COMPARATIVE ANALYSIS OF PRE AND POST-EARTHQUAKE ON LAND USE LAND COVER AND ITS IMPACT ON URBAN HEAT ISLAND IN MUZAFFARABAD CITY

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A thesis submitted in partial fulfillment of the requirements for the degree of MS Remote Sensing and GIS

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I dedicate this thesis to my parents who have given me invaluable educational opportunities

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
BUI	Built Up Index
DEM	Digital Elevation Model
GWR	Geographically Weighted Regression
LST	Land Surface Temperature
LULC	Land Use Land Cover
NDVI	Normalized Difference Vegetation Index
OLS	Ordinary Least Square
SAVI	Soil Adjusted Vegetation Index
UHI	Urban Heat Island

ABSTRACT

On October 8, 2005, an earthquake of magnitude 7.6 magnitude struck the Kashmir region of Pakistan causing widespread damage to buildings and infrastructure and environmental components. Most of the physical infrastructure was damaged. The state rehabilitates and reconstructs most of its physical infrastructure. Land Use Land Cover (LULC) change analysis assists decision-makers to ensure sustainable development and to understand the dynamics of our changing environment. During the past 17 years the study area has undergone many LULC changes due to rapid urban growth, poorly planned infrastructural development, and a devastating earthquake event. This study was proposed to detect LULC changes and to investigate the urban heat island in the study area. Urban heat island (UHI) effect, the side effect of rapid urbanization, has become an obstacle to the further healthy development of the city. Understanding its relationships with impact factors is vital to provide useful information for climate adaptation urban planning strategies. Muzaffarabad is a mountainous city and hit by and devastating earthquake in 2005, in result most of the infrastructure was damaged. In process of rehabilitation and reconstruction many of the buildings were reestablished but many of people from suburbs shift to the city, which increases in built-up area in city. Supervised classification was done observe land use land cover maps and OLS and GWR are run to check the urban heat island effect in city. 24% increase was observed in built-up, and 15% decrease in vegetation. GWR show better performance than OLS as its AICc values are lower than OLS AICc values.

CHAPTER 1

Introduction

Pakistan is situated in the high-seismic region. Three tectonic plates, that is, the Indian (or Indo-Pakistan plate), the Eurasian (or Asia) and the Arabian plates, represents the active seismological zones of Pakistan and the adjacent regions (Wheeler, Bufe et al. 2005). The collision of the Eurasian and Indo-Pakistani plates gave birth to the world-famous peaks of the Himalayas, Hindukush, Pamir, and Karakoram. Likewise, the active faults within and around Pakistan are the outcomes of the ongoing collision of these two plates (Nakata, Otsuki et al. 1990). Main Boundary Thrust (MBT) is the major thrust in the region of Hazara-Kashmir syntax of north Pakistan (Monalisa, Khwaja, et al. 2007).

Pakistan was struck with the most devastating earthquake (magnitude Mw= 7.6) in its history on October 8, 2005, at 8:50 am local time causing damage and casualties over a vast area of 30,000 km2 in the NWFP, province of Pakistan and certain regions of Pakistan administered Kashmir. The main event was followed by more than 978aftershocks of magnitude Mw= 4.0 and above as of October 27, 2005. The epicenter of the main earthquake was located at a latitude of 34° 29" 35' N and longitude of 73° 37" 44' E. The focal depth of the main earthquake was determined as 26 km by the USGS. It was the deadliest earthquake in the recent history of the Subcontinent that resulted in more than eighty thousand causalities, two hundred thousand injured, and more than 4 million people displaced. The adverse effects of the earthquake were estimated to be higher than that of tsunamic of December 2004. The major cities that were affected were Muzaffarabad, Bagh, and Rawalakot in Kashmir and Balakot, Shinkiari, Batagram, Mansehra, Abbottabad, Murree, and Islamabad in Pakistan. Almost all the buildings, mainly stone and block masonry laid in cement sand mortar with RC slabs or GI sheet roofing, collapsed in the areas close to the epicenter. In regions approximately 25 km away from the epicenter nearly 25 % of the buildings were severely damaged. The structures in the affected region are mainly reinforced with stone, concrete block and brick masonry, and reinforced concrete frames with concrete block or brick masonry infill panels.

In case of assessment of post-earthquake urban damage, remotely sensed data offers extraordinary advantages over traditional methods of field survey- it is low risk and offers a fast overview of building collapse across an extended geographic region. Accordingly, damage detection techniques are now seen in the literature, employing either direct or indirect methodological approaches. For instance, urban damage is inferred from a surrogate measure like nighttime lighting levels (HAYASHI, MATSUOKA, et al. 1999). The impacts and performances of the reallocated reconstruction mode are mixed. As a different post-earthquake reconstruction mode, reallocated reconstruction is typically adopted in the following conditions: 1) the original locations is exposed to natural hazards. 2) the original location is extraordinarily damaged and rebuilding the structure in the original settlement is inconvenient for rapid recovery, 3) when the land for resettlements belong to the government, and there is a chance relocating victims to the land (Bayulke 1983). Abe and Shaw observed various post-earthquake reconstruction performances at varying time stages, who divided the 10 years process of settlement into three stages, including carnival conflict and renaissance. In carnival and renaissance stages, the evaluating of resettlement impact was positive, while it was negative in conflict stage. Their study suggested that the success or failure of post-earthquake reconstruction was related to the reconstruction phases (Abe and Shaw 2015). Dunford and Li pointed out that the post-earthquake reconstruction was a long-term process probably requiring the development of up- to 10 years. Although some researches have studied the long-term post-earthquake reconstruction, no research has compared the long-term effects and differences of different post-earthquake reconstruction modes from the perspective of measured satisfaction of residents so far (Dunford and Li 2011).

Many humanitarian organizations assume that the quickest and most effective way to rebuild Houses after a disaster are to employ professional construction companies. At same time, however, there is a growing awareness of the limitations and risks of the contractor-led approach. Contractor-built reconstruction may lead to housing that does not respond to the cultural or social needs of disaster-affected communities. An emphasis on safety – increasing earthquake resilience, for instance – may see the introduction of modern technologies and construction materials that may be inappropriate to the local environment, and may make subsequent repairs and maintenance difficult or impossible (Duyne Barenstein 2006). The bulk of the reconstruction work after the earthquake was carried out by the AJK government under the State Earthquake Reconstruction and Rehabilitation Authority (SERRA). The government also invited national and international governmental, non-governmental and private sector organizations to take part in the reconstruction effort.

1.1 Land Use Land Cover

Land cover refers to the physical characteristics of the earth's surface, as seen in form of distribution of water, soil, vegetation and other physical features including man-made infrastructure e.g., settlements while the land use refers to the way in which land has been utilized by the humans and their habitats, usually with the clue on the functional role of land for economic benefits (Kumar et al., 2013). The land use land cover pattern of any region is an outcome of natural and socioeconomic factors and their usage by man in space and time (Rawat et al., 2013).

The composite term land use land cover comprises of both categories LU and LC and analysis of change is of key importance. In the recent past, LULC change analysis has become an important research question, as LULC change has been observed as a vital factor for environmental change globally. Although the LULC change can be detected by conventional surveys and inventories Satellite remote sensing apart from being beneficial in terms of cost-effectiveness and time saving for regional-scale also offer large scale data on LULC changes with details of their geospatial distribution. Information about change is essential for updating LULC maps and management of natural resources. It is very critical to have continuous, historical and precise information on LULC changes of Earth's surface for a healthy sustainable development program in which LULC provides one of the main essential input criteria (El-Kawy, Rød, et al. 2011).

The LULC is considered as a significant measure to assess the impact of applied watershed management measures. Several studies have been carried out to improve the accuracy of classification using various GIS and RS based ancillary data at different stages of classification. Therefore, appropriate information on LULC is critical for implementing numerous developments, planning, and land-use schemes to fulfill the ever-increasing demands of the basic human needs (Yacouba et al., 2009).

1.2 Urban Heat Island

Rapid urbanization and growth in urban areas with increasing populations gives rise to a common phenomenon, urban heat island (UHI), where urban areas have higher air and surface temperature as compared to the rural surrounding (Luo and Peng 2016). The Urban Heat Island effect has received exceptional attention because of its negative impacts on the healthy development of the city and health of the urban population, like the increase in heat and pollution-related mortality, the lowered habitat's comfort, and the elevation of the mean and peak energy demand of the infrastructure (Mirzaei 2015). Urban Heat Island (UHI) is considered as the most critical phenomenon of urban climate, with further strong impact on the several aspects of urban environment. The most significant features describing UHI are its magnitude and spatial-temporal structure. The general spatial structure of UHI is categorized by the occurrence of three separate zones, i.e. cliff, plateau, and peak. This general structure of UHI can be highly modified depending on the land use types and urban features (Oke 1976).

The UHI effect is strengthened due to the modification of nature of the cities, as an alarming result of a reduction in vegetation and evapotranspiration, a higher prevalence of dark surfaces with low albedo, and higher anthropogenic heat production (Stone et al., 2010).

The regional geographic and atmospheric conditions are key determinants of the UHI effect and its intensity in cities and towns. The UHI effect in significantly impacted by the geographic features, climatic scenarios, and seasonal variations of a region of the cities. Even the time of the day dramatically affects the intensity of the UHI. For instance, during the night time, during which the emissivity of pavement and the heat radiated back into the atmosphere are the most significant contributors to the temperature of the surface and lower atmosphere within an urban location (Santamouris, 2013b).

