EFFECTS OF RAPID URBANIZATION ON LAND SURFACE TEMPERATURE AND GREEN SPACES IN THE METROPOLITAN TWIN CITIES OF ISLAMABAD AND RAWALPINDI, PAKISTAN

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DEDICATION

I dedicated this work to my loving parents, brother, sisters, teachers, supervisor and my friends who are always a source of happiness for me. I express my Acknowledgments sense of donation and appreciation to my worthy Supervisor Associate Professor Dr. Muhammad Hassan Ali Baig, Institute of Geo-informatics and Earth Observation on his kind support. I am extremely grateful to his sympathetic attitude, generous assistance, and inspiring guidance, and timely advice, constructive and enlightened supervision in the accomplishment of this manuscript.

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ABBREVIATIONS

RS – REMOTE SENSING

GIS – GEOGRAPHICAL INFORMATION SYSTEM

NDVI- NORMALIZED DIFFERENCE VEGETATION INDEX

LST—LAND SURFACE TEMPERATURE

TM – THEMATIC MAPPER

OLC – OPERATIONAL LAND IMAGER

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If oceans turn into ink and all of the woods become pens, even then the praises of Allah Almighty can't be expressed, who created the universe and bestowed upon me the intellectual ability and wisdom to search for the secrets. I must bow my head before Allah Almighty who is compassionate as well as merciful and enable me to complete this work, which marks an important turning point in my life. Countless salutations are upon the Holy Prophet Hazrat Muhammad (PBUH) who has guided his "Ummah" to seek knowledge from cradle to the grave.

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ABSTRACT

One of the significant environmental consequences of urbanization is reduction in vegetation cover and formation of urban heat island effect. The study of Land Use Land Cover (LULC) changes and their patterns enhance our understanding about various man caused phenomenon on earth surface. The Pakistan's metropolitan twin cities, Islamabad and Rawalpindi has experienced high rate of urbanization and population increase in the last 2-3 decades and as a result, the LULC changes have occurred in an unsustainable way. The accurate and reliable data of LULC changes for the study period is not available. The main aim of this study was to provide compatible data on LULC change during the last 21 years for the functional Pakistan's metropolitan twin cities, Islamabad and Rawalpindi. The unchecked and unplanned expansion of urban areas has led to the conversion of millions of green areas to gray areas. The recent urban growth patterns of Pakistan's metropolitan twin cities, Islamabad and Rawalpindi, is a matter of concern for the surrounding green areas. The present study aimed to categorize and quantify the land-use and land-cover change (LULCC) patterns and the corresponding impacts on the LST around Islamabad and Rawalpindi. The present research utilized Landsat data from 2001 to 2021 to study the spatio-temporalpattern of NDBI, NDVI and land surface temperature (LST) in Twin cities (Islamabad, Rawalpindi).Globally, urban temperature is gradually increasing day by day. The prominent climatic condition called Urban Heat Island (UHI) is rising especially in the rapidly developed cities. For this purpose, different time series of Landsat images were selected through which land

surface temperature and NDVI (Normalised Difference Vegetation Index) has been calculated and urban heat island effect is analysed. LST has been calculated from thermal data of Landsat TM/TIRS using emissivity derived from NDVI images.A very strong correlation between the LST and the NDVI has also been established The implication of the uncontrolled unprecedented expansion in the twin cities may exacerbate environmental and ecological problems such as the Urban Heat Island if not properly ameliorated. This study actually exploits the possibility of using Remote Sensing and Geographic information systems (GIS) in the drive towards achieving sustainable urban environment in terms of planning, policy and decision making.

CHAPTER 1

INTRODUCTION

The rapid modification of Land Use and Land Cover (LULC) by human activities are well recognized worldwide. The fast population growth, urbanization and economic development have significantly altered the Earth's terrestrial surface processes, leading to undesirable impacts on environmental attributes at a local, regional and global levels (Verburg and Overmars, 2007; Jiang Li et al., 2018). The monitoring of land use land cover changes, has become a fundamental component of various strategies for managing natural resources (Lambin et al., 2003; Sekela and Manfred, 2019). In last few decades, studies of LULC changes have emerged as an important research area, as abrupt LULC changes are responsible for natural landscape modification worldwide (Xiao et al., 2006; Nath et al., 2020). Though it is possible to detect and monitor LULC by traditional surveys and inventories, yet Geographical Information System (GIS) and Remote Sensing (RS) techniques are more useful in terms of availability of temporal data, time saving, cost effectiveness and the ability of forecasting of LULC changes in future (Yuan et al., 2005; Talukdar et al., 2020). The reliable, historical and persistent LULC data is also important for achievement of the Sustainable Development Goals (SDGs), (El-kawy et al., 2011; Frank et al., 2020). The study of LULC changes can also help in identifying, whether a given developmental activity is consistent with particular environmental targets. This in turn assist in developing environmentally sustainable spatial planning for future urban expansion (Świąderet al., 2018; De Jung et al., 2018). The studies of land use land cover changes have diverse applications in many disciplines such as ecology,

environment, hydrology, forestry and geology. The abrupt urban LULC changes, such as unregulated development, loss of agriculture lands, soil erosion, deforestation, damage of wildlife habitat and pollution are not only harmful for the urban environment, but also degrade the land (Weng, 2002; Hassan et al., 2016).

Urbanization and urban sprawl is one of the main causes, which are altering the land cover of the earth's surface. The process of urban complex is determined by the interactions of environmental and human factors in different spatio-temporal scales. Urban sprawl has been studied widely due to increasing interest of researchers and policy makers in environmental issues and challenges (He et al., 2006; Kamh et al., 2012). Sporadic development of urban inhabitants and its increased footprint on the urban environment has been widely reported. Urban expansion can lead to significant environmental modification as main ecosystem services, such as availability of water, food, raw material, natural vegetation and landscape beauty, may degrade as a result of rapid growth of urban areas (Sieber and Pons, 2015; Manzoor et al., 2018). For analysis of LULC changes in the urban centers, around the world, moderate resolution Satellite images have been widely used. The urban expansions of Dhaka Bangladesh, Hangzhou China. Komb Ombo desert of Egypt, Izmir Turkey, Mumbai India, Islamabad Pakistan, Puerto Rico and Delhi India were studied with the help of GIS & RS techniques (Dewan and Yamaguchi, 2009; Jingsong et al.,2009). Similarly the urban sprawl in major cities of Europe and An-Nummayimah City of Jordan was also analyzed with GIS and RS techniques (Daniel Arribas et al., 2010; Ann A.G et al., 2020). Most of the provinces in China have been witnessing urban sprawl

during 2001–2007, as analyzed by Jingwei Han (2020), while using these techniques.

The world's most populous cities are located indeveloping countries and most of these are experiencing unplanned urban expansion. Although, in developed countries consequences of rapid urban expansion are repeatedly documented, yet the LULC studies in developing countries like Pakistan, remain scant (Jafari et al., 2016). In South Asia, Pakistan is a fastest urban growing country, the process of urbanization increased due to rapid population growth, industrial expansion, increased economic and social activities and intensive use of land resources. In Pakistan the annual growth rate of urban population is nearly 3% (Shaikh and Ijaz, 2017). In the last two decades, Punjab province of Pakistan has experienced rapid population growth and economic development accelerated the process of urbanization and caused extensive deforestation and conversion of agricultural land to built-up area, leading to environmental degradation (Lee et al., 2017; Pakistan Bureau of Statistics, 2018). Only 3% of the country is under forest cover, as against the earlier plan of the government to increase the forest cover to 7% by 2015, which has not been achieved as yet. A forest cover of 20–25% of the total areas is needed for a sustainable economy and ecosystem in Pakistan (Manzoor et al., 2018; Zizinga et al., 2018). There is no formal organization in Pakistan to monitor and organize the use of land according to its potentials. Hence quantification of the land uses becomes a difficult task. Besides, desertification of land, water logging and salinity, the quality of the land is also degraded by change in the uses of land and development of specific infrastructure. The change of land cover from agriculture to built-up demand for urban land (Dewan and Yamguchi,

2009). Worldwide anthropogenic activitiesarea, desertification of fertile land after changing its use to construction purpose also degrade the adjoining land. Hence monitoring of land quality in terms of its uses and changes in land cover, is very important to avoid degradation of land. In urban areas, built-up land is obtained by changing the barren land, lands under agriculture, vegetation, water bodies, which indicate the existence of high pressure on natural resources to fulfill the growing are responsible for such rapid factor of barren and habitat destruction as well as loss of biodiversity. The rural areas are converting into urban land through rapid population growth and development occurring at an unprecedented rate in recent human history leading to severe degradation of functioning of ecosystem services (Lopez, Bocco, Mendoza and Duhau, 2001).

