DETECTION OF LAND USE/LAND COVER CHANGES (LULC) AND URBAN SPRAWL IN ISLAMABAD, PAKISTAN: AN ANALYSIS OF MULTI-TEMPORAL REMOTE SENSING DATA

By

Furqan Haider

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Supervised by

Sir Aqeel Anwar

PIDE School of Economics

Pakistan Institute of Development Economics

Islamabad

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Pakistan Institute of Development Economics, Islamabad

PIDE School of Economics

CERTIFICATE

This is to certify that this thesis entitled: **"Detection of Land Use/Land Cover Changes (LULC) and Urban Sprawl in Islamabad, Pakistan: An Analysis of Multi-Temporal Remote Sensing Data"** submitted by **Mr. Furqan Haider** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Economics.

Supervisor: Mr. Aqeel Anwar Signature: ________

External Examiner: Dr. Abdul Saboor Signature: ________

Head,
PIDE School of Economics: Dr. Shujaat Farooq Signature: ________

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Name of Student

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Dedication

Dedicated to my loving Parents

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I bow my head and pay a great devotion to Allah, who is the beneficent, gracious, omniscient, almighty, and a great judge of this world and worlds after this, for His guidance that made me capable of doing this Task.

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ABSTRACT

This paper used RS and GIS techniques to detect and monitor LULC changes and urban sprawl in Islamabad, Pakistan for the period of 1990, 2000, 2010 and 2020. It analyzed multi-spectral Landsat data by utilizing the Maximum likelihood classification (MLC) algorithm to classify the satellite data of Landsat 4-5 ™, Landsat-7 ETM+ and Landsat-8 OLI/TIRS in raster form collected from USGS for the period between 1990 and 2020. The objective of the study was to classify LULC types, detect changes in each class and measure the rate of urban sprawl. The study employed Arcmap software to obtain all these objectives. The accuracy assessment of all the classified maps was assessed by constructing an error matrix and calculating overall accuracy and kappa coefficient. It then calculated change detection by using overlay procedure and urban sprawl by applying built-up index (BU) technique and by clipping built-up areas to extract and create a map of urban sprawl. Both pre-classification and post-classification techniques were used to classify and detect changes. The result showed that the classified map of 1990, 2000, 2010 and 2020 had overall accuracy of 91%, 91%, 86% and 94%. Similarly these maps had kappa coefficient values of 90%, 89%, 83% and 93%. The classification result of 1990 to 2020 depicted that built-up area increased by 18% while the decline trend was found in forest land 4.92%, Agricultural land 10.31%, barren land 2.17% and water bodies 0.03%. Furthermore, the urban sprawl map showed compact sprawl in the center and scattered sprawl in the periphery areas as urban sprawl increased from 56.93 sq. km in 1990 to 214.46 sq. km in 2020, and had a substantial increase of 157.93 sq. km from 1990 to 2020. The policy lessons drawn from this research suggested that vertical development should be encouraged in Islamabad and CDA bylaws should be flexible to promote vertical development and to restrict sprawl. Future research should be conducted in better urban management using RS and GIS.

Keywords: LULC, Urban sprawl, RS, GIS, Islamabad

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LIST OF ABBREVIATIONS

LULC	Land use and Land Cover
RS	Remote Sensing
GIS	Geographic Information System
USGS	United State Geographic System
MLC	Maximum Likelihood Method
AOI	Area of Interest
BU	Built-up Index
NDBI	Normalize Difference Built-up Index
NDVI	Normalize Difference Vegetation Index
OLI	Operational Landsat Imager
ETM	Enhanced Thematic Mapper
TM	Thematic Mapper
TIRS	Thermal Infrared Sensor

CHAPTER 1

INTRODUCTION

1-Introduction

Globally, and particularly in emerging countries, the rapidly expanding urban population is a serious issue for planning organizations and governments. Today, 55% of the world's population lives in cities, which is predicted to expand to 6.3 billion by 2050, with over 90% of the urban population anticipated to grow in developing nations' cities (UN 2018). Without a doubt, this tendency has resulted in significant urban sprawl, which will continue in the future. The unavoidable outcome of this process is the spatial extension of cities and towns beyond their legal boundaries and into their peripheries and hinterlands in order to support a growing urban population, resulting in LULC changes and urban sprawl. The modification of the Earth's terrestrial surface by human activity is known as LULC changes, and urban sprawl is the chaotic growth of a city. Although humans have been altering land for thousands of years to obtain livelihoods and other necessities, the extent, intensity, and rate of LULCC are significantly larger now than they were previously. These shifts are driving unprecedented changes in ecosystems and environmental processes at the local, regional, and global levels. As a result, LULC changes play a crucial part in today's study and analysis of global change scenarios, as the data available on such changes is critical for providing critical input to ecological management and environmental planning decisions(Zhao et al. 2004; Dwivedi et al. 2005; Erle and Pontius 2007; Fan et al. 2007). The growth of urban areas and changes in LULC cover around rapidly growing urban centers in the developing world have attracted considerable attention from city and regional planners and urban geographers (Alphan, 2003). Population growth in terms of increased population density is considered as the primary cause of urban sprawl and changes in LULC. Population growth demands the construction of new commercial, residential, utility, and transportation infrastructure. Additionally, they require the conversion of cropland, forest areas, and bare soils, resulting in LULC changes and urban sprawl. Urban sprawl has its threshold limits. At the lower end of the range, a city retains its vulnerability and uniformity in the face of change, but uncontrolled and rapid urban sprawl that exceeds its maximum threshold limit causes chaos and degrades the quality of the city's utility and transportation services. Hence, coordinated, planned, and organized urban sprawl is critical for the development of a socially, ecologically, and economically viable community (Cabral et al, 2015; Xu et al, 2013).

Urbanization is a key factor in global land use changes. The fast spread of artificial surfaces in urban areas has resulted in a variety of conflicts between society and nature, as well as sustainability concerns (R.H, 2008). Urban periphery regions are particularly vulnerable to "urban sprawl," as large sections of rural land next to cities have been transformed into urbanized surfaces (Anas et al, 2008; Brueckner, 2000). Land cover changes in suburban areas are influenced by a large number of socioeconomic factors and frequently result in land fragmentation, landscape degradation, environmental degradation, and the loss of wildlife habitat, as well as undermining the ecological balance and agricultural capacity of peri-urban areas (Livanis et al, 2006). Yet, experts believe that suburban intensive farming is necessary to feed a rising population while maintaining transparency, food quality, security and traceability (Cavailhes, j., 2004). Numerous writers have already highlighted how urbanization has resulted in a fast loss of green surfaces and agricultural land surrounding cities, resulting in adverse effects on sustainability and bio capacity. As a result, planning and controlling urban expansion will be important in the future for guaranteeing food security and agricultural growth in the areas around cities, as well as for the sustainable development of metropolitan areas (Gumma et al, 2017). Urban sprawl and agricultural land loss are issues not just in the mega-cities of Africa, Asia, and the United States, but also in vast urbanized areas throughout Europe (couch et al, 2007; Guastella et al, 2019). Historically, European metropolitan areas have developed an uneven mix of rural and urban functions. Heterogeneous, fragmented mosaics of cultural landscapes predominate, with complicated land use patterns interacting with the main socio economic features in the vicinity of large metropolitan areas (Ravetz, J et al, 2013). During the post productivity transition, environmental preservation gained popularity (Lowe et al, 1993). Numerous studies have examined the economic, ecological, and infrastructural issues posed by suburbanization in many countries. Scientific study has been conducted on the environmental costs associated with urbanization processes, with a particular emphasis on soil consumption and soil consumption sealing, as well as the effects they create (Burchell et al, 2005). The expanding urban sprawl has affected many countries environmentally, economically and socially. On the one hand, uncontrolled urban expansion, often referred to as sprawl, has brought brief benefits for residents in new settlements, satisfying the demand for inexpensive single-family homes with a garden and more privacy (Bruegmann et al, 2005). On the other hand, it has resulted in significant environmental, economic, and social repercussions. The environmental effects are a result of the conversion of agricultural land into built or simply waterproofed areas that are no longer suitable for food production, altering the landscape and resulting in a drastic degradation of water and air quality, the loss of the majority of soil's ecological functions, a reduction in ecosystem resilience, and increased energy consumption (Johnson et al, 2001). Socioeconomic consequences include increased commute times, increased reliance on motor vehicles, increased congestion on public transportation, and geographical segregation of social classes (Ewing, R.H, 2008). Last but not least, there is an economic impact on individuals as a result of increased spending on essential public services and infrastructure. There are only a few examples in the literature of the influence of urban sprawl on local public expenses. The first is by Ladd, who predicted a U-relationship between the population and current government spending. The population imposes two opposing forces: on the one hand, as population density increases, per capita costs decrease due to economies of scale in the production of public services; on the other hand, as the population grows, public expenditure increases due to increased demand for public services and overcrowding in the use of infrastructure. Ulfarsson and Carruthers (2003) demonstrated that when population density and urbanization increase, the per capita cost of a variety of public services falls. Sole '-Olle' and Hortas-Rico (2010) revealed a non-linear and increasing link between extensive urbanization and the cost of primary local public services in Spain. In analyzing these issues, these articles concluded that the absence of proper policies and governance structures had a significant influence on megacities' urban expansion.

A growing population plus urban sprawl are indicators of economic progress. Nevertheless, human-induced deforestation and the conversion of natural land into built-up structures such as buildings, water supplies, transportation, and sewage networks have a variety of negative impacts on land and soil, biodiversity, vegetation, noise levels, air and water quality, and contribute to overall environmental degradation both within and around cities (Byomkesh et al, 2001). Additionally, the impervious surface created by massive constructions leads to the formation of urban heat islands, which affect both regional and local climates and raise the risk of flooding and other natural disasters (Nazimuddin et al, 2015). Besides that, urban sprawl increases living costs, land prices, class division, and inequities (Bhatta et al, 2010). Likewise, this rapid urbanization has resulted in a chaotic development of the city, deteriorated living conditions, and degraded the environmental scenario, all of which have a negative impact on human health. To mitigate the negative effects of urban sprawl and plan for the future expansion of a city, regional and local government officials, urban planners, and policymakers must conduct an in-depth analysis of the city's current LULC patterns and their spatio-temporal changes. Additionally, they must assess the extent to which urban sprawl is occurring around the city in terms of population and economic growth. Similarly, it is necessary to determine the pattern and rate of LULC change in order to formulate a logical and reasonable land use policy (Mallupattu et al, 2013).

Not only the debate over these issues resulted in the emergence of novel methods to achieve a more sustainable urban form, but also in the development of new tools and procedures for analyzing and monitoring urban sprawl and its impacts during the previous decades. To study and analyze urban sprawl, some academics and research institutions use indicators, while others rely on spatial and temporal technologies such as remote sensing (RS) and geographic information systems (GIS). LULC research requires the analysis of a large amount of spatio-temporal data. Historically, they were obtained by field surveys conducted on the ground. Rapid advancements in remote sensing technologies have motivated city managers and urban experts to use remote sensing data to analyses urban sprawl and Spatio-temporal LULC changes in recent years, owing to their low cost, extensive spatial coverage, efficient data processing capabilities, and repeated observations (Shalaby,A, et al, 2007). Remote sensing has developed into a fundamental instrument for comprehending and developing the global physical processes that influence the earth. The recent progress in the use of satellite data is to use the increased quantities of geographical information that are accessible in association with GIS to help interpretation. GIS is a coordinated system of computer software and hardware that enables the storage, capture, retrieval, examination, manipulation, and visualization of geologically referenced (spatial) data in order to aid in decision-making and development-oriented management. GIS and RS have been used to cover a broad range of sectors, including agriculture, the environment, and integrated eco-environmental assessment. Numerous analysts have concentrated on LULC studies due to their detrimental effects on the area's vegetation and ecosystem. The methods for detecting changes in LULC using RS data are classified as pre-and post-classification (Yuan, D, et al, 1998). The pre-classification approach consists of a collection of multi-time RS imagery to generate maps denoting areas of change or no change in LULC without identifying the type of change. In comparison, the post-classification approach compares two classified temporal RS imagery to generate maps that illustrate changes over time within and between LULC classes. Therefore, it allows researchers and planners to determine the type and direction of LULC transformations and urban sprawl throughout cities (Jensen et al, 2004; Coppin et al, 2004).

Like in other underdeveloped countries, in Pakistan, most developments are unplanned and generally lack adequate planning techniques. Pakistan has the fastest pace of urbanization in South Asia, and by 2030, the urban population will outnumber the rural population. Rapid urbanization and population growth are encroaching on prime agricultural land and reducing forest cover. Islamabad, like many other cities, exhibits this high rate of sprawl. It has been facing growing urbanization and massive levels of pollution from residential, industrial, and transportation sources in recent years, as a result of various ongoing construction operations. It is one of Pakistan's most diversified cities, having a sizable proportion of foreigners and immigrants. Unprecedented population growth and migration have resulted in urban expansion and the conversion of green space and agricultural land to built-up areas. Islamabad's unchecked population growth as a result of fast urbanization has degraded the living environment and exacerbated the negative ecological consequences for human health.

Numerous researchers have analyzed the land use/land cover changes in Islamabad utilizing remote sensing data (RS) and geographic information systems (GIS) during the past three decades. Zahra Hassan et al. (2016) used geospatial techniques to examine the dynamics of land use and land cover changes in Islamabad from 1992 to 2012. They used two multispectral LANDSAT satellite images of Islamabad for two separate time periods, 1992 and 2012, in addition to aerial photos, topographic maps, and ground truth data. They discovered that built-up regions, waterways, and cropland showed rising patterns throughout time, while forest cover and the barren regions decreased. The main factors behind these changes seem to be growth in the population, industrial expansion, and road expansion. Muhammad et al. (2018) used a combination of operational Landsat imager (OLI), multispectral data from Landsat-5 thematic mapper (TM), and Landsat-8 enhanced thematic mapper (ETM), as well as a thermal infrared sensor (TIRS), to estimate changes in land use and land cover, their cooling and warming effects, and their contribution to urban heat island (UHI) effects between 1993 and 2018. It demonstrated that the warming effect of converting natural surfaces to built-up surfaces was greater than the cooling effect of converting built-up surfaces to natural surfaces. Previous research has investigated LULC changes in various aspects by applying GIS technologies.

1.1 Problem Statement

Urbanization led to LULC changes in many parts of the world, especially in the developing countries, and these changes had a significant impact on the functioning of global and local ecosystems. Islamabad, like many other cities in Pakistan, exhibits this high rate of sprawl. Unprecedented population growth and migration resulted in urban expansion and the conversion of green space and agricultural land into built-up areas. Only a few researchers had studied LULC changes in Islamabad over the last three decades by employing RS and GIS. However, none of these investigated the urban sprawl rate resulting from changes in LULC and population growth using geospatial approaches. Therefore, this study examined land use and land cover changes (LULC) in Islamabad and their impact on urban sprawl during the past three decades. This study classified LULC classes, detected changes in each class, and measured the urban sprawl rate.

1.2 Research Questions

- What was the rate of changes occurring in each LULC type?
- What was the rate of conversion from one LULC type to another?
- How much urban sprawl has increased in Islamabad?
- How much was the population density per built-up square kilometer?