Rapid urban expansion has significantly been observed in China, especially in the cities located in Pearl River Delta and Yangtze River Delta. Over the past decade, the pressure provided by the urbanization motivated city planner and managers to assess the magnitude of urban expansion and the associated UHI effect (Han and Xu, 2013).

1.2.1 Ordinary Least Square and Geographically Weighted Regression

With the advancements in the remote sensing technology, the remote sensing data is widely utilized to study the impact of the UHI for the ground surface as it offers a relatively cheap and rapid method of gaining up to date information over a large geographical region and acquiring data from remote regions (Price 1984).

Advanced and sophisticated interpolation algorithms became popular with increasing access to more efficient computers and the development of accessible GIS software. Most recent researches on the spatial traits of UHI are based on the multidimensional interpolation algorithms with multiple linear regression (MLR) being the most commonly used (Unger, Savić et al. 2011).

Multiple regression analysis like Ordinary Least Squares (OLS) model is based on the assumption of independence of observation, resulting in a failure to capture the spatial dependence of the data when it is applied to the georeferenced data analyses (Li, Zhao et al. 2010). Brundson and Eringham (2003), developed a local regression technique, geographically weighted regression (GWR) to overcome the shortcomings of the OLS. (Fotheringham, Brunsdon, et al. 2003).

The above research studies on the quantitative analysis of the relationships between UHI and impact factors are mainly dependent on the global regression models, like the OLS and the neural network predictive model. The global regression model is dependent on the assumption that the relationships are spatially invariant in the entire study area, however, in fact the relationships are often characterized by the local and the global regression model may hide the important details in the spatial distribution (Brown, Versace, et al. 2012).

1.3. Objectives

The targeted objectives of the study were:

1) To monitor and map the temporal changes in the land cover before and after Earthquake (2005) in Muzaffarabad district.
2) To compare pre and post-Earthquake urban heat island by using two statistical models Ordinary Linear Square and Geographically Weighted Regression models.

CHAPTER 2

Materials and Methods

2.1 Study Area

Muzaffarabad district consists of Muzaffarabad city, which is the capital of Azad Jammu and Kashmir, and suburban areas. The district is administratively subdivided into three tehsils and fifty-one Union Councils. The total population of the district according to the 1998 census was 725,000. Muzaffarabad city in the district serves as capital of Azad Jammu and Kashmir. The city of Muzaffarabad is located at the confluence of Jhelum and Neelum rivers (Figure 1). The city was near the epicenter of the 2005 Kashmir earthquake, which had a magnitude of 7.6. The earthquake destroyed 50% of the buildings in the city (including most of the official buildings) and is estimated to have killed up to 80,000 people.

Muzaffarabad district is situated at the latitude of 34°N and longitude of 73°E of and altitude of 3000 feet on the banks of Jhelum and Neelum rivers. It borders on the East with Indian Administered Kashmir, to the South with District Bagh, to the West with District Abbottabad, to the North-West with District Mansehra, and to the North with District Neelum.

Muzaffarabad is the main city and is also the capital of Azad Kashmir. It is situated at a distance of 138 Kilometers from Rawalpindi and Islamabad, and about 76 kilometers from Abbottabad. It became a district headquarter approximately 80 years ago. A town committee in 1938, it was upgraded as Municipal Committee in 1960 and a municipal corporation in 1990. The total area of the district Muzaffarabad is 2449 sq km. Total populations according to 1991 census was 0.746 million and was projected for year 2006 and 0.88 million. However, now this has decreased after the separation of Neelum valley as an independent district in 2005. The average population density is 210 persons per sq. km at an annual growth rate of 2.90. District Muzaffarabad is divided into two tehsils, Muzaffarabad and Hattian which contain one Municipal Corporation one town committee, 38 Union Councils, 528 villages inhabited by 106338 households. Muzaffarabad is generally hilly and mountainous and can broadly be categorized as mountain plateaus, mountain slope, and Inter mountainous valleys.

Much of this area is highly eroded and is characterized by deeply cut ravines and undulating hilly terrain. The city of Muzaffarabad, its land-use map reveals that residential areas are predominantly situated at the river bank. The predominant species of tree found are deodar, blue pine, spruce, chir, walnut, ash, maple, poplar, willow, and oak. The climate varies considerably in the north and south. The Muzaffarabad city experiences warm summer and cold winter. June, July, and August are the hottest months. The mean maximum and minimum temperature during July are about 35 and 23°C respectively. December, January, and February are the coldest months. The average temperature in district Muzaffarabad ranges from 25 to 42 in summer and between -3 to 15 in winter. Average annual precipitation of the district is 1511 millimeters.

2.2 Satellite Images

Landsat remote sensing program started in 1972 by the launch of its first satellite, Landsat 1 and the latest functioning satellite is Landsat 8. Over the years, the Landsat image resolution has been improved by the addition of 2 additional spectral bands (Band 1 and 9) thus giving much-detailed information in the Landsat 8.

For this study, the 30-m satellite imagery (less than 10% cloud cover) for the years 1990, 2000, 2010, and 2016 were attained from Landsat 5 and 8. The images were taken from the summer season (June through September). These raw images were initially preprocessed, mosaicked together and clipped to extract the required region.

2.3 Software Used

The GIS software used for this study includes ArcGIS version 10.5, ERDAS IMAGINE version 2014.The other software used includes Microsoft Office (Word, Excel, and PowerPoint).

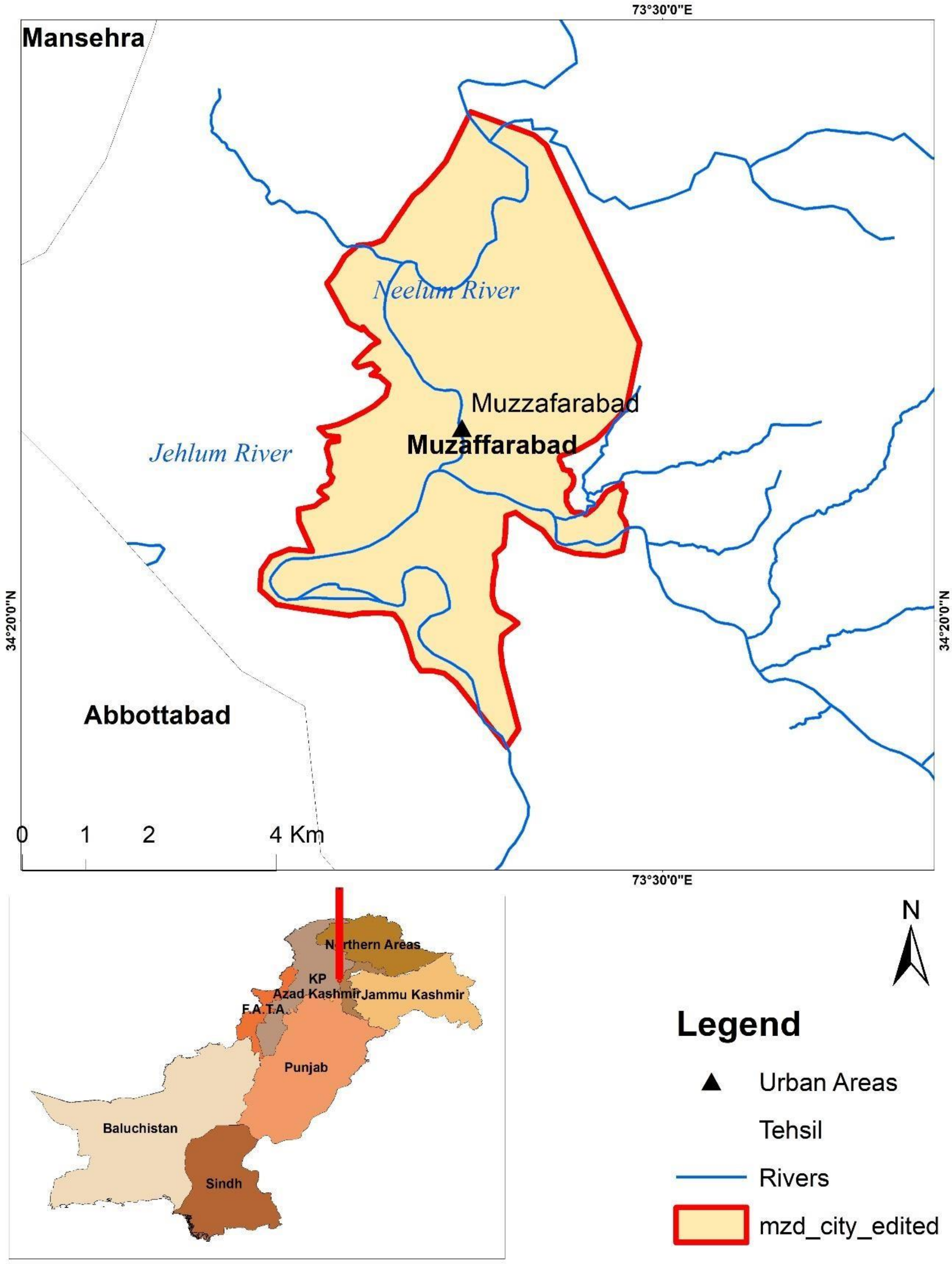
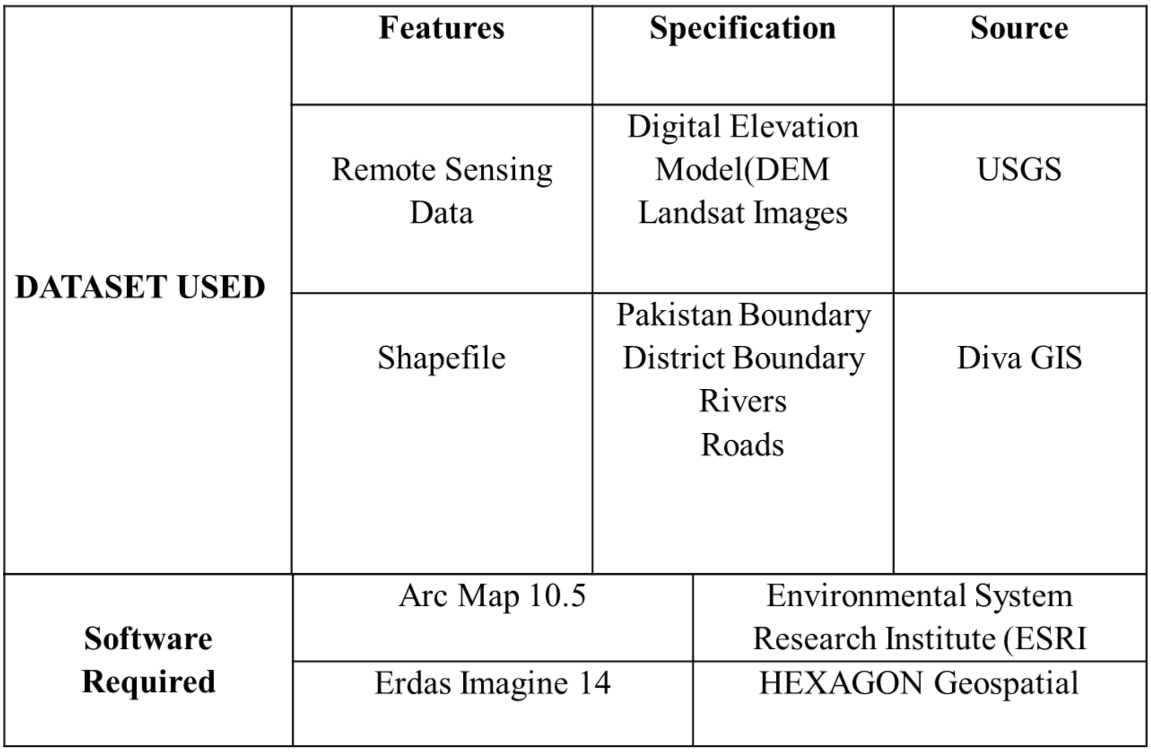


