Four Decade Land Degradation in Capital City of Islamabad Pakistan during 2017-2019- A Comparative Assessment

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Abstract

The study of Land Use Land Cover (LULC) changes and their patterns enhance our understanding of the causes and consequences of various natural and man caused phenomenon. The Capital City of Pakistan, Islamabad has expereinced high rate of urbnization and population increase in the last 3-4 decades. The main aim of our study was to provide compatible data on LULC change during the last 40 years for the functional city Islamabad, Pakistan. LULC statistics were extracted from Landsat Multi-spectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) images. For each of the target years (1979, 1989, 1999, 2009 and 2019) LULC information was obtained through a supervised classification algorithm. The study area was classified into five major landscape categories, namely built-up, agriculture, forest, water bodies and barren land. The results have indicated that the urban expansion has been increasing due to mass migration and uncontrolled urbanization in the city. The urban sprawl analysis revealed that built-up area and farmland has expanded by 41.7% and 5.20% during (1979-2019). On the other hand, the forest and water bodies declined from at 9.03% and 1.21% respectively. The land degradation has forced the planners to revise the original master plan of the city and including the agricultural sector in the housing area during 2019. This degradation of land has also led to increase in the temperature of the city.

Introduction

The rapid modification of Land Use and Land Cover (LULC) by human activities are well recognized worldwide. The rapid population growth, urbanization and economic development have significantly altered the Earth's terrestrial surface processes, which causes undesirable impacts on environmental attributes at a local, regional and global level (Verburg and Overmars, 2007). The monitoring regarding land use land cover change has become a fundamental component in recent strategies for managing natural resources (Lambin, Geist, and Lepers, 2003). In recent decades, LULC change studies has emerged as an important research question due to abrupt LULC changes which are responsible for natural landscape modification worldwide (Xiao et al., 2006). Though it is possible to detect and monitoring LULC by traditional surveys and inventories, however, Geographical Information System (GIS) and Remote Sensing (RS) techniques are more advantageous in terms of temporal, time saving and cost effectiveness, as well as future monitoring of LULC (Yuan *et al* ., 2005). It is very important to have historical, persistent and accurate data on LULC of the earth' surface for sustainable development program in which LULC work as one of the main input criteria (Elkawy *et al* ., 2010).

The land cover change detection and monitoring by various disciplines found that LULC has diverse applications such as ecology, environment, hydrology, forestry and geology. Urban landscape change is a major concern for eco-friendly and sustainable development for the economic growth of any area. The abrupt urban LULC such as unregulated development, loss of agriculture lands, soil erosion, deforestation, damage of wildlife habitat and pollution are very harmful for the environment (Weng, 2001; Hassan et al., 2016). Urbanization and urban sprawl is one of the main causes, which re altering the land cover of the earth's

surface. The process of urban complex is determined by the interactions of environmental and human factors in different spatio-temporal scale. In the past decades, urban sprawl has been studied widely due to the increasing interest in environmental issues and challenges (He *et al* ., 2006; Kamh et al., 2012).

Sporadic development of urban inhabitants and its footprint on the urban environment has been widely reported. Urban expansion can lead significant environmental modification as main ecosystem services, such as availability of water, food, raw material, natural vegetation and landscape beauty, may degrade as a result of rapid growth of urban areas (Sieber and Pons, 2015; Manzoor et al., 2018). Studies indicates the effects of unplanned urban growth on ecosystem services and to incorporate the evaluations into urban management plans. For instance, environmental carrying capacity of a landscape can be assessed by its ecological footprint and bio-capacity, and identified whether a given development activities is consistent with particular environmental targets, hence assisting to develop environmental sustainable spatial plan for future urban expansion (Świąder, Szewrański and Kazak, 2018; De Jung et al., 2018). It is essential to identify Ecosystem Services Bundles (ESB) and socio-cultural preferences in urban landscape development where human-environmental relations creates desirable or undesirable ecosystem services (Raudsepp-Hearne, Peterson and Bennett, 2010; Spake et al., 2017).

The world's most populous cities are located in developing countries, therefore, rapid and unplanned urban expansion produces server impacts on ecosystem services and facing difficulties and challenges in urban landscape management. Although, in developed countries consequences of rapid urban expansion are repeatedly documented (Jafari *et al.,*2016). LULC studies in developing countries like Pakistan, remain scant. In South Asia, Pakistan is a fastest urban growing country, the process of urbanization increased due to rapid population growth as well as industrial expansion, economic and social activities and intensive use of land resources. In Pakistan the annual growth rate of urban population is nearly 2.5 percent (Shaikh and Ijaz, 2018). In the last two decades, Punjab province of Pakistan has experienced rapid population growth and economic development accelerated the process of urbanization and caused extensive deforestation, agricultural land to build up area and environmental degradation (Lee *et al* ., 2017, Pakistan Bureau of Statistics, 2018). The country has cover only 3% of forest whereas government aimed at 7% forest by 2015 which has not been achieved yet; forest cover of 20-25% is needed for a stabled economy (Manzoor et al., 2018; Zizinga *et al* ., 2018). Recently, China-Pakistan Economic Corridor (CPEC) project is likely to have impacts on socioeconomic conditions of the provinces

Not many studies on LULC changes have been conducted in urban areas of Pakistan and for Islamabad in particular. For example, Hassan *et al* . (2016) conducted a study using GIS and remote sensing methods at capital Islamabad area. They observed increase in agriculture area, build up area and water bodies from 1992 to 2012. Samie *et al* . (2017) scenario based analysis indicated that cultivable and build up land would expand, the findings mentioned sustainable land use planning and management in Punjab province is essential. Therefore, regular and up-to-date data on urban sprawl is needed for urban planning, land use management and for proper distribution of services and infrastructure within the urban area. Islamabad city is a functional city, rapid LULC change due to population growth, economic development and climate change resulted in wide range of environmental impacts, including degraded habitat quality (Hassan et al., 2016). While remote sensing technology has been the main provider of cost-effective, high quality datasets for land surface management and monitoring in the past decades (Lunetta et al., 2002). Pakistan urban areas needs an appropriate interdisciplinary policy guideline and political wills to device a sustainable management and protection of forest, vegetation and ecological sensitive sites. In this context, the main objective of the study was to assess the nature, significance and rate of land cover change from 1979 to 2019 based on the analysis of satellite Imagery.

Materials and methods

In this study, we focus on Islamabad, the capital city of Pakistan and come under Federally Administered Capital Territory. Islamabad was planned as capital city of the country, in the 1960s to replace Karachi. It is located in the northeastern part of the country, between 33^{o} 49′ North latitude and 72° 24′ East longitude, at the crossroads of Punjab and Khyber Pakhtunkhwa provinces with the Margalla pass as the gateway between

the two regions. The total area of Islamabad is 906 square kilometers including diverse geographic features and land cover. Islamabad lies at an altitude range of 457-610m. The monsoon and western disturbance are the two main factors that change the weather over the Islamabad, according to *Koppen* climate classification system Islamabad has a humid subtropical climate. The average monsoon rainfall of Islamabad is 790.9 mm, June is the hottest moth, where average temperate is 38 °C. The map of study area shown in Fig.1.

Data collection

Data obtained was divided into satellite data and ancillary data. Ancillary information acquired through ground truth data of the land cover classes, topographic maps. Census data is also attributed to the respective locations of classes to make various analysis of social significance. The ground control points were in the form of reference data points gathered using Global Position System (GPS), applied for image classification and overall accuracy assessment of the image classification results. Satellite data for the 40 years consisted of multi-spectral data developed from Landsat satellite mission data provide by USGS glovis. The specifications of MSS, TM, ETM, OLI and Sentinel-2 are given in Table 1. All the sensors have different characteristic in terms of spectral, spatial, temporal and radiometric resolution.

Image pre-processing and classification

Satellite image pre-processing is an improvement of satellite data that suppresses unwanted distortions and main objective to generating a more direct linkage between the obtained data and real world phenomena (Coppin et al., 2004; Butt, et al., 2015). Satellite data were preprocessed in ERDAS imagine 14 software for layer stacking, mosaicking, and subsetting of the image on the basis of Area of Interest (AOI). All image data were assessed by allocating per-pixel signatures and distinguishing the Islamabad capital into five classes with reference to specific Digitial Number (DN) value. The identified land cover classes were built-up area, agriculture, water bodies, forest and barren land (Table 2). For the individual pre-determined land cover type, training sites were identified by demarcating polygons around representative sites. In this study, for supervise classification thirty spectral signatures for each class were taken from the each satellite imagery by using the pixels enclosed by these polygons. According to Gao and Liu (2010) an adequate spectral signature is the one ensuring that there is minimal confusion among the land covers to be mapped. The maximum likelihood algorithm was applied for supervised classification of the images. Supervise classification is mainly controlled by the analyst as the analyst choose of the pixels which demonstrate the desired classes. For medium spatial resolution data, such as Landsat mixed pixels are a common problem, especially for the urban surfaces are a mixture of features such as build-up land, grass, trees, roads and water. For the improvement of classification accuracy and to produce quality of land LULC maps, visual interpretation is very important. Therefore, with help of field observations, reference data as well as local knowledge can improve the results acquired using the supervised algorithm (Jensen and Im, 2007; Butt et al., 2015).

Accuracy assessment

Assessment of classification accuracy is the procedure used to quantify the reliability of classified image. Accuracy assessment of image classification 1979, 1989, 1999, 2009 and 2019 images were carried out to determine the quality of information obtained from the data. For each classified images it is essential to perform an accuracy assessment in order to obtain a useful data for the change detection and analysis (Owojori and Xie, 2005). In this study stratified random sampling was done by comparing the reference image with classified image with some random points. The accuracy assessment was obtained using 50 random points of every classified image. In addition, a nonparametric Kappa test was also applied to assess the extent of classification accuracy.

Land use/cover change detection and analysis

For performing LULC change detection, post-classification change detection technique, performed in the ArcGIS 10.5 was used in the study. Various researchers have used post classification for the urban land cover change detection and analysis (Hardin et al., 2007). In this study, to measure the quantity of conversion from a particular land cover to other land cover category and their corresponding area over the evaluated period,

cross tabulation analysis on a pixcelby-pixel basis was conducted. Thus, the data of the overall LULC change as well as gains and losees in each class between 1979 and 2019 were then compiled.

Results and Discussion

In this study, Landsat satellite imageries were used to classify the LULC change in class transition. The classified LULC maps of Islamabad for four decades are presented in Fig.2. In addition, the LULC change in class areas is graphically shown in Fig 3. The achieved overall classification accuracy of LULC maps for the years 1979, 1989, 1999, 2009 and 2019 were 90.5%, 91.13%, 95.32%, 94.44% and 95.1%, respectively. The overall Kappa statistics of the agreement were 0.90, 0.92, 0.94, 0.92 and 0.93 respectively. In the image classification process, the accuracy assessment is an important component. According to Lea and Curtis (2010), the Kappa statistics above 0.9 and overall classification accuracy above 90% indicate a successful classification which succeeded in the present study. The individual LULC class area statistics and rate of change over the various study periods are summarized in Table 3.

The image classification results indicated that the total land area of Islamabad is 906.62 km^2. Our results showed that in 1979 approximately 10.7% of the land was covered by build-up land and 14.3% by agriculture and 19.3% by forest and 1.7% by water bodies, adding up to 53.1% of the land area as barren. Whereas, our result indicated that in 2019 approximately 52.4% of the land was covered by build-up land and 19.5% by agriculture and 10.3% by forest and 0.7% by water bodies whereas 17.1% of the land area was covered by barren land. The results revealed that a major expansion with respect to area coverage in Islamabad city was observed in built-up and agriculture land whereas, the forest and barren areas were declined. The assessment of individual class of 1979 and 2019 indicated that there has been a noticeable LULC change during the study period of 4 decades. According to an earlier study (Hassan et al., 2016) that in Islamabad city rapid development has been observed in agriculture, commercial, industrial and urban. This significant trend of LULC use change in urban centers reinforces that increase economic development, population growth, traffic infrastructure, administrative services, topographic and geographic are the major factors of change in land (Mundia and Aniya, 2007; Butt et al., 2015). According to Hassan et al. (2016), the main driving factors of rapid expansion in LULC of Islamabad city is increased in economic activity, population growth and climate change. Rapid development in commercial, industrial, residential and expansion in agriculture land into forest and barren land has been observed in surrounded areas of Islamabad. The barren and the forest area near the population has been cleared for the residential, commercial and agricultural production in order to fulfill the basic necessities of life (Hagler Bailly, 2007).

The results presented in Table 4 and Fig. 2 depict that both negative and positive change followed in the LULC pattern in the Islamabad city of Pakistan. During the period of 1979-2019, the area and amount of change in the build-up and agriculture has account +41.7%, +5.2% added of the total urban sprawl whereas, forest (-9.03%), water bodies (-1.21%) and barren areas (-36.8%) were subtracted in the study area. To understand land expansion in various LULC categories, a change detection matrix (Table 5) was developed which indicate class conversions during the last four decades (1979-2019). The conversion between various LULC categories in different years were studied using cross-tabulation matrix method of Pontius and others (2004).

According to cross tabulation, barren land was converted primarily to build-up and agriculture land. About 417.45 km^2 gained by build-up class from barren land as well as from other classes while only 39.87 km^2 area converted to other classes. The LULC with respect to build-up land primarily due to rapid population growth and economic development. The area of forest lost about 85.78 km^2 while only 21.85 km^2 gained from other landscape categories. The rapid expansion of residential, commercial, industrial and infrastructure as well as political driving forces contributing to the decline in forest, vegetation and barren areas (Butt et al., 2015; Hassan et al.,2016). In urban LULC build-up land obtained by changing areas that were previously barren land, agriculture, vegetation, water bodies, which indicate that the existence of high pressure on natural resources to fulfill the growing demand for urban land (Dewan and Yamguchi, 2009). Worldwide anthropogenic activities are responsible for such rapid factor of barren and habitat destruction as well as loss of biodiversity. The rural areas converting into urban land through rapid population growth and

development occurring at an unprecedented rate in recent human history and severely degrading functioning of ecosystem services (Lopez, Bocco, Mendoza and Duhau, 2001; Alphan 2003 and Dewan and Yamguchi, 2009).

Water class loss about 10.37 km^2 during the last 40 years period. The results indicate that water resources are at decreasing rate. Water source are under stress and such uncertain fluctuations in water bodies may be due to increased urbanization as well as change in climatic patterns. Water bodies are under high stress of high demand of water to Islamabad and Rawalpindi and also for irrigation purposes. Apart from that, water bodies are not only reducing due unban and agriculture demands but also decline due to seepage, percolation and evaporation as well as miss management of water resources (Ashraf et al., 2007; Hagler Bailly, 2007; Keller et al., 2000; Butt et al., 2016). According to IUCN (2005), due to use of herbicides and pesticides in the agriculture land as well as urban waste degrade water quality and quantity (Ahad et al., 2005; Iram et al., 2009). According to IPCC, due to global warming the Earth temperature is rising which lead to change in temperature and precipitation patterns. Consequently, extreme climatic events are occurring such flooding, drought and heat waves. Such changes in climatic patterns can affect water resources and biodiversity (Hassan et al., 2016). In 2015 a severe heat wave struck southern parts of Pakistan and more than 1500 loss their life due to heat stroke in the Karachi city (Chaudhry, 2015).

Generally land dynamic is a complex process and any one approach is unable to describe the pattern of LULC change completely (Verburg and Overmars, 2007).The study indicates that the GIS and remote sensing technique provide an important information about the spatial distribution as well as natural of LULC changes. In our study, we focused only GIS and Remote sensing techniques to examine the LULC change pattern, but could not consider other factors such as climatic, geophysical, socioeconomic, housing factor and land use policy related variables. Therefore future study use policy and other factors along with current study to achieve sustainable urban LULC management.

Conclusion

This study has assessed LULC changes in the capital city of Islamabad, Pakistan using remote sensing data. Islamabad was found to have experienced rapid changes in LULC in 40 years, particularly significant change in built-up areas. Analysis revealed that from 1976 to 2019, build-up land (residential, commercial, industrial and infrastructure) increased from 10.7% to 52.4%, agriculture land increased from 14.3% in 1979 to 19.5% to 2019. Simultaneously, there was a decline in the forest and barren land category, in 1979 forest and barren was 19.3% and 53.9% respectively whereas, in 1979 forest and barren land was 10.3%, and 17.1% respectively. The decrease in the water bodies was significant, the city water bodies have negatively declined by -1.21 in 40 years. This trend of LULC indicates haphazard expansion of built-up and agriculture area was mainly due to lack of proper management, unchecked growth in population size, no EIA for land development, such as extension of road networks, residential and commercial development and a number of allied reasons. Urban growth. Hence, all these alterations in the landscape will become more fragmented and environmental problems will adversely affect the functioning of ecosystem services if the historical pattern of LULC is maintained. The rapid and massive conversion of built-up area may have serious impacts on natural environment. Therefore, proper environmental management plans should be implemented and conserve valuable natural resources for the sustainable urban planning and management. The findings of the study would provide an input to policy makers to understanding the LULC change scenarios and formulating an effective and eco-friendly land use policy in the capital city of Islamabad Pakistan.

References

Ahad, K., Mohammad, A., Mehboob, F., Sattar, A., & Ahmad, I. 2006. Pesticide residues in rawal lake, Islamabad, Pakistan. Bulletin of environmental contamination and toxicology, 76(3), 463-470. doi:https://doi.org/10.1007/s00128-006-0944-8

Alphan, H. 2003. Land-use change and urbanization of Adana, Turkey. Land degradation & development, 14(6), 575-586. doi:https://doi.org/10.1002/ldr.581

Ashraf, M., Kahlown, M. A., & Ashfaq, A. 2007. Impact of small dams on agriculture and groundwater development: A case study from Pakistan. Agricultural Water Management, 92(1-2), 90-98. doi: https://doi.org/10.1016/j.agwat.2007.05.007

Butt, A., Shabbir, R., Ahmad, S. S., & Aziz, N. 2015. Land use change mapping and analysis using Remote Sensing and GIS: A case study of Simly watershed, Islamabad, Pakistan. The Egyptian Journal of Remote Sensing and Space Science, 18(2), 251-259. doi: https://doi.org/10.1016/j.ejrs.2015.07.003

Butt, M. J., Waqas, A., Iqbal, M. F., Muhammad, G., & Lodhi, M. A. K. 2012. Assessment of urban sprawl of Islamabad metropolitan area using multi-sensor and multi-temporal satellite data. Arabian Journal for Science and Engineering, 37(1), 101-114. doi:https://doi.org/10.1007/s13369-011-0148-3

Chaudhry, Q. Z., Rasul, G., Kamal, A., Ahmad Mangrio, M., & Mahmood, S. 2015. Technical report on Karachi heat wave June 2015. Government of Pakistan Ministry of Climate Change, Ministry of Climate Change, Pakistan. (Report).

De Jong, R., Verbesselt, J., Schaepman, M. E., & De Bruin, S. 2012. Trend changes in global greening and browning: contribution of short-term trends to longer-term change. Global Change Biology, 18(2), 642-655. doi:https:doi: 10.1111/j.1365-2486.2011.02578.x

Dewan, A. M., & Yamaguchi, Y. 2009. Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied geography, 29(3), 390-401. doi:https://doi.org/10.1016/j.apgeog.2008.12.005

El-Kawy, O. A., Rod, J. K., Ismail, H. A., & Suliman, A. S. 2011. Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. Applied Geography, 31(2), 483-494. *doi:*https://doi.org/10.1016/j.apgeog.2010.10.012

Gao, J., & Liu, Y. 2010. Determination of land degradation causes in Tongyu County, Northeast China via land cover change detection. International Journal of Applied Earth Observation and Geoinformation, 12(1), 9-16.*doi:https://doi.org/10.1016/j.jag.2009.08.003*

Hagler, B. 2007. Environmental baseline study of Margala and Margala north blocks. MOL Pakistan Oil and Gas Company BV, Islamabad.(Report)

Hardin, P. J., Jackson, M. W., & Otterstrom, S. M. 2007. Mapping, measuring, and modeling urban growth. In Geo-spatial technologies in urban environments (pp. 141-176). Springer, Berlin, Heidelberg.*doi:https://doi.org/10.1007/s41748-017-0028-4*

Hassan, Z., Shabbir, R., Ahmad, S. S., Malik, A. H., Aziz, N., Butt, A., & Erum, S. 2016. Dynamics of land use and land cover change (LULCC) using geospatial techniques: a case study of Islamabad Pakistan. SpringerPlus, 5(1), 812. *doi:*https://doi.org/10.1186/s40064-016-2414-z

He, C., Okada, N., Zhang, Q., Shi, P., & Zhang, J. 2006. Modeling urban expansion scenarios by coupling cellular automata model and system dynamic model in Beijing, China. Applied Geography, 26,*doi:https://doi.org/*10.1016/j.apgeog.2006.09.006

Iram, S., Ahmad, I., Ahad, K. A. R. A. M., Muhammad, A., & Anjum, S. O. B. I. A. 2009. Analysis of pesticides residues of Rawal and Simly lakes. Pak J Bot, 41(4), 1981-1987.

IUCN. 2005. Rapid environmental appraisal of developments in and around Murree Hills, IUCN Pakistan. (Report)

Jafari, M., Majedi, H., Monavari, S. M., Alesheikh, A. A., & Zarkesh, M. K. (2016). Dynamic simulation of urban expansion through a CA-markov model case study: Hyrcanian region, Gilan, Iran. European Journal of Remote Sensing, 49(1), 513-529. *doi:10.3390/su8080810*

Jensen, J. R., & Im, J. 2007. Remote sensing change detection in urban environments. In Geo-spatial technologies in urban environments (pp. 7-31). Springer, Berlin, Heidelberg. *https://doi.org/10.1007/*

978-3-540-69417-5_2

Kamh, S., Ashmawy, M., Kilias, A., & Christaras, B. 2012. Evaluating urban land cover change in the Hurghada area, Egypt, by using GIS and remote sensing. International Journal of Remote Sensing, 33(1), 41-68. https://doi.org/10.1080/01431161.2010.550331

Keller, A. A., Sakthivadivel, R., & Seckler, D. W. 2000. Water scarcity and the role of storage in development (Vol. 39). IWMI. *doi: https://doi.org/10.22004/ag.econ.44575*

Lambin, E. F., Geist, H. J., & Lepers, E. 2003. Dynamics of land-use and land-cover change in tropical regions. Annual review of environment and resources, 28(1), 205-241.*doi:* https://doi.org/10.1146/annurev.energy.28.050302.105459

Lea, C., & Curtis, A. C. 2010. Thematic accuracy assessment procedures: National Park Service vegetation inventory, version 2.0. Natural resource report NPS/2010/NRR-2010/204. Fort Collins: National Park Service, US Department of the Interior.

Lopez, E., Bocco, G., Mendoza, M., & Duhau, E. 2001. Predicting land-cover and land-use change in the urban fringe: A case in Morelia city, Mexico. Landscape and urban planning, 55(4), 271-285. *doi. https://doi.org/10.1016/S0169-2046(01)00160-8.*

Lunetta, R. S., Knight, J. F., Ediriwickrema, J., Lyon, J. G., & Worthy, L. D. 2006. Land-cover change detection using multi-temporal MODIS NDVI data. Remote sensing of environment, 105(2), 142-154.*https://doi.org/10.1016/j.rse.2006.06.018*

Manzoor, S. A., Griffiths, G., Iizkuka, K., & Lukac, M. 2018. Land cover and climate change may limit invasiveness of Rhododendron ponticum in Wales. Frontiers in plant science, 9, 664. *doi:* https://doi.org/10.1002/ece3.6036

Manzoor, S. A., Malik, A., Zubair, M., Griffiths, G., & Lukac, M. 2019. Linking Social Perception and Provision of Ecosystem Services in a Sprawling Urban Landscape: A Case Study of Multan, Pakistan. Sustainability, 11(3), 654. https://doi.org/10.3390/su11030654

Mundia, C. N., & Aniya, M. 2005. Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS. International journal of Remote sensing, 26(13), 2831-2849.

Mundia, C. N., & Aniya, M. 2006. Dynamics of landuse/cover changes and degradation of Nairobi City, Kenya. Land Degradation & Development, 17(1), 97-108. https://doi.org/10.1080/01431160500117865

Owojori, A., & Xie, H. 2005. Landsat image-based LULC changes of San Antonio, Texas using advanced atmospheric correction and object-oriented image analysis approaches. In 5th international symposium on remote sensing of urban areas, Tempe, AZ.