Urban growth and urbanization significantly affectsthe different facets of the ecosystem including land, water, ecology, environment and climate systems. Theworld is undergoing the largest wave of urban growth in history. At present, more than half of the world's population is living in urban areas such as towns and cities, and it is expected that by 2030 this number will increase to about 5 billion (UNFPA). United Nations Population Fund (UNFPA) also predicted that much of this urbanization will take place in Africa and Asia, bringing huge social, economic and environmental transformations. Urbanization in Pakistan is increasing at 3% annually, the highest in South Asia. 50% of the population is expected to urbanise by 2025. Recent decades, the number of people moving to urban cities from rural areas has increased exponentially. The rate of urban migration and settlement varies across-different parts of the world. In Asia, the urbanization rate is 6.6% for Nepal, 5.3% for Bangladesh, 4.4% for Pakistan,

2.9% for India, and 2.2% for Sri Lanka. The rates for these developing countries are higher compared to other Asian countries and to the rest of the world.The capital city of Pakistan; Islamabad has experienced phenomenal increase in the urban population and extent in the last four decades (Attaullah Shah and Karamat Ali, 2021). Rapid urban growth normally exceeds the capacity for local governments to deliver services and infrastructure, which increases urban poverty and slums, especially in developing countries (Duque et al. 2015). Urban growth further leads to serious problems in cities, including urban flooding, pollution, epidemic diseases, social inequality, and political instability (Netzband et al. 2007).The most overbearing problem in urban zones is increase in surface temperature. When vegetative areas are converted in constructed areas, it affects the surface temperature by maximum absorption of solar radiation, evaporation rates, heat storage, dissenting wind and significant changes in the near-surface atmospheric conditions of the cities (Weng, Lu and Schubring 2004). The urban heat island (UHI) or surface urban heat island (SUHI) event is described as higher air temperature built in urban areas as compared to rural areas (Sobrino et al., 2013). Vegetation is a vital element of global environment. It modifies the ecosystem through water preservation, terrestrial soil constancy and atmospheric circulation. It also helps to sustain a balance of ecosystem prominently. Rapid expansion leads to the declination of vegetation areas in cities. Topographic changes include loss of forest lands, diminishing of agricultural lands, expansion of impervious surface of the area, extension of barren land because of the built-up area (Kumar et al, 2012). NDVI is generally considered as a good indicator of vegetation vigour, density and health in an area and is the most commonly

used vegetation index. NDVI is a numerical indicator that uses red and NIR bands of remote sensing data to assess whether the land cover includes live, green vegetation or not. The index, first conceived by Rouse et al. (1973), is based on the absorption of light by vegetation in the red band and its reflectance in near-infrared band. The formula for measuring NDVI is given in equation 3. The value of NDVI ranges from -1 to +1 where -1 corresponds to pixel having no vegetation and +1 to pixel with dense vegetation cover. Literature indicates a consistent correlation between NDVI and vegetation biomass and dynamics in a number of ecosystems globally. Further, extensive exploration of NDVI's relationship with climatic variables has helped in making future predictions possible (Gong and Shi, 2003; Wand et al., 2003). Therefore, the NDVI represents the first usefultool which can amalgamate vegetation, ecosystem, climate and environment and perform studies at large spatial and temporal scales (Pettorelli et al., 2005). In the present study, the main focus is to highlight the fact of notable decrease of vegetative areas due to rapid urbanization which affects the urban microclimate and increases the surface temperature.

1.1 Problem statement

The main focus is to highlight the fact of notable decrease of vegetative areas due to rapid urbanizationwhich affects the urban microclimate and increases the surface temperature.Planners and decision makers need reliable, current and accurate information on LST and NDVI in order to make suitable decisions to improve declining environmental conditions in the area. Conducting such research is imperative for understanding the causes and consequences of the changes in the urban

areas, as no research on LST monitoring has been carried out in the study area, especially using remote sensing and GIS techniques. There is a need for this study and this research is a beginning for filling this knowledge gap. As a result, this study is important and unique. Particularly, because it is using remote sensing and GIS techniques.

1.2 Objectives

This research has following objectives.

- Assess urban change by calculating LULC for the years 2001 to 2021 in the study area.
- Calculate Land Surface Temperature (LST) in the study area from 2001 to 2021.
- Examine vegetation change by calculating NDVI from 2001 to 2021.
- To correlate and determine the relationship between the urban structures as defined by LULC, NDVI and NDBI in the estimation and prediction of LST.

CHAPTER 2

LITERATURE REVIEW

Tariq et al (2021) analyzed the images of Landsat 7 (ETM+) for the years of 2000, 2005, and 2010 to monitor the land use, and land cover changes in FatehJang, Attock District. The study used multi-temporal remote sensing data, and spatial analysis to assess the land changes. The researchers tend to identify the changes like, build-up area, barren land, vegetation, and water area. The study had found that the area of vegetation has decreased by about 176.19 sq. km as converted to other land cover types from the year of 2000 to 2015. The built-up area has increased by 5.75%, as overall Accuracy, and Kappa coefficient were estimated at 0.92, and 0.77, 0.92, and 0.78, 0.90 and 0.76, 0.92 and 0.74, for the years 2000, 2005, 2010and 2015, respectively. The study concluded that major factors for the effects of changing land use types on Land Surface Temperature (LST) over a given time period are, economic development, climate change and population growth.

Gillani et al (2020) carried out a research study to monitor the urban landscape ecology dynamics of Islamabad Capital Territory, Pakistan. The study used the measurement, and characterization of land cover changes by the analysis of Landsat satellite imagery for the years of 1976, 1990, 2000, 2010, and 2016.Annual rate of change, landscape metrics, and urban forest fragmentation spatiotemporal analyses have been carried out, along with the calculation of the United Nations Sustainable Development Goal (SDG) indicator 11.3.1 Land Consumption Rate to the Population Growth Rate (LCRPGR). The results show consistent increase in the settlement class, with highest annual rate of 8.79% during 2000–2010. Tree

cover >40% and <40% canopy decreased at an annual rate of 0.81% and 0.77% between 1976 to 2016, respectively. Forest fragmentation analysis reveals that 'core forests of >500 acres' class decreased from 392 km2 (65.41%) to 241 km2 (55%), and 'patch forest' class increased from 15 sq. km (2.46%) to 20 sq. km (4.54%), from 1976 to 2016. The LCRPGR ratio was 0.62 from 1976 to 2000, increasing to 1.36 from 2000 to 2016.