1.3 The Objective of the Study

- To classify LULC classes and to monitor changes within each class- The earth's territorial surface is covered by a variety of land cover types, including water bodies, forests, and vegetation, etc. The researchers categorized each type and evaluated how each type changed over time.
- To calculate the rate of conversion of one LULC type to another-The researcher calculated the amount of conversion of one land cover type to another.
- To measure Islamabad's rate of urban sprawl-When a city's population grows, it extends to accommodate the growth, resulting in urban sprawl. The researchers measured Islamabad's rate of urban sprawl.

- To measure the population density per built-up square kilometer—the researchers found out how much the population density per built-up square kilometer had grown over time.

1.5 The significance of study

The study would be beneficial for municipal administrators, city managers, and land use decision-makers. Additionally, it would help the government assess Islamabad's unplanned sprawl and the associated expenditures, such as higher food and transportation costs, that the government must bear as a consequence of this unplanned growth. It would also help other studies to determine the cost of mobility, the increase in travel time, and the increase in food costs related to urban development.

1.6 Organization of the Study

The study is structured as follows. The study is introduced in chapter 1. Chapter 2 discusses the literature on importance of RS and GIS, classification of LULC, impact of LULC on urban sprawl and literature Gap. Chapter 3 discusses the data and methods, as well as the sources of data. Chapter 4 provides the present study's findings and discussion. The concluding part is concluded in chapter 5 and references are given in chapter 6.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review is a narrative format in which the author examines and narrates the work of other academics and authors in order to develop arguments. To make the literature review simpler to comprehend, it has been split into numerous themes that are essential to this study. The topics covered include the importance of GIS and RS in monitoring and detecting LULC changes and urban sprawl, importance of methodology, suitable data sources for LULC, land use/land cover (LULC) classes, changes in these classes and their impact on urban sprawl, as well as the importance of GIS in assisting with the design process of LULC analysis and urban sprawl measurement.

2.2 Literature on the Importance of RS and GIS

Globally, geographic remote sensing and GIS applications are widely utilized in natural and land resource management. Changes in land use and cover are a primary cause of environmental changes occurring on a global scale, as well as for sustainable development. Modern technologies, for example, geographic information systems (GIS) and remote sensing provide a cost-effective and accurate method of data collection for comprehending the characteristics of the landscape. Detection of LULC on a digital basis using multispectral and multi-temporal remote sensing data has shown an enormous potential for comprehending landscape dynamics with the purpose of detecting, identifying, mapping, and monitoring changes in the pattern of LULC over time. Detection of changes in land use and land cover is a significant landscape dynamic during a specific time period that has sustainable management. Changes in land use and land cover (LULC) have a huge impact on peri-urban planning and environmental management (Deng et al., 2009). GIS shows spatial urban sprawl patterns by estimating the distances of extended urban areas from the city centers (Gar et al. 2001). Due to the irreversibility of urban development, GIS simulates future land development (Lee et al., 1998).

GIS and RS are the most common techniques for mapping, quantification, and detection of LULC patterns due to their repetitive data acquisition, suitable digital format for computer processing, and accurate geo-reference procedures (Lu et al., 2004). The digital change detection approach has been frequently used to determine and describe the frequent LULC changes properties based on multi-temporal RS data (Chan et al., 2001). The monitoring and mapping of LULC changes and urban sprawl using RS and GIS techniques has mostly proved to be efficient and valuable tools and has attracted a large interest in estimating and monitoring urban sprawl over a time period (Yen et al, 1997, Master 2001, Dadras et al). These techniques are also effective for time and cost-related barriers (Haack et al., 2006).

Muhammad et al. (2005) explained the importance of RS and GIS technologies in dealing with dynamic phenomena like LULC changes and urban sprawl. RS and GIS are essential to estimate and monitor urban sprawl effectively, particularly for elapsed time periods. Dhaoui et al. (2014) assess the importance of GIS and RS data in measuring urban sprawl. A map offers a visual basis for studying urban sprawl in association with urban expansion. GIS is helpful for mapping the spatial distribution of cities. In contrast to traditional methods of cartography, GIS enables the manipulation of a variety of data within a single map. In quantifying sprawl, urban mapping is a critical part. While different layers of data are needed to develop a map, it is eventually the map that conveys the story about the extent of urban sprawl across a given area. This kind of mapping employs a temporal signature in which the level of sprawl is compared over two or more time periods. One map shows the built up areas in a given year, while another shows the developed areas at the end of the year. Thus, mapping the scope of urban expansion through time is critical for comprehending urban sprawl. Furthermore, to understand urban sprawl, it is important to have successful LULC change detection. This is made possible by RS technology and its accurate registration of satellite images.

2.3 Literature on Methodology

MLC is one of the most common and powerful algorithms available in the GIS software. ML algorithm calculates the probability for each pixel to belong to a certain class. Basically, to initiate the ML algorithm which is similar to the work of many other algorithms in pixel-based classification, it needs to calculate the spectral statistics for each pixel in the training sample of a given class, while at the same time creating a classification signature. (Lillesand et al. 2008). Supervised classification is one of the features of MLC. It is one of the most used classification techniques to detect LULC changes. In supervised classification, the images investigator regulates the pixel classification measure by determining the PC calculation and mathematical descriptor speaking to different land cover types in a scene. Oneself preparing calculation utilizes the past arrangement results to prepare the classifier iteratively. The co-training algorithm trains two classifiers with the examples in two free subsets. It chooses the unlabeled examples with high quality to prepare the other classifier (Lu X., et al 2020). In supervised classification, from the prior knowledge on all cover types to be planned inside the characterized scene is accepted. This information is utilized to characterize marks of the classes of interest, to be applied to the whole scene (L. Wang, et al 2020).One important and critical task in supervised classification is obtaining an acceptable number of training areas, whereas the training areas are usually collected from the field, from high spatial and temporal resolution of aerial photographs, and/or satellite images. Not only the number of the training areas that matters but also the collection methods of training areas, such methods can be done by collecting single pixels to represent the class or group of pixels, other approaches are also possible, in all cases the method has a large effect on the classification results (Chen and Stow 2002). Furthermore, post-classification comparison was found to be the most accurate procedure by a variety of studies as it offered an advantage of representation of nature of occurring changes. It compares classifications of images from different dates, which are independently produced in order to detect land cover changes (Yuan et al. 1999). Thus, making use of the PCC method minimizes associated problems with multi-temporal images that are recorded under different atmospheric and environmental conditions. It separately classifies the data from different dates, and thus, this multi-date data does not require any adjustment for direct comparison (Zhou et al. 2008; Warner and Campagna 2009). An additional advantage of the PCC method is the indication of the nature of change (Yuan et al. 2005).

2.3 Literature on LULC changes

Zahra Hassan et al. (2016) used geospatial tools such as geographic information systems and remote sensing to examine the dynamics of land use and land cover changes in Islamabad from 1992 to 2012. The advantage of geospatial approaches is that they facilitate the identification of regions within a region classified as industrialized, agriculture, or urban. Due to its repeated data gathering, a digital format adequate for computer processing, and an accurate geo-referencing approach, it is the most often used approach for mapping, qualifying, and pattern identification of land use and land cover changes (LULCC). SUPARCO, the USGS, and an Earth science data interface were used to collect data for the project. Two multispectral LANDSAT satellite pictures of Islamabad were included in the data collection for two distinct time periods, 1992 and 2012. Additionally, ancillary data such as aerial pictures, maps of topographic and ground truth data were obtained. Geometric correction of satellite data was performed using ERDAS software, and the images were categorized into five classes: agricultural, built-up, forest, barren, and water bodies. Moreover, the post-classification classifier (PCC) approach was used to decrease misclassifications and enhance satellite image classification accuracy. It was carried out using the ArcGIS 10 application. The benefit of using PCC is that it provides a representation of the nature of occurring changes and correlates the classification of satellite images that were produced independently at different times, thereby reducing problems associated with multi-temporal images captured under varying environmental and atmospheric conditions. Also, an error/confusion matrix was performed to verify the images' accuracy. Both images were found to have a map accuracy of 89 percent. Islamabad's total area is 89,958 hectares (ha), and the barren and forest areas have been shrinking during the research period. In 1992, barren land covered 49,789 ha (55.35 percent) of total LULC, but had decreased to 1678 ha (1.87 percent) in 2012. Likewise, the forest area portion was 12,136 ha (13.49 percent) in 1992 but decreased to 6138 ha (6.82 percent) in 2012. The three remaining classes demonstrated a positive trend, with built-up area increasing from 16281 ha (18.09 percent) in 1992 to 51,039 ha (56.73 percent) in 2012, agriculture area increasing from 10,336 ha (11.49 percent) to 29000 ha (32.23 percent), and water bodies increasing from 1416 ha (1.57 percent) in 1992 to 1579 ha (1.75 percent) in 2012. Furthermore, it discovered that the settlement area increased by more than 213 percent throughout the research period. The primary drivers of these changes were the growing population, industrial expansion, and road expansion.

Muhammad et al. (2018) assessed changes in land use and land cover, their cooling and warming effects, including their contribution to Islamabad's urban heat island (UHI) from 1993 to 2018. The USGS provided the satellite images, which comprised operational Landsat imagery (OLI), multispectral data from Landsat-5 thematic mapper (TM), and Landsat-8 enhanced thematic mapper (ETM), as well as thermal infrared sensor (TIRS), for June 1993 and 2018. Before doing image interpretation, all pre-processing procedures were completed, including radiometric correction, atmospheric correction, area of interest extraction, and band composition. The digital numbers of the spectral bands and a random forest classifier were used to classify LULC. The land surface temperature (LST) was measured using a standard radiative transfer equation (RTE) using Landsat-8 and Landsat-5 thermal bands. The result demonstrates that built-up surfaces increased by 11.9 percent between 1993 and 2018, at the cost of water bodies (0.2 percent), agricultural land (2.6 percent), forests (1.4 percent), and barren land (7.7 percent). Moreover, the change detection map showed that 64.74 percent of the urban areas stayed unchanged during the research period, whereas changes were observed in 35.26 percent of LULC classes. Additionally, the result demonstrates an average positive temperature increase (warming effect) of 1.52 degrees centigrade and an average negative temperature increase (cooling effect) of -0.8 degrees centigrade as a result of land use and land cover changes in Islamabad during the aforementioned period. It reveals that the warming effect of converting natural surfaces to built-up surfaces is higher than the cooling effect of converting built-up surfaces to natural surfaces. Moreover, given the standardized scale of LULC changes (10percent), the average warming impact of LULC changes is 1.2 percent, due to forest area conversion to built-up areas. Similarly, the average cooling contribution of LULC changes to the urban heat island is 0.2 percent, due to the conversion of built-up surfaces to forest areas. This implies that the warming effect of LULC changes is higher than the cooling effect.

Parviz A.Bhat et al. (2017) examined the land use and land cover of a portion of India's Dehradun city during two distinct time periods, 2004 and 2014, in order to discover changes and estimate urban sprawl. The study analyzed a variety of data sets, including toposheets, Indian remote sensing (IRS) LISS-IV imagery, and India's surveys between 2004 and 2014. To develop a better understanding of the dynamic phenomena of urban sprawl, ArcGIS and ERDAS software were used to produce several thematic layers, such as a road map, land use map, railway line, and other accessible maps. Visual interpretations were also used to verify the satellite image's accuracy. Positive and negative outcomes were detected in the research. Positive changes occurred in fallow land, urban areas, and built-up areas, whereas negative changes occurred in agricultural, forest, river bed, and mixed vegetation. During the research period, the built-up areas expanded from 27.16 sq. km to 34.08 sq. km. It indicates an extraordinary urban expansion all across Dehradun, as 6.13 square kilometers of open land and agricultural areas were converted to built-up land between 2004 and 2014. Additionally, it has been discovered that some forms of urbanization are occurring in the region's protected zones.

Parveen Kumar et al. (2013) examined land use/land cover changes in Tirupati, India, from 1976 to 2003 using Geospatial technologies. The article analyzes several data sets. This included data from multi-temporal remote sensing and topographical maps. The 1996 topographic map was derived from an Indian survey and georeferenced with a coordinate system using spatial analytic tools and ArcGIS. The remotely sensed data was extracted from the National Remote Sensing Agency (NRSA), which contains the PAN of IRS ID 2003 and the LISS III. Prior to classification, ERDAS software was employed to enhance the satellite data in order to improve image quantification and classification accuracy. Additionally, the research region was classified into eight classes depending on remote sensing data, geographical conditions, and field work. These include urban areas, agricultural areas, thick forest areas, open forest regions, mining areas, other lands, waterways, and plantation areas. According to the post-classification of two periods, the built-up area rose from 5.91 kilometers squared in 1976 to 18.34 kilometers squared in 2003. The primary factor was the study area's growing population and urban expansion. On the other hand, agricultural land dropped from 68.23 kilometers in 1976 to 21.45 kilometers in 2003. This occurred as a result of the conversion of huge tracts of agricultural land to urban areas. Likewise, the water bodies decreased in size from 12.09 sq.km in 1976 to 9.9 sq.km in 2003. Additionally, it is shown that forest land decreased dramatically from 22.35 sq.km in 1976 to 4.25 sq.km in 2003, owing mostly to rapid urbanization. In conclusion, the results indicated a considerable increase in urbanization and built-up areas. On the other hand, forest cover, agricultural areas, and water bodies all declined significantly. The primary drivers of these LULC changes were mass migration, population expansion, uncertainty of biophysical limitations, and a rise in urban settlement, among other factors.

Jing Jang et al. (2010) examined the impact of land use/land cover changes on surface temperature (LST) in Beijing, China, for both April 9, 1995, and April 30, 2000, utilizing satellite data. For each time period, the study gathered three satellite image data sets, including Landsat TM and ETM+. A digitized topographical map has also been utilized to correct geometric flaws in the images and to correct atmospheric errors. MODTRADE was used to eliminate atmospheric influence and get real surface characteristics. The ETM+ thermal infrared band (band 6) was utilized to determine the land surface temperature. Additionally, the study used supervised and unsupervised classifications to develop comprehensive LULC classes, which included forests, agricultural lands, grasslands, water sources, unoccupied land, and built-up land. However, this article used LULC classes as a unit of analysis rather than geographical subgroups and classified green space as brush forest, forest land, and different gardening plots. Moreover, the temperature vegetation index (TVX) was developed to examine the effect of land changes on land surface temperature (LST). The data indicates that land-use change is a significant cause of LST rises. Also, research has demonstrated a strong positive relationship between LST and land changes, indicating that as urban areas grow and agricultural and forest land is converted to built-up areas, LST increases.

2.4 Literature on LULC changes and their impact on urban sprawl

The idea of sprawl was first put forward by Early Draper, who was from the USA and was one of the prominent and first city planners. However, the debate on urban sprawl became the center topic due to its connection to income and transportation at the end of WW2 (Black.J, 1996). F.J. Osborn (1946) summarized these issues. According to him, suburban sprawl-a form of urban sprawl disadvantageous socially and wasteful from an economic standpoint-was mainly fuelled by new forms of transportation. The increase in real incomes and rapid transportation has facilitated residents to migrate from the city centers and reside in the surroundings they desire. However, these migrants, coupled with immigrants from rural areas, obtained these surroundings at the expense of costly and long journeys to and from work. This weakened the life of the local community and most residents in the center found it difficult to access the surrounding areas.

Muhammad et al (2015) used multi-temporal remote sensing data to assess the urban sprawl in Lahore. Both primary and secondary data sets were acquired for the study. The data set includes a survey of Pakistan topo-sheet for the year 1995-96, Landsat TM image of 1991, Landsat ETM + image of 2000, Landsat OLI image of 2014 and an administrative boundary map of Lahore. The ERDAS imagery and GIS application were employed to perform both supervised and unsupervised classification techniques on the data, and the unsupervised classification proved to be more accurate with an accuracy rate of 81%. The area of Lahore was classified into four classes, including vegetation, barren land, built-up areas and water areas. The result concluded a positive increase in vegetation and built-up areas, whereas barren land and water areas showed a decreasing trend. The urban sprawl expanded from 2279.7 sq. km to 5214.9 sq. km from 1991 to 2000. However, the urban sprawl increased almost double from 2000 to 2013, i.e., 6451.6 sq. km.

Abdul et al (2016) monitored LULC changes and urban sprawl in Peshawar, Pakistan by utilizing GIS techniques and RS data for the time period of 1999 to 2016. They extracted a set of Landsat data from the USGS for their study. The data set includes Landsat 7 ETM+ + and Landsat 8 oli. The satellite images were free from atmospheric distortion. Both images were analyzed by using the ArcGIS application and both pre-processing and post-processing were performed. Furthermore, supervised classification was performed by using the maximum likelihood method to classify the image into different classes. A signature file was also created by using training samples and data was classified into different classes. Additionally, Boolean techniques were used to extract built-up areas from the classified map. Finally, the area of each class was estimated by using a raster calculator. The result indicates that in 1999 the total share of agricultural land was 46.34 %, the barren share was 7.58% or 7.92 ha, the built-up area was 44.60% or 41.36 ha and the water area was 0.26% or 0.24 ha. A rapid decline was found in agriculture and barren land in 2016. These classes decreased to 23.56 % and 3.30% from 46.34% and 7.58%. The water body was increased by 0.27% and the built-up area was increased by 3.30% in 2016. Furthermore, the result of urban sprawl shows that the total urban area was 4% in 1999, which was expanded to 71% in 2016. The total change in urban sprawl between the two periods was 26%.

Hassan et al (2016) used field observation, satellite images, and socio-economic data to monitor LULC changes and measure urban sprawl in Qom city, Iran for the period of 1987 to 2013, and LULC change and urban simulation for 2022 was also simulated. Landsat TM images were acquired for the years of 1987, 1999, and 2013 by the USGS. The images include Landsat 8, Landsat 5 and Landsat 4 with a spatial resolution of 30 m. Furthermore, reference data was used, including land use maps and aerial photographs. By using ENVI 5.1 software, the researchers applied multiple techniques to analyze the Landsat data. For image pre-processing, quick atmospheric correction (QUAC) and top of atmosphere (TOA) techniques were used for atmospheric correction. After that, a signature file was created by using training samples and supervised classification was conducted to classify the land cover into different classes. Moreover, an error matrix was formed to check the accuracy of each class and then change detection was calculated by using cross tribulation analysis. To measure urban sprawl, the Shannon entropy technique was used and to find the change, the CA-Markov model was employed. The findings revealed that the overall accuracy of classified images ranged from 91% to 98% and the kappa coefficient ranged from 76% to 96%. Built-up areas showed a major shift during the study period. It increased from 5453.73 ha in 1987 to 10163.79 ha in 2013. However, the other classes, including agriculture, wasteland and garden areas, decreased tremendously from 8333.91 ha to 5032.62 ha, 315 ha to 45 ha and 60 ha to 50 ha during the study period. Also, the obtained value of Shannon entropy showed that the city experienced a high rate of urban sprawl during the last three decades. The CA-Markov technique showed that by 2022, the built-up area will further increase by 10%, which will result in the potential loss of 638.37 ha of wasteland, 438.08 ha of agricultural land and 17.01 ha of gardens. This indicates further expansion of urban sprawl in the city.

Mohsen Dadras et al. (2014) examined the process of urbanization in Bandar Abbas, Iran, from 1956 to 2012, concentrating on land-use change and urban sprawl. The research calculated urban sprawl and land-use changes using satellite images, aerial photographs, and nine periods of remote sensing data. There were three auxiliary periods (Aerial photo Ultra cam-d 2013, Satellite images IRS 2008, and Landsat 2003) and six primary periods (aerial photos: 1956, 1965, 1975, 1987, 2001; GeoEye-1 satellite image in 2012). ERDAS, ESRI, and ArcGIS 10 software were used to conduct the post-classification procedure. The results indicated that the city sprawled more than doubled in size throughout the study period. Urbanization has led to a drastic reduction in cliffs, agricultural land, and barren terrain. Between 1956 and 2012, the urban region's area increased from 403.77 to 4959.59 ha. The city's built-up area has expanded from 403.77 to 4959.59 ha. Between 1956 and 2012, the coastline zone, agricultural zone, and rough terrain declined in size from 210.96 to 60.31 ha, 155.62 to 6.92 ha of land, and 2097.24 to 262.16 ha of land, respectively. Furthermore, the overall population of Bandar had grown by more than thirtyfold during the same period. The primary driver of the population increase was migration. This rate of urban sprawl shifted the city's size and function from medium to large and trans-regional.

Sunil et al. (2014) used geospatial methods such as remote sensing (RS) and geographic information systems (GIS) to evaluate urban sprawl and land use/land cover changes in the years 1995, 2000, 2006, and 2010 in Jaipur, India. The satellite data was obtained from the National Remote Sensing Center (NRSC) and the National Security Agency (NRSA), and included IRS LISS II (1995), IRS LISS III (2000, 2006), and LANDSAT TM (2010). The images were geo-corrected using resampling methods. This was accomplished via the use of well-known points from the survey of India's top-sheets. The images were interpreted and analyzed, as well as pre- and post-processed, using ERDAS imagery and ArcGIS software. The advantages of working on this program include improved image quality and classification accuracy. Moreover, multiple layers like drainage systems, land use/land cover, railway networks, and roadways were digitized to identify particular sprawl areas using the Survey of India's top-sheet and satellite images. The study's findings indicated that the city's overall area increased over time. The entire area was originally 143.83 km square in 1995, but has since expanded to 228.22 km square in 2002, to 248.22 sq. Km in 2006, to 278.28 km square in 2010. Additionally, the city saw economic and demographic changes. Also, the findings indicated that urban sprawl has expanded throughout the research period, with the city spreading to the south-east and north-west, respectively. Between

1995 and 2006, the agricultural area fell by 13% while fallow land grew by 9%. Additionally, the built-up area grew by 15%, indicating a significant rise in urban sprawl throughout this time. Moreover, between 2006 and 2010, agricultural land dropped by 18%, fallow land rose by 18%, and built-up areas increased by 1% of total area.

Yanyan et al. (2015) used Landsat imagery to track urbanization and consequent changes in land use and cover in Guangzhou, China, during a 35-year period, from 1979 to 2013. The research gathered long-term data on land use/land cover changes from 1979 to 2013 by assessing a time series of cloud-free Landsat multispectral images. Thematic mapper (TM; bands 1-5 and 7), Landsat multispectral scanning system (MSS; bands 1-4), and operational land imager data were retrieved (OLI; bands 2-7). Earth resources observation (ERS), the Global land cover facility, and the scientific center provided the data. Additionally, the research utilized a nearest-neighbor method to resample all the reflectance bands in MSS imagery to a spatial resolution of 30m using a nearest-neighbor approach. All images were adjusted using the universal transverse Mercator projection and the wooll geodetic system of 1984. ENVI 5.0 Sp3 and ENVI 5.0 were utilized for atmospheric correction, image mosaics, and geometric accuracy correction. Also, it classifies Landsat images using a maximum likelihood method in conjunction with Guangzhou's real land cover and international geosphere-biosphere programme (IGBP) schemes. The research discovered that Guangzhou has seen significant urbanization during the last 35 years. From 395.27 sq.km in 1979 to 1907.52 sq.km in 2013, the urban area increased by 1512.34 sq.km. It grew at a pace of 11.25 percent each year. The overall area in 2013 was 4.83 times more than the entire area in 1979.

Jo Owoeye and Foakinluyi (2018) used GIS and remote sensing methods to examine the pattern of land use/land cover changes, as well as urban sprawl, in the Akure area of Nigeria between 1985 and 2014. The study's essential data was gathered using aerial imagery overlay (AIO) methods in conjunction with GIS and remote sensing (RS). A few other data sources were explored, including government departments and institutions for information about the area's historical context, and also base maps and population data for the research. The research period was split into three segments: 1985–1994; 1995–2004; and 2005–2014. Post-classification comparisons were performed to examine satellite images of Akure acquired at three separate decadal variations. The research area's land cover was categorized into four classes: dense vegetation, built-up areas, waterways, and light vegetation. The research discovered that in 1986, 64.53 percent of the total study area was covered in dense vegetation, 30.33 percent was farmed and covered in light vegetation, 5.1 percent was developed, and 0.04 percent was covered in water. This indicates a very small degree of progress in 1986. However, in 2002, the proportion of built-up land rose to 16.63 percent, while the percentage of light vegetation increased to 55.06 percent and the area covered by dense vegetation dropped to 26.34 percent. In 2007, the built-up area grew to 18.36%, the agricultural area to 65.82%, while dense vegetation and waterways decreased to 15.18% and 0.64 percent, respectively. The built-up area increased by 27.40 percent in 2014, while the agricultural area declined. The finding demonstrates unexplained urban sprawl in Akure's development, which has a significant impact on the city's and surrounding areas' land use patterns. This growth occurred as an outcome of the study area's excellent economic conditions throughout these eras.

Mehboob et al. (2015) sought to evaluate urban sprawl in Karachi, Pakistan, from 1991 to 2013. They used GIS applications and remote sensing data. The research gathered data from both primary and secondary sources. The main data sources were Karachi topo-sheets as well as the Pakistan survey, while secondary sources included multispectral Landsat MSS, TM, ETM+sensors, and a map of Karachi's administrative boundaries. They adopted three separate image processing methods to get more accurate and superior results: supervised classification, unsupervised classification, and normalized difference built-up index (NDBI). The Unsupervised method was shown to be the most accurate of the three strategies. The satellite images were pre-and post-processed using the ERDAS and ArcGIS software. The data shows that urbanization grew in Karachi from 486 to 729.2 square kilometers between 1991 and 2000. Between 2000 and 2013, it almost doubled to 1582.5 sq. km. The research discovered that the primary causes were economic development, population increase, and rural-urban mobility.

Iram et al. (2012) make an attempt to explain how urban sprawl affects public health. The paper's research area was Ravi town in Lahore, and its target population was the area's residents, both men and women. They chose a sample size of 120 respondents using a non-probability sampling method. They collected data via survey methods and also arranged semi-structured interviews with uneducated respondents. Furthermore, SPSS version 16.0 was used to analyze the data. To clarify goals, Pearson chi-square and descriptive statistics were employed. The results indicated that the majority of respondents (75%) lack access to safe drinking water in their neighborhood, and another 67 percent cited mental health issues as a result of their isolation from the main metropolis. Additionally, it was discovered that the research region lacked adequate health services, and the majority of participants identified intensive transportation as the primary source of air pollution. Also, it was found that the majority of participants had physical health issues such as malaria and diarrhea, with the primary issue being obesity and being overweight.

2.5 Literature Gap

Few researchers had analyzed the land use/land cover changes in Islamabad employing remote sensing data (RS) and geographic information systems (GIS) during the past three decades. Zahra

Hassan et al. (2016) used geospatial techniques to examine the dynamics of land use and land cover changes in Islamabad from 1992 to 2012. They used two multispectral LANDSAT satellite images of Islamabad for two separate time periods, 1992 and 2012, in addition to aerial photos, topographic maps, and ground truth data. They discovered that built-up regions, waterways, and cropland showed rising patterns throughout time, while forest cover and the barren regions decreased. The main factors behind these changes seemed to be growth in the population, industrial expansion, and road expansion. Muhammad et al. (2018) used a combination of operational Landsat imager (OLI), multispectral data from Landsat-5 thematic mapper (TM), and Landsat-8 enhanced thematic mapper (ETM), as well as a thermal infrared sensor (TIRS), to estimate changes in land use and land cover, their cooling and warming effects, and their contribution to urban heat island (UHI) effects between 1993 and 2018. It demonstrated that the warming effect of converting natural surfaces to built-up surfaces was greater than the cooling effect of converting built-up surfaces to natural surfaces. Previous research had investigated LULC changes in various aspects by applying GIS technologies. But, none of these studies investigated the rate of urban sprawl that has happened as a consequence of land cover land-use changes and a growing population by applying geospatial methods in Islamabad. Furthermore, since Islamabad's population has grown at a fast pace throughout the past decades, and changes have been detected in the LULC pattern, there was a need to evaluate the temporal land use/land cover changes in Islamabad. To develop an environmentally friendly land use plan for this rapidly growing city's expansion, it was critical to assess the dynamics of LULC changes, the growing population, and the rate of urban sprawl in the city over recent decades. Therefore, this research intended to investigate LULC changes and their impact on urban sprawl by employing GIS technologies.

CHAPTER 3

DATA AND METHODOLOGY

3.1 Data and Methodology

The current paper is a mixed-methods study in which the researchers examined satellite images of Islamabad for the time periods of 1990, 2000, 2010, and 2020 in order to identify changes in land use/land cover and urban sprawl.

3.2 Study Area

Islamabad, Pakistan's capital is the area of study in this paper. Islamabad's master plan was designed by C. A. Doxiadis, a well-known Greek architect, designer, and town planner. It is located 14 kilometers northeast of Rawalpindi, on the northeastern fringe of Punjab's Potohar plateau. It is located at 33°49′ north and 72°24′ east of Greenwich. It is situated between 457 and 610 meters above sea level. It has a total area of 906.50 sq. km.

The city of Islamabad was established in 1960,s when the Pakistani government relocated the federal capital from Karachi. Ever since, the population has increased exponentially. In 1961 Islamabad had a population of only 118 thousand, in 1998 the population increased to 0.84 million and in 2017, it increased to more than 2 million. People from all across the country rushed to the capital, expecting to benefit from the city's development in order to better their job, living circumstances, and educational opportunities. Islamabad's administrative area is split into five zones. The master plan was restricted to Zones I and II (Butt et al. 2012) and split the intended construction area into sectors of about 2 square kilometer. They are named from north to south in the alphabetical sequence A to I and are further classified numerically from east to west in order G1 to G18.

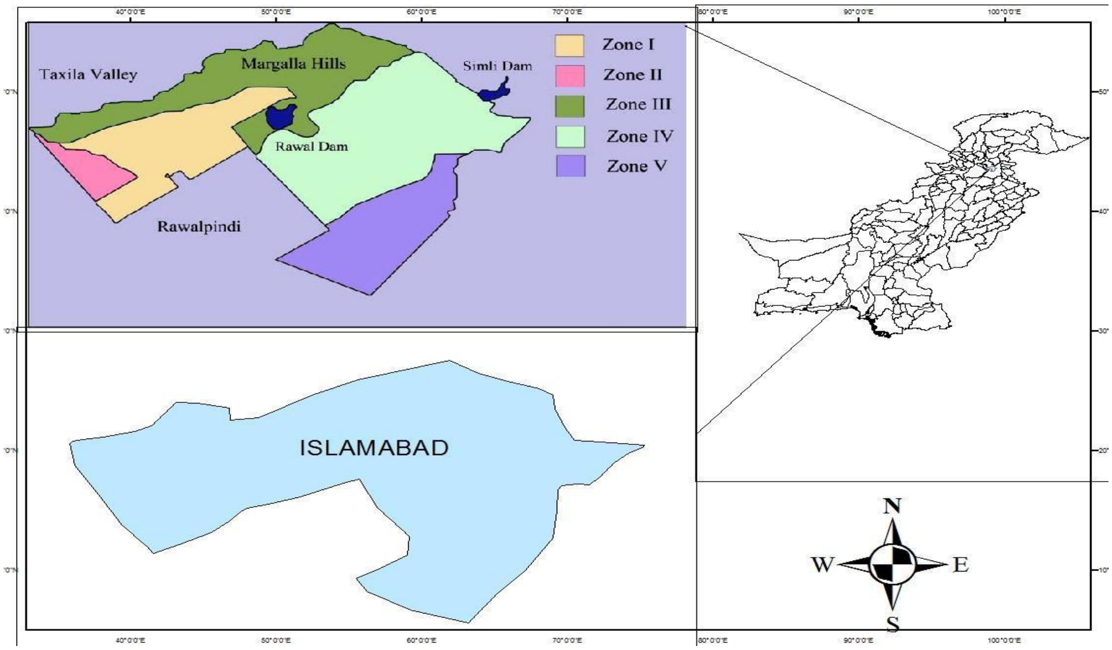

Figure 3.1: Map of the study area

3.3 Data Collection

To determine changes in land use and cover in Islamabad, four multispectral satellite data from United States geological surveys was collected for the time periods of 1990, 2000, 2010, and 2020. The data was taken in an interval of ten years because LULC was a time taking phenomena and it takes several years to convert one LC to another LC type. The data includes Landsat satellite data, namely Landsat TM 1-4, Landsat TM 4-5, Landsat 7, and Landsat 8 images are used. Furthermore, the population data was acquired from Pakistan bureau of statistics. The specifications of the satellite data are given in table 3.1.

Table 3.1 Specifications of the Satellite data

Data	Year	Number of Bands	Resolution (m)	Source
Landsat 4-5 TM C1 Level-1	1990	7	30	USGS
Landsat 4-5 TM C1 Level-1	2000	7	30	USGS
Landsat 7 ETM+ C1 Level-1	2010	8	30	USGS
Landsat8 OLI/TIRS C1 Level-1	2020	11	15	USGS

3.3.1 Remote Sensing and Landsat Satellite Program

Remote Sensing is distance detecting is the study of getting the physical properties of a region where It permits clients to catch, picture, and dissect articles and highlights on the land surface (A.D. Vibhute, B.W. Gawali; 2013). Remote sensing, as it is known to everyone, is that you get data on certain things on the ground without direct contact with those things (Rajendran, G.B.et al; 2020). Remote sensing is a broad science in and of itself to obtain, process, interpret and store images from ground, airborne, or space devices for many years for many purposes, including those used to classify the use of the land (J. Spruce et al;2010).The Landsat satellite program is a features of the remote sensing satellites, formerly known as Earth Resources Technology Satellite, has a history of more than 50 years and has utilized 8 satellites (Landsat 1, 2, 3, 4, 5,7, 8, 9) and seven sensor types (Multispectral Scanner (MSS; 1972–83), Thematic Mapper (TM; 1984–2011), enhanced Thematic Mapper (ETM +; 1999–present), operational land imager (OLI), Thermal infrared sensor (TIRS), OLI-2 and TIRS-2]. The sensors aboard each of the Landsat satellites were designed to acquire data in different ranges of frequencies along the electromagnetic spectrum. Each band collects a set of data for different wavelengths. Some are in infrared, and others correspond to blue, green and red visible light. Each band provides a different piece of information about what is down on the surface. The different depiction of earth's surface can be created by combining any three of the bands. The Spatial Resolution of the bands describe how much detail in a photographic image is visible to the human eye. The ability to "resolve," or separate, small details is one way of describing what we call spatial resolution. Spatial resolution of images acquired by satellite sensor systems is usually expressed in meters. For example, we often speak of Landsat as having “30-meter" resolution, which means that two objects, thirty meters long or wide, sitting side by side, can be separated (resolved) on a Landsat image. The Landsat data archive is unique in its ability to evaluate specific portions of the Earth's surface from 1972 to the present. This spatio-temporal historical extension is ideal for the detection, interpretation, and explanation of information such as landscape and land-use changes (USGS).

3.4 Methods

The methods for detecting changes in LULC using remote sensing data and GIS are classified as pre-and post-classification.

3.4.1 Pre-classification and processing of images

The pre-classification technique utilizes a series of multi-spectral remote sensing images to generate maps displaying regions of change or no change in LULC without identifying the type of change. It is necessary to establish a more direct link between biophysical phenomena and acquired data. Remotely sensed data from satellites and aeroplanes is usually geometrically distorted as a result of platform movements and acquisition systems. Geometric correction is performed on the satellite data after it is loaded into the ArcMap application in an image format. When the images are georeferenced, they are divided into subsets based on Area of Interest (AOI). All satellite images are analyzed by assigning per-pixel signatures and classifying the land area into five classes based on the Digital Number (DN) value of various landscape elements: the classes are built-up areas, agricultural areas, forest areas, barren land, and water bodies. Each class is assigned a distinct color and a unique identity to help distinguish it from the others. Furthermore, the supervised classification method is used to conduct the classification of the data. The shape file of Islamabad is extracted from Google earth in Kml form and converted into polygon in arcmap by using the “kml to layer” converter tool. The AOI is extracted from the satellite image by using the shapefile of Islamabad. After that, different training samples are created for each class and developed a signature file. Finally, with the help of a signature file MLC is performed to conduct supervised classification. The detail of land classification of Islamabad is given in table 3.2 where the total land of Islamabad is classified into five classes.

Table 3.2 Detail description of classes on the basis of supervised classification

Feature Name	Description
Agricultural Land	Farm land, Crop fields, Green belt
Barren Land	Barren area and exposed soil influenced by anthropogenic activities, Rock surfaces
Built-up Land	Commercial, Residential, Industrial, Roads, Mixed urban
Forest Land	Forest lands, Pine forest and Mixed forest
Water	Open water, lakes, Dams, Rivers, Reservoirs and ponds

3.4.2 Accuracy Assessment

It is necessary for individual classifications if the classification data is to be helpful for change detection (Owojori et al., 2005). For the purpose of determining the accuracy of satellite images, the overall accuracy and kappa tests are performed by using an error matrix with the help of this matrix overall accuracy, kappa coefficient, producer accuracy and user accuracy are calculated.

$$Overallaccuracy = \frac{\text{Total number of corrctly classified pixels (diagnoll)}}{\text{Total number of referannce pixels}} \times 100 \qquad (3.1)$$

$$produceraccuracy = \frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{(Total Number of Reference Pixels in that Category (The Column Total)}} \times 100 \qquad (3.2)$$

$$\text{User Accurecy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{TOTAL NUMBER OF Classified pixiels in that catogary(the row total)}} \times 1oo \quad (3.3)$$

$$Kappacoefficient = \frac{((\text{TS} \times \text{TCS}) - \Sigma(\text{Column Total} \times \text{Row Total}))}{(\text{TS}^\wedge 2 - \Sigma(\text{Column TotalxRow Total}))} \times 100 \quad (3.4)$$

Where,

$$Ts \ = Total\ sample \quad (3.5)$$

$$Tcs \ = Total\ corrected\ samples \quad (3.6)$$

3.4.3 Post-classification and processing of images

The post-classification technique analyses two classified temporal remotely sensed images to generate maps showing changes over time within and across LULC classes. Post-classification refinements are used to reduce misclassifications and increase classification accuracy due to the method's efficiency and simplicity. It is carried out using the ArcGIS application. Numerous studies have successfully used post-classification in urban areas thanks to its effectiveness in identifying the type, location, and pace of change.

3.4.4 A map of urban sprawl

Two techniques are used to develop a map of urban sprawl. First, a sprawl map is created by using the Built-up Index (NDBI) method. This method is used to automatically extract built-up areas from satellite images, since built-up areas reflect more SWIR than NIR. Second, the raster map is converted into polygon and then by merging the attributes of each class, urban sprawl map is created by clipping the built-up area for all the four time period. The following formula is used to estimate Built-up Index (BU).

$$BU = NDBI - NDVI \quad (3.7)$$

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \quad (3.8)$$

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (3.9)$$

Where,

$$NDBI = Normalized\ difference\ builtup\ index \quad (3.10)$$

$$NDVI = Normalized\ difference\ vegetation\ index \quad (3.11)$$

$$SWIR = Short\ wave\ infrared\ band \quad (3.12)$$

$$Red = Red\ band \quad (3.13)$$

3.5 Explanation of key terms

3.5.1 Land use and land cover changes (LULC)

LULC are two distinct terms that are frequently used together. Land cover refers to the physical qualities of the earth's surface, such as vegetation, water, and other physical characteristics. Additionally, it comprises the physical surface that humans have constructed, such as built-up regions. In contrast, land use refers to how humans have utilized the land. LULC transformations are a rapid and widespread phenomenon that is mostly triggered by human activities and natural occurrences that affect the natural ecosystem. It is the process by which one land cover type transforms into another, and it is one of the most visible and rapid changes the earth is undergoing, with enormous environmental and social consequences on a wide range of scales.

3.5.2 Urban Sprawl

Earle Draper, one of the prominent American city planners, coined the phrase urban sprawl during WWII. However, this concept received the attention it deserved following WWII. Since the war, urban sprawl has remained one of the most prevalent patterns of urban spatial extension around the world, with distinct causes, dates, and consequences. When the population of a region or city grows, the city's borders extend to accommodate the population; this expansion is referred to as urban sprawl. It is the transition of agricultural land to non-agricultural land as a result of the unrestrained growth of residential, roads, and commercial development across many urban areas. In general, this refers to particular forms of urban spatial extension into the peripheries and suburbs that include large motorways and road infrastructure, low density, vehicle dependent, scattered, and ribbon expansion within a mono-centric urban framework. In developed economies, it has been fueled by the market economy, global economic integration, and the ideals of capitalism, particularly in the fuel market and the auto industry. In developing economies, it is primarily the result of urbanization surpassing urban planning, ineffective government housing and land policies, rural-to-urban migrations, and low-and middle-income families' efforts to find affordable housing in the cities. The negative social, economic, and environmental impacts are a key issue for LULC change and urban sprawl. On a socioeconomic level, urban sprawl results in increased public service costs and excess infrastructure, limiting social cohesion, shrinking public space, eroding community spirit, destroying community welfare, safety, and security, increasing income inequality, eroding cultural values, traffic jams, increased travel distance, and restricted access, particularly for non-drivers.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Classification of LULC

The LULC classification results for the time periods of 1990, 2000, 2010 and 2020 using supervised classification and the maximum likelihood method within the study area are shown in Figures 4.2, 4.3, 4.4 and 4.5. The table 4.1 shows the quantitative findings of all periods after converting the raster images into polygons and estimating areas by using a calculated geometry technique. For all the images, five classes were selected to classify the Landsat 1-4, Landsat 5, Landsat 7 and Landsat 8 images to obtain reliable results.

The Classification map of 2020 had an accuracy of 94%, whereas the 2010 map had an overall accuracy of 86%. Similarly, the map of 2000 had an accuracy of 91% and the 1990 map had also an accuracy of 91%. All the maps accuracy was checked by creating an error matrix. The Kappa coefficient was also estimated to verify the accuracy of all maps. The final classification maps of the time period of 1990, 2000, 2010, and 2020 had a kappa coefficient of 90%, 89%, 83% and 93% respectively. The result showed that the total area of Islamabad was 906 sq. km and the total area of each class in 1990, 2000, 2010 and 2020 showed that the agricultural area had the largest area in 1990; 540.59 sq. km. However, it declined to 501.45 sq. km in 2000 and further reduced to 481 sq. km in 2010 and 447 sq. km in 2020 respectively. This class went through a significant transformation over the time period, as it was reduced from 59% of the total area in 1990 to 55.38% in 2000. Similarly, this class further declined to 53% in 2010 and 49% in 2020. The total change that occurred in agricultural land was -10% during the study period. The other classes which faced reductions during the study period were forest areas and barren land. The total area of forest area was 230.05 sq. km in 1990, which declined to 210.65 sq. km in 2000. In 2010, it further declined to 190.28 sq. km and this trend continued in 2020 as the area decreased to 185.70 sq. km. In terms of percentage, it accounted for 25.415% of total land area in 1990, 23.27% in 2000, 21.02% in 2010 and 19% of total land area in 2020. The total change detected in this class was -6% from 1990 to 2020. The Barren area's total area was 71.39 sq. km of total land area in 1990. However, from 1990 to 2000, it declined to 66.89 sq. km. It further decreased to 61.38 sq. km in 2010 and 51.72 sq. km in 2020. It covered 8% of the total land area in 1990, which decreased to 7% in 2000, 6% in 2010 and 5% in 2020. The total change that occurred in this class was -3% during the study period. On the other hand, the water class showed a mixed trend. It declined from 6.44 sq. km to 4.73 sq. km from 1990 to 2000. After that, this class showed an increasing trend as it increased to 5.91 sq. km from 4.73 sq. km in 2010 and 5.91 sq. km in 2020. The total percentage of water bodies was 0.71% of total land area in 1990, 0.52% in 2000, 0.65% in 2010 and 0.68% in 2020. An overall change occurred in this class -0.03% from 1990 to 2020. The only class that showed a positive trend during the study period was the built-up area. It accounted for 56.93 sq. km of total land area in 1990 and rose to 121.68 sq. km in 2000. In 2010, it further increased to 166.83 sq. km and in 2020 it increased to 214.46 sq. km. The built-up area went from 6% of the total land area in 1990 to 24% of the total land area in 2020. The decadal growth rate in this area was significantly higher than in other classes. It depicts a 6% decadal growth rate from 1990-2020. From 1990 to 2000, it increased from 6% to 13.44%. Furthermore, its share increased from 13.44% to 18.43% from 2000 to 2010 and from 2010 to 2020 it increased from 18.43% to 24%. The total change that occurred in the built-up area was +18% during the whole study period.

Table 4.1 LULC changes comparison in square kilometers and percentage from 1990 to 2020.

LULC	1990		2000		2010		2020		Area change (1990-2020)	% change (1990-2020)
	Area	%	Area	%	Area	%	Area	%		
Agricultural	540.59	59.71	501.45	55.38	481.00	53.13	447.29	49.40	93.3	-10.31%
Barren	71.39	7.89	66.89	7.39	61.38	6.78	51.77	5.72	19.62	-2.17%
Built Up	56.93	6.29	121.68	13.44	166.83	18.43	214.46	23.69	157.53	+17.4%
Forest	230.05	25.42	210.65	23.27	190.28	21.02	185.70	20.51	44.35	-4.92%
Water	6.44	0.71	4.73	0.52	5.91	0.65	6.17	0.68	0.27	-0.03%
Total	905.40	100	905.40	100	905.40	100	905.40	100	315.07	

Source: Author generated through ArcMap analysis.

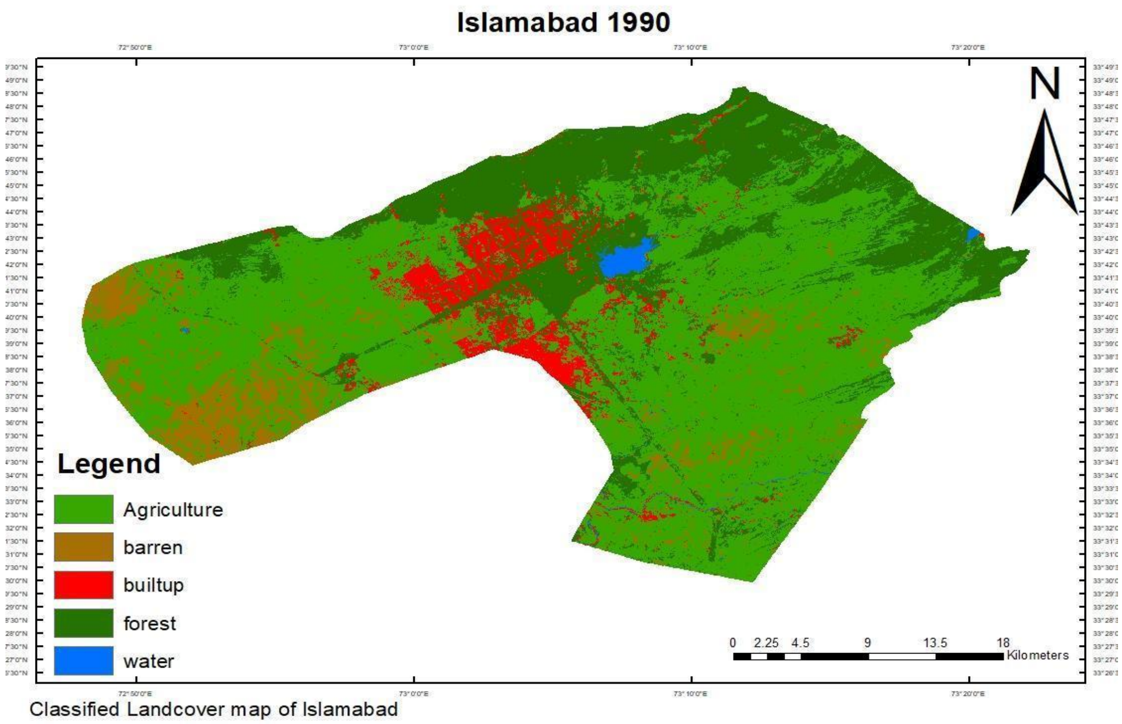

Figure 4.1: Classified Land cover map of Islamabad in 1990

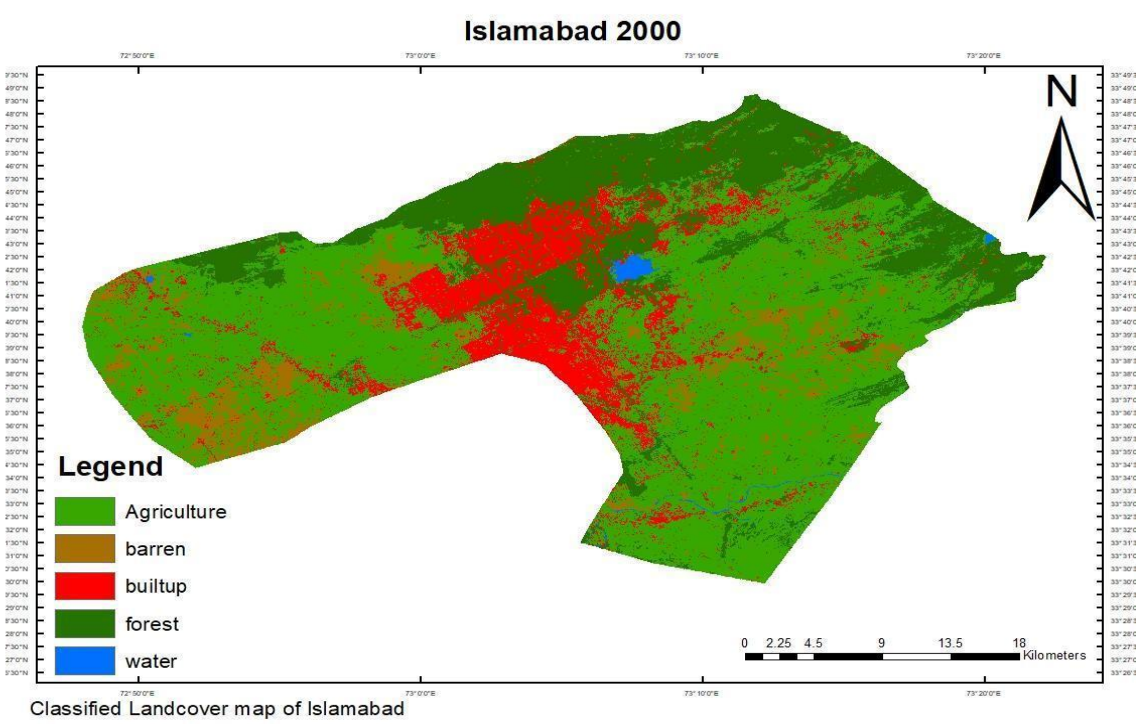

Figure 4.2: Classified Land cover map of Islamabad in 2000

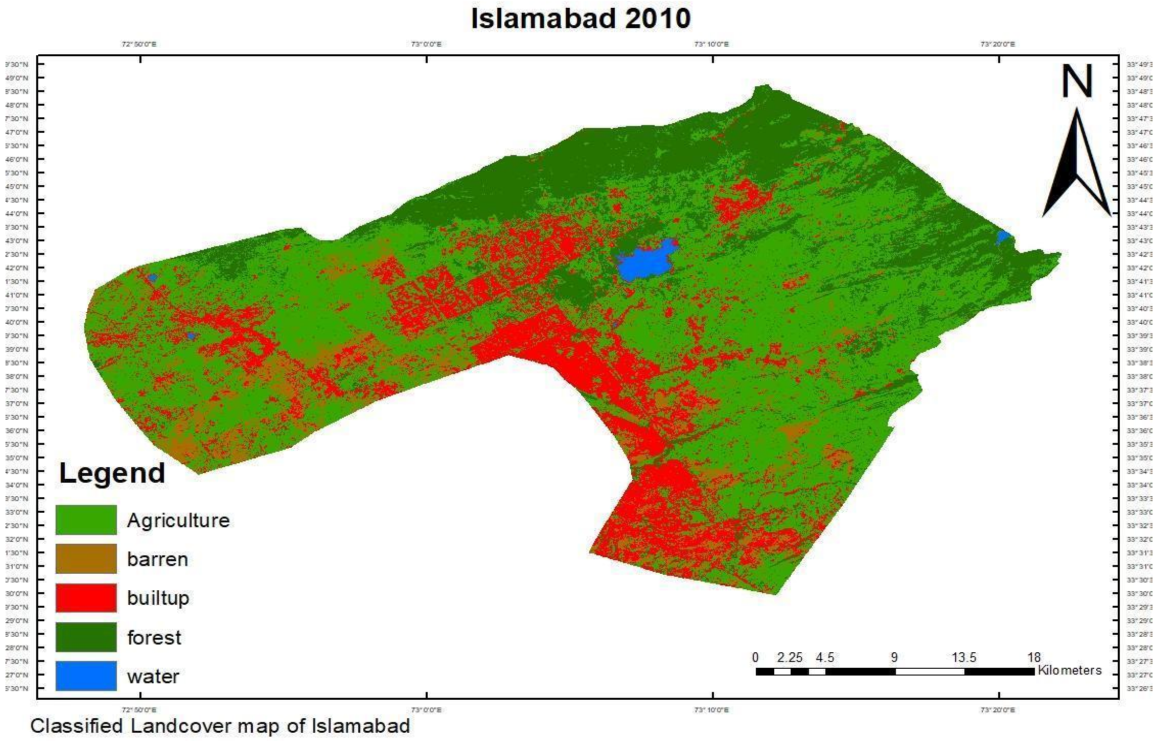

Figure 4.3: Classified Land cover map of Islamabad in 2010

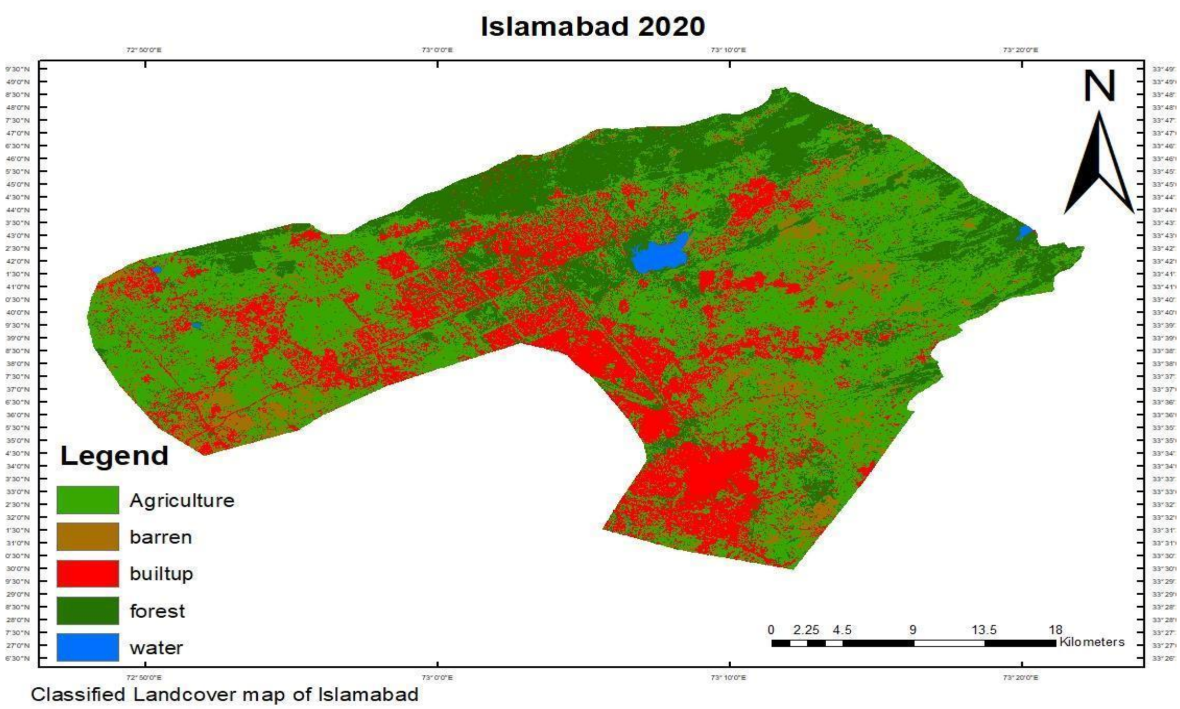

Figure 4.4: Classified Land cover map of Islamabad in 2020

4.2 Accuracy Assessment

It is necessary for individual classifications if the classification data is to be helpful for change detection (Owojori et al., 2005). The table 4.2 shows the result of the accuracy assessment. It was evaluated using a random error matrix and the stratified random method was employed to show different LULC classes of the study area. Total 36 points were drawn on the classified map randomly and compared with them ground truth data acquired from Google earth then visually interpreted.

Table 4.2: Specifications of Accuracy Assessment

Year	Overall accuracy	Kappa coefficient	Producer accuracy	User accuracy
1990	91%	90%	92%	92%
2000	91%	89%	91%	91%
2010	86%	83%	90 %	87%
2020	94%	93%	100%	94%

Source: Author generated through ArcMap analysis.

4.3 Change Detection

The change detection results for the time periods of 1990 to 2020 using an overlay procedure and cross tabulation among the five classes are shown in the figure 4.5. The table 4.3 shows the quantitative findings of change detection after converting the raster images into polygons and estimating areas by using a field calculator technique. The post classification technique was used to analyses the maps of 1990 and 2020 to generate a map which shows changes across LULC classes. The result indicated that most change occurred in the built-up area, as 135 sq. km of agricultural land was converted into built-up area from 1990 to 2020. Similarly, 21 sq. km of barren land and 17 sq. km of forest land were converted into built-up areas. Whereas, from 1990 to 2020, 14 sq. km of built-up area, 65 sq. km of forest area, and 37 sq. km of barren area were transformed into agricultural land. Furthermore, 37 sq. km of agricultural land, 1 sq. km of barren land and 5 sq. km of built-up land were converted into forest land from 1990 to 2020. The barren land also showed medium change as 34 sq. km of agricultural land, 5 sq. km of forest land and 1 sq. km of built-up land were converted into barren land during the study period. The only class that did not detect any change during the study period was the water bodies, as this class did not convert into any other class nor did any other convert into this class from 1990 to 2020. As indicated by the result, major land from all the classes has been converted into built-up areas, which reflects the high rate of urban sprawl occurring from 1990 to 2020.

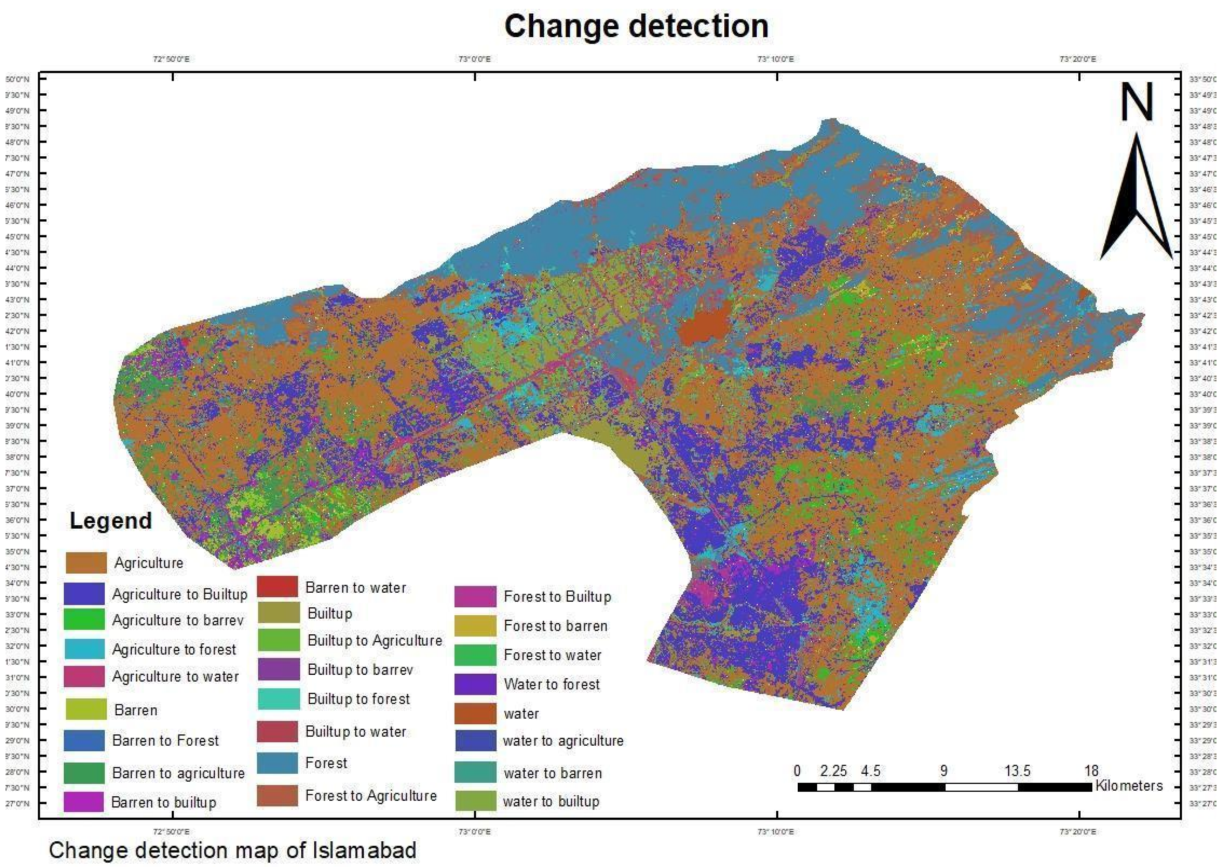

Figure 4.5: Change detection map of Islamabad between 1990 and 2020

That shows the transformation of one land cover class into another

Land covers class.

Table 4.3: “From-to” conversion of one class into another class from 1990 to 2020.

From	To	1990-2020 Area (sq. km)
Agriculture	Built-up	135
	Forest	37
	Barren	34
Forest	Built-up	17
	Agriculture	65
	Barren	5
Barren	Built Up	21
	Forest	1
	Agriculture	37
Built-up	Agriculture	14
	Forest	5
	Barren	1

Source: Author generated through ArcMap analysis.

4.4 Urban Sprawl Measurement

Urban sprawl is an international phenomenon. It is spreading globally at an increasing rate and numerous cities are sprawling to a lesser or greater extent around the world. It is directly related to the built-up area. Built-up areas account for a significant portion of the land use related with urbanization. Classifying the built-up areas through the use of satellite images is also a top priority for relevant agencies or organizations tasked with investigating urban sprawl. While urban regions account for a small proportion of the world's total land mass, their population density and resource usage intensity are significantly higher than in rural areas, demanding efficient resources management techniques (Geist and Lambin 2001, Cohen 2006). Understanding the geographical distribution and expansion of urban sprawl is critical for resource management and urban planning, and mapping the built-up region is fundamental to accomplish this purpose (Chucat and Barraud 2000). When carried out using traditional methods such as aerial photography and ground surveying, this mapping activity consumes a significant amount of resources (Richard 2013). Additionally, the frequently fast urban growth complicates the process of mapping urban built-up areas in a timely and accurate manner (Lein 2006, Small 2003). For numerous reasons, remote sensing (RS) data, particularly from satellite remote sensing systems, is an essential resource for mapping urban areas. It gives a complete and synoptic perspective that ground surveys cannot provide in the case of big urban areas (Richard 2013). Another practical advantage of RS data for urban studies is the availability of historical archives that can be used to track and explain urban expansion through time (Griffiths et al. 2010, Xu 2008).Population growth and the physical extension of the city are the main reasons of Urban sprawl. The city of Islamabad has also experienced urban sprawl due to the diffusion of vehicles, population growth and physical extension. Urban sprawl is measured by using the BU index and by clipping built-up areas. Urban sprawl from the classified maps of 1990, 2000, 2010 and 2020 shows significant changes. Moreover, the built-up (BU) index value range from -1 to 1 and the positive value indicates the presence of urban sprawl in the city. The BU index value of Islamabad in 1990, 2000, 2010 and 2020 is 0.9, 0.15, 0.19 and 0.26 that indicates the presence of urban sprawl in the city of Islamabad. In 1990, the total urban sprawl area of the city was 56.93 sq.km and, in terms of percentage, it was only 6.29%. Figure 4.6 shows the map of urban sprawl in 1990, in which the urban sprawl area is shown in red. Also, by visual interpretation of the map, it is clear that the sprawling areas are less and compact at the center of the city in 1990. However, from 1990 to 2000, urban sprawl increased from 56.93 sq. km to 121.68 sq. km. It was spread more than double in 2000. The urban sprawl map of 2000 is shown in figure 4.7 and the sprawling area is depicted in green. The map shows that in 2000, urban sprawl is compact in the center and scattered in the surroundings of the city, the total area of urban sprawl was 13%. Furthermore, the area of urban sprawl increased from 121.68 sq. k to 166.83 sq. km between 2000 and 2010. The urban sprawl map of 2010 is shown in figure 4.8 and the urban sprawl area is depicted in yellow. The map shows that the urban sprawl is scattered around the surrounding and in the vicinity of center and in terms of percentage urban sprawl area was 18% of the total area in 2010. Finally, from 2010 to 2020, the urban sprawl area increased from 166.83 sq. km to 214.46 sq. km. The map of urban sprawl for the year 2020 is shown in figure 4.9 and the urban sprawl area is depicted in brown. The map shows that the pattern of urban sprawl is both compact and scattered and the total area of urban sprawl is 24% of the total area. The total increase in change that occurred in urban sprawl between 1990 and 2020 is 17.71%. Furthermore, the total change in urban sprawl in terms of sq. km between 1990 and 2020 is 157.53 sq. km. The table below shows the total area of urban sprawl in each year, the trend of urban sprawl and changes that occurred in urban sprawl between 1990 and 2020.

Table 4.4: Urban sprawl change trends between 1990 and 2020.

Year	Square Kilometer (sq. km)	Percentage (%)	Built-up index value
1990	56.93	6.29	0.9
2000	121.68	13.44	0.15
2010	166.83	18.43	0.19
2020	214.46	24	0.26
Total change	157.53	17.71	

Source: Author generated through ArcMap analysis.

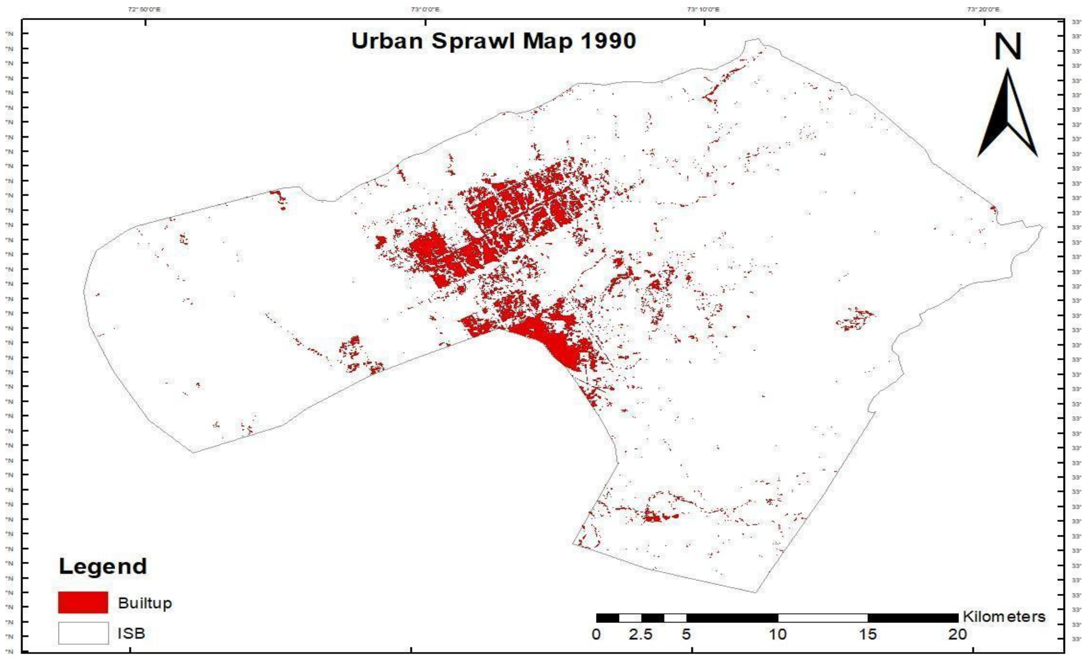

Figure 4.6: Urban sprawl map of Islamabad in 1990

and the sprawl area is depicted in red.

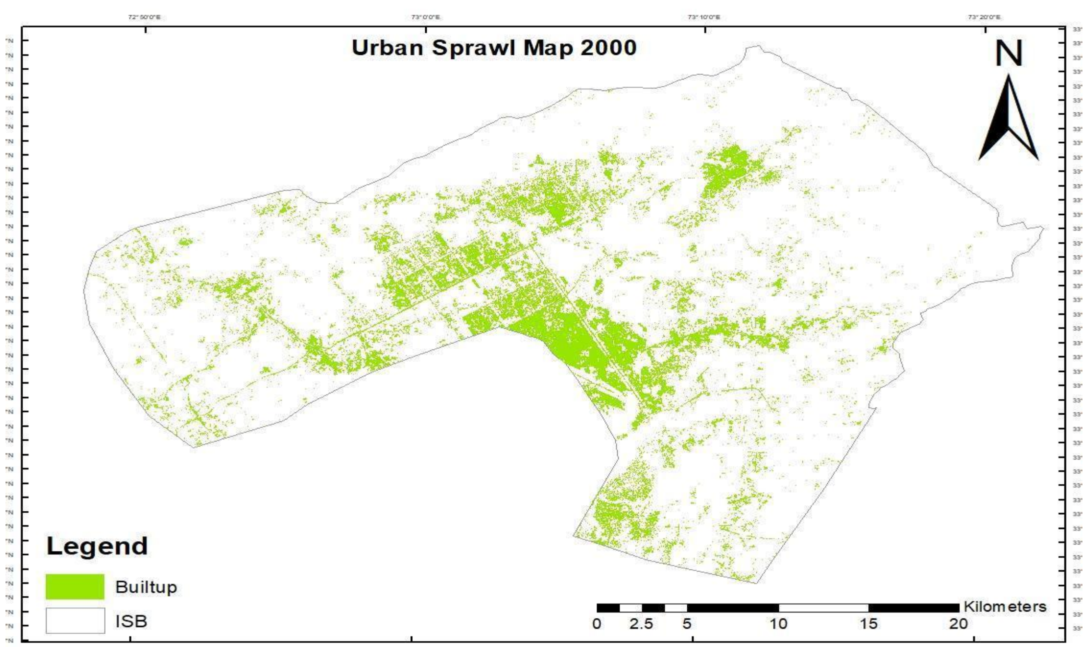

Figure 4.7: Urban sprawl map of Islamabad in 2000

and the sprawl area is depicted in green.

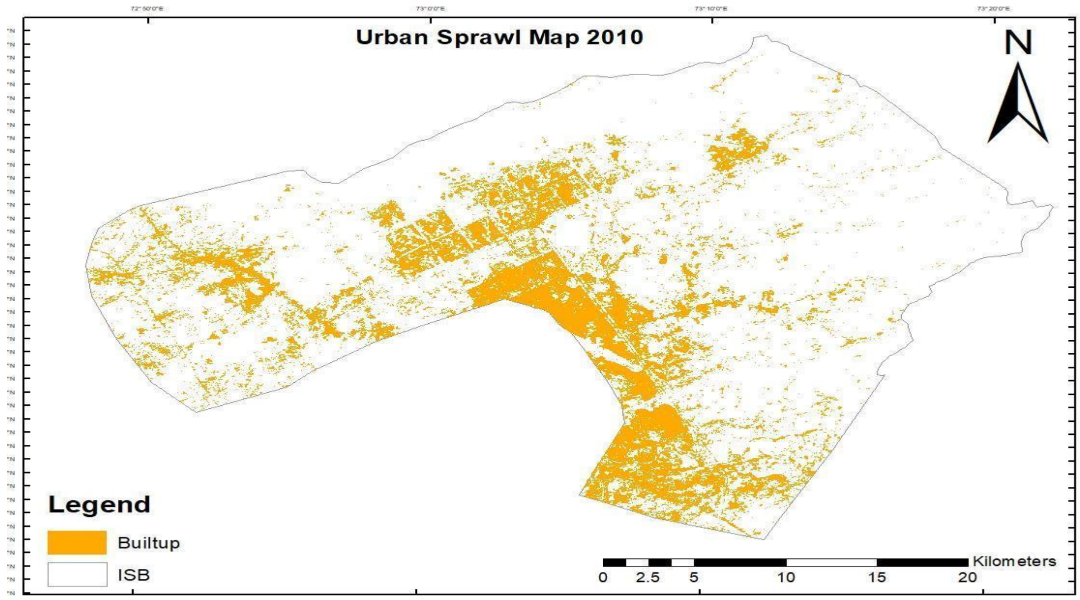

Figure 4.8: Urban sprawl map of Islamabad in 2010

and the sprawl area is depicted in yellow.

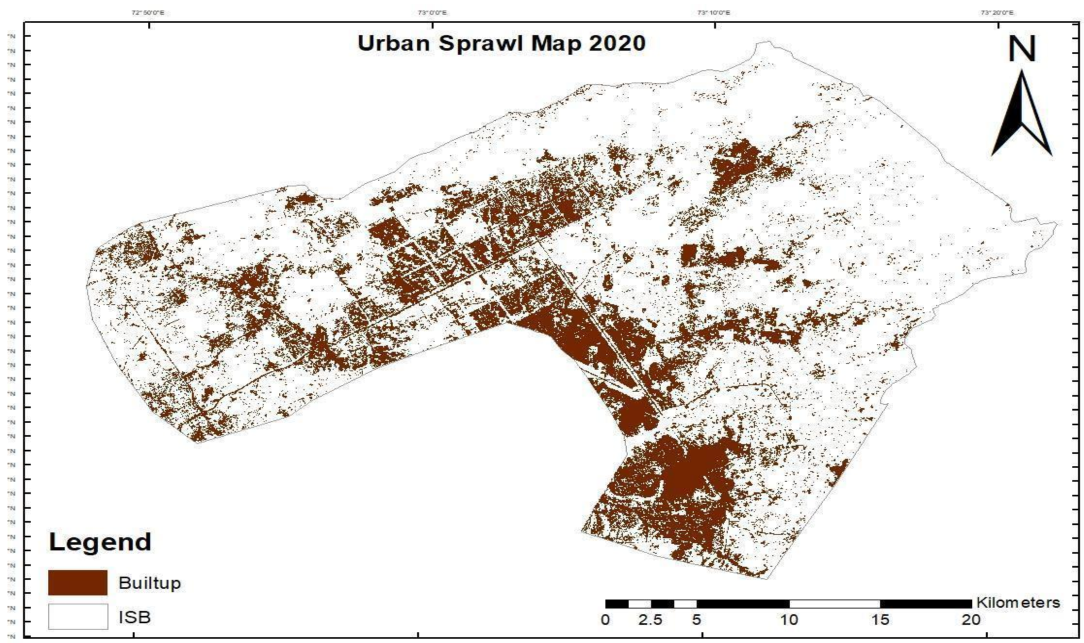

Figure 4.9: Urban sprawl map of Islamabad in 2020

and the sprawl area is depicted in brown.

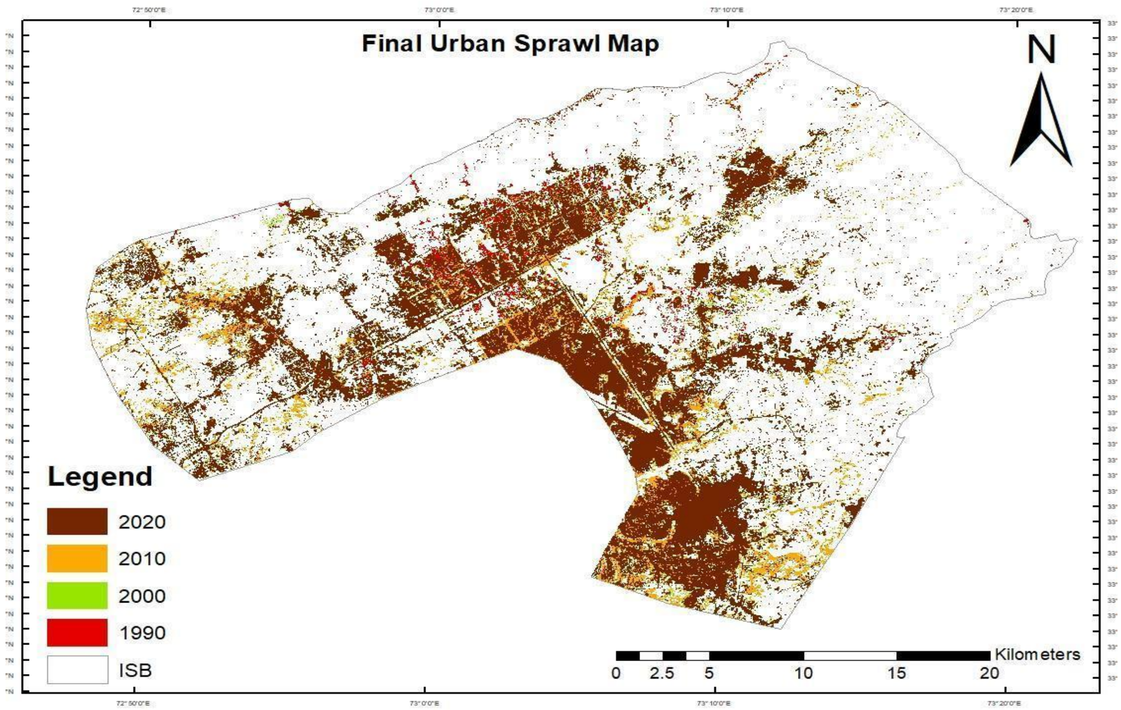

Figure 4.10: Final Urban sprawl map of Islamabad

4.5 Population Growth

The population of the region has an influence on sprawl. A measure of quantify sprawl is the proportion of a region's total population to the region's total built-up area. (Barnes et al, 2001). The city of Islamabad has witnessed rapid population growth and urban sprawl during the last three decades. In 1998, the total population of Islamabad was 805235 residents living on 121.68 sq. km of built-up area. During 1998 to 2017 the city population increased from 805253 (0.81m) to 2,003,368 (2.0 m). This results in the conversion of an additional 92.78 sq. km area into built-up area resulting in an increase in built up area from 121.68 sq. km in 1990 to 214.46 sq. km in 2020 to accommodate the growing population. The population density of Islamabad in 1998 was 889 persons per sq.km with a total 805253 residents living in the city which increased to 2211 persons in 2017 with a total 2,003,368 residents living in the city. The table below shows the details of population density and increase in population between 1998 and 2017.

Table 4.5: Population growth and urban sprawl in Islamabad

Year	Total population	Built-up area (sq.km)	Population density per sq.km	Population density per built-up sq.km	Average annual growth rate in population
1998	805253	121	889	6655	
2017	2,003,368	214	2211	9362	
Growth rate					4.90

4.6 Discussion

Using Landsat images from 1990, 2000, 2010 and 2020, this study examined agriculture land, built up area, forest area, barren land and water area as five key LULC classes that have changed significantly in Islamabad, suggesting fast urban sprawl as a result of population increase and economic development in Islamabad. Among the most noteworthy LULC conversions was the transformation of agriculture and forest areas into built-up areas. The city got almost 1198115 new residents during the last three decades, as shown by Pakistan bureau of statistics, thanks to the migration of people from rural areas and the influx of foreign population into the city. Due to economic prosperity and population growth, the residents of Islamabad began investing in real estate through the development of new private residential and commercial residences and properties. Simultaneously, urban infrastructure development, including highways, roads, schools, residential hotels, and mosques, banks, retail complexes, and healthcare institutions, all contributed significantly to the city's expansion and urban sprawl.

This research discovered that built-up areas increased from 51 sq. km to 214 sq. km between 1990 and 2020. This number reflected the huge shift in land cover in the area of built-up surfaces, which put excessive pressure on non-built-up surfaces, particularly on forest areas and agricultural areas. The expansion of pre-existing urban fabrics by fast development of residential areas, commercial and industrial areas, road infrastructure and footpaths, leisure facilities, and other built-up surfaces have all contributed to the continual expansion of built-up areas. Habitat loss and deforestation are the primary environmental effects of urbanization along the city highway. According to the results found in this study, forest area has decreased by roughly 50 sq. km during the previous three decades, from 1990 to 2020. One of the major causes of the change in the forestland is the enormous damage caused by wild and unintentional fires throughout the summer, when there is no rain for months and temperatures reach 45 °C, reducing hundreds of hectares to cinders. Another major cause was also the conversion of forest areas into agricultural land settlements. The result of change detection clearly showed that 65 sq. km of forest land has been converted into agricultural settlement during the last three decades, making it one of the primary reasons for deforestation, but some forest areas were repurposed for other gardens around the region. Additionally, the conversion of forest areas into built-up areas was another main reason for deforestation in Islamabad, as 17 sq. km of forest land was transformed into urban settlements. If deforestation continues, the area will undoubtedly suffer from soil erosion, high temperatures, and dust storms (Ellis et al. 1994). These negative consequences would further contribute to climate change and global warming, and the ripple effect would contribute to future global warming

(Siddiqui 1991). During the research period, 50% of the forest area remained intact, whereas 8% of the forest land deteriorated, showing a tendency toward forest degradation and scant vegetation. Classified maps also revealed a moderate rate of growth in the water class area. This variation might be attributed to the monsoon season's rainfall.

The agricultural areas and barren areas also declined as a growing population in the core region compelled wealthy residents to relocate to side areas away from the center of the city, resulting in the conversion of agricultural land and barren land into commercial and residential areas, resulting in the urban sprawl of the city. This has led to the establishment of residential colonies on the city's outskirts, resulting in the urban sprawl of the city. The agricultural class and the Barren class had a downward trend during the course of the study years, and the primary reason for this downward trend was urban sprawl in the city during the period of 1990 to 2020.

4.6.1 Economic cost of sprawl:

Cities are frequently referred to as economic growth engines. For decades, this concept has captivated decision-makers, from the seminal report Urban Policy and Economic Development: A 1990s Agenda (World Bank, 1991) to the Commission on Growth and Development (Spence et al., 2009) and the Global Commission on the Economy and Climate (Floater, et al., 2014). Rapid economic growth normally associated with urbanization can be partially attributed to structural transformation, as agricultural labor migrates to industry and services. It can also be attributed to aggregation and scale economies, as density and proximity lower the per capita cost of services and infrastructure, while simultaneously fostering knowledge spillovers and specialization that significantly boost urban residents' productivity. Agriculture's share of gross domestic product (GDP) diminishes as a country develops, and industry and services come to dominate the economy. Often, the most efficient production of goods and services occurs in densely populated places because they provide access to a pool of skilled workers, a network of complementary enterprises that operate as suppliers, and a critical mass of customers. As a result, sustained economic growth is closely linked to urbanization. However, not all cities become engines of growth, since urbanization brings with it its own set of issues that must be handled in order to fully realize it's potential. With an increasing urban population, pressure on basic infrastructure and services such as sanitation, water, waste management, transportation and housing has increased. Cities suffer from major deficiencies in the creation and implementation of holistic spatial plans, which results in low-density, sprawling, and chaotic development. Cities in Pakistan are likewise confronted with the same issues. As a result, rather than serving as a catalyst for growth, the government is forced to spend more owing to a lack of planning in the development of a city.

The federal capital is also an example of sprawling urbanization. There is no central business district in Islamabad, which is essential for the economic activities and growth of a city. The Master Plan, like other master plans, has resulted in contrived urban expansion and economic stifling. Land and building regulations are excessively rigid, which has resulted in Islamabad being over-regulated, restricting the city's social and economic potential. This resulted in the city's sprawling pattern of urbanization. Sprawling patterns of development increase travel costs; diminish the economic vitality of urban centers; increase tax burdens due to extensive road, utility, and school construction and maintenance costs; increase health care costs due to pollution caused by automobile-centered neighborhood designs; and result in the loss of productive agricultural and forestry lands, as well as natural lands that support wildlife.

In Islamabad, the majority of residential development is based on a density-averse urban planning approach, which results in spacious single-family homes with adequate green space and vehicle parks, creating sprawling neighborhoods. Infrastructure provision in sprawling communities, where houses and businesses are separated by large distances, is typically more expensive than in more compactly developed areas, leading to higher tax bills. Because new housing societies are only feasible when the government provides new road infrastructure and other public commodities (electricity, gas, and piped water). Thus, the supply of public goods via taxpayer funds is critical to the commercial viability of these housing societies. Profits, in other words, are privatized, whereas costs are socialized.

Mobility and travel time is very important in a city. The space to live and time travel determines the productivity of workers in the city. Mobility doesn't mean more cars and roads. There are cheaper and environment friendly ways of mobility than cars like walking, bicycling etc. The city managers need to understand that public transport begins with walking and ends with walking and Islamabad needs mobility not transport. However, city management is fixated on automobiles. They are constantly extending roads, constructing flyovers, stifling commerce to make room for automobiles, and slicing up city areas to ensure that automobiles flow freely. Although the world is starting to make driving more expensive and environmentally aware in the city center, Pakistani planners are doing everything they can to make the city more car-friendly. Continuously, flyovers and large streets are being built at the expense of community and commercial coherence. Because sprawl growth is vehicle-dependent, as opposed to compact development, it increases automobile use, reduces the efficiency and effectiveness of public transit, increases expenses associated with car accidents, and decreases the use of transit, bicycles, and walking. The suburban sprawl lengthens the average commute to work. In Islamabad, the average distance travelled by wagon is only 22 kilometers (Haque).

This type of urbanization is concerning for the agriculture industry and also increases the cost of energy. Since independence, agriculture has dominated the economy, employing about half of the worker force. Numerous questions arise as a result of the sprawling pattern. How will agricultural employees be absorbed into other sectors if they lose their jobs, particularly given the constraints of the country's broader labor economy? If waves of unemployed farm workers seek work in cities, how will authorities handle these fresh influxes given the cities' existing acute water, electricity, and housing shortages? Additionally, the automotive centric expansion raises the energy bill. Pakistan currently spends 7% of GDP on oil imports (Haque).

The capital management needs to realize the effects of sprawl and implement plans to curb it. They should shift their focus away from the rigid master plan and look for other approaches to control sprawl and boost economic activities in Islamabad. In this context, PIDE Policy Viewpoint 13 has pointed to how a modern city finances itself through proactive value creation which benefits citizen’s real estate wealth. If city administration adopts this approach rather than rigid master-planning and allows value creation for the benefit of cities, welfare will increase.

4.6.2 Policy discussion

The master plan was made in 1960 and the city administrative control was given to CDA under the CDA ordinance 1960. The city was originally planned as a small community for civil servants and government. The MP was reviewed in 1986 and 2005 however, no change and reforms were made in the MP as both reviews failed to be approved by the federal cabinet. The capital faced many problems concerning the way it is growing because the primary focus of the MP was on zone 1 and zone 2 that led to planned manner development in zone 1 and 2 however haphazard manner development in other zones. Furthermore, restrictive zoning law becomes a barrier to sustainable development of the capital. As mentioned in the clause 4 of Revised Modalities & Procedures (2020) framed Under ICT (Zoning) Regulation, 1992 (As Amended) for Development of Private Housing/ Farm housing Schemes in Islamabad Capital territory Zoning Plan, in zone 2, 4 & 5 only

15 % of land in any housing scheme is allowed to develop vertically. Under the zoning regulation 1992 construction of private housing schemes and commercial activities were not permissible in Zone-4, however, it was amended in 2010 and zone 4 was divided into 4 sub zones and private housing schemes were allowed in sub zones. Vertical development was discouraged as it allowed construction of single units for residential (Ground+1+basement) and for apartments, offices & commercial building it allowed three storeys (Ground+3+basement) building. These laws discourage high density mixed use city center and residential areas and encourage single family homes. They were more in favor of Euclidean zoning that favors single family residence as the most preferable land use. Furthermore, to curtail the growing housing demands CDA allowed private housing schemes and projects under the zoning regulation 1992. An extensive regulatory regime was given the authority to govern the development of private housing societies in Zone-2, 4, and 5 of ICT under the zoning regulation 1992 and revised Modalities & Procedures (2020) framed Under ICT (Zoning) Regulation, 1992 (As Amended) for Development of Private Housing/ Farm housing Schemes. CDA was given broad powers to regulate the development of housing societies. The scrutiny of the Layout Plan (LOP), issuance of NOC, and regular inspection of the quality of work, among many other requirements, all provide CDA an overarching framework to monitor housing societies. CDA can even take possession of a society if the sponsor cannot complete it within due time. However, CDA failed to exercise these powers successfully and failed to stop the maniac of illegal housing societies. As per the Capital Development Authority (CDA) estimates, there are around 140 illegal housing societies in Islamabad. The civic authority issued a list stating that there are only 64 societies that are authorized. Upon further study by the Pakistan Institute of Development Economics (PIDE), it was concluded that from a list of 64 approved societies, only 22 had a NOC.A special audit of the Housing Societies Directorate of CDA for

2011-16 by the Auditor General of Pakistan (AGP) uncovered serious irregularities and non-compliance in issuing of NOCs (AGP, 2017). They issued NOCs without proof of ownership of land, based on fake documents, or for areas outside of ICT. CDA had issued only 22 NOCs in the past 30 years in Zones 2, 4, and 5. These schemes cover only 6.8% of the total land of these zones. 1.26 million kanals of land are under illegal possession and being sold under the garb of housing societies, and 99% of these illegal societies are incomplete. People have lost their hard-earned money to the tune of PKR. 5200 billion (AGP, 2017) in these illegal societies. These led to horizontal urban sprawl and inefficient use of land. The federal government formed a commission to review MP again in 2019. The interim report recognized the problem of sprawl and proposed vertical development in the capital through changes in zoning law. The ICT residential sectors zoning regulation 2020 was also notified. The by-laws allowed unauthorized construction owners in zone 2, 4 and 5 to regularize their buildings. These by-laws do not apply to zone 3, where unauthorized buildings' fate will be determined by a consultant. The commission also formed a framework for the Islamabad master plan 2040.

CDA was approached to get their response on urban sprawl in Islamabad. Several questions were asked in order to know their policies and approaches to restrict sprawl in Islamabad, i.e, Why are there so many illegal housing societies in Islamabad? What is the CDA doing to stop illegal construction? What will be the future of these illegal constructions? Why are high rise buildings not encouraged in Islamabad? How is CDA going to control sprawl in Islamabad? Under The bylaws notified in 2020 unauthorized construction in zone-2, zone-4 and zone-5 can regulate their buildings. Won't it be an umbrella for illegal housing societies?

Upon asking about illegal housing societies, the CDA officials said, under the direction of Islamabad high court and Supreme Court, CDA has started a crackdown on unauthorized and unapproved structures that are in violation of building rules. CDA is ready to take action against the illegal buildings in Islamabad. The crackdown on illegal buildings in breach of building ordinances continues, while the CDA's Building Control Department issued notifications to many residential buildings and show cause notices to some commercial illegal buildings during this time. The copy of direction has also been sent to SNGPL and WAPDA to cut gas and electricity connection to illegal societies. Further, the CDA bylaws allowed construction of high rise buildings for commercial activities and in markaz and under the bylaws residential units are allowed to construct single family units. However, a commission was formed in 2019 to review the master plan of Islamabad and it acknowledges the problem of sprawl. The commission recommended promoting construction of high rise buildings in zone-2 and zone-5 to restrict sprawl and regeneration of G-6 in a vertical way by changing zoning laws. The official further commented, these by-laws will not benefit illegal housing construction however; it will be applicable for homes and buildings built on private land. The official said, these laws will not be regarded as an umbrella for illegal construction that violates zoning regulations. The official further commented, the new by-laws aim to promote vertical development and high rise buildings. Moreover, commercial building owners have been asked to construct elevated parking garages.

4.7 Driving forces

Regardless of the term used, urban sprawl is growing internationally, with an escalating number of cities sprawling to varying degrees. Cities in the western and central United States were the first to undergo dispersed urbanization (polese et al 2003). However, as Polese and Champagne or Gilbert demonstrate, this urban paradigm was soon adopted to Latin America and, subsequently, to numerous Asian cities, as Bunnell shows. Urban sprawl has become a global phenomenon in the modern era.

It is self-evident that the spread of automobiles as a mode of transportation is responsible for the growth in sprawl. The cities which experienced the propensity to scatter earliest and most intensively are those that expanded when automobiles began to dominate their avenues and streets, influencing urban planning and the manner these cities grew. Even though the vehicle reduces the significance of distance, the logic of maintaining a compact city should remain important, even if its dimensions are increased. What is noticed, however, is that as cities grow, their centers degrade and their boundaries become blurry. In other words, we did not see a change in the logic of urban expansion in response to new technology, but rather a significant paradigm shift in the city's characteristics and configuration. The per capita income level also has an effect on residential decisions and, as a result, on urban shape and sprawl (Squires 2002). The average floor space occupied by a person in developed countries is two to three times that in underdeveloped ones. Without any other change, this phenomenon frequently explains why the physical size of cities doubles or triples as a country grows. In short, even in the absence of population increase, it appears as though physical extension of a city is an inevitability of development.

Urbanization in Islamabad led to the transition of agricultural land, forest land and barren land into built-up areas (Sudhira et al). The city of Islamabad also faced urban sprawl because of a number of reasons. There are few major causes driving urban sprawl in Islamabad; these patterns are slum sprawl, transportation networks and vehicle diffusion, population, Industrial and real estate, master planning, and neighbor urban effect. Islamabad's urban development is falling short of the master plan's objectives. Urban development is unequal, mostly due to its lack of economic strength. The master plan concentrated on Zone I and Zone II in Islamabad's western sector and ignored development planning in the remaining zones. Construction initiatives in a maximum of twenty sectors may be considered finished or near completion. Additionally, Islamabad's urban economic development has been weak, and urban growth has been harmed by slum sprawl. Unemployment and poverty have long been a hindrance to cities' sustainable growth. Additionally, its impoverished population has increased proportionately to the extent of its slums. Islamabad's urbanization has been accompanied with slum sprawl. Indeed, as early as the 1960s, when Islamabad was established as the capital city, several slums emerged in Zone 1, including the Christian colony, French colony, Musharraf colony, and communities alongside natural drains and streams in sectors F-6, F-7, G-7, and G-8. All other zones have continuously spawned new slums during the previous three decades. Furthermore, Islamabad's population has increased dramatically during the last three decades. The population of the city was less than a half million before 1990, but increased to two million in 2017. The built-up area has been continuously growing on this basis. Thus, we may conclude that Islamabad's urban expansion is accelerated by the growing population. Another component that stimulates urban expansion is the transportation infrastructure and vehicle diffusions that are made up of roads and railroads. The increase in automobiles leads to the construction of many roads and highways in the city contributing to the chain of transportation networks. The fourth component is the growth of industry and real estate with the support of private and government. In 1988, Pakistan's government introduced industrial incentives to stimulate the country's economic growth. This led to many industrial and real estate developments in Islamabad that contributed to the expansion of the city. The fifth factor that causes urban expansion is the master planning because it mainly focused on zone 1 and zone 2 resulted in the scattered expansion in other zones. Another factor that causes urban sprawl is the urban neighboring effect. Rawalpindi is a city that borders Islamabad on the southwest and southeast side and contiguous to Islamabad. Urban sprawl occurred in these sides from Rawalpindi's boundary. Numerous settlements in these areas sprawled from the eastern outskirts of Rawalpindi.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The purpose of this article was to detect and monitor both urban sprawl and LULC changes in Islamabad, Pakistan, employing RS data and GIS software. The multi-temporal satellite Landsat data was downloaded from USGS to monitor and detect changes. Five LULC classes were classified by using maximum likelihood classification (MLC) algorithm and technique in the city of Islamabad between 1990 and 2020. The accuracy assessment of MLC technique was also evaluated for all the four time periods. In all the four year of satellite data, the maximum likelihood algorithm showed good results. The MLC identified changes in LULC during the previous three decades and discovered a significant rise in built-up area, suggesting that the majority of agricultural and forest areas had been converted, indicating significant urban sprawl between 1990 and 2020. The paper also calculated change detection and found major increments in the built-up area at the cost of forest and agricultural land. The MLC results indicated that between 1990 and 2020 built-up area increased by 18% in terms of percentage while decline trend was found in forest land 4.92%, Agricultural land 10.31%, barren land 2.17% and water bodies 0.03%. Similarly, in terms of sq. km built-up area increased by 157.53 sq. km however, forest area decreased by 44.55 sq. km, agricultural area 93.3 sq. km, barren area 19.62 sq. km and water bodies 0.27 sq. km. During the last three decades Islamabad witnessed significant LULC changes. Major changes were observed in the built-up area which increased by 18% whilst significant decrease was observed in agricultural area 10.31% and forest area 4.92%. The driving force behind urban sprawl was economic development, vehicles diffusion, infrastructure development and population growth. The map of urban sprawl observed quite compact urban development in the city center and its immediate surroundings, scattered development in the periphery area and somewhat organized urban development between the center and periphery. Future research should be conducted in better urban management using RS and GIS.

5.2 Way Forward

- Vertical sprawl or high rise building construction should be encouraged to restrict horizontal sprawl.
- The process of getting permits for high rise buildings should be simple.
- Urban mobility models supported by public transport should be promoted to limit use of private vehicles.
- There is a need to enhance strict monitoring and watch & ward systems to remove encroachments and stop illegal construction.
- The zoning law should be flexible to adjust according to the physical requirement of the city.
- A platform needs to be developed where residents of Islamabad give their suggestions in the planning and decision making of the city because the city is for people so they should have a say in it.
- New methods like the neighborhood effect that is exercising around the world should be adopted instead of decadal old master

CHAPTER 6

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APPENDIX

Accuracy Assessment 2020

	Water	Built-up	Forest	Barren	Agriculture	Total(user)
Water	7	0	0	0	0	7
Built-up	0	7	0	1	0	8
Forest	0	0	7	0	0	7
Barren	0	0	0	7	0	7
Agriculture	0	1	0	0	6	7
Total(producer)	7	8	7	8	6	36

Overall accuracy=

$$(\frac{\text{Total number of corrctly classified pixels (diagnoll)}}{\text{Total number of referannce pixels)}} \times 100$$

$$= \frac{34}{36} \times 100$$

=94 %

$$\text{User Accurecy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{TOTAL NUMBER OF Classified pixiels in that catogary(the row total)}} \times l\mathit{oo}$$

User Accuracy calculation

Water=7 /7*100 =100 %

Built-up=7/8*100 =87 %

Forest=7/7*100 = 100%

Barren=7/7*100 = 100%

Agriculture=6/7*100 = 85%

Produceraccuracy=

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{(Total Number of Reference Pixels in that Category (The Column Total)}} \times 100$$

Producer Accuracy calculation

Water=7 /7*100 = 100%

Built-up=8/8*100 = 100%

Forest=7/7*100 = 100%

Barren=8/8*100 = 100%

Agriculture=6/6*100 =100%

Kappa coefficient (T) = $\frac{((TS \times TCS) - \Sigma(\text{Column Total} \times \text{Row Total}))}{(TS\text{^}2 - \Sigma(\text{Column TotalxRow Total}))} \times 100$

$$= \frac{\langle 34 \times 36 \rangle - [\langle 7 \times 7 \rangle + \langle 8 \times 8 \rangle + \langle 7 \times 7 \rangle + \langle 7 \times 8 \rangle + \langle 7 \times 6 \rangle]}{36\text{^}2 - [\langle 7 \times 7 \rangle + \langle 8 \times 8 \rangle + \langle 7 \times 7 \rangle + \langle 7 \times 8 \rangle + \langle 7 \times 6 \rangle]}$$

=93 %

Ts= Total sample

TCS= Total corrected sample

Accuracy Assessment 2010

Features	Water	Built-up	Forest	Barren	Agriculture	Total(user)
water	5	0	0	1	0	6
Built-up	0	6	0	0	0	6
Forest	0	0	5	0	0	5
Barren	0	1	0	6	0	7
Agriculture	0	0	0	2	4	6
Total(producer)	5	7	5	9	4	30

Overall accuracy=

$$\frac{\text{Total number of corrctly classified pixels (diagnoll)}}{\text{Total number of referannce pixels}} \times 100$$

= 86%

$$\text{User Accurecy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{TOTAL NUMBER OF Classified pixiels in that catogary(the row total)}} \times \text{l}oo$$

User Accuracy calculation

Water= 5/5*100 = 83%

Built-up=6/6*100 = 100%

Forest=5/5*100 = 100%

Barren=6/7*100 = 86%

Agriculture=4/6*100 = 67%

Producer accuracy= $\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{(Total Number of Reference Pixels in that Category (The Column Total)}} \times 100$

Producer Accuracy calculation

Water= 5/5*100 = 100%

Built-up=6/7*100 = 86%

Forest=5/5*100 = 100%

Barren=6/9*100 = 67%

Agriculture=4/4*100=100%

Kappa coefficient (T) = $\frac{((TS \times TCS) - \Sigma(\text{Column Total} \times \text{Row Total}))}{(TS\text{^}2 - \Sigma(\text{Column TotalxRow Total}))} \times 100$ = 83%

Ts= Total sample

TCS= Total corrected sample

Accuracy Assessment 2000

	Water	Built-up	Forest	Barren	Agriculture	Total(user)
water	7	0	0	0	0	7
Built-up	0	6	0	1	0	7
Forest	0	1	7	0	0	8
Barren	0	0	0	7	0	7
Agriculture	0	1	0	0	6	7
Total(producer)	7	8	7	8	6	36

Overall accuracy=

$$\left(\frac{\text{Total number of corrctly classified pixels (diagnoll)}}{\text{Total number of referannce pixels)}} \times 100 \right.$$

=91 %

$$\text{User Accurecy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{TOTAL NUMBER OF Classified pixiels in that catogary(the row total)}} \times 1oo$$

User Accuracy calculation

Water=7 /7*100 =100 %

Built-up=6/7*100 =85 %

Forest=7/8*100 = 87%

Barren=7/7*100 = 100%

Agriculture=6/7*100 = 85%

Produceraccuracy=

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{(Total Number of Reference Pixels in that Category (The Column Total)}} \times 100$$

Producer Accuracy calculation

Water=7 /7*100 = 100%

Built-up=6/8*100 = 75%

Forest=7/7*100 = 100%

Barren=7/8*100 = 87%

Agriculture=6/6*100=100%

Kappa coefficient (T) = $\frac{((TS \times TCS) - \Sigma(\text{Column Total} \times \text{Row Total}))}{(TS\text{^}2 - \Sigma(\text{Column TotalxRow Total}))} \times 100$

=89 %

Ts= Total sample

TCS= Total corrected sample

Accuracy Assessment 1990

	Water	Built-up	Forest	Barren	Agriculture	Total(user)
water	7	0	0	0	0	7
Built-up	0	6	0	1	0	7
Forest	0	0	7	0	0	7
Barren	0	0	0	7	0	7
Agriculture	0	1	1	0	6	8
Total(producer)	7	8	8	8	6	36

Overall accuracy=

$$\left(\frac{\text{Total number of corrctly classified pixels (diagnoll)}}{\text{Total number of referannce pixels)}}\times 100\right.$$

=90 %

$$\text{User Accurecy} = \frac{\text{Number of correctly classified pixels in each category}}{\text{TOTAL NUMBER OF Classified pixiels in that catogary(the row total)}}\times 1oo$$

User Accuracy calculation

Water=7 /7*100 =100 %

Built-up=6/7*100 =85%

Forest=7/7*100 = 100%

Barren=7/7*100 = 100%

Agriculture=6/8*100 = 75%

Produceraccuracy=

$$\frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{(Total Number of Reference Pixels in that Category (The Column Total)}}\times 100$$

Producer Accuracy calculation

Water=7 /7*100 = 100%

Built-up=6/8*100 = 75%

Forest=7/8*100 = 87%

Barren=7/8*100 = 87%

Agriculture=6/6*100=100%

Kappa coefficient (T) = $\frac{((TS \times TCS) - \Sigma(\text{Column Total} \times \text{Row Total}))}{(TS^2 - \Sigma(\text{Column TotalxRow Total}))} \times 100$

=89 %

Ts= Total sample

TCS= Total corrected sample