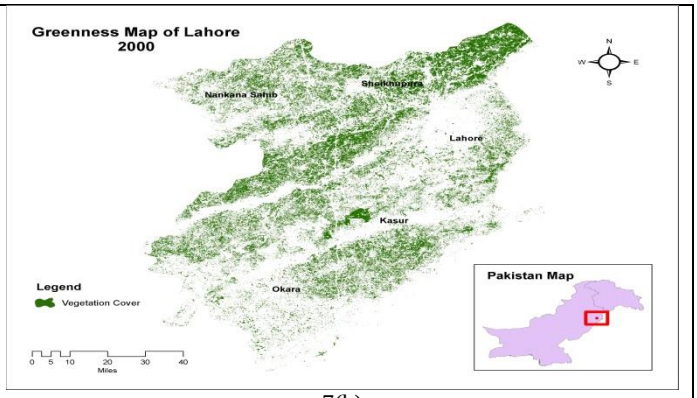
Figure 5: Landcover maps of Karachi Division as per Unsupervised Classification Technique.



7(a)



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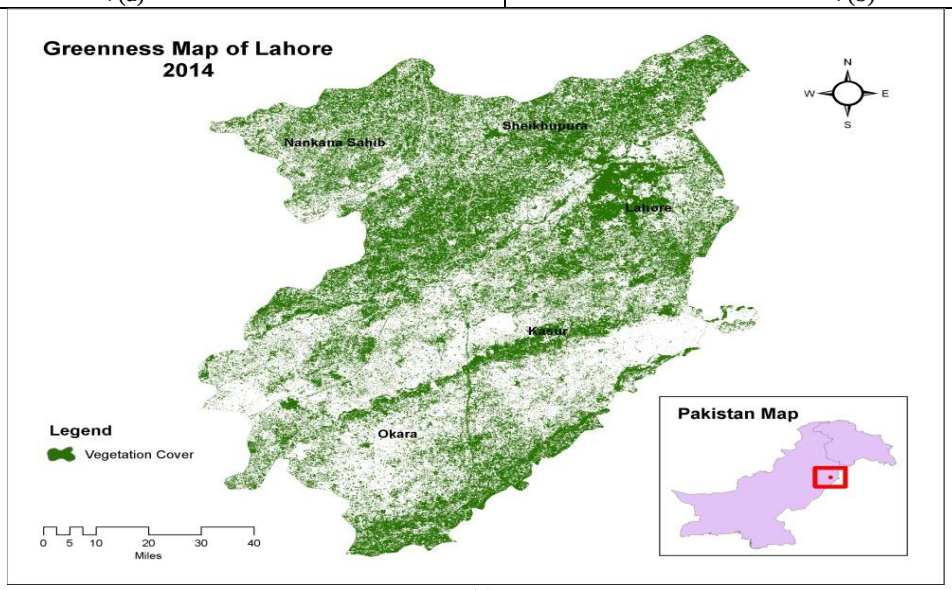

7(c)

Figure 7: Greenness map of Lahore as per Normalized Difference Vegetation Index (NDVI).

The overall accuracy of supervised classified images of Lahore division for year 1991, 2000 and 2014 was 71%, 88% and 87% respectively.

Detecting Urban Growth Using Unsupervised Classification:

The second method to classify satellite images into built-up and non-built-up areas was unsupervised classification. The same three temporal instants has resulted in the creation land cover of Lahore division (figure. 5a,5b,5c) which define the urban extents of specified times. The results show that over the period of time the barren land decreased whereas the built-up area had been increased significantly.

The unsupervised classification also shows that the major urban sprawls are on South-West. The square kilometer area of each land cover is given in the table 3. Also the square kilometer area graphical information is given in figure 6.

The overall accuracy of unsupervised classified images of Lahore division for year 1991, 2000 and 2013 is 76%, 85% and 84% respectively.

Table 3: Area in sq.km of landcover of Lahore Division.

Year	Barren Land	Vegetation	Built-up Area	Water
1991	7378.4	5882.7	2279.7	588.2
2000	2446.1	8097.1	5214.9	370.9
2014	3130.6	6332.8	6451.6	214

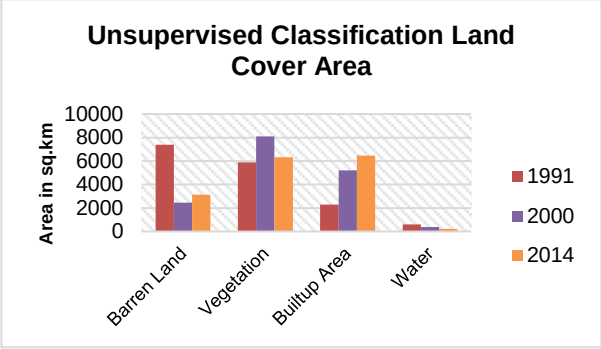

Figure 6: Area in sq.km of landcover of Lahore Division as per Unsupervised Classification Technique.

Detecting Greenness Using Normalized Difference Vegetation Index (NDVI):

The vegetation cover of Lahore division was also extracted using NDVI technique for 1991, 2000 and 2014 as shown in figure 7. The results show that vegetation ha been increased over the time and during 1999–2000 and 2000–2014, the area of higher mean annual NDVI accounted for 61.3% and 79.6% of the total area respectively. This is mainly due to the provincial government's efforts for increasing vegetation cover through engaging private sector besides providing economic incentives to the communities of the local area in order to get their support for conservation and protections of green resources. Also Lahore Development Authority (LDA) is responsible for new planned development in Lahore, Punjab, Pakistan. It also manages Lahore's parks and green areas. The private housing socities were urged to increase the vegetation/planatation in the socities and hence provision of new more green spapces to the citizens.

The overall urban sprawl of Lahore has been increased while decreasing the barren land in the division. Also the green spaces increase over the time from 1991 to 2014.

CONCLUSION

The urban sprawl is seen as one of the potential challenge to sustainable development where urban planning with effective resource utilization, allocation of natural resources and infrastructure initiatives are key concerns. The study was aimed to analyze the urban growth of Lahore division from remote sensing data with three different techniques. Unsupervised classification technique proves to be more effective and accurate as compare to supervised classification.

In the future, the spatio-temporal modeling of urban sprawl may be done and will help us to better understand the evolved urban patterns of Lahore division.

Remote sensing technology is essential for dealing dynamic phenomenon, like urban sprawl. Without remote sensing data and GIS analysis, one may not be able to monitor and estimate the urban sprawl effectively over a time period, especially for elapsed time period.

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