Ahmed et al (2020) examined the impacts of spatial-temporal changes in land use, and land cover on the groundwater quality, and Human health in the District of Peshawar, Pakistan. The study evaluated the temporal changes of groundwater quality, its relation to land use/land use, and impacts on the residents. The researchers collect samples of 112 tube wells between the years of 2012, and 2019. Samples were then analyzed for seven standard water quality parameters (i.e., pH, Electric Conductivity (EC), Turbidity, Chloride, Calcium, Magnesium, and Nitrate). Patient data for waterborne diseases were also collected for the years 2012 and 2019 to relate the impact of groundwater quality on human health. Landsat satellite images were classified for the years 2012 and 2019 to observe Land use/landcover dynamics concerning groundwater quality. Results manifested a decrease in groundwater quality for the year 2019 compared to 2012 and were more highlighted in highly populated areas. The nitrate concentration level was found high in the vicinity of agricultural areas due to the excessive use of nitrogenous fertilizers and pesticides, and thus the methemoglobinemia patients ratio increased by 14% (48- 62% for the year 2012 and 2019, respectively). Besides, Urinary Tract Infections, Peptic Ulcer, and Dental Caries diseases increased due to the high calcium and magnesium

concentration. The overall results indicate that anthropogenic activities were the main driver of Spatial-temporal variability in groundwater quality of the District Peshawar.

Tariq, and Shu (2020) used Markov Chain model for the analysis of seasonal land surface temperature, land use, and land cover change with a Cellular Automata-Markov-Chain (CA-Markov-Chain) in Faisalabad, Pakistan. The researchers analyzed multi-temporal satellite data from Landsat 5, 7, and 8 during the months of May, and November for the years 1990, 1998, 2004, 2008, 2013, and 2018. Furthermore, CA-Markov-Chain was developed for simulating long-term landscape changes at 10-year time steps from 2018 to 2048. The surface temperature during summers, and winters were predicted well by Urban Index (UI), a non-vegetation index, demonstrating the highest correlation of R2 = 0.8962 and R2 = 0.9212 with respect to retrieved summer and winter surface temperature. Through the CA-Markov Chain analysis, the study expected that high density and low-densityresidential areas will grow from 22.23 to 24.52 sq. kmand from 108.53 to 122.61 sq. km in 2018 and 2048, as inferred from the changes occurred from 1990 to 2018. Considering UI as the predictor of seasonal LST, we predicted that the summer and winter temperature 24–28◦C and 14–16◦C and regions would decrease in coverage from 10.75 to 3.14% and from 8.81 to 3.47% between 2018 and 2048, while the summer and winter temperature 35–42◦C and winter 26–32◦C regions will increase in the proportion covered from 12.69 to 24.17% and 6.75–15.15% of city.

Khan (2013) conducted a case study in the area of Rawalpindi to examine the land use, land cover change, and Human impacts. The study used Landsat MSS,

and TM images of 1972, 1979, 1998, and 2010. Also, Census of Pakistan dates were classified using the Maximum Likelihood classifier.. The results of the study revealed that the built-up area of the study area has been increased from 7,017 hectares to 36,220 hectares during the 1972 -2012 period. This expansion has been accompanied by the loss of agricultural and forest land. There has been a decrease of approximately 10,000 hectares in cropped area and 2,000 hectares in forest land of the study area during the 1998-2012 inter-censal period. Corroboration of official census data, remote sensing results and field based qualitative data supports the view that high population growth rate, industrialization, better educational and transportation facilities and proximity of the study area to the capital (Islamabad) are the major factors of urban expansion and resulting land cover changes.

CHAPTER 3
MATERIALS AND METHODS

The title of the chapter affirms the attempt to explain data sources, methods and techniques used while acquisition of data, image pre-processing (layer's staking, geo- reference, geometric and radiometric correction), image processing, Spatio-temporal analysis, impact assessment, mapping and presentation of the data. The methods used in this study helped in acquiring the designed objectives and in responding to the research questions of the study. This chapter gives us Spatio-temporal analysis of change detection and helps us to draw conclusion on the expansion of the city and its influence on surface temperature of study area. The data types used for the analysis is, satellite remote sensing data and reference data.

The present study has utilized time series of Landsat satellite imagery, Landsat 5/ Thematic Mapper (TM), Landsat 7/Enhanced Thematic Mapper plus (ETM+) and Landsat 8/Optical Land Imager (OLI) for the years from 2001 to 2021. Satellite remote sensing images are used increasingly for the analysis of change detection of urban expansion and estimation of land surface temperature because it is technologically efficient and cost effective (Epstein et al., 2002). Reference data comprises aerial photographs, topographical maps, and land use of the study area,

3.1 STUDY AREA

Islamabad (33.7294º N, 73.0931º E) is the federal capital of Pakistan, adjacent to Rawalpindi (33.5984º N, 73.0441º E). The Islamabad city was built in 1960 to replace Karachi as the Pakistani capital, which it has been since 1963. Due to Islamabad's proximity to Rawalpindi, they are considered sister cities. Total area is 1,385.5 km2 Rawalpindi 479 km2 Islamabad 906.5 km2.They are commonly

referred as twin cities and are often considered as a single unit. The Rawalpindi-Islamabad metropolitan area is considered the third largest in Pakistan, with a population over 3.7 million the current metro area population of Islamabad in 2022 is 1,198,000, a 2.92% increase from 2021. The current metro area population of Rawalpindi in 2022 is 2,327,000, a 2.02% increase from 2021. In Islamabad, the summers are sweltering, humid, wet, and clear and the winters are short, cold, and partly cloudy. Over the course of the year, the temperature typically varies from 38°F to 100°F and is rarely below 33°F or above 107°F. In Rawalpindi, the summers are short, sweltering, humid, wet, and clear and the winters are short, cold, and mostly clear. Over the course of the year, the temperature typically varies from 39°F to 101°F and is rarely below 34°F or above 108°F..Rawalpindi-Islamabad lay in a semi-arid zone with hot summers followed by monsoons and cold winters. The twin cities have with five seasons: winter (November-February).

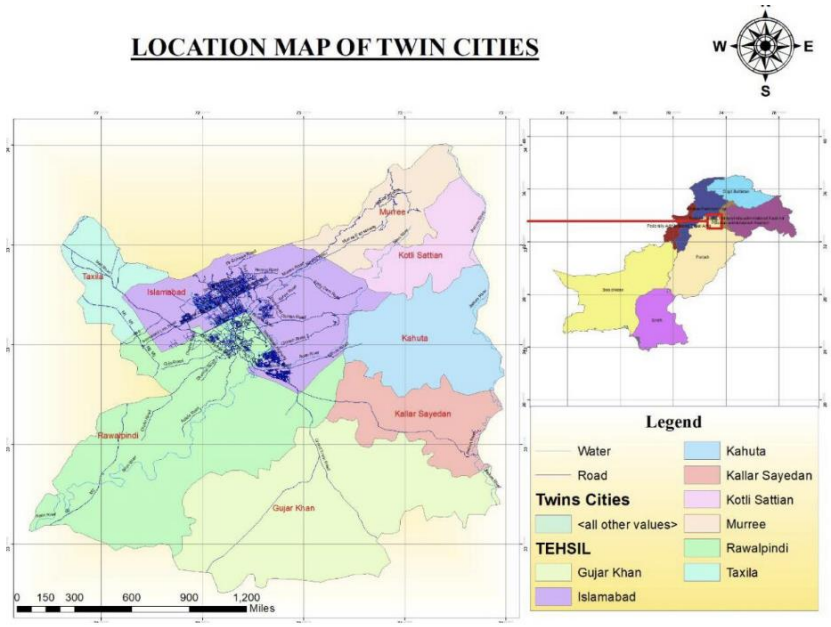


Figure 3.1: Location map of study area

3.2 DATA SOURCE

Data used for Spatio-temporal analysis in the present study include Landsat satellite imagery, In this research, spatial data of sequential nature of land use type and urban expansion has been accumulated from Landsat satellite imagery, topographic sheets and along with aerial photographs of the study area. Monitoring of urban expansion and evaluating its impact on LST via multi-temporal, multi-source remote sensing imagery have claimed great interest in the recent decade. Remote sensing is, certainly, the most effective tool in monitoring urban expansion and detecting land use changes with estimation of temporal variation of land surface temperature .

