

REMOTE SENSING AND GIS APPLICATIONS FOR MONITORING AND ASSESSMENT OF THE URBAN SPRAWL IN FAISALABAD-PAKISTAN

M. N. Bhalli, A. Ghaffar* and S. A. Shirazi*

Department of Geography, Govt. Postgraduate College Gojra, Pakistan

*Department of Geography, University of the Punjab, Lahore, Pakistan

Corresponding author nasarbhalli@yahoo.com

ABSTRACT: Urban sprawl is a global phenomenon of present era and is mostly taking place in less developed countries. In LDCs there is a consistent and vibrant trend among the people to agglomerate in mega cities and large urban centers. This phenomenon has gained the attention of researchers in the fields of urban geography, environmental studies and city & regional planning. Keeping in view its importance, an attempt has been made to explore the use of geo-informatics techniques for the assessment of urban sprawl in Faisalabad city. The result inferred from the classified Landsat image for year 1980 revealed that the total built-up area of Faisalabad was 5661 hectares (26 per cent of total) while year 2010 classified Landsat image depicts that the total built-up area was 9480.44 hectares (44 per cent) of the City. The total areal change for 30 years research span (1980-2010) was 44 per cent in built up land, contrary to this non built-up /open area decreased to 32 per cent during the same period. The total area in 1980 was 102 sq. km while the city grew up to 213 sq. km by year 2010. This appreciable change in built up lands was at the expense of fertile agricultural tracts once part of the fringe of Faisalabad city.

Key words: Urban Sprawl, Urban Expansion, Assessment, Geo-informatics.

INTRODUCTION

Today rapid urban growth is a worldwide phenomenon. Like many other human-induced land use and land cover changes, urbanization portrayal and signifies, better socioeconomic, political, demographic and environmental conditions, characterized by an exceptional attention of human population into cities and urban areas (Masek *et al.*, 2000). Influx of people, predominately from rural to urban areas throughout the world is taking place at alarming rate, particularly in developing countries (Kumar *et al.*, 2007) such as Pakistan. The cities and urban centers offer sufficient opportunities of industrial growth, employment, health and academic facilities along with better socio-economic conditions (Ghaffar, 2007) which are the main reason for migration of people from surrounding country side to Faisalabad city, Pakistan. Due to this massive rural-urban migration, the rapid growth has legitimated various problems including congestions and land use issues for the inhabitants and for the city planners and managers. Among many of such problems, few are the agricultural land loss, unplanned residential areas, high value of arable lands, real estate and developer's speculations about land values, degradation of civic environment and other related issues (Maktav and Erber, 2005). In order to investigate these issues on scientific grounds, the present research has been under taken. The integrated use of GIS & RS techniques has been used to identify the spatial and temporal dynamics of urban sprawl in Faisalabad city.

With an advent of remote sensing and GIS techniques augmented with satellite images, a new era has offered canvas for monitoring, assessing and mapping urban sprawl pattern. This has also benefitted the urban planners and geographer to predict the urban sprawl more effectively than the conventional approaches (Okabe, 2006). Spatial data of historical nature of urban landscape acquired from the Landsat satellite images, land use maps and topographic sheets have been utilized in this study. It also contributes to the existing literature relating to use of geospatial techniques to identify and analyze the urban sprawl in Faisalabad city- Pakistan. The study has been conducted with two objectives in mind: firstly to evaluate urban sprawl in Faisalabad city through geo-informatics techniques and secondly to identify the extent and rate of spatial growth patterns of built-up land in the City.

MATERIALS AND METHODS

Study Area: In order of population size, Faisalabad is the third largest city of Pakistan. It is situated between 30°42' and 31°47' North latitudes and 72°40' and 73°40' East longitudes. It is an important industrial center, located in the central Punjab province of Pakistan, about 130 kilometers west of Lahore. The population of Faisalabad is growing rapidly in the past few decades. At present its estimated population is about 6.7 million, out of which about 40 per cent or 2.7 million lives in Faisalabad city with a growth rate just below 3 per cent (CDGF, 2010). In future with a continuous decline in birth rates in

Pakistan, the rate of population growth is likely to be under 2 per cent per annum. However, it is estimated that

by the year 2025, Faisalabad will be a city of over 4 million people.

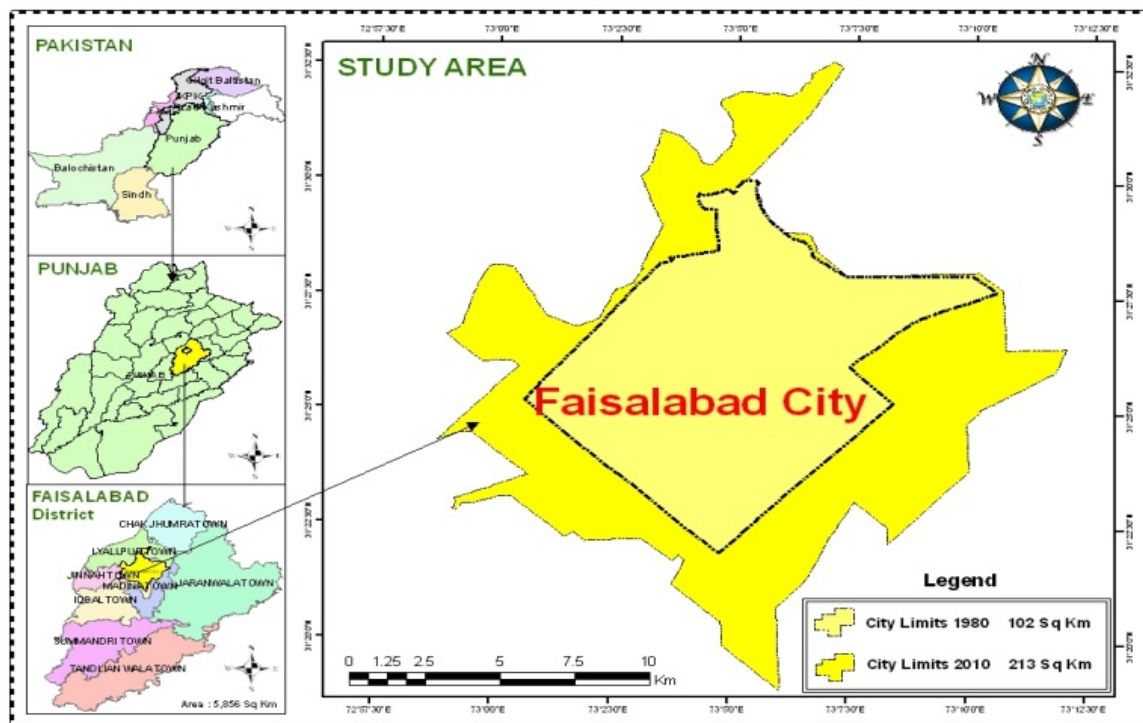


Fig. 1: The study Area Faisalabad City

Source: Bhalli, 2011

Faisalabad is located on a fairly flat plain, with adequate open/vacant lands to meet the future needs. The city is well connected to other cities of the Punjab as well of Pakistan. This peculiar location in itself has demonstrated a strategic importance in the national urban order. The rapid strides made in the national system of motorways-Faisalabad lies on the major roads like M3 highway, which connects it to Islamabad and Lahore through Motorway (M2), and in near future to Multan-Karachi via M4 (CDGF, 2010). The district Faisalabad has an aerial extent of 5,856 sq. km. with 1295 sq. km area under metropolitan City District Administration. The present study is limited only to Faisalabad city with an area of 213 sq. km.

In order to carry present research, remotely sensed Landsat images for a period of 1980-2010 have been used. The SRS data is an efficient and effective tool in urban studies as it is in expensive, flexible and easily accessible to be utilized in quick updating of maps than aerial photographs (Ishaya *et al.*, 2008). In order to achieve our objectives through spatial data analysis related to the chronological nature of urban land use, five Landsat satellite images were acquired through multi-date and multi-source from 1980 to 2010. These satellite images were downloaded from the USGS Earth Resources Observation Systems data center while the

vector layer of Faisalabad city was acquired from the office of Faisalabad Development Authority. The secondary /statistical data was acquired by the District Census Report of Faisalabad published by Census Organization of Pakistan and found useful for spatial analysis (Bhalli, 2011). In addition to this Economic Survey of Pakistan and Punjab Development Statistics (for various years), were also been consulted. Finally, topographic maps, union council maps, land use maps ,strategic development plans, reports and other maps prepared by FDA and City District Govt. Faisalabad, Urban Unit, Govt. of Punjab, Lahore have been consulted for analysis.

The following remote sensing imageries (Fig. 2) were utilized to extract the urban built-up land of Faisalabad City. All the Landsat satellite images and their traits have been presented in Table 1. The Landsat images are widely in use as SRS data and provide vital support for planning, monitoring and mapping of cities because of their spatial, temporal and spectral resolutions (Sadidy *et al.*, 2009).

The Landsat imageries were acquired by standard procedures, i.e. radio metrically and geometrically rectified digital data (Bhatta, 2009). Initially, different bands of the land sat images were stacked to get false color composite image (Jensen,

2004). The vector layers of Faisalabad city were used to clip and subset the Landsat imageries from a complete scene. Composite false color images were again subset for clipping the study area. The comparison of classified images has been made to detect the change patterns of the study area. The digital image classification of the satellite images was imperative for this purpose (Bhandari, 2010). The image classification is a process whereby the total pixels in the image are categorized into a land use class or theme (Lillesand and Kiefer, 2000).

In present study, we have employed the supervised digital image classification scheme upon the Landsat satellite images pertaining to the year 1980, 1992, 2000, 2005 and 2010. These chronological Landsat imageries have been used as basic tool for the determination of image analysis. At the later stage, co-registered images were clipped by the vector layer of Faisalabad city.

Table 1: Description of Landsat image data

Year	Sensor	Resolution	Path/Row	Date of Acquisition
1980	Landsat MSS	80 m	161/38	20-11-1980
1992	Landsat TM	30 m	149/38	20-09-1992
2000	Landsat ETM+	30 m	150/38	10-11-2000
2005	Landsat ETM +	15 m	150/38	16-09-2005
2010	Landsat ETM +	15 m	149/38	10-03-2010

Source: GLCF, <http://glcf.umiacs.umd.edu>

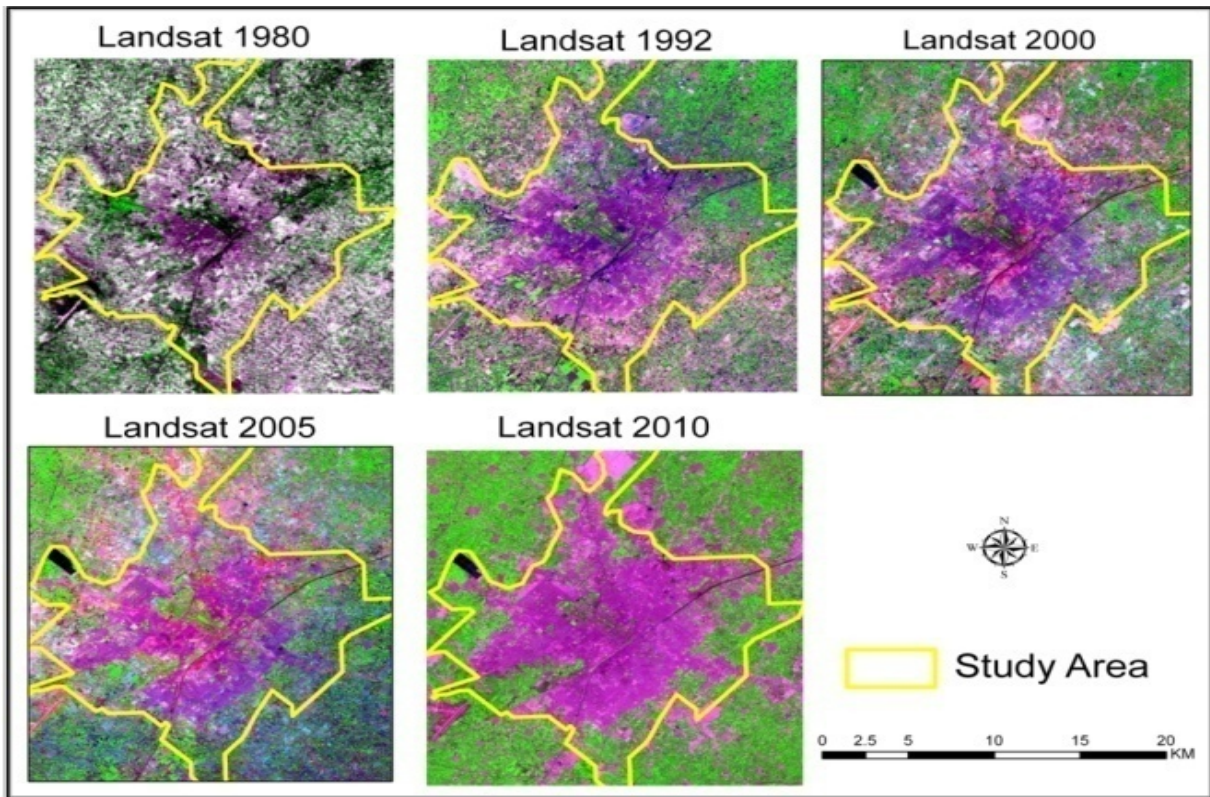


Fig. 2: Landsat Imageries Used for Supervised Classification

Source: GLCF, <http://glcf.umiacs.umd.edu>, Bhalli 2011

The clipped images were then classified using a Maximum likelihood algorithm, nonparametric parallelepiped classifier to extract the built-up area from this research (Almeida *et al.*, 2005). It is pertinent to mention that since this research is dealing with the urban sprawl therefore, built up (urban) and open/vacant (non-urban) land use classes have been identified therefore simple binary classification of remote sensing

data is adequate for the purpose (Bhatta, 2009). An overall accuracy assessment of the temporal Landsat images for the five epoch viz; 1980, 1992, 2000, 2005 and 2010 have resulted in 73, 76, 75, 85 and 86 per cent respectively and is in good agreement with previous researches of similar nature. The results derived from the digital image classification carried weight while taken as a whole. The producer's accuracy assessment ranged

from 55 per cent to 100 per cent while the user's accuracy assessment for every selected category ranged from 71 per cent to 100 per cent (Bhalli, 2011).

RESULTS AND DISCUSSION

The use and application of SRS data in urban development, sprawl analysis and sustainable planning is a major field of research all over the world among the researchers (Chang, 2002; Herold, 2003; Sudhira *et al.*, 2004). Urban sprawl always remained an important area of research in relation to RS and GIS applications in academic circles the world over (Huang *et al.*, 2009; Zhang, 2009). Consequently, the application and use of Remote Sensing and GIS provide an alternative for urban sprawl to be effectively mapped and monitored (Weng, 2010). Such technologies like geo-informatics advance important methodologies to resolve spatial problems and consequently play a vital role in sustainable urban sprawl management. The use of geo-informatics techniques helps to identify the patterns of urban sprawl, its extent, nature and rates. It can also be employed to determine future planning and scenario as well (Otoo *et al.*, 2006).

The assessment of sprawl and urban landscape has been a key issue in urban geography, which emphasizes on the location, development and spatial

arrangements of towns and urban center. The study of urban sprawl is a pertinent topic for analysis and assessment for the sustainable development of the city. As mentioned before, the urban landscape of Faisalabad City has been monitored and mapped using RS and GIS techniques. In order to study the factors behind the nature of its physical expansion, digital data layers have been generated and have analyzed in GIS to create a spatial database of these layers. Furthermore, population data have also been used to augment the results obtained through image analysis.

The findings of this research reveal that the total area of Faisalabad in 1980 as calculated through Arc GIS 9.3 was 102 sq. km. (Fig. 3). While an areal growth of 168 sq. km. have been observed in 1998. This is largely because of the initiatives taken by the private sector by inducing new colonial infrastructure like Motorway city and FDA city in Faisalabad city area. This has resulted into an increase in the land values in study area. Further, mass influx and resettlement of the people from adjoining villages also added into its land consumption rate which ultimately altered from agricultural land use to build up land use. This is the major reason responsible for this unprecedented areal increase in the city up to 213 Km² in 2010 (Fig. 3).

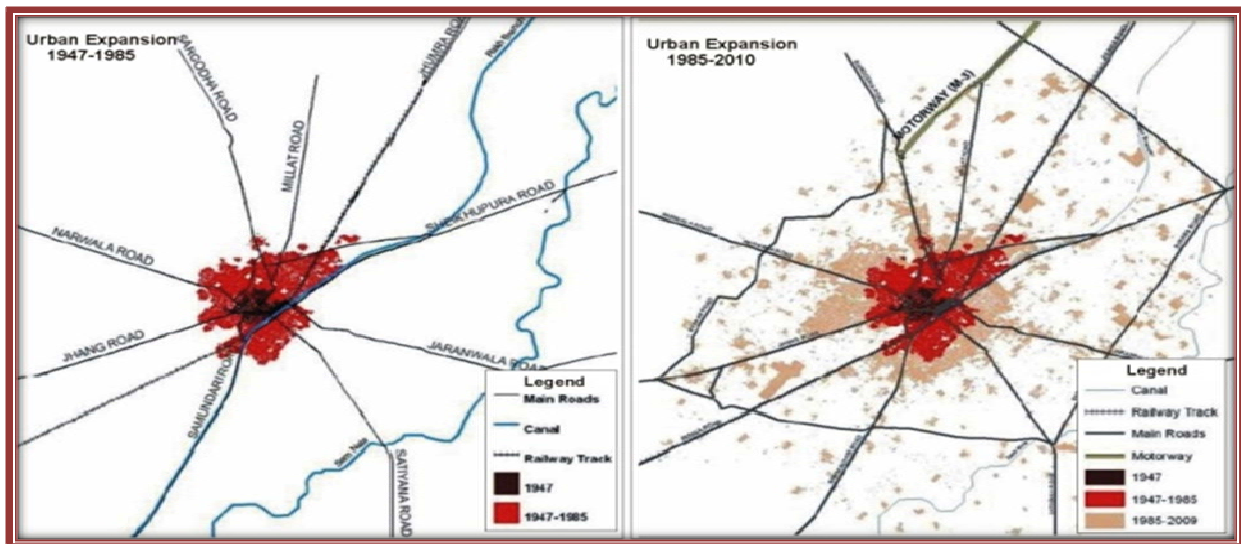


Fig. 3: Urban Expansion of Faisalabad 1947-2010

Source: Quershi, 2011

Table 5: Area Change in Hectare and % of urban land

Land Use type	Area In hectare				Area Change In %					
	1980	1992	2000	2005	1980	1980	1992	2000	2005	1980
	-	-	-	-	-	-	-	-	-	-
	1992	2000	2005	2010	2010	1992	2000	2005	2010	2010
Urban/ Built Up land	+502.11	+1221.3	+906.9	+1189.1	+3819.4	+9	+20	+12	+14	+40
Non- built Up land	-502.1	-1221.3	-907	-1189	-3819.4	-8	-8.	-6	-9	-32

Source: Bhalli, 2011

The results of 1980 Landsat image reveals that the city's urban/ built-up area was 5661 hectares (26 per cent) of the total area of 213 sq. km. While for the year 2010 from the classified Landsat ETM+ image demonstrates a total urban land /built-up area was 9480 hectares (44 per cent) of the total area (213 sq.km). A total built-up land in research area-Faisalabad during 1980-2010 was 40 per cent while 32 per cent decrease has been

witnessed in the non-built-up area (Bhalli, 2011). The latest data i.e.; the 2010 image demonstrates a rapid and massive transformation of agriculture land to urban built-up land. This substantial transformation from agricultural land use to urban built-up zones is noticeable from the earlier existing built-up land maps and thus it can be concluded that the urban sprawl has been taken place at the expense of fertile agricultural land parcels.

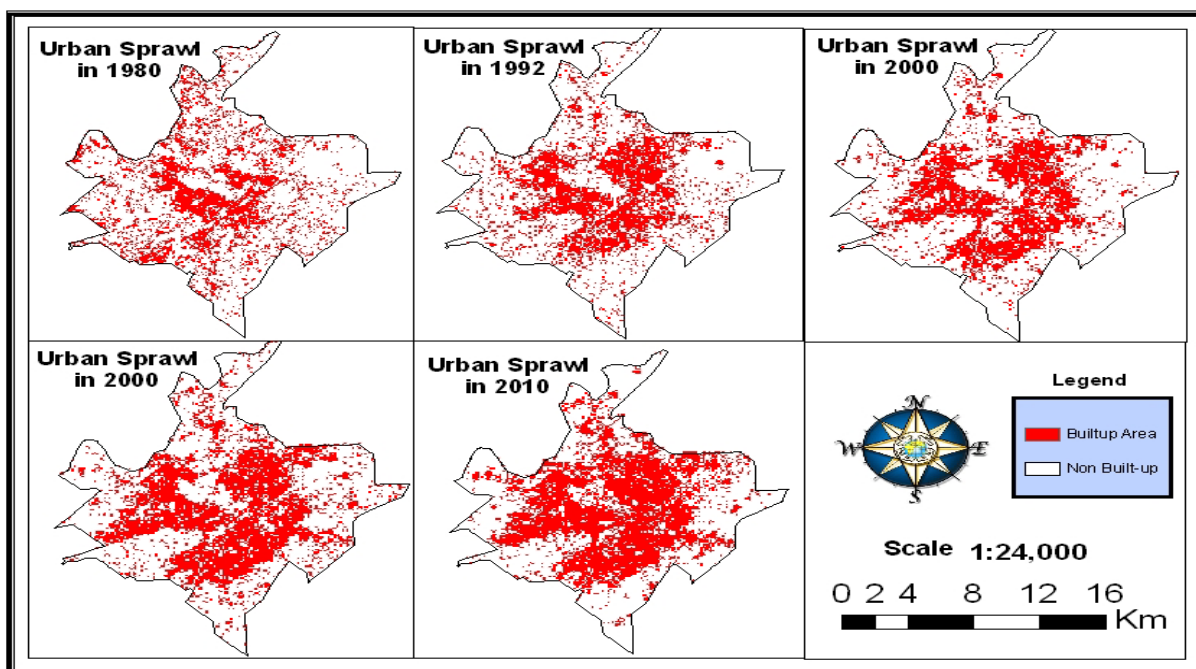


Fig. 4: Urban Sprawl in Faisalabad city 1980-2010

Source: Bhalli, 2011

Several factors are responsible for present patterns of sprawl and are persistent towards a definite direction. Among these factors one is the accessibility through various transportation nodes which has led to creation of new residential neighborhood alongside these nodes. This is one of the factors which foster a steady and persistent growth in the city. It is therefore, argued that an efficient transportation system plays a significant role in urban sprawl and its spatial trend dynamics. The second potent factor contributing in the present growth of city could be the industrialization. With the establishment and growth of industrial enterprises, population is being attracted from adjoining rural neighborhoods for a prosperous future in Faisalabad city.

In addition to these two, tertiary activities like services, commercial and other activities have also been contributed in the spatial spread of city. In other words, road network and transportation provide the direction of growth but industrialization has shown substantial impact on the rapid growth of the city. If we compare Faisalabad with other canals colonies of the Punjab, we can infer that it has a major advantage due to its geographical location

in the province. It is well connected to other cities of Punjab as well as with the rest of Pakistan. Faisalabad is linked to M 3, the Islamabad-Lahore M 2 and soon by M4 to Multan and then Karachi (Bhalli, 2011). In future Faisalabad's expansion is expected to be governed by construction of main roads, particularly the one like M4 motorway, which will link the city to Nar'wala and Jhang road to the West. With the establishment of new industrial zones in North and North-East, accessibility to existing developed and an easy approach towards South (along Jhang Road towards City's Airport) is also a contributing factor in City's spatial growth. It is likely that in the quadrant between Jhang and Sargodha roads, future growth will also take place. It is further argued that the urban development is likely to get momentum if redevelopment and regeneration of inner-city areas will be the policy of city managers, especially if more industrial units shifted to the newly established estates outside the City.

Conclusions: This study has explored the utility and potentials of geo-informatics techniques for a sustainable development with regard to urban sprawl, agricultural

land losses. It has also studied the management of other ecological and natural resources and its effects on the surface features in the environs of Faisalabad city. The urban built-up area and open land have increased to all directions with a major increase in urban built-up category with a development in both the North West and South West of Faisalabad city. The phenomenon of urban sprawl in Faisalabad city is noteworthy because of some similar socio-economic conditions prevalent in neighboring countries of the region of South Asia besides its industrial potentials. Further research can be carried out to evaluate the patterns of urban sprawl, amalgamation of villages into city and loss of agricultural fields on more rigorous basis using and integration of the state the art technologies like Remote Sensing and GIS.

REFERENCES

- Almeida, C. M., A. M. V. Monteiro, G. Mara, B. S. Soares-filho, G. C. Cerqueira, C. S. L. Pennachin and M. Batty. GIS and remote sensing as tools for the simulation of urban land-use change. *Intl j. Remote Sensing*, 26:759–774 (2005).
- Bhandari, S. Urban change monitoring using GIS and remote sensing tools in Kathmandu valley, Nepal. Thesis unpublished, (M.Sc.). University of Munster, Germany (2010).
- Bhalli, M. N. A GIS based analysis of spatial patterns of urban growth in Faisalabad city 1981-2010. Thesis unpublished, (M.Phil.). GC University Faisalabad, Pakistan (2011).
- Bhatta, B. Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India. *Intl J. Remote Sensing*, 30(18):4733–4746 (2009).
- CDGF, *Pre-Feasibility Study for Urban Transport and Industrial Waste Management Faisalabad*. Faisalabad: City District Govt. Faisalabad, Pakistan (2010).
- Chang, K. T. Introduction to Geographic Information Systems: McGraw-Hill Companies Inc. (2002).
- Ghaffar, A. Patterns of urban growth in the Punjab 1951-1998. *Pakistan Geographical Review*, 62 (1): 31-44 (2007).
- Herold, M., N. C. Goldstein and K. C. Clarke. The spatiotemporal form of urban growth: measurement, analysis and modeling. *Remote Sensing of Environment*, 86(3): 286-302 (2003).
- Huang, B., L. Zhang and B. Wu. Spatiotemporal analysis of rural-urban land conversion. *Intl J. Geographical Information Science*, 23(3): 379-398 (2009).
- Ishaya, S., O. O. Ifatimehin and C. Okafor. Remote sensing and GIS applications in urban expansion and loss of vegetation cover in Kaduna town, northern Nigeria. *American-Eurasian Journal of Sustainable Agriculture*, 2(2): 117-124 (2008).
- Jensen, J. R. Introductory image processing: A remote sensing perspective. New Jersey: Prentice-Hall (2004).
- Kumar, J. A. V., S. K. Pathan and R. J. Bhandari. Spatio-temporal analysis for monitoring urban growth: A case study of Indore city. *J. Indian Society of Remote Sensing*, 35:11–20 (2007).
- Lillesand, T. M. and R. W. Kiefer. *Remote Sensing and Image Interpretation*. 4th ed. John Wiley and Sons, New York (2000).
- Maktav, D. and F. S. Erber. Analysis of urban growth using multi-temporal satellite data in Istanbul, Turkey. *Intl J. Remote Sensing*, 26:797–810 (2005).
- Masek, J. G., F. E. Lindsay and S. N. Goward. Dynamics of urban growth in the Washington DC metropolitan area, 1973-1996, from Landsat observations. *Intl J. Remote Sensing*, 21(18): 3473-3486 (2000).
- Okabe, A. *GIS-Based Studies in the Humanities and Social Sciences*. USA: CRC Press Taylor & Francis (2006).
- Otoo, E. A., D. J. Whyatt and U. E. Ite. Quantifying urban growth in Accra metropolitan area (ama), Ghana and exploring causal mechanisms. England promoting land administration and good governance 5th fig regional conference Accra, Ghana (2006). Available from: http://www.fig.net/pub/accra/papers/ts10/ts10_0_otoo_et al.pdf [Accessed: 20 September 2010].
- Quersh, P. L. Urbanization & urban planning issues. Urban Form 2011, Urban Unit Lahore, Pakistan (2011).
- Sadidy, J., P. Z. Firouzabadi and A. Entezari. The Use of Radar sat and Landsat Image Fusion Algorithms and Different Supervised Classification Methods to use Map Accuracy: A Case study Sari Plain Iran (2009). Available from: http://www.cirgeo.unipd.it/cirgeo/convegna/mmt2007/proceedings/papers/sadidy_javad.pdf [Accessed 15 May 2009].
- Sudhira, H. S., T. V. Ramachandra and K. S. Jagdish. Urban sprawl: metrics, dynamics and modeling using GIS. *International Journal of Applied Earth Observation and Geoinformation*, 5: 29–39 (2004).
- Weng, Q. *Remote Sensing and GIS Integration; Theories, Methods, and Applications*. McGraw-Hill Companies Inc. (2010).
- Zhang, Q. Spatial-temporal patterns of urban growth in Shanghai, China: monitoring, analysis, and simulation. Thesis Unpublished, (PhD). Stockholm University, Sweden (2009).