Use of Geospatial Techniques in Monitoring Urban Expansion and Land Use Change Analysis: A Case of Lahore, Pakistan

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Abstract: Rapid urban expansion and resultant temporal land use changes have a profound effect on the city's environment and its surroundings. Due to its significance, it is essential to evaluate the urban expansion patterns and land use change analysis of mega cities of the world. For land use change detection, multi-source & multi-temporal satellite images along with GIS & remote sensing (RS) techniques are significant aspects in analyzing urban expansion all over the world. In present study, two image data sets of the Landsat system in 7/ETM+ and 8/OLI modes, along with ground truthing data were utilized to examine the spatio-temporal dynamics of land use changes and assess the spatial patterns of urban expansion in Lahore, Pakistan from the year 2000 & 2014. Supervised classification using maximum likelihood algorithm has been carried out for land use classification and Post classification change detection technique was used to produce change detection map of the study area. The output land use and change detection map revealed that the areal expansion has been attributed due to loss of agricultural land and urban sprawl while major change in land use has taken place in built-up and agricultural areas. The results indicated that 40.81% of built-up area increased, while agricultural land has decline by -12.98% during the study period (2000-2014). Due to this the observed expansion of the city has been toward the South-east, South and South-west along with major roads. The results infer can provide better understanding and information about the past and current spatial dynamics of land use change in Lahore, Pakistan.

Keywords: Urban Expansion, Land use, Landsat 8, Remote sensing, Lahore.

1. INTRODUCTION

Urban expansion is one of the most important geographic phenomena that can be observed globally, particularly in the cities of developing country [1]. Urban expansion is one of the major factors in changing land use [2], which has caused for global change of urban land use because it can affect ecosystem processes, biodiversity, hydrology, energy balance, climatic condition and anthropogenic activities [3, 4]. Changes in urban landscape have always been an area of interest for geographers and environmentalists concerned in analysis of spatial phenomena. Land surface has been recording changes throughout geological times but with recent rapid temporal urban expansion, this change has been occurring at a considerable faster rate. This change needs to be measured, mapped and detected at frequent intervals so that we can have real time information on it [5]. Therefore, a comprehensive research should be the priority in order to understand the dynamics of the change and it is equally essential for further planning and management of land resources and sustainable development.

Nowadays urban areas experience rapid growth due to economic and massive urban population growth, industrial and anthropogenic activities in cities and movement of people from rural to urban areas [2]. Urban growth is typically accelerated and driven by the population concentration in an area. The extent of urban expansion drives the change in urban land use pattern [6, 7]. Globally, more people live in urban areas than in rural areas [8]. In 2008, the world has attained an important milestone, that for the first time in urban history, half of the world's population lived in urbanized areas. It is projected that by 2030, over 56% of the world's population will live in cities [8]. This urban population growth will be most significant in developing world, notably in Africa and Asian countries [9].

The rapid expansion of cities is a demographic phenomenon in most of the developing countries including Pakistan. In Pakistan, the proportion of total population living in urban areas has increased from only 17.8 % in 1951 to about 32.5 % in 1998 and 37 % in 2011 [10], although within the Asia-Pacific region, based on both the level of urbanization and urban growth, Pakistan is grouped with countries having moderate level of urbanization, it has the highest level (37%) of urban population residing in town & cities among the South Asian countries. It is expected that about 50% population of Pakistan will be residing in urbanized areas by the year 2030 [10]. The geographic expanse of district Lahore has witnessed random population growth from 0.67 million in 1941 and 6.3188 million in 1998 [11]. This alarming growth rate has heaved the population density from 379 to 3,566 people per sq. km. Lahore comprising 82% urban population of the total population of district and the remaining is residing in countryside [12]. Urban

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expansion is an excessive concern for the local government because the rapid growth of urban population giving rise to congestion, commuting problems, environmental pollution and inadequate delivery of civic amenities to the citizens [12, 13]. Urban expansion can be observed as a characteristic of the urban population growth, as a characteristic of specific types of land uses, as well as a characteristic of socio-economic processes and interactions affecting both urban land and population concentration [14].

The spatio-temporal patterns of urban expansion can be accurately monitored and mapped from satellite remotely sensed (SRS) data along with ground data. Remote sensing and GIS are very efficient & effective tool and technologically comprehensive, so these are increasingly used for assessing urban expansion and change detection analysis [15-17]. SRS offers spatially reliable data sets that cover very big area of earth surface with both high temporal frequency high spatial information about land surface [3]. Change detection techniques are worthwhile in several applications that have been effectively & efficiently employed to recognize different land use changes. These techniques range from simple image differencing as used by [18], to post classification comparison [19].

On the other hand, various procedures have been established for detecting, measuring, and mapping urban temporal expansion from remotely sensed data: e.g. Mundia & Aniya (2005), examined the spatial dynamics of land use changes and recognized the urbanization process using multi-spatial & multi-temporal resolutions of Landsat satellite data; Xiao, *et al*., (2006) identified land use change and urban expansion trends using annual urban growth rate reinforced by two scenes of multi-spectral satellite images, Batisani & Yarnal, (2009) evaluated urban landscape pattern change using Landsat TM images [20, 21]. Spatial information of land use changes within urban area over time is a vital means for city planning, decision-making & resource management towards sustainable urban development. Analysis of the spatio-temporal changes in urban land use is one of the most effective way to understand the current environmental status of an area and ongoing change [22]. The specific objectives of the study is to examine the temporal dynamics and spatial patterns of land use changes and evaluate temporal & spatial urban expansion of Lahore using Geospatial techniques.

2. THE STUDY AREA

Lahore is the largest district of the Punjab province in terms of population size comprising 82% of urban population and provincial capital as well. It is the second largest Metropolitan city of Pakistan after Karachi having estimated population of 9,086,000 in 2014 [23]. Lahore is hub of economic & cultural activities and academic center of the country which is often referred to as the heart of Pakistan and, therefore, a place of interaction of people from all across the country. Lahore is an old cultural center of Pakistan with a history of more than 10 centuries. It is

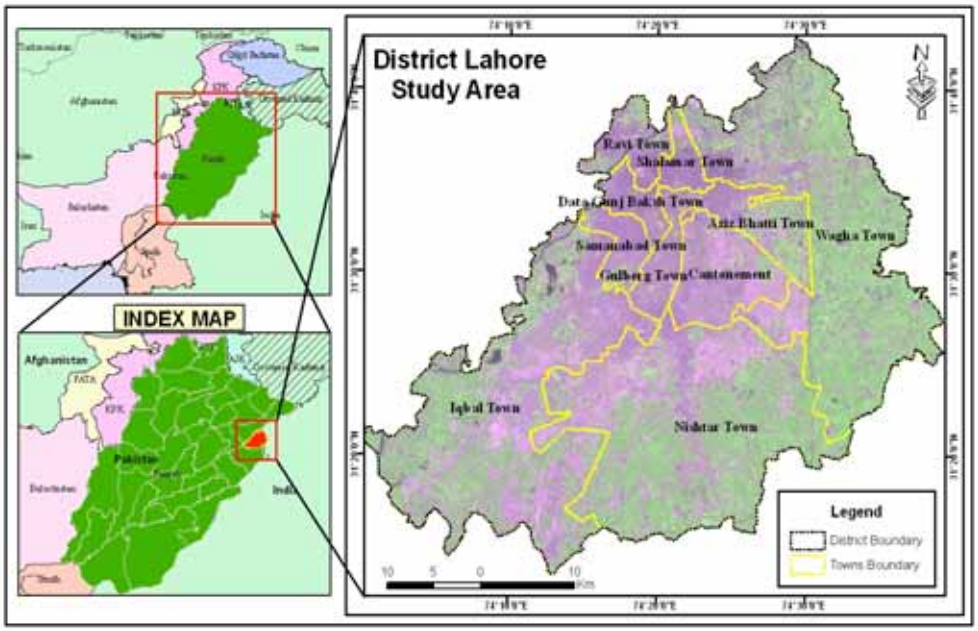

Figure 1: Location of the study area District Lahore.

situated within the geographic extents of 31° 13' and 31°43' N latitude and 74° 0' and 74° 39.5' E longitude. Lahore is located at the left bank of River Ravi, consisting of an area of 1772 sq. km. [11]. The Lahore City District comprises of nine towns which are controlled by TMA (Town Municipal administration) except Lahore cantonment (Figure **1**).

3. MATERIALS AND METHODOLOGY

3.1. Data Source

In order to carry out the present study, Landsat satellite imagery for a period from 2000-2014 have been utilized. Satellite remotely sensed data, including aerial photographs, offer consistent information for studying historical land use change and assessing temporal and spatial urban expansion [24]. Satellite remotely sensed data is an efficient and effective tool for urban analysis because it is easily accessible to be utilized and some images are available free of cost at USGS website. The images were got as standard products, i.e. radiometrically and geometrically corrected [25, 26]. In order to accomplish the desired objectives of the study, satellite image datasets of the Landsat system in 7/ETM+ and 8/OLI modes were acquired for March 18, 2000 and March 19, 2014 respectively. The other ancillary data files comprise of geo-registered vector layer of district & towns boundary, land use base map and topographic map acquired from the office of Urban Unit, Lahore and Survey of Pakistan, while population data of district Lahore was acquired from Population Census Organization and Punjab Development Statistics. Besides above data, Google Earth was utilized for better interpretation & visualization purposes. Spectral details of the above-mentioned Landsat images are given below in Table **1**. It is worth mentioning that the thermal bands of Landsat were not considered for the analysis.

3.2. Methodology

First of all, different bands of satellite images were stacked by layer stacking method to get false color composite image [27, 28]. Each Landsat image was rectified to a common coordinate system UTM43 & WGS 84 datum [12]. The vector layer of district Lahore was used as masks to subset images for clipping the study area from the complete scene. With the aid of ERDAS 9.2, all satellite images were enhanced by histogram equalization method in order to increase the volume of visible information and to gain a higher level contrast in the 'peaks' of the original histogram [29]. This method is significant for serving the identification of ground control points and in rectification process [30]. Training samples for supervised image classification were defined with the aid of field acquired ground data.

Classification of satellite images is a procedure whereby every pixel in the satellite imagery is characterized into a distinct land use class or theme [31]. After gathering the information & visual interpretation of satellite images, classification criteria are recognized on the basis of spectral & land analysis [32]. Then, a supervised image classification with the Algorithm of Maximum Likelihood was executed for the imagery of two different time spans (2000 and 2014 respectively), and four land use classes are identified and utilized in this research, which include: (a) Urban/Built-up area, (b) Agricultural area, (c) Barren land, and (d) Water bodies, the detail of all these classes of urban land use are shown in Table **2**. The subset Landsat imagery were then classified using a nonparametric parallelepiped classifier to extract the urban built-up area. It is worth mentioning that if the study is concerned only with urban expansion & growth, only the classes of urban Built-up area and non-urban/built-up area are under consideration, detailed land use maps are no longer necessary and a

Table 1: Landsat Images Description

Year	Sensor	Bands	Spatial Resolution	Thermal Resolution	Path/Row	Date of Acquisition
2000	ETM+	1-5 & 7	30 m	-	149/38	19-03-2000
		Pan (8)	15 m	-		
	TIR	6	-	60 m		
2014	OLI	1-7 &9	30 m	-	149/38	18-03-2014
		Pan (8)	15 m	-		
	TIR	10 &11	-	100 m		

Source: http://www.usgs.gov/.

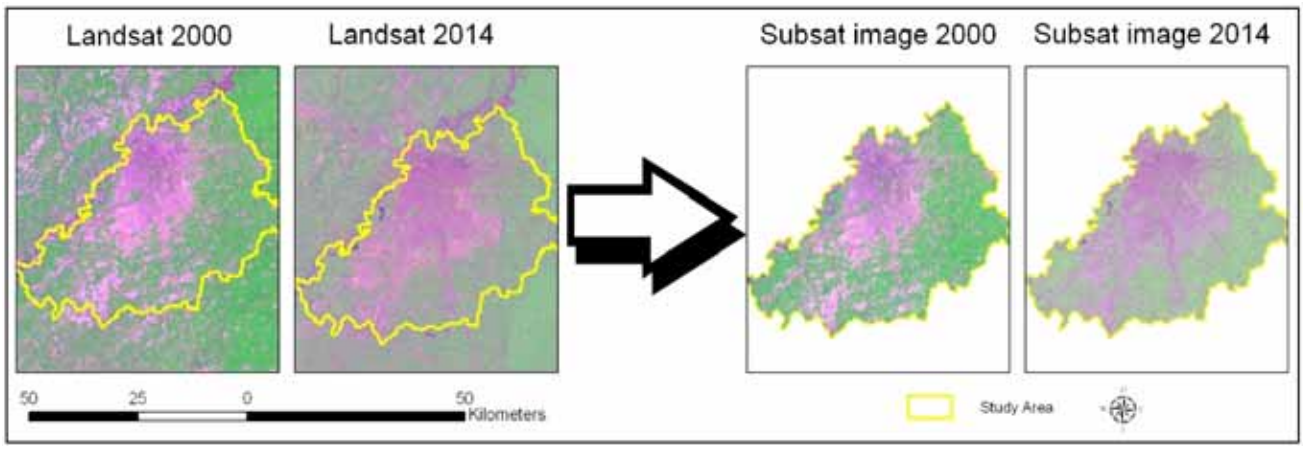

Figure 2: Landsat images used for urban change analysis.

simple binary classification of satellite remotely sensed data is enough [26].

The accuracy & precision of the image classification is a verified method of stratified random sampling and utilization the reference ground data composed of the field work and land use base map of Lahore. In order to increase the accuracy of land use mapping of the two image data sets, supplementary data and the result of visual interpretation were incorporated with the image classification result using RS & GIS techniques to increase the image classification accuracy assessment of the classified image. A standard overall classification accuracy for land use maps is set between 85 and 90 percent [33, 34]. In the present study, the classification overall accuracy of land use reaches 85% for 2000 and 89% for 2014 respectively and the values of kappa statistics ranges from 0.80 and 0.86, respectively for the year 2000 and 2014.

4. RESULTS AND DISCUSSIONS

4.1. Urban Land Use Changes

After image analysis, study found that two categories i.e. built-up area & water bodies recorded increase in the area while the other two categories i.e., agricultural land and barren/open land recorded decline in their respective areas. Major impact of urban expansion on land use has been found in built up area as it has increased by 40.81% (2000-2014). Water bodies have also shown an increase of 20.57% (2000-2014). Though built up area has grown in all directions but major change has taken place in this era at South-east, South and South-west of the Lahore city. The change in water bodies does not show any regular pattern. Major change has been reported in agricultural land as it has declined from 1151.91 Sq. Km. (2000) to 1002.29 Sq. Km. (2014) registering a decline of 12.98%.The decline in agricultural land and increase in built up have taken place due to expansion of built up at the cost of agricultural and partially bare land as shown Figures **3** and **4**.

4.2. Temporal Urban Expansion

A prominent temporal expansion of the urban area of Lahore is shown in the classified image datasets (Figure **5**). The major expansion of the city can be observed in the direction of south-east, south and south-west. The River Ravi blocks the side of north and north-east of the city while a zone in the district in east

Table 2: Description of Different Land Use Classes of the Study Area

Land use Type (Level I)	Description (Level II)
Urban or Built-up land	Residential, commercial and services, industrial, transportation, Communications and utilities, Industrial and Commercial Complexes, Mixed Urban or Built-up Land
Agricultural Land	Cropland and Pasture, Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas, Confined Feeding Operations, Other Agricultural Land.
Barren/Open land	Area of thin soil, sand, landfill sites, Transitional Areas, Mixed Barren land and almost has no vegetation.
Water Bodies	All areas of open water, including streams and Canals, lakes, ponds and reservoirs, River.

Source: [33. 35].

Table 3: Land Use Statistics of Lahore 2000 and 2014

Land use Type	Area (Sq. Km)		Change Area	Growth %
	2000	2014		
Urban or Built-up Land	395.53	556.95	161.42	40.81
Agricultural Land	1151.91	1002.29	-149.62	-12.98
Barren/Open Land	213.09	198.93	-14.16	-6.64
Water Bodies	11.47	13.83	2.36	20.57
Total Area km^2	1772	1772		

Source: Author.

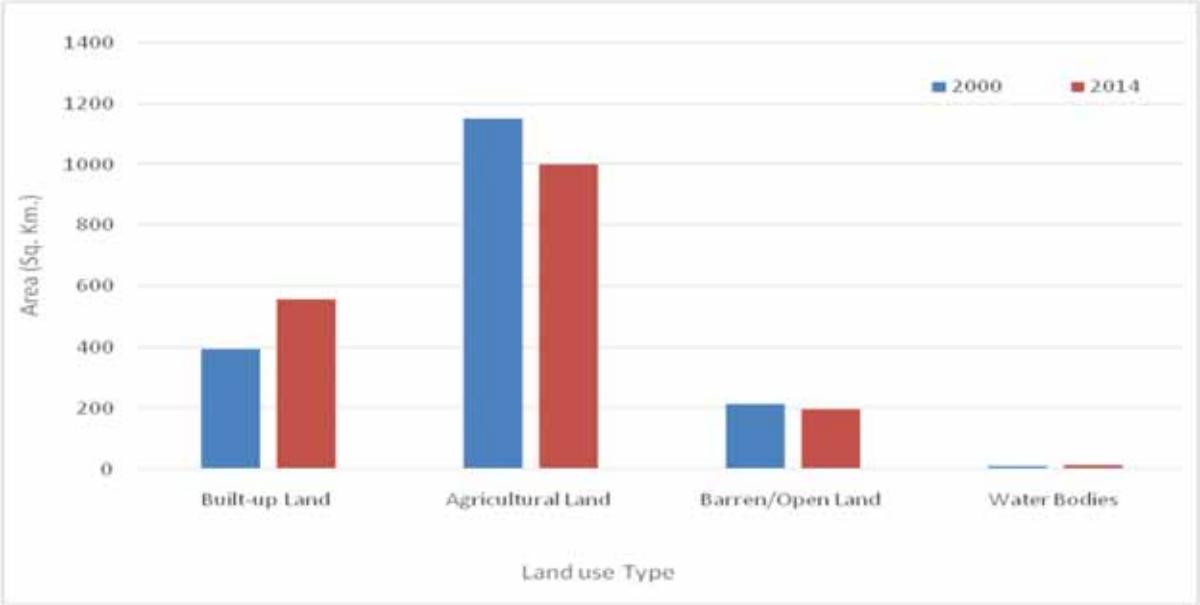

Figure 3: Land use change of Lahore from 2000-2014.

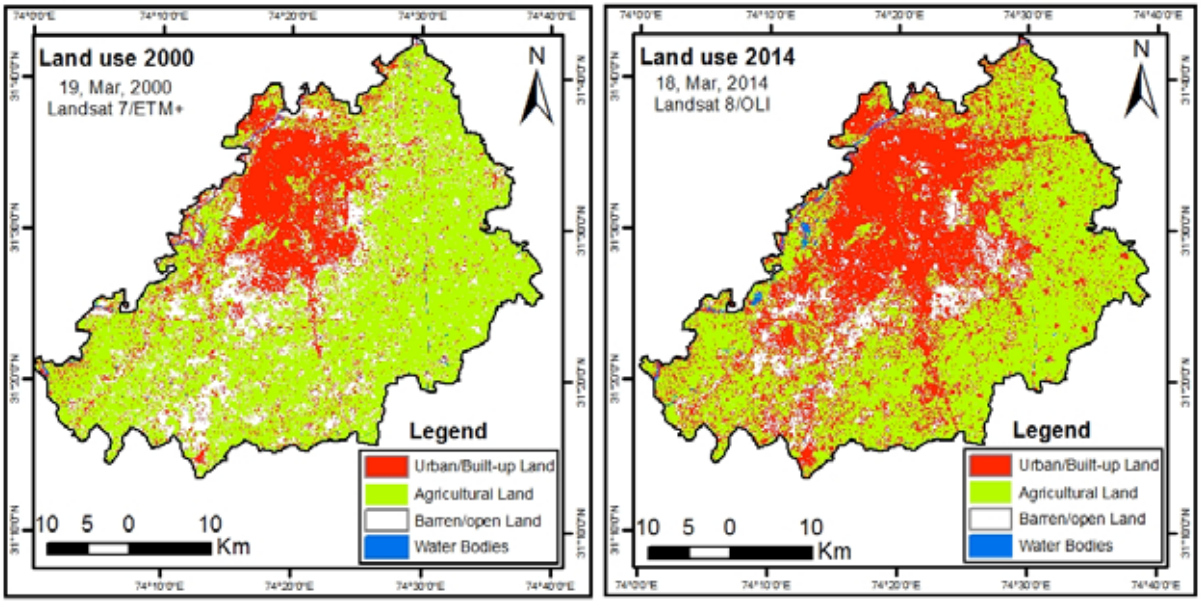

Figure: 4: Land use map of Lahore (2000-2014).

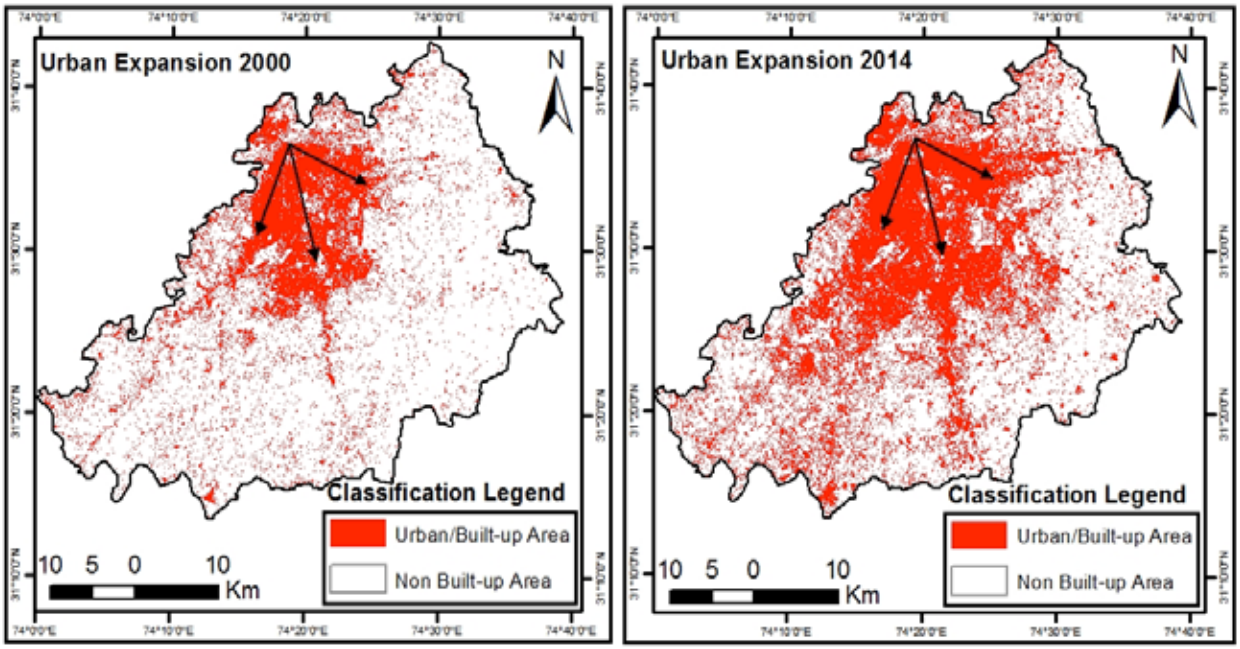

Figure 5: Temporal Urban expansion of Lahore (2000-2014).

is bounded by Pak-India border (Figure **5**). These natural barriers impose limitations on further urban expansion in all its features. The major expansion in the city of Lahore is observed along the major roads resulting in high density population, haphazard growth, air, noise and water pollution, and distribution of infrastructure along Ferozpur, Riwind and Canal road (Figure **5**). This haphazard growth and expansion led to a change in the land use profile of Lahore from agriculture to urban use. The land use patterns of the Lahore have been considerably modified due to urban expansion in the last few decades. The urban built-up area of Lahore has significantly increased at the cost of vegetation cover or partially barren land.

4.3. Urban Change Detection

The urban/built-up area of Lahore district was 395.53 sq. km in 2000. It increased to 556.95 Sq. Km in 2014, thus recording a growth of 40.81% (Table **3**). While there is a loss of agricultural and barren land 12.98 % and 6.64% respectively (Table **3** & Figure **6**). The fact is pertinent to be revealed that the loss of agricultural and barren land was converted to acquire urban expansion. The increase in population of Lahore is noted to be 6,319,000 in 1998 to 9,086,000 in 2014. This rapid population growth is one of the major factor for urban expansion in the city of Lahore and another reason for radical changes in land use of Lahore. The major expansion took place along Ferozpur road, Riawind road and Canal road. The expansion and physical growth of the city is observed in southeast, south and south-west direction. The Key factor behind the urban expansion in these directions is availability of open spaces & large parcels of land, connected roads, pollution free environment and accessibility and possibilities for the residents who reside far away from the center of the city.

The vegetation loss in the city has been caused by vacant pockets in the areas which are filled by the inhabitants. Besides being densification in the built up area, the establishment of residential as well as commercial schemes at the fringes, sub-urban zone and periphery is still gaining momentum. A larger number of housing schemes are introduced towards the south-west direction of Lahore. An assessment can be made as a corridor for the future development of the urban areas and their respective loss of agricultural lands. In this phase of Lahore, both private and public housing schemes are setting in a rapid and scattered way. This growth trend led to the ribbon expansion along Ferozepur Road, Multan and G.T. Road. It was observed that the Lahore city had grown in, Aziz Bhatti Town, Data Ganj Baksh Town, Wagha Town, Nishtar Town, and Raiwind.

5. CONCLUSION

Study highlights the use of geo-spatial techniques in analyzing the patterns of urban expansion and land use changes of district Lahore from 2000-2014. GIS and remote sensing techniques are very helpful in assessing the direction of the urban expansion and its

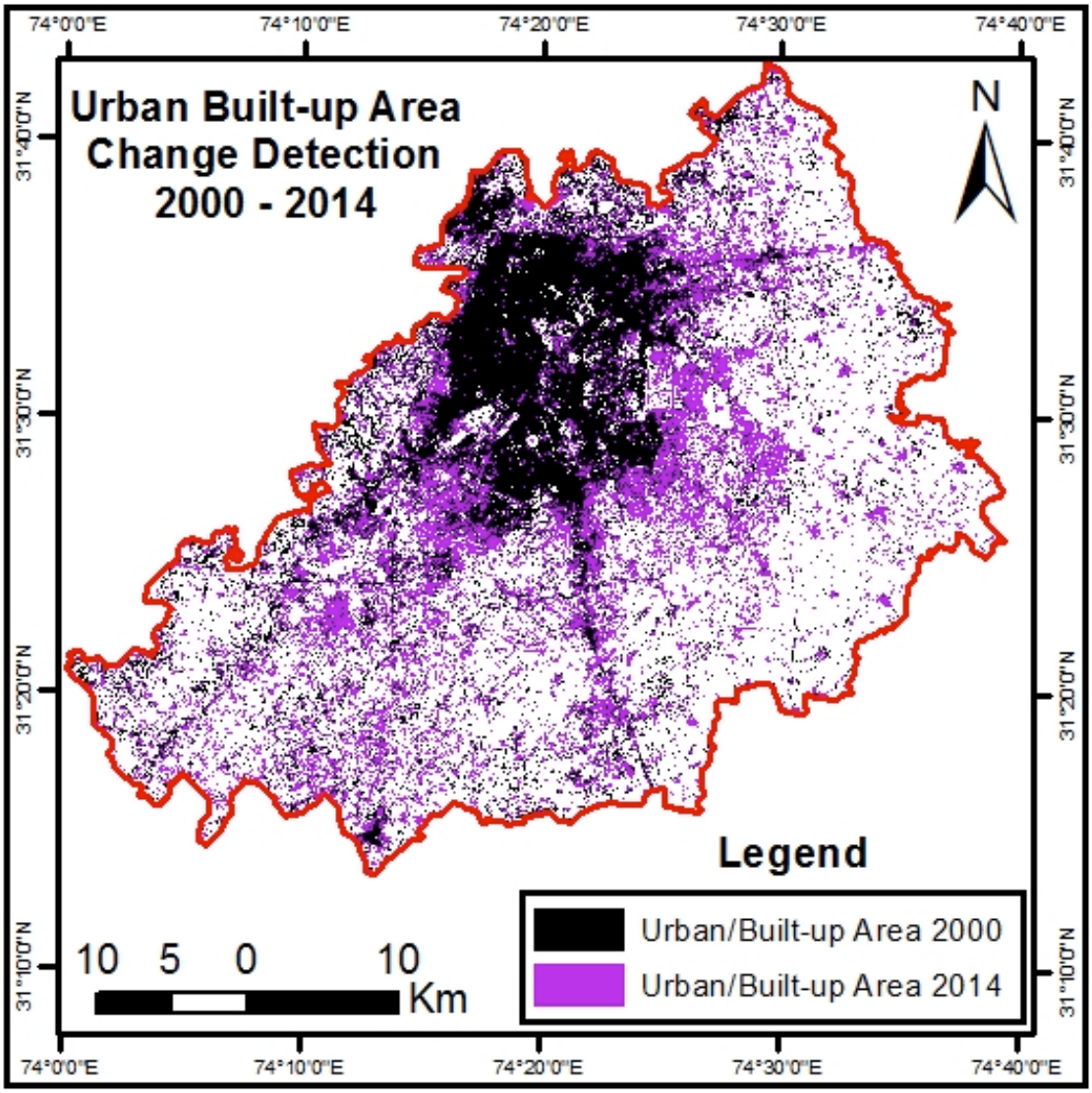

Figure 6: Spatial Urban Expansion of Lahore & Change Detection (2000-2014).

effect on existing land use type, as the change in urban land is a major geographic phenomenon in today's world. The encroachment of agricultural land for the purpose of urban land uses is global as well as local practice. Rapid Land use changes have been marked for a time period of 14 years in Lahore. As shown in the Table **3** and Figures **4, 5** and **6**, the increase in the area used for built up land is 395.53 Sq. Km. in 2000 to 556.95 Sq. Km. in 2014 (overall increase is 40.81 %), respectively. Subsequently, the area used for agricultural purpose and barren/open land has decreased in study span. This situation is alarming as the rapid increase will crop up associated problem related to the population residing in the newly acquired urbanized land use, which would enhance the necessity including housing and other amenities day by day. The economic development, increasing population growth, industrial growth & employment opportunities were the chief driving factors of changing land use and rapid urban expansion in Lahore, Pakistan. The expansion area was mainly distributed along the both sides of Ferozpur, Riwind and Canal road. The urban expansion trends can be seen in the directions of south-east, south and south-west. The key factor behind this expansion is the availability of infrastructure, connected roads, accessibility and possibilities for the residents who reside far away from the center of the city. North and north-east sides of the city are blocked by the River Ravi, while the area of district Lahore in east is restricted by the Pak-India border. These natural barriers impose limitations on further urban expansion and spreading out of population in those directions. The south-west direction of the city is the main focus of a number of housing schemes. These assessment on the part of the urban planner invites future development schemes related to

the vegetation loss and urban expansion. Integrating remote sensing & GIS provided valuable evidence on the nature & rate of land use changes, especially the spatial distribution and area of different temporal land use changes.

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