3.2.1 Primary Data

Landsat satellite imagery is the primary source of data because of its temporal resolution and free availability. In total, six Landsat satellite images were collected for this research. Primary data is acquired through multi-source and multi-date satellite images from 2001 to 2021 . Urban expansion and consequent change in temperature are assessed through Landsat 5/TM, 7/ETM+ and Landsat 8/OLI_TIRs images for the year 2001, 2005, 2010, 2015 and 2021 respectively. These Landsat images are acquired and downloaded from U.S. Geological Survey database according to the suitability and availability due to cloud cover (the acceptable cloud cover should not be more than 5%).

3.2.2 Satellite Images

Urban areas are ideally analyzed by high resolution satellite images but the availability of such images is not easy and it costs very high. The selection of accurate satellite system and right image for urban change detection is an art we

can learn with passage of time and experience. Nevertheless, resolution, time, availability, and cost are some of the significant constituents for its data acquisition. The present study has utilized the times series of Landsat (5, 7 and 8) imagery at different intervals, ranging from five to ten years since 2001 to 2021. Images of moderate resolution like satellite Landsat imagery are accessible free of cost from the USGS in Earth Explorer website, so the images required for different time spans were acquired and downloaded from their official site (http://earthexplorer.usgs.gov). These images were used to determine the urban expansion and land use changes and also estimating land surface temperature of Rawalpindi and islamabad. Satellite images of year 2001, 2005, 2010, 2015 and 2021 were required for the urban analysis.

Landsat 5 7 and 8 data were used to carry out this research work. Landsat 5/TM and 7/ETM+ sensor have 6 spectral bands with 1 thermal band and Landsat 7/ETM+ has one panchromatic band with resolution 15m (Table 3.1). Landsat (5 and 7) images of bands 1–5 and 7 have a spatial resolution of 30m (Chen et al., 2006). Landsat 5/TM, 7/ETM + imagery precisely the thermal infrared (band 6) with a spatial resolution of 120m and 60m respectively has been used for local-scale urban studies of retrieving land surface temperature (Weng, 2002; Chen et al., 2002). Bands 1-5 and 7 were utilized for Land use type supervised image classification, while band 6 for land surface temperature extraction in both cases Landsat 5TM and Landsat 7/ETM+ images.

3.3 METHODOLOGY

Research methodology is based on such scientific methods as are manipulated by the researcher in a given situation for the purpose of data collection and deduction of results from acquired facts and figures. Then researcher is able to draw some conclusions and present recommendations for further research in that particular field. Assessing the impact of urban expansion on land surface temperature is a complicated phenomenon involving various activities. Likewise research involves the process of satellite images to acquire precise, essential and exact information on the land use variations.

Methodology Flow Chart:

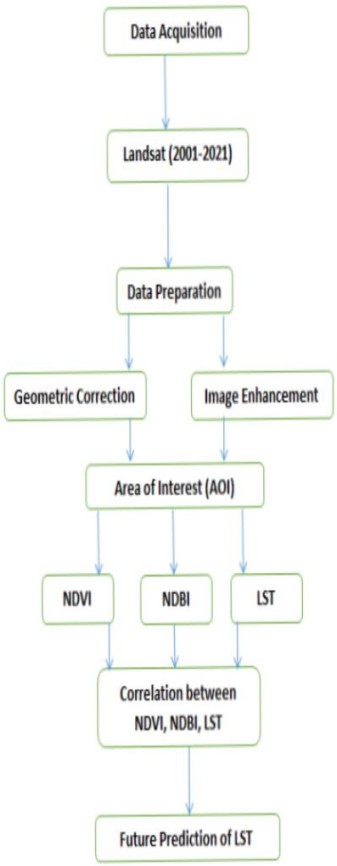


Figure 3.2: Methodology flow Chart

3.3.1 Image Pre-Processing

Image pre-processing is the most important part of satellite remote sensing imagery processing and analysis, having impact on final product quality and further processing. The aim of digital image pre-processing is to reinstate suitable image from the distorted raw image. Image pre-processing typically consists of a series of processes including; geometric, radiometric correction and registration of image (Lillesand et al., 2007). To attain precise urban expansion, retrieving land surface temperature and calculating NDVI, multi-temporal, Landsat images must be pre-processed both radiometrically and geometrically to correct errors arising from the earth's curvature, imaging sensors and due to atmospheric effects (Schroeder et al., 2006). Image Pre- processing techniques, which are sometimes termed as image rectification and restoration, are proposed to correct sensor and platform specific radiometric and geometric distortions found in satellite imagery

Landsat satellite images were acquired and downloaded in "GeoTIFF" image format along with each spectral band layer in separate file. Before further images processing, all band layers of each Landsat image were stacked in one image and the image was thus converted into ".img" format, excluding unnecessary bands by using ERDAS imagine 9.2. Layer stacking of different bands of each image is important procedure for the production of a false color composite satellite image.

Description of Landsat Imagery Spectral Resolution

Satellite	Sensor	Spectral Bands	Spectral Range	Scene Size	Pixel Resolution
L 5	TM multi-spectral	1,2,3,4,5,7	0.45 - 2.35 µm	185 X 185 km	30 meter
	TM thermal	6	10.40 - 12.50 µm		120 meter
L 7	ETM+ multi-spectral	1,2,3,4,5,7	0.450 - 2.35 µm		30 meter
	ETM+ thermal	6.1, 6.2	10.40 - 12.50 µm		60 meter
	Panchromatic	8	0.50 - 0.90 µm		15 meter
L8	OLI (Coastal aerosol)	1	0.43 - 0.45		30 meter
	OLI multi-spectral	2,3,4,5,6,7	0.45- 2.29		30 meter
	OLI (Panchromatic)	8	0.50 - 0.68		15 meter
	OLI (Cirrus)	9	1.36 - 1.38		30 meter
	TIRS	10	10.60 - 11.19		100 meter
	TIRS	11	11.50 - 12.51		100 meter

Source: http://landsat.usgs.gov/

Table 3.1: Description of landsat imagery spectral resolution

3.3.2 Geometric and Radiometric Correction

Geometric correction helps to remove the geometric distortions of the raw image data due to the perspective of the optical scheme, the motion of the sensor and terrain factors. Geometric correction in general, re-projects the satellite image to the suitable projection and geographic coordinate system from the sensor's projection. Many researchers utilize the correction level (1T & 1G) provided by United State of Geological Survey (USGS), while other researchers accomplish their own geometric correction on Landsat satellite images.

3.3.3 Image Enhancement

In order to increase the visual interpretation of the satellite images, which is pertinent, all the subset images of the study area were enhanced. The image cells are highlighted and become prominent for easy recognition and better comprehension of the image features by using image enhancement techniques.

Such techniques of image enhancement help in identifying land use classes and selecting area of interest practically. For example, 742 and 743 as RGB were used for identification of built-up structure and water bodies respectively and Similarly 543 as RGB was utilized for better recognition of vegetation cover and water. Some other band combinations of satellite image such as 741, 321 as RGB were also considered for precise decisions about different land uses variations.

Band combinations in RGB comparisons

Image	RBG	Landsat 7 & 5	Landsat 8
	Color Infrared	4, 3, 2	5,4,3
	Natural Color	3, 2, 1	4,3,2
	False Color	5,4,3	6,5,4
	False Color	7,5,3	7,6,4
	False Color	7,4,2	7,5,3

Source: http://landsat.usgs.gov/L8_band_combos.php

Table 3.2: Band combinations

3.3.4 Image Classification

Image classification is a procedure whereby all the pixels of satellite imagery are characterized into land use land cover classes and further thematically classify each pixel of the satellite image, based on its spectral response (Lillesand

et al., 2004). Digital image classification technique is among the most helpful procedure of satellite remote sensing image analysis, which can be utilized for land use (LU) mapping as well as socio- economic and other environmental applications (Lillesand et al., 2007).

Digital image classification procedure is very complicated as various factors have to be taken into account. Main steps of images classification include; selection of the most suitable image classification technique and its process, finding training area, classification theme and selection of a class scheme suitable for the study area, image classification itself and post-classification method with classification accuracy assessment.

Image classification scheme is typically designed and based on the desired result and the input satellite data. In case of land use mapping, the spectral pattern recognition scheme is most appropriate. Numerous types of land use retain different blends of radiance values forming distinctive spectral patterns (Matinfar, 2007). This system utilizes recognition of such a pattern pixel-by pixel. Such technique helps in acquiring the significant information about the real world. This kind of information determines to make the thematic maps with availability of detail about the entity such as land use type; vegetation cover, bare land, built up land and water (Bhandari, 2010).

In the broader perspective, spectrally oriented two main image classification techniques are recognized: supervised classification and unsupervised image classification. The information about the entities attained through the spectral reflectance has been used by the supervised image classification in order to

explain the guidance data for designing the categories of image classification (Ratanopad and Kainz, 2006).

Supervised classification investigates spectral inconsistency which is defined productive information according to the category. Whereas the later approach is unsupervised image classification, an automatic classification system, where training samples are not required at all. Unsupervised classification technique is mainly helpful inmaking classification of the unknown areas and to evaluate the number of classes for further supervised image classification (Kaiser et al., 2008). In remote sensing application, supervised image classification approach has been widely used (Yuksel et al., 2008).

3.3.5 Supervised Classification

The present study has adopted supervised classification technique for the time series of Landsat images of 2001, 2005, 2010, 2015 and 2021 and set it forth as a base data for the Spatio-temporal exploration of land use variations and determining expansion of urban area of Rawalpindi and islamabad. In Supervised classification method, the researcher defines the category and the numerical description in terms of computer algorithm, to determine the class to which each pixel belongs. The classes were defined for the area of interest, to have a universal classification scheme for the study. Keeping in view the demography of the study area, based on prior knowledge and literature review, four classes were defined as follows: built-up area, Barren land, vegetation, and water bodies for the purpose of Spatio-temporal analysis. After the supervised classification procedure, Universal color scheme was also employed and conventional colors were assigned to each

and every class. Blue color was allotted to water bodies, green for vegetation, Yellow for Barren land and red color was allotted to built-up area.

Description of the Land use Classification Scheme used in the Study

Level I Main land use	Level II Sub land use Class	Description
URBAN	Urban/Built-up Area	All infrastructure: commercial, residential, industrial areas, mixed use, and man-made structures. It comprises areas of intensive use with much of the land covered by structures. Included in this category are cities, towns, villages, settlements, pavements, road network, highways and transportation, power, and communications facilities.
WATER BODY	Water and Wetland	This consists of areas persistently covered with water; provided that if linear they are at least 200m wide. This category includes; River, lakes, permanent open water, ponds, streams and canals, lakes, reservoirs, bays and Estuaries.
NON-URBAN	Barren Land	Construction sites, excavation sites, developed land, Fallow land, earth and sand land infillings, open space, bare soils, and the remaining land cover types. Barren Land is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. Land area that is non-cultivable and has no specific land use and any other radiating land surface.
	Vegetation	Natural vegetation, Trees, mixed forest, gardens, playgrounds and Parks, vegetated lands, grassland, crop fields and agricultural lands. Agricultural Land may be defined broadly as land used primarily for production of food and fiber. This category includes; Cropland and Pasture, Ornamental Horticultural Areas.

Table 3.3 Land use classification scheme

3.3.6 Classification Accuracy Assessment

Image classification is not valid without its accuracy assessment. There were several reasons responsible for occurrence of errors and they come not only from the image classification itself, but poorly selected training areas and also from image registration etc. Therefore, it is very important to conduct an assessment of

classified result. Accuracy assessment assumes all differences between image classification consequences and reference data derivation from the image classification errors. The confusion/error matrix encompasses a category comparison of relationship between known, ground-truth and result of classification. The overall accuracy shows the accuracy process of image classification. Overall accuracy is evaluated in percent and denotes the number of pixels properly categorized and divided by the total number of pixels. Producer's and User accuracy can be well defined in relation to the error of omission and error of commission. Producer's accuracy is confined to the percentage demonstration of the specified class which can exactly be recognized on the map. Whereas User's accuracy is the presentation of the probability that the specified pixel executes on the ground as it has been classified. Kappa coefficient is a statistical quantity of agreement and measures the overall results of image classification. The kappa measure of statistical agreement integrated off- diagonal elements of the confusion/error matrices that were image classification error. It also supplements in representing acquired agreement after excluding number of classes which cause to occur error if there is strain with confusion matrix and kappa coefficient.

3.3 METHODS OF RETRIEVING LAND SURFACE TEMPERATURE

LST is the radiative skin surface temperature of the land, which always plays an imperative role in the physics of the land surface through the process of water exchanges and energy with land to the atmosphere and determining surface radiation.

1.- Calculation of TOA (Top of Atmospheric) spectral radiance.

$TOA\ (L) = M_L * Q_{cal} + A_L$

where:

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_**x**, where x is the band number).

2.- TOA to Brightness Temperature conversion

$BT = (K_2 / (\ln (K_1 / L) + 1)) - 273.15$

where:

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_**x**, where x is the thermal band number).

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_**x**, where x is the thermal band number).

3.- Calculate the NDVI

NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

Note that the calculation of the NDVI is important because, subsequently, the proportion of vegetation (P_v), which is highly related to the NDVI, and emissivity (ε), which is related to the P_v, must be calculated.

NDVI = Float(Band 5 – Band 4) / Float(Band 5 + Band 4)

4.- Calculate the proportion of vegetation P_v

P_v = Square (($NDVI - NDVI_{min}$) / ($NDVI_{max} - NDVI_{min}$))

Usually the minimum and maximum values of the NDVI image can be displayed directly in the image (both in ArcGIS, QGIS, ENVI, Erdas Imagine), otherwise you must open the properties of the raster to get those values.

5.- Calculate Emissivity ε

$\varepsilon = 0.004 * P_v + 0.986$

Simply apply the formula in the raster calculator, the value of 0.986 corresponds to a correction value of the equation.

6.- Calculate the Land Surface Temperature

LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε)))

Finally apply the LST equation to obtain the surface temperature map.

CHAPTER 4

RESULTS AND DICUSSION

4.1 RESULTS

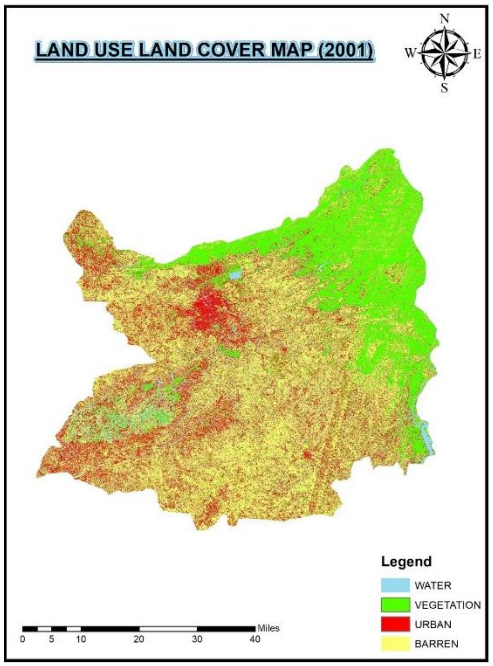


Figure 4.1: Land use land cover map 2001

Table 4.1 : Area Statistics of Land use of 2001

YEAR	URBAN AREA IN Km2	VEGETATION	WATER	BARREN LAND
2001	1400	2050	870	1872

In order to observe the patterns of urban expansion , extent, trends, green area degradation and rate of land use changes of twin cities, supervised image classification for the year 2001 shows that the urban area is 1400 Km2 and green area is 2050 Km2.Barren land is 1872 Km2. Murree and margala hills have more vegetation area.

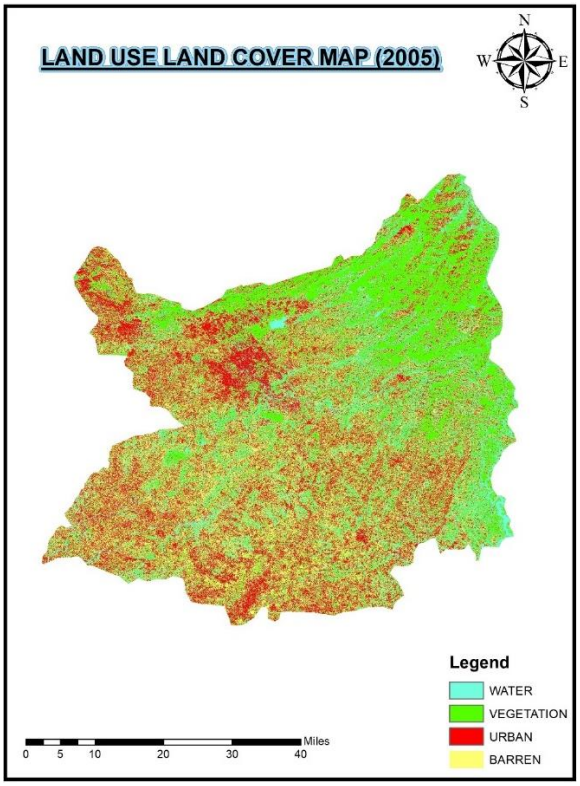


Figure 4.2: Land use land cover map 2005

Table 4.2 : Area Statistics of Land use of 2005

YEAR	URBAN AREA IN Km2	VEGETATION	WATER	BARREN LAND
2005	1638	1916	891	1747

Urban land use profile of Rawalpindi and Islamabad changed extensively from 2001 to 2005. In 2001, the urban land of twin cities was 1400 Km2 which increased to 1638 Km2 in 2005. It is also revealed that the agricultural land decreased from 2050 Km2 in 2001 to 1916 Km2 in 2005, while area under barren land decreased from 1872 Km2 in 2001 to 1747 Km2 in 2005.

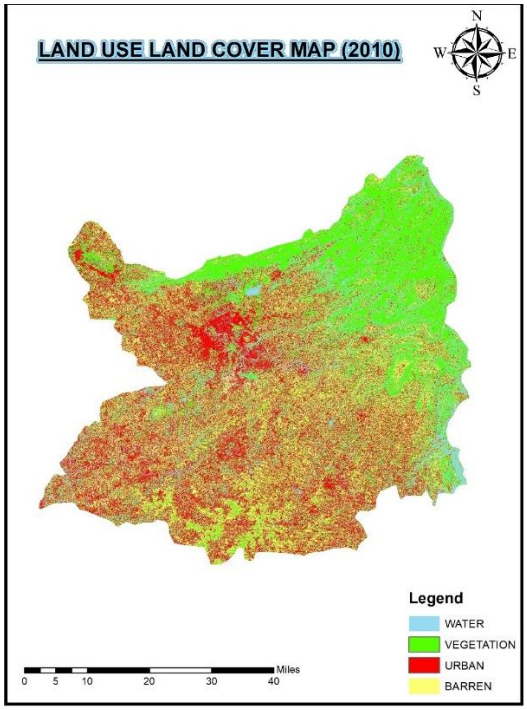


Figure 4.3: Land use land cover map 2010

Table 4.3 : Area Statistics of Land use of 2010

YEAR	URBAN AREA IN Km2	VEGETATION	WATER	BARREN LAND
2010	1811	1804	879	1698

During the period from 2005 to 2010, the land use change of Lahore became slightly slow than the preceding period (2001-2005). The urban built-up area of twin cities increased from 1638 km2 in 2005to 1811 km2 in 2010.). During this phase, the urban/built-up land of twin cities increased 173 Km2 while agricultural land constantly transformed and decreased 112 Km2 while barren land decreased 49 Km2 was altered into urban/built-up area during 2005-2010.

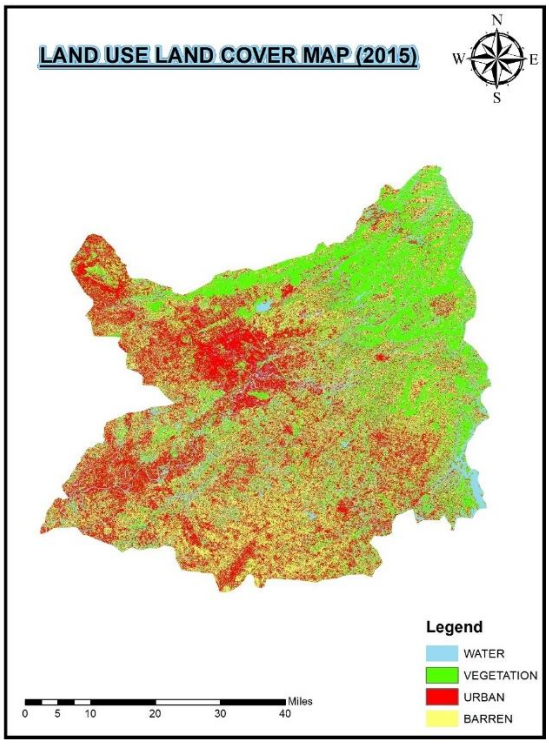


Figure 4.4: Land use land cover map 2015

Table 4.4 : Area Statistics of Land use of 2015

YEAR	URBAN AREA IN Km2	VEGETATION	WATER	BARREN LAND
2015	1910	1743	887	1652

Urban land use profile of Lahore changed extensively from 2010 to 2015. In 2010, the urban/built-up land of twin cities was 1811 Km2 which increased to 1911 Km2 in 2015. The portion of built-up area increased. It is also revealed that the agricultural land decreased from 1804 Km2 in 2010 to 1743 Km2 in 2015, while area under vacant land decreased from 1698 Km2 in 2010 to 1652 Km2 in 2015.

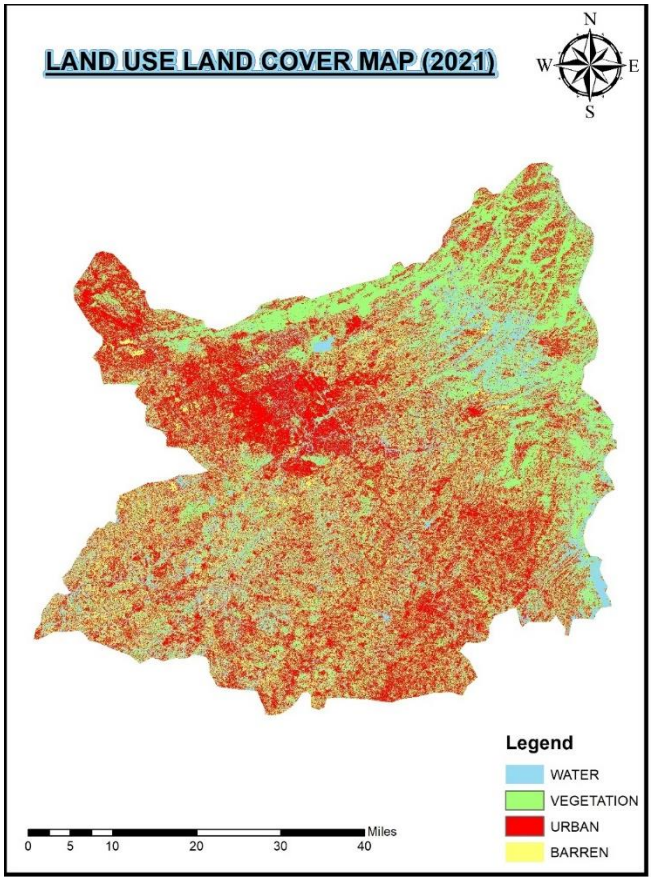


Figure 4.5: Land use land cover map 2021

Table 4.5: Area Statistics of Land use of 2021

YEAR	URBAN AREA IN Km2	VEGETATION	WATER	BARREN LAND
2021	2302	1614	893	1383

The years from 2015 to 2021 beheld a phenomenal increase in the urban expansion of twin cities. The urban built-up area of of twin cities increased from 1910 km2 in 2016 and 2302 km2 in 2021. The land used for agriculture reduced from 1743 km2 in 2015 to 1614 km2 in 2021. It is noted that agricultural and vacant land was altered into urban land. It can be analyzed through maps that urban territory increased while there has been decline in vegetation and agricultural land.

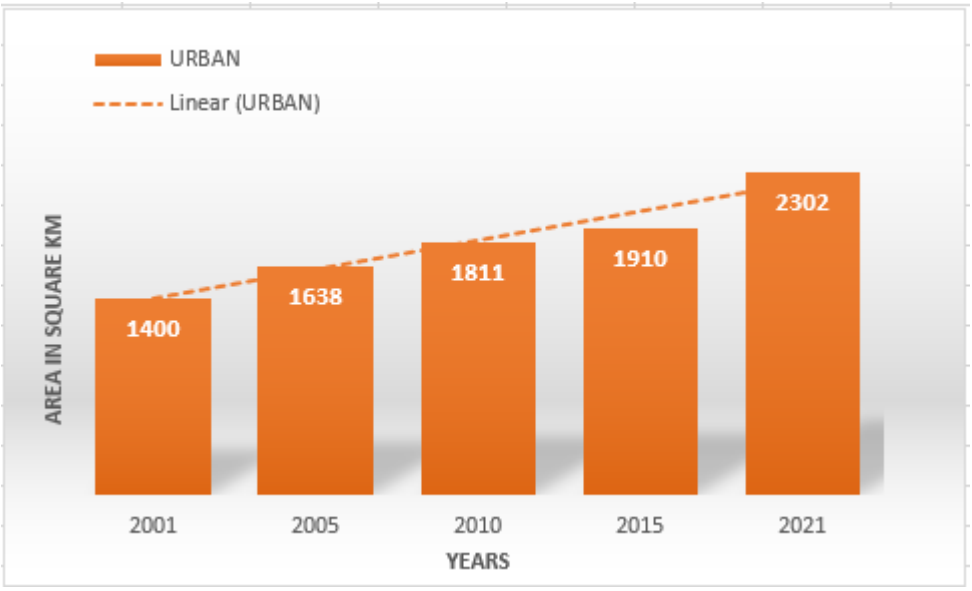


Figure 4.6: Urban Trend From 2001 To 2021

The graph shows that the growth of urban built- during the period between 2001-2021 as the graph showing that the build up area in 2001 is 1400 km2, in the period of 2001 to 2005 the build up area increased 1400 km2 to 1638 km2 there is a increment of 238 km2.from 2005 to 2010 build up area increase from 1638 km2 to 1811 km2 with the increment of 173 km2.from the period of 2010 to 2015 the build up area increased from 1811 km2 to 1910 km2. And 2015 to 2021 the build up area increases from 1911 km2 to 2302 km2. This indicates a vivid change in urban expansion and morphology of twin cities according to its extent and size. The areal extent of urban built–up area observed positive increasing trends while all the study period agricultural area and vacant spaces showed continuous decreasing trends. Phenomenal increase in urban spatial expansion of twin cities is seen during the period 2001-2021. During the period (2001-2021), the rate of the encroachment of urban/built up areas expanded much more extensively in the similar direction of the preceding period.

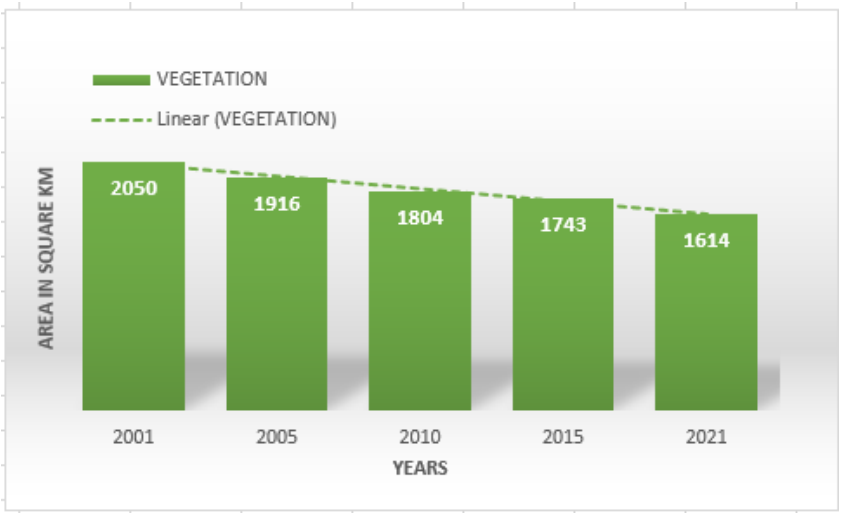


Figure 4.7: Green Area Degradation From 2001 To 2021

This graph is showing that the green area is gradually decreasing with the passage of time in the year of 2001 the vegetation area was 2050 km2 in the period of 2001 to 2005 green area decreased from 2050 km2 to 1916 km2 in 2005. In the period of 2005 to 2010 green area decreased from 1916 km2 to 1804 km2 in 2010. In 2015 green area decreased from 1804 km2 to 1743 km2 ,from 20015 to 2021 green area decreased from 1743 km2 to 1614 km2. as natural greenery and agricultural land are turned into non-transpiring surfaces like metal asphalt and concrete. Such changes produce the urban-rural disparity with relevance to air and land surface temperature. Increasing urban development is seen all over the world particularly in developing countries like Pakistan. It is necessary to keep the effects of such change in land use on the climate in check. At the moment, global change in temperature is the biggest issue surrounding mankind. The massive, unplanned urban development created environmental disturbances that is vulnerable and sensitive to the reduction of agricultural land and vegetation cover transformed into the impervious surfaces which affect the temperature and create urban heat island phenomenon.

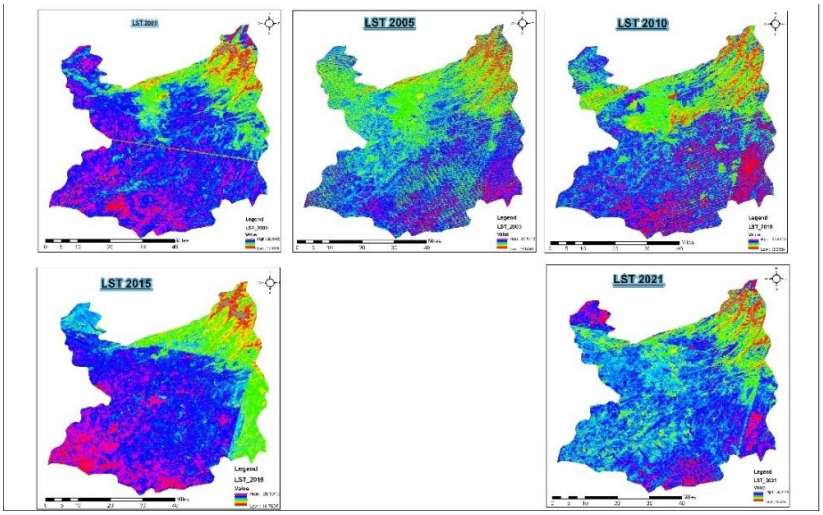


Figure 4.8: LST Maps From 2001 To 2021

Table 4.6: Monthly Average Temperature From 2001 To 2021

MONTH	2001	2005	2010	2015	2021
JAN	14.1615	16.5105	15.182	18.0645	18.448
FEB	21.312	19.0755	16.7885	18.962	25.152
MAR	25.2965	24.3955	25.7525	28.458	32.064
APR	29.774	31.074	30.74	35.372	37.7905
MAY	35.9345	35.6165	36.571	42.146	40.4595
JUN	35.303	37.93	40.7995	42.1175	35.0815
JUL	33.222	32.93	31.667	35.6425	32.2935
AUG	31.287	31.3515	30.1025	30.443	31.483
SEP	32.008	31.5915	31.361	30.0305	30.8005
OCT	28.3305	26.775	27.283	27.535	28.8185
NOV	20.4475	21.9535	22.633	24.267	24.647
DEC	16.679	16.9495	18.206	16.991	19.683
AVERAGE	26.97	27.17	27.25	29.16	29.72

The readings of the land surface temperature for the year 2001 show that the highest temperature is 35.93°C and the lowest temperature is 14.16°C. The mean temperature is 26.97°C. in 2005 the average temperature is 27.17°C in 2010 average temperature 27.25°C in 2015 average temperature 29.16°C and in 2021 average temperature 29.72°C. Higher land surface temperatures mainly increase in industrial zones and urban centers. The LST observed in the River , water channels, along with green spaces was lowest surface temperature.

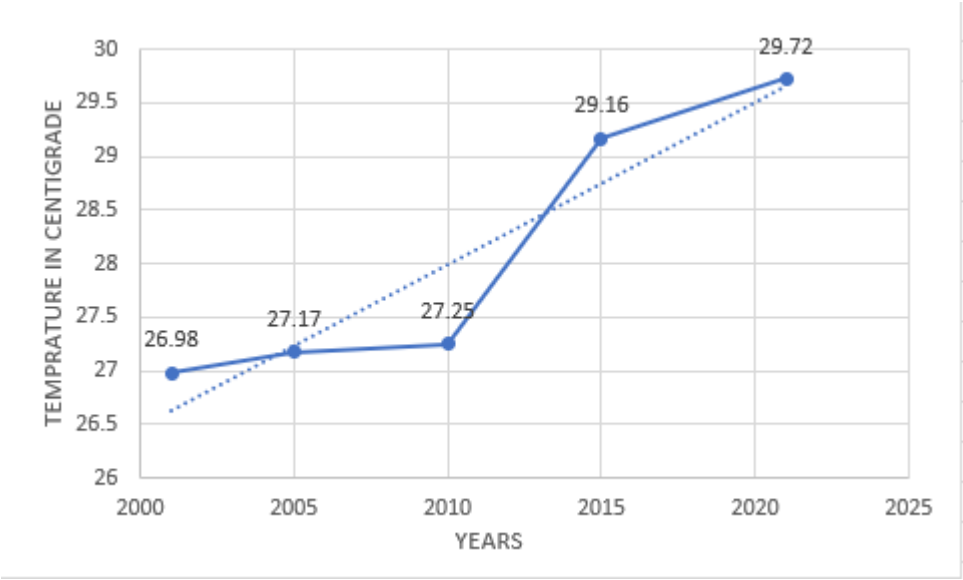


Figure 4.9: Average Annual Temperature Trend From 2001 To 2021

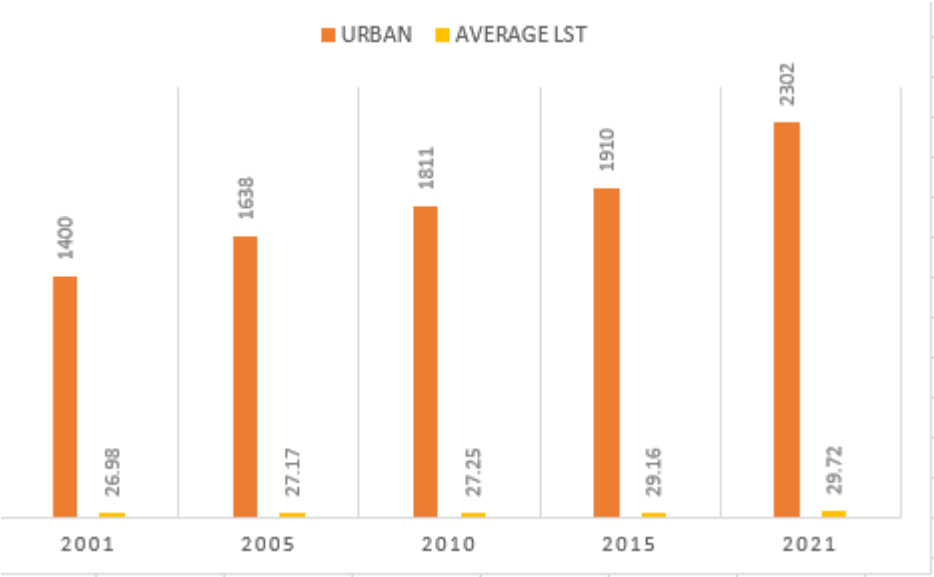


Figure 4.10: LST And Urbanization Relation

The graph showing that as the direct relation of LST with urbanization as the urban area is increasing with the passage of time the average LST is also increasing as we can see if the fig 4.10

4.2 CONCLUSIONS

The land surface temperatures in urban areas are increasing gradually as a consequence of massive land use changes taking place due to urban expansion. It has led to reduction in agricultural land and loss of vegetation in cities around the world. Cities are multifunctional centers of industrial and anthropogenic activities. These functions are causing urban growth and indicate the impact of urbanization on local climate. Since 1800, studies concerning the recognition of rising temperature phenomenon in urban areas have increased manifold. A number of scholars (Howard, 1818; Harwood, 2008, Gabler et al., 2009, James et al., 2014) documented that temperatures in urban areas, varied from those of the nearby countryside, in line with the greenhouse effects produced by use of carbon fuelled machinery. UHI is a quantifiable pocket of warm air produced by a large urban area. This comes as to no surprise as cities signify areas with higher density of population and centre of concentration of human activities. The cities, in this regard, consume 60 to 80% of energy produced globally and are contributing to CO2 emission with equal share (OECD, 2010). A number of studies indicate that the land surface temperatures of cities are generally (1-6°C) warmer than those of the adjacent rural areas (Gabler et al., 2009). Several contributing factors include energy use, automobile, industry, heat generating human activities, thermodynamic capacities of material, structural geometry and impervious surfaces are responsible for storage of heat and re- radiation of heat in the atmosphere. These factors in turn change the conditions that alter the near-surface atmospheric temperature over the urban areas.

The findings of the present study reveal that the city of Rawalpindi and islamabad over the last few decades has experienced a rapid population and urban growth. The expansion of urban areas in Rawalpindi and islamabad city has influenced the local climate. The urban climate of Rawalpindi and islamabad is affected not only by factors of global climactic change in the South Asian region but indigenous factors of this change have also exercised an adverse impact. The significant variations in temperature trends of Rawalpindi and islamabad show increase in temperature during various years. Moreover, land surface temperature is also progressively rising in Rawalpindi and islamabad. One of the leading causes is reduction in the agricultural area in the city. This notable change creating the climatic condition is known as 'Urban Heat Island' in Rawalpindi and islamabad.

4.3 RECOMMENDATIONS

•Increase vegetation in the area.

•Administrative boundaries of most urban areas do not include their peri-urban settlements.

•Growing urbanization means more consumption and need of different products, and as a results of growing population demand for water, food, housing, heat, energy, clothing and consumer goods will increase dramatically.

•So administrative authorities have to take serious action against urbanizations and plant more vegetated areas in this city

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