Figure 1. Study area map showing the Muzaffarabad city, Neelum and Jhelum rivers.

Table 1. Data set used for the current study.



	Features	Specification	Source
DATASET USED	Remote Sensing Data	Digital Elevation Model(DEM Landsat Images	USGS
	Shapefile	Pakistan Boundary District Boundary Rivers Roads	Diva GIS
Software Required	Arc Map 10.5		Environmental System Research Institute (ESRI
	Erdas Imagine 14		HEXAGON Geospatial

2.5 Land use land cover mapping

The methodology flowchart for land use land cover change mapping is shown in Figure 2. Image classification of the land cover includes allocating pixels to the classes which give information about the land use. It represents the piece of land used for various purposes such as forests, urban areas, agriculture, etc. Land use land cover classification is an integral component of remote sensing and has been utilized in several analyses including change detection, urbanization research, etc. Image classification is mainly divided into two main groups; per-pixel based and object-based classification. Per-pixel based image classification is most commonly used in the researches.

In this study, forest cover change was assessed using the per-pixel based supervised image classification is performed. The classification was performed using the following three steps; selecting the training sites, evaluating training samples by their signatures and spectral patterns and Image classification. For each land cover class, approx. 20-30 samples were selected as the training sites. Supervised Image Classification is performed in ArcGIS 10.5 (Figure 2).

By image classification we classify image in four major classes i.e. Built up it includes urban settlements like roads and houses, vegetation class includes urban vegetation such as agriculture fields, parks etc., open land class includes barren mountains and areas with no vegetation and water class includes all water bodies.

2.5.1 Accuracy Assessment

The interpretation of the images is performed visually and is reinforced by the image classification. Accuracy assessment is a fundamental part of the classification. The concept is to compare the classification results to other data source which is deemed to be more accurate or using the ground truth data.

Ground truth can be performed in the field; however, it is not preferred because it is an

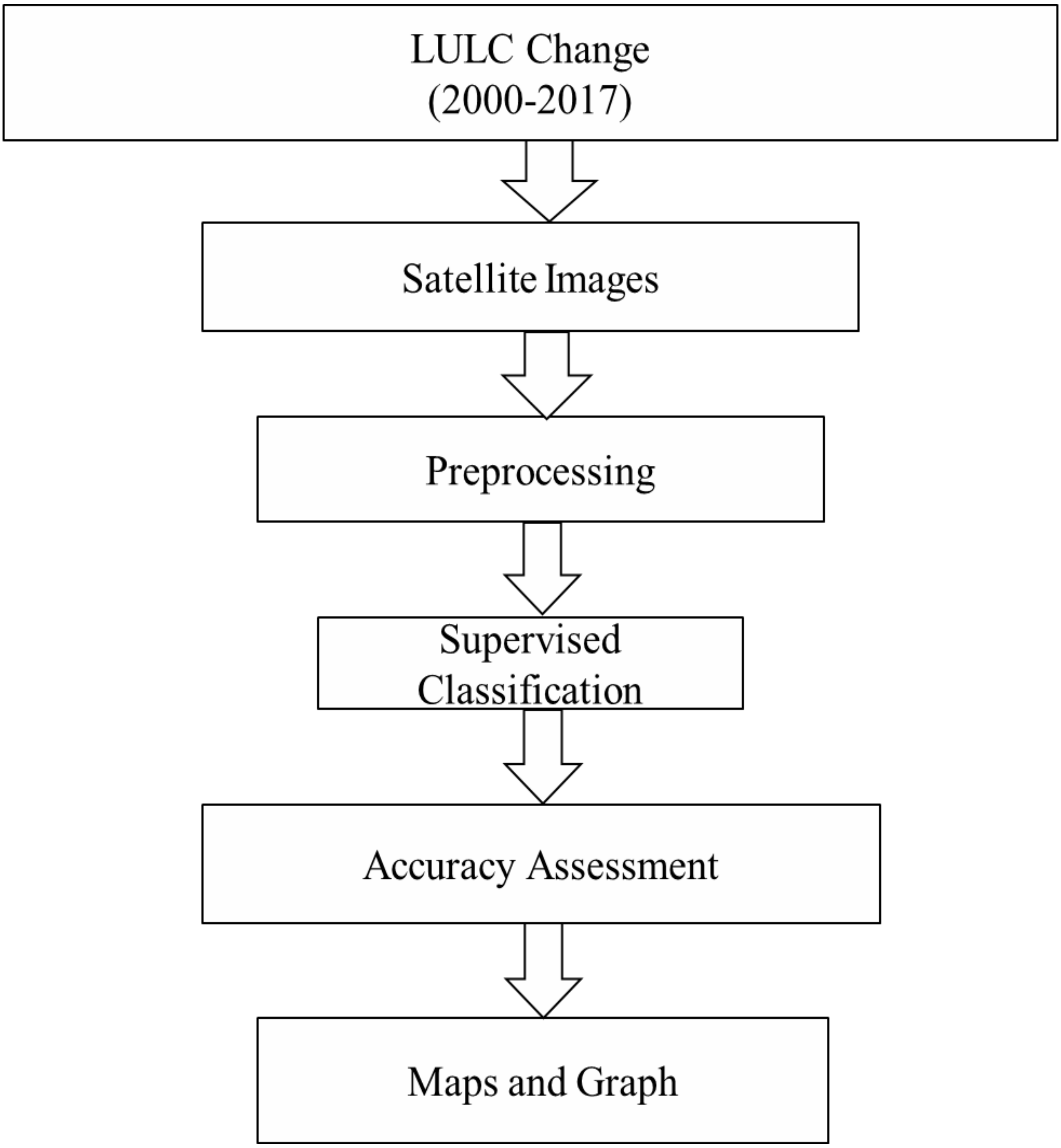


Figure 2. Methodology of land use land covers change detection for Muzaffarabad city (Objective 1).

expensive and time-consuming process. Ground truth data can be generated from the interpretation of high res image, current classified imagery or the GIS layers.

Accuracy assessment for the classified images is performed in ArcGIS using three geoprocessing tools: Create Accuracy Assessment Points, Update Accuracy Assessment Points, and Compute Confusion Matrix. The accuracy assessment is a 2-step process; in the first step, a set of random points were generated from the ground truth data, and in the next step these are compared to the classified data in the confusion matrix. In the current study, Google Earth is used as the reference data for accuracy assessment.

2.6 Urban Heat Island

For the estimation of Urban Heat Island across the study area, different indices were selected Built-up index, Normalizes Vegetation index and Soil Adjusted Vegetation Index and Land surface temperature. Aster DEM was downloaded from the USGS website. To analyze the regression analysis that is Ordinary least squares and global weighted regression Land surface temperature was considered as dependent variable and BUI, NDVI, SAVI and DEM as explanatory variable (Figure 3).