Raudsepp-Hearne, C., Peterson, G. D., Tengo, M., Bennett, E. M., Holland, T., Benessaiah, K., & Pfeifer, L. 2010. Untangling the environmentalist's paradox: why is human well-being increasing as ecosystem services degrade?. BioScience, 60(8), 576-589.

Samie, A., Deng, X., Jia, S., & Chen, D. 2017. Scenario-based simulation on dynamics of land- use-land-cover change in Punjab Province, Pakistan. Sustainability, 9(8), 1285 https://doi.org/10.3390/su9081285

Shaikh, H.; Ijaz, N. International Growth Center. 2017. Available online: https://www.theigc.org/blog/thesix-biggest-challe (accessed on 3 August 2018)

Sieber, J., & Pons, M. 2015. Assessment of urban ecosystem services using ecosystem services reviews and GIS-based tools. Procedia Engineering, 115, 53-60. https://doi.org/10.1016/j.proeng.2015.07.354

Spake, R., Lasseur, R., Crouzat, E., Bullock, J. M., Lavorel, S., Parks, K. E., ... & Mouchet, M. 2017. Unpacking ecosystem service bundles: Towards predictive mapping of synergies and trade-offs between ecosystem services. Global environmental change, 47, 37-50. 10.1016/j.gloenvcha.2017.08.004

Świader, M., Szewrański, S., & Kazak, J. (2018). Foodshed as an example of preliminary research for conducting environmental carrying capacity analysis. Sustainability, 10(3), 882. https://doi.org/10.3390/su10030882

Verburg, P. H., & Overmars, K. P. 2007. Dynamic simulation of land-use change trajectories with the CLUE-s model. In Modelling land-use change (pp. 321-337). Springer, Dordrecht. *https://doi.org/10.1007/978-1-4020-5648-2_18*

Weng, Q. 2002. Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling. Journal of environmental management, 64(3), 273-284.https://doi.org/10.1006/jema.2001.0509

Xiao, J., Shen, Y., Ge, J., Tateishi, R., Tang, C., Liang, Y., & Huang, Z. 2006. Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. Landscape and urban planning, 75(1-2), 69-80.*doi:10.1016/j.landurbplan.2004.12.005*

Yuan, F., Sawaya, K. E., Loeffelholz, B. C., & Bauer, M. E. 2005. Land cover classification and change analysis of the Twin Cities (Minnesota) Metropolitan Area by multitemporal Landsat remote sensing. Remote sensing of Environment, 98(2-3), 317-328.*Doi:*10.1016/j.rse.2005.08.006

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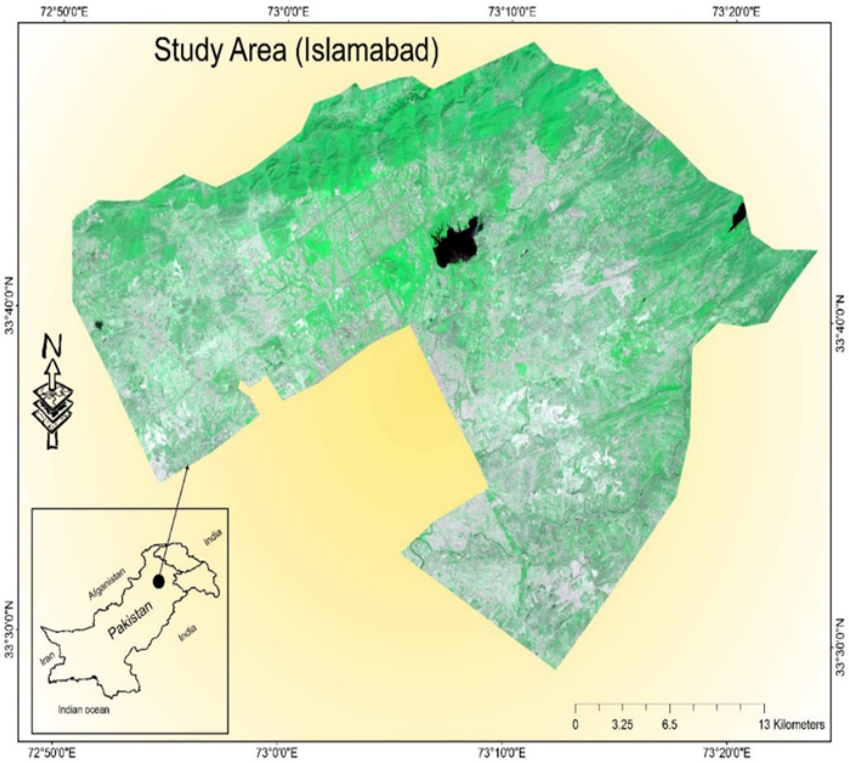

Figure 1. Location map of the study area (Islamabad Capital of Pakistan

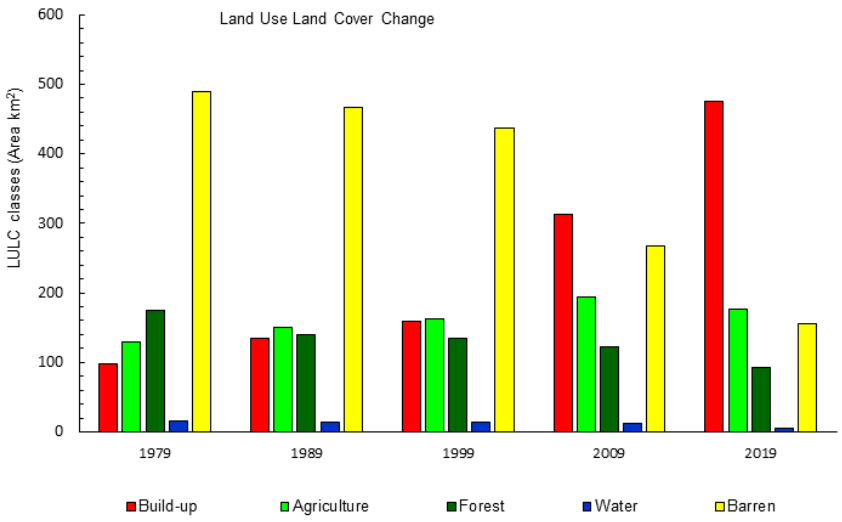

Figure 2. The LULC change areas studied in four epoch time series in city Islamabad

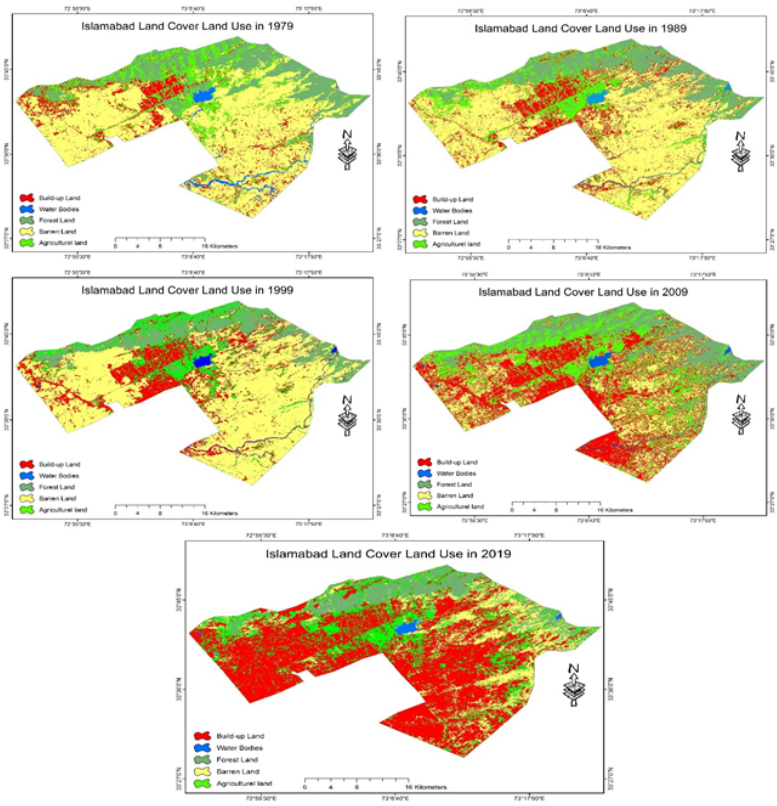

Figure 3. Spatio-temporal LULC changes from 1979 to 2019 in city Islamabad