2.6.1 Parameters

Normalized Difference Vegetation Index

NDVI is a famous index to demarcate vegetation from other land features. Its value range from -1 to +1. Values greater than 0.3 are considered vegetation with more values reflecting dense vegetation.it formula is given by

$$NDVI = (NIR - RED)/(NIR + RED) \text{ ……………… Eq. (1)}$$

Soil Adjusted Vegetation Index

Soil Adjusted Vegetation Index is same as NDVI with the exception of soil brightness correction factor (L). It is good for areas where soil is exposed and vegetation is less. Its formula is given by

$$SAVI = ((NIR - RED)/(NIR + RED + L)) * 1 + L \text{........................ Eq. (2)}$$

RED and NIR are Red and Near Infrared spectral bands, whereas the brightest factor of soil is L, if vegetation cover is absent L has 1 value and if vegetation cover is very high L has 0 values.

Built-up Index

Built-up index is used to demarcate built-up area from rest of land features. It is calculated by following formula:

$$BUI = (MIR - NIR)/(MIR + NIR) \text{ .... Eq. (3)}$$

Where MIR is Middle Infrared and NIR is Near Infrared.

Digital Elevation Model

For the present study 30 m SRTM Dem is also downloaded from USGS website for Muzaffarabad district. The highest elevation is 1488 m and lowest elevation is 636 m for Muzaffarabad district Figure 8.

Land Surface Temperature

To calculate Land Surface temperature first Landsat images were converted to top of atmospheric (TOA) spectral radiance by the following formula.

$$TOA\ (L) = Ml * Qcal + Al \text{ .... Eq. (4)}$$

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

Q_{cal} = corresponds to band 10.

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ ADD_ BAND_ **x**, where x is the band number).

After that TOA to Brightness temperature conversion is performed by following formula:

$BT = (k2/(lnK1/L)) + 1)) - 273.15$……………………….Eq. (5)

Where:

- K_1 = Band-specific thermal conversion constant from the metadata
- K_2 = Band-specific thermal conversion constant from the metadata
- L = TOA

Finally Land surface temperature is calculated by following formula:

$LST = (BT/(1 + (0.00115 * BT/1.4388) * Ln(\in))))$……………… Eq. (6)

- $\varepsilon = 0.004 * P_v + 0.986$

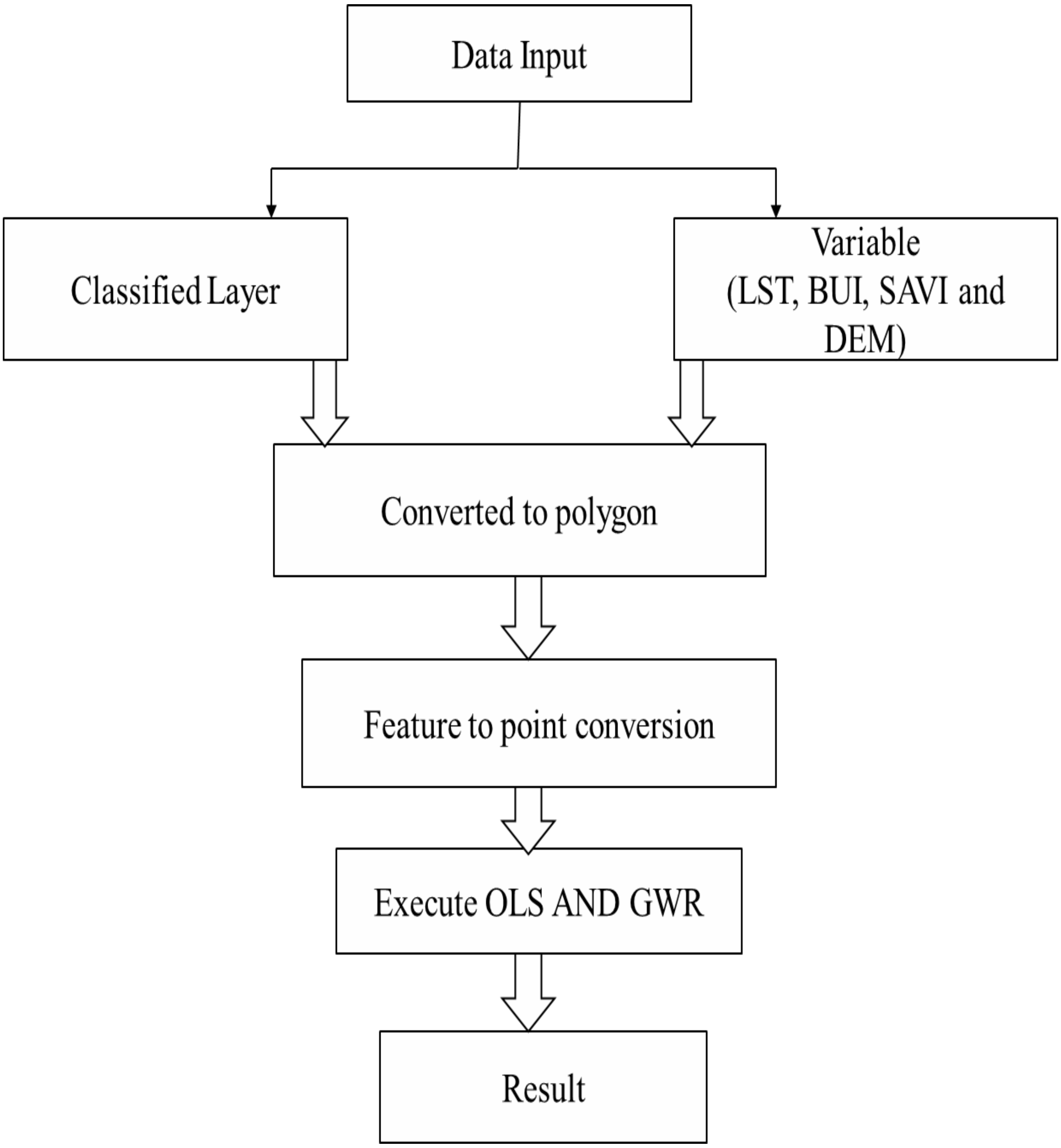


Figure 3. Methodology for urban heat analysis using OLS and GWR (Objective 2).

CHAPTER 3

Results and Discussion

3.1 Pre and post-earthquake Land use land cover

To monitor Land Use/Land Cover changes for Muzaffarabad district, before and after Earthquake is one of the objective of the study. For that, Landsat images were acquired for the years 2000, 2005, 2006, 2010 and 2017. First atmospheric corrections were applied to these images so that haze cannot interfere with the classification quality. After that supervised classification was applied on all of these images. All these images were classified under four categories; Built-up, Water, and Open Land and Vegetation. For spectral signature training, all human-related structures were characterized under Built-up. Lakes and river were classified under Water. Barren land and rock outcrops were classified under Open land. Forest and agriculture land is classified under vegetation. All Landsat images are acquired for same month of all the years so that seasonal activity cannot affect present study. Land use land cover (LULC) change detection facilitates the dynamic phenomenon of the ever changing environment. During the last one and half decade, the study area has undergone numerous changes due to rapid urbanization, poor infrastructure planning and development, and a catastrophic earthquake incident.

Information regarding land change is essential for updating the LULC maps and the effective management of natural resources. It is noteworthy that historical, continual, and precise information on the LULC changes of the earth's surface for any sustainable development programs in which LULC serves as one of the key input criteria (El-Kawy, Rød, Ismail, & Suliman, 2011).

Mainly such information obtained (using LULC change detection) can be useful for planning rehabilitation in the Muzaffarabad district and also the surrounding regions which experienced a significant earthquake in October 2005 ((Kamp, Growley, Khattak, & Owen, 2008; Owen et al., 2008)

Figure 3 is the year wise classification maps of Muzaffarabad city categorized under Built-up, Water, Open Land, and Vegetation. Whereas Figure 4 is area change of year 2000, 2005, 2006, 2010 and 2017.

3.2 Land Use Land Cover Pre Earthquake (2000-2005)

In the year 2000 Built-up, Water, Open Land, and Vegetation areas are 5, 1, 4 and 14 km^2. In year 2005 just before Earthquake Built-up, Water, Open Land, and Vegetation areas are 8, 1, 9, 7 Km^2. Built-up area increased by 3 km^2 Water remained unchanged, Open land increased by 5 Km^2 and Vegetation decreased by half to 7 km^2 (Table 2).

If observed spatially Built-up area is centered at Muzaffarabad city and along the river in form of villages. There is a slight change in Built-up area from 2000-2005 mainly the built-up density is increased (Figure 4).

From 2000-2005 unchanged Built-up, Open Land, Water, and Vegetation area is 15%, 12%, 4%, and 26% respectively. If significant interconversions between classes are considered then Open land to Built-up conversion is 4%, Built-up to Open land is 6%, Vegetation to Built-up is 13%, Vegetation to open land is 15% and water to open land is 2%.

3.3 Land Use Land Cover after Earthquake (2005-2006)

In the year 2005 just before Earthquake Built-up, Water, Open Land, and Vegetation areas are 8, 1, 9, 7 Km^2. In year 2006 right after Earthquake Built-up, Water, Open Land, and Vegetation areas are 3, 1, 15, 6 Km^2.Built-up area decreased from 8 km^2 to 3 km^2. 5 km^2 of Built-up got devastated by Earth Quake. These figures show the severity and extent of 8-Oct-2005 Earth Quake.

The district was paralyzed and more than 70% of casualties have occurred in Muzaffarabad. All the infrastructure from bridges buildings were severely damaged. The government put ban on the concrete buildings and no citizen was allowed to construct. This decreased the Built-up area and most of previous Built-up area changed into open land. Moreover, Water remained unchanged, Open land increased by 6 Km^2 and Vegetation decreased by 1 km^2 (Table 3).

If observed spatially Built-up area is centered at Muzaffarabad city and along river in form of villages. Built-up density has decreased from 2005-2006 due to Earth quake. Open land is increased in expense of Built-up. (Figure 4).

3.4 Land Use Land Cover Post Earthquake (2005-2017)

In the year 2006 Built-up, Water, Open Land, and Vegetation areas are 3, 1, 15, 6 Km^2. Whereas in year 2017 Built-up, Water, Open Land, and Vegetation areas are 13, 2, 4, 6 Km^2. Built-up has increased significantly by 10 km^2 (Table 4).

Water bodies have increased by 1 km^2, Open land has decreased significantly by 11 km^2 and vegetation has remained unchanged. Interestingly all urban sprawl has happened on open land and vegetation class is not affected on the long run (Figure 4). Same is reflected in spatial maps (Figure 3).

From 2006-2017 unchanged Built-up, Open Land, Water, and Vegetation area is 13.5%, 13%, 3%, and 13% respectively. If significant interconversions between classes are considered, then Open land to Built-up conversion is 30%, Open land to vegetation is 12%, Vegetation to Built-up is 6.5%, Vegetation to open land is 3% and open land to water is 4% (Table 2).

In the year 2000 Built-up, Water, Open Land, and Vegetation areas are 5, 1, 4 and 14 km^2. Whereas in year 2017 Built-up, Water, Open Land, and Vegetation areas are 13, 2, 4, 6 km^2. Built-up has increased significantly by 8 km^2. Water bodies have increased by 1 km^2, Open land has remained unchanged and vegetation has decreased by 8 km^2. Interestingly it seems urban sprawl has happened on vegetation class and open land is not affected on long run (Figure 4). Same is reflected in spatial maps (Figure 4).

From 2000-2017 unchanged Built-up, Open Land, Water and Vegetation area is 19%, 0.2%, 5% and 23% respectively. If significant interconversions between classes are considered then Open land to Built-up conversion is 7%, Open land to vegetation is 2%, Vegetation to Built-up is 24%, Vegetation to open land is 6.5% and open land to water is 2% (Table 3).

Some limitations were also observed while conducting this research. One of these was that the Landsat TM satellite images used for the desired study had comparatively low spatial resolution, i.e., 30 m that only allows the land cover classification of level 1 -2 of the Anderson System.

Therefore LULC of the study area has only been characterized into broad classes. The region is mountainous and has rugged topography. In the mountainous regions, the complexities of terrain make the land cover classification challenging task due to the differences in the surface cover illumination. Elevation, slope, and aspect all have a solid impact in the interpretation of spectral signatures and thus, accuracy of the land cover classification may be affected. Land use land cover mapping the mountainous areas by the integration of remote sensing technology poses several challenges due to the steep slope angle, topographic shadows, complex land cover patterns, and high spatial diversity particularly where large scale fragmentation is present (Poudel, 2008; Weiss & Walsh, 2009; Wundram & Löffler, 2008).

On October 8, 2005, the study area was struck with a devastating earthquake that destroyed the housing and infrastructure. The epicenter of the earthquake was situated almost 10 km northeast of the Muzaffarabad city (Kamp et al., 2008) and this fatal disaster left the city to meager rubble. Muzaffarabad was one of the most affected regions “where approximately 90 % of the total buildings were either damaged or entirely destroyed during the earthquake” (Sudmeier-Rieux et al., 2007). This catastrophe posed severe damage to the city and several people lost their homes and it was estimated that about 89 % of the housing structures from the private housing sector were completely diminished (ERRA, 2007). LULC changes between 2000 to 2017 were the outcome of different natural and anthropogenic activities. Throughout the study period, a decline in vegetation cover was observed where the built-up and bare soil has considerably increased.

Vegetation category comprises the sparse vegetation (including broadleaved trees/conifers, shrubs, farmlands, and crops) distributed randomly along densely populated forests, roadsides on communal and farmlands. After the cross verification, several spectral signatures were merged to characterize this class. Since this class does not precisely contain thickly populated forest patches but also various vegetation types including tall trees and farm crops, spread over a vast area in fragmented form, therefore several factors contributed in the destruction and vegetation degradation. Private landholdings in the region are very minute i.e. 210 acres/family (AJK P&D, 2008), the high population urges the citizens to increase their residential facilities over the farmlands and on the forested land through illegal invasions.

Post-earthquake several families increased their housing units and this lead to the damage of the farm trees and resulted in the encroachment on the terraces underneath the agricultural lands and gardens. The reconstruction and repair of the housing infrastructure greatly increased the timber demand in the AJK forest department on priority basis from the current forest resources. Construction of road also added fuel to the increasing problem of destruction of vegetation. The road network has tremendously extended during the last decade and visibly has damaged the vegetative cover. According to the AJK Local government department, the road network of the region has increased from 270 km to 760 km during the 2000- 2017 period.

Table 2. Interconversions between classes from 2000-2005.

Category	Percentage Change
Unchanged Built-up	15%
Open land to Built-up	4%
Unchanged Open land	12%
Unchanged Water	4%
Built-up to Open land	6%
Vegetation to Built-up	13%
Unchanged Vegetation	26%
Vegetation to Open Land	15%
Open land to Water	0.5%
Water to Open land	2%
Built-up to Water	0.1%
Water to Built-up	0%
Vegetation to Water	0%
Open land to Vegetation	1%
Built-up to Vegetation	0.6%
Water to Vegetation	0%

Table 3. Interconversions between classes from 2006-2017.

Open land to Built-up	30%
Unchanged Water	3%
Open land to Vegetation	12%
Open land to Water	4%
Vegetation to Built-up	6.5%
Unchanged Open land	13%
Unchanged Vegetation	13%
Unchanged Built-up	13.5%
Vegetation to Open land	3%
Built-up to Open land	0.4%
Water to Open land	0.4%
Vegetation to Water	0.5%
Built-up to water	0.1%
Built-up to Vegetation	0.3%
Water to Built-up	0.1%
Water to Vegetation	0%

Table 4. Interconversion between classes from 2000-2017.

Unchanged Built-up	19%
Open land to Built-up	7%
Unchanged Water	5%
Built-up to Vegetation	0%
Vegetation to Built-up	24%
Built-up to Water	0.6%
Open land to Vegetation	2%
Unchanged Vegetation	23%
Open land to Water	2%
Vegetation to Open land	6.5%
Built-up to Open land	2%
Water to Open land	0.6%
Unchanged Open land	0.2%
Water to Built-up	0.2%
Vegetation to Water	0.4%
Water to vegetation	0.6%

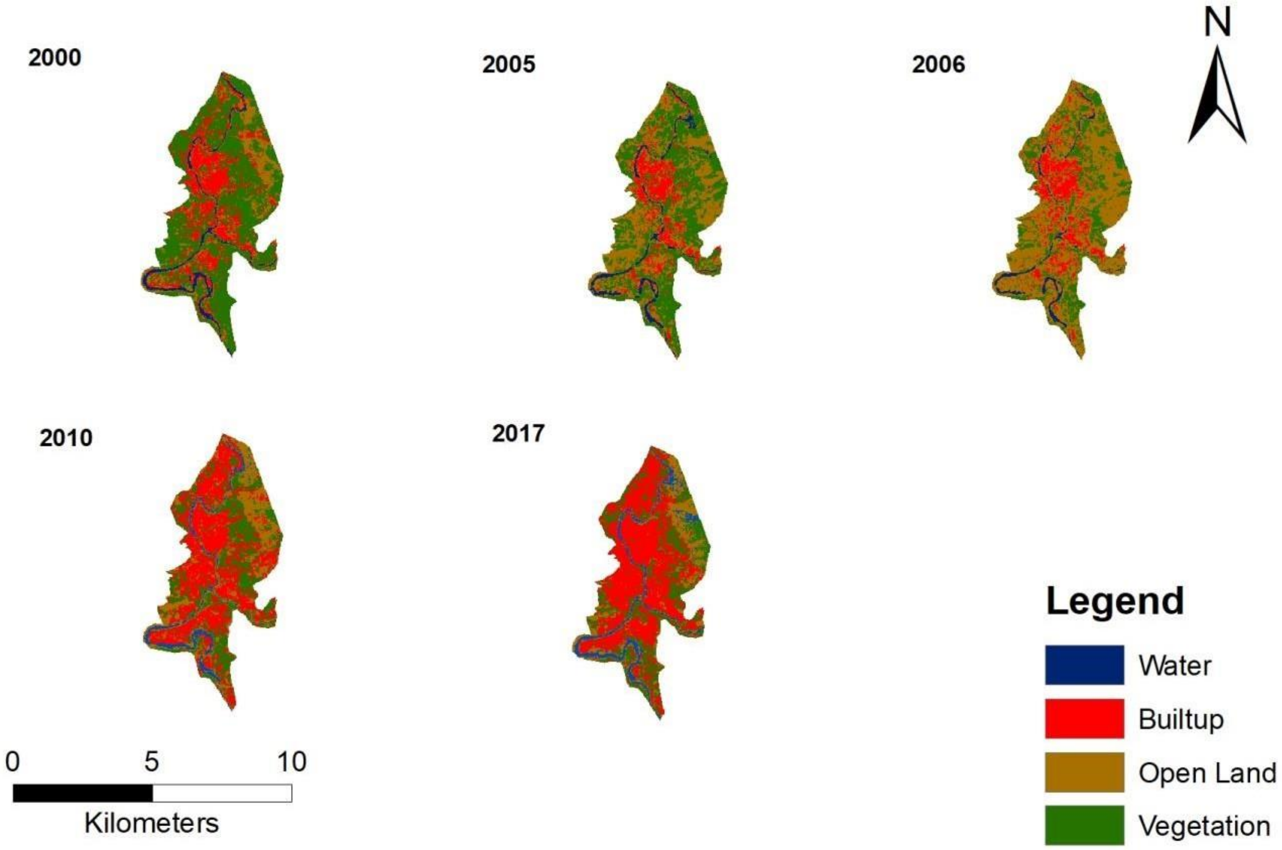


Figure 4. Supervised Classification of the year 2000, 2005, 2006, 2010 and 2017.

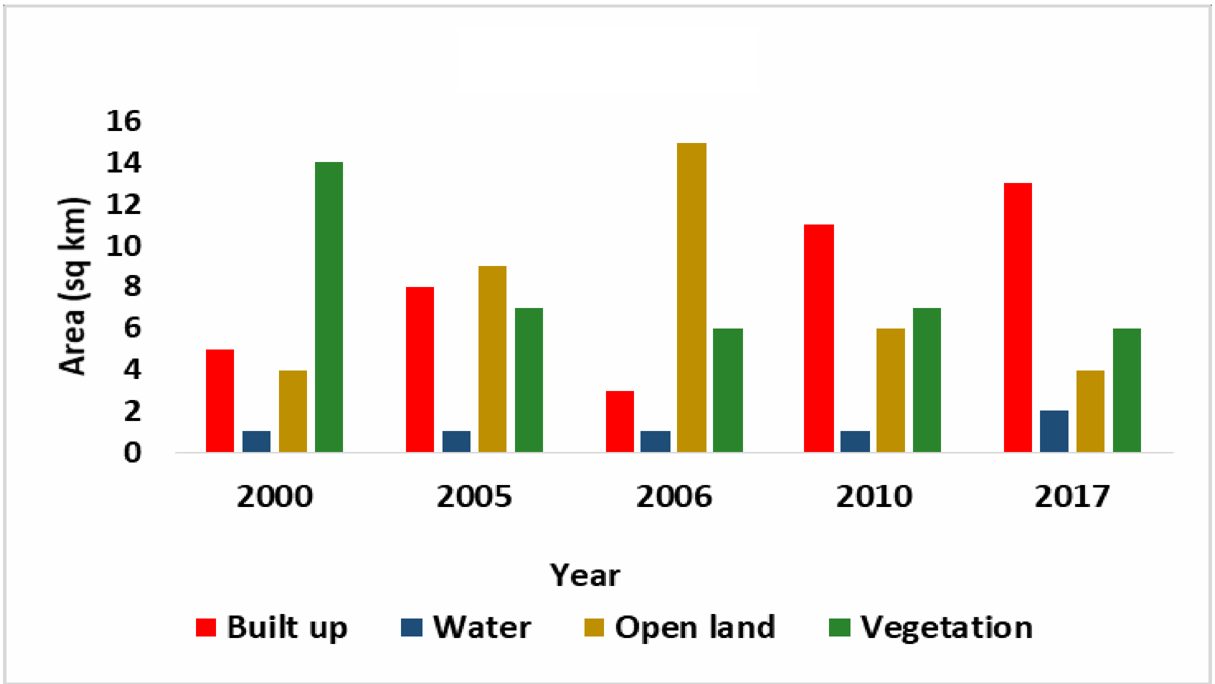


Figure 5. Area Change of the year 2000, 2005, 2006, 2010 and 2017

The open land class comprises of the bare soil patches without the vegetation cover, landslides, and the earthen roads. The built-up and bare soil classes had similar spectral response that made it confusing to separate the two. The problem is more visible in the year 2010 and 2017 classified images, therefore a slight over or underestimation may be observed. Various factors contribute to the increased bare soil category from 1998 to 2009. One of the significant factor is landslides, which had been a common phenomenon in the region already however it became more frequent after the 2005 earthquake. The disaster affected the study area significantly and triggered numerous landslides (Sudmeier-Rieux et al., 2007). Majority of the landslides happened over moderate elevations on south-facing slopes (Kamp et al., 2008).

Moreover, in the post-earthquake conditions, the landslide initiation is a major environmental challenge that was observed in several studies as the 2005 earthquake triggered many landslides (Fujiwara et al., 2006; Sato et al., 2007). According to (Petley, Dunning, Rosser, & Kausar, 2006), Muzaffarabad is likely to observe more frequent landslides in the following monsoon season due to the existence of large slope cracks. Landslides bared the soil and cause an overestimation in the bare soil class. With the increasing population, construction of link roads as a component of infrastructural development also served as a contributing factor in soil exposure, thereby, increasing the area covered by bare soil class. Furthermore, as an expected outcome of deforestation and vegetation degradation for various land uses, soil is deprived of the green cover and blank patches add to the heap of bare soil. The forests and vegetation cover have decreased over the study period which may have expanded the volume of bare soil.

Water covered around 1-2 % of the study area in 2000 that is almost same in 2017 with minor differences. This reveals that there is not a noteworthy change in this class and area covered by water class remained constant over the study period. At some instances, the spectral response of water and straight cut landslides were confusing and thus considering it as the same entity. This remained unavoidable despite of the fact that the training samples were fed again and again to avoid this problem.

Over the study area, the population of Muzaffarabad subdivision significantly increased from 0.453 to 0.650 million (AJK &PD, 2011) that visibly justifies the increase in built-up area. Not only the urban concentration was increased but the rural families also showed their interest in extending the accommodation facilities as per the growing family size. After the catastrophe of 2005, the State Earthquake Reconstruction and Rehabilitation Authority (SERRA) entered the market and took up the task of rehabilitation and restoration. By 2009, 106, 423 house units were installed in the private sector and 309, 044 ft^2 area was covered by the under-construction public sector buildings in the study area. (SERRA, 2009). After the earthquake, the population of the city has significantly increased due to the influx of people from adjacent villages. The earthquake caused large scale destruction of infrastructure and housing facilities which compelled the surrounding suburban population to flock and settle within the city where the necessities of life would be easily accessible. This too serves as a contribution in high built-up area.

3.5 Urban Heat Island Analysis for Muzaffarabad

As seen from classification built-up area has drastically increased from 2000 to 2017 except from 2005 to 2006 when Earthquake occurred and built-up area decreased. Built-up areas are directly associated with Urban Heat Island. For Urban Heat Island analysis Land Surface Temperature was derived from Landsat images; 2000, 2005, 2006, 2010 and 2017. Moreover NDVI, SAVI, and BUI were also calculated using LANSAT images and used in regression model for Muzaffarabad.

3.5.1 Normalized difference Vegetation Index

Its value range from -1 to +1. The green part is showing moderate to healthy vegetation and purple color is showing no vegetative area. NDVI calculated for Muzaffarabad of year 2000, 2006, 2010 and 2017 is shown in Figure 6.

3.5.2 Soil Adjusted Vegetative Index

Its value ranges from-1 to +1. The green part is showing high vegetative area while pink color is depicting low. Calculated SAVI is shown in Figure 7.

3.5.3 Built up Index

Its value also ranges from -1 to +1. The red color is depicting high built-up area while green color is showing non built-up area. Calculated BUI is shown in Figure 8.

3.5.4 Digital Elevation Method

For the present study 30 m SRTM Dem is also downloaded from USGS website for Muzaffarabad district. The highest elevation is 1488 m and lowest elevation is 636 m for Muzaffarabad district (Figure 8). As surface temperature also depends upon on height so DEM.

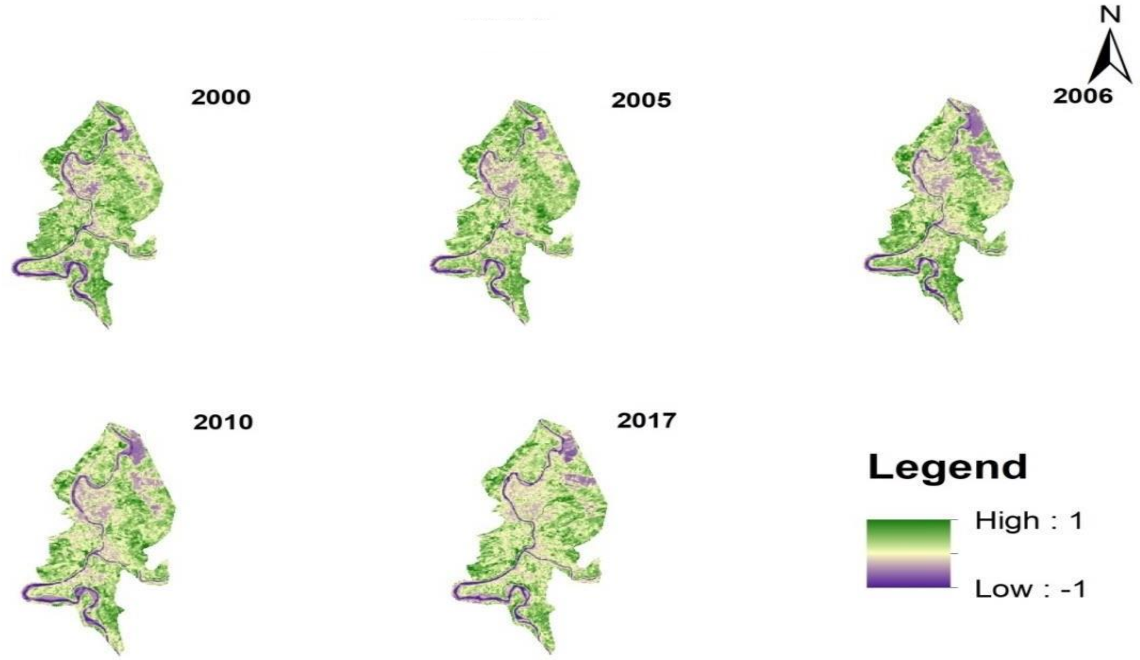


Figure 6. NDVI for Muzaffarabad of the year 2000, 2005, 2006, 2010 and 2017.

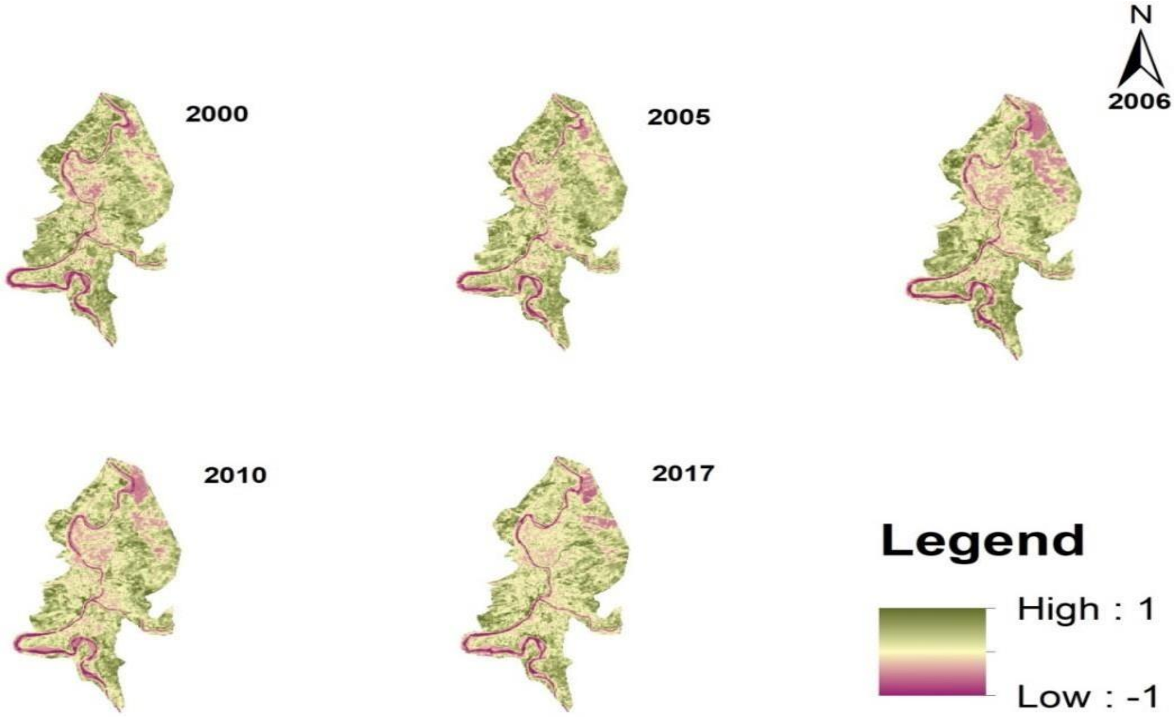


Figure 7. SAVI for Muzaffarabad of years 2000, 2005, 2006, 2010 and 2017.

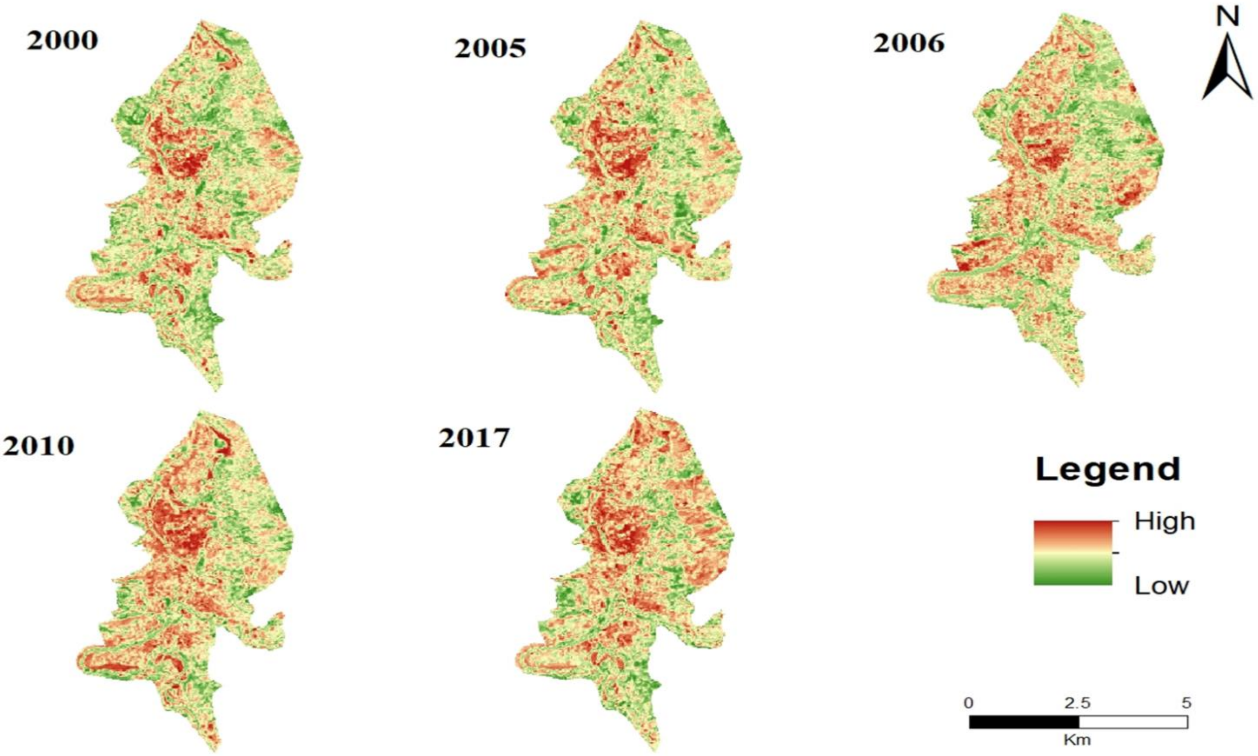


Figure 8. BUI for Muzaffarabad of years 2000, 2005, 2006, 2010 and 2017.

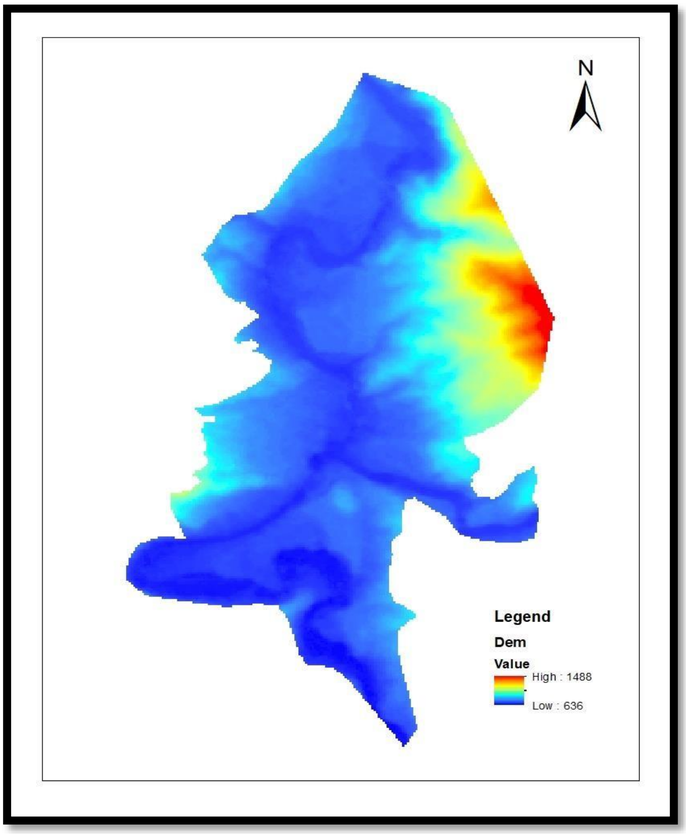


Figure 9. DEM of Muzaffarabad with highest elevation approximately 1500 and lowest 650 meters.

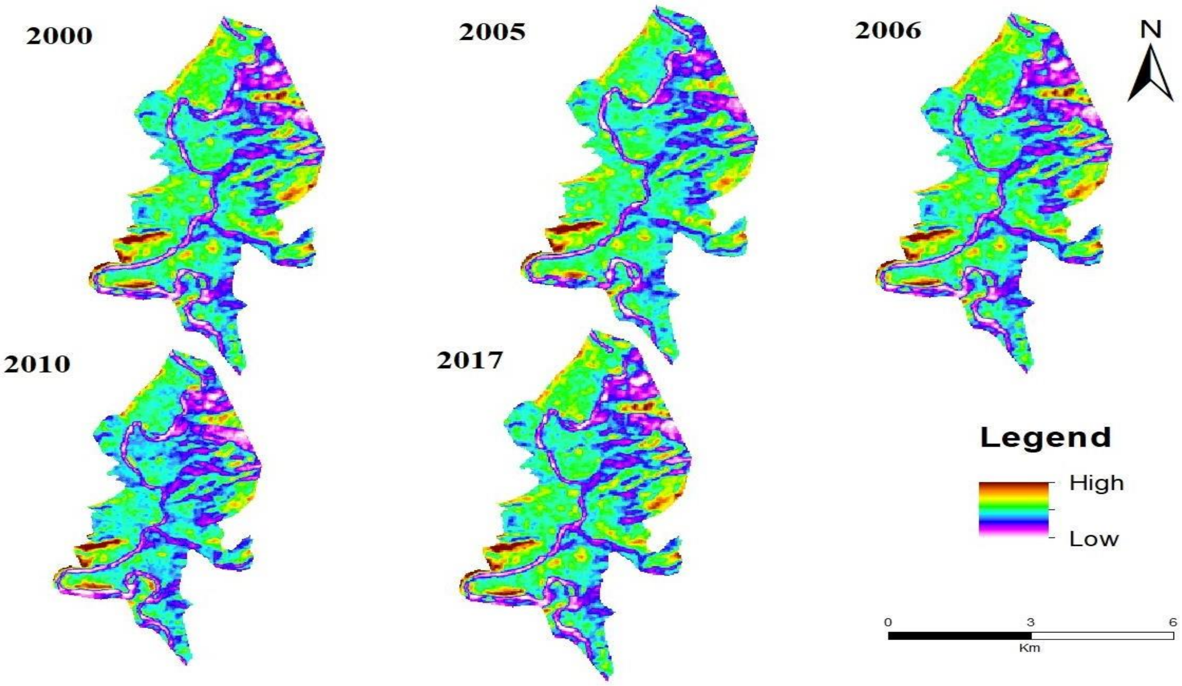


Figure 10. LST map for years 2000, 2005, 2006, 2010 and 2017.

3.5.5 Land Surface Temperature

For Muzaffarabad LST is calculated for all the under-discussed years whose maps are shown in Figure 10:

To access Urban Heat Island statistics, zonal statistics technique is applied on LST images. In this technique minimum, maximum, range, mean and standard deviations of LST are calculated for all the pixels within the study area (Table 5). Interestingly if built-up area over the years is plotted with mean land surface temperature they show similar trends. Starting from 2000 built-up area in Muzaffarabad is 5 km^2 and mean temperature for Muzaffarabad is 24.27 °C. In 2005 built-up area rose to 8 km^2 and mean temperature rose to 25.45 °C right before Earth Quake. In 2006 built-up area shrunk to 3 km^2 due to Earthquake destruction and mean temperature dropped to 24.30 °C.

Similarly in 2010 and 2017 built-up area is 11 and 13 km^2. Mean temperature also increased with the built-up area due to Urban Heat Island effect and temperature rose to 26.03 in 2010 and 26.90 in 2017 (Figure 11). Thus built-up area in Muzaffarabad is affecting mean temperature over the region. To validate this, OLS and GWR Modeling techniques are applied in the study region to find other variables responsible for increase in Land Surface Temperature over Muzaffarabad.

3.6 Spatial Regression Analysis

Regression analysis is used to examine, model and spatially explore different factors so that a better understanding can be developed. It is used to model and predict the outcome by developing a spatial relationship. For the present study OLS and GWR regression methods are applied to find the relation between dependent and explanatory variables. LST is taken as dependent variable whereas NDVI, SAVI, DEM, and BUI are taken as explanatory variables.

Table 5. Zonal Statistics of LST for Muzaffarabad.

Year	**MIN**	**MAX**	**RANGE**	**MEAN**	**STD**
2000	17.62	33.60	15.98	24.27	2.35
2005	16.55	36.38	19.83	25.45	2.62
2006	17.62	38.66	21.04	24.30	3.05
2010	16.55	38.21	21.66	26.03	2.98
2017	16.14	33.99	17.85	26.90	2.22

Figure 11. Built-up and Temperature trends over the years.

3.6.1 OLS (Ordinary Least Square)

OLS is a global regression method. After running OLS some key statistics is generated, which determines whether GWR should be applied or OLS regression is enough to explain the relationship. For the present study classification layer for each year is taken as zones for running OLS. For that first classification raster is converted to polygons. Then feature to point conversion is applied and for each point underlying values of all the explanatory variables are extracted. Then point data is joined with classification polygon and OLS model is executed in ArcMap. Before running the model-dependent and explanatory variables are defined in model. After model is executed successfully a statistical report is generated and corresponding residual layer for input zones is analyzed.

OLS method is applied or each year. Its adjusted R^2, AICc, and residual error values are shown in table 6. Adjusted R^2 values tell how well the relationship between dependent and explanatory variables is explained. Except for years 2005 and 2006 Adjusted R^2 values are in acceptable ranges. AICc values determine how well the model has performed for example if someone wants to compare OLS with GWR.so model having less AICc value will be the one which has performed better. In regression analysis there is always over and under predictions which is called noise. For a good model it should be always random. If residual error is clustered, then this indicates that model is missing one or more key explanatory variables. For present study all the years had random residual error hence null hypothesis is accepted. This was found by Jarque-Bera test. All the years had non-significant Jarque-Bera values. If Jarque-Bera test values had been significant then this would have mean that our model is missing key explanatory variables. (Table 6).

VIF values should be less than 7.5 for each explanatory variable if VIF values are greater than 7.5 for any of explanatory variable then this indicates that particular explanatory variable is telling the same story as other and it has over count biases in model.

Moreover, it is increasing redundancy in the model. This kind of variable should be removed. For our study, only NDVI had VIF values greater than 7.5, so it was removed from OLS model.

3.6.2 Geographical Weighted Regression

GWR is a locally spatial regression method in which dependent and explanatory variables relationship vary across the region. During OLS analysis Koenker test came significant for all the years. That means the relationship between dependent and explanatory variables is location-dependent and it's more likely that Adjusted R^2 will increase if GWR is applied. Then for each year GWR is applied. For present study 50 neighbors are used to calibrate each local regression for good results. AICc and Adjusted R^2 values are shown in table 8. If AICc values of GWR (Table 8) are compared with AICc values of OLS (Table 6) it can be seen that GWR has lower AICc values, even 3 points deduction is good improvement.

As AICc is used to compare models so for our study area GWR model had good results then OLS. Thus LST depends upon DEM, SAVI, and BUI in Muzaffarabad. This relation is positive for DEM and BUI but negative for SAVI. Meaning areas where there are more built-up and which has high elevation, there would be more land surface temperature. Areas, where there is more vegetation here, would be less Land Surface Temperature.

Table 6. Adjusted R2, AICc, Residual error values of each year.

Year	Adj-R2	AICc	Residual Error
2000	0.306778	9770.782	Random
2005	0.022332	12211.84	Random
2006	0.066907	26986.94	Random
2010	0.430943	12656.96	Random
2017	0.539136	7977.172	Random

Table 7. VIF values of each year.

Year	SAVI	BUI	DEM	NDVI
2000	4.814	4.83	1.01	5.32
2005	1.02	1.05	1.07	2.35
2006	1.06	1.01	1.06	1.32
2010	4.48	4.48	1	1.3
2017	3.33	3.37	1	1.25

Table 8. AICc and R2 values of GWR.

Year	AICc	R2
2000	9118.8	0.484
2005	11770.9	0.227
2006	10455.6	0.186
2010	12030.2	0.577
2017	7240.6	0.681

CHAPTER 4

Conclusion

It is observed that the study area has experienced various LULC changes in past 17 years. With the passage of time, the vegetation cover has reduced significantly, whereas an increase in built-up and bare soil has been observed. This trend indicates growth in population size, increased deforestation, conversion of farmlands to built-up or bare soil, extension in roads network, continuation of uncontrolled grazing activities, commercial logging/harvesting and a number of allied reasons. Population growth seems to be an important factor in causing shrinkage of vegetation cover. Rural communities have considerable dependence on forests for their wants of timber, firewood, fodder and to some extent livelihoods. The increasing population not only overburdens the state's forests but equally causes tremendous pressure on privately owned, communal and farmland plantations. Injudicious infrastructural development plans (road construction, erection of transmission lines, widening of main roads, extension in housing facilities, etc.) also tend to cause destruction of vegetation cover.

The area under bare soil and built up has increased over time by 24.00% and 7.20% which is an indication of expansion in settlements, increase in number of landslides, particularly after earthquake of October 8, 2005, extension in earthen/ un-metaled link roads, vegetation removal for different purposes and abandonment of farmlands. Apart from the increase in population, earthquake has also been a key change factor in built-up and bare soil land covers, because it initiated many landslides and caused almost complete destruction of housing facilities. In post-earthquake era, the number of housing units increased per family and reconstruction and rehabilitation of public sector facilities have also lead to an increase in the built-up cover.

The other part of the study shows that with time increase in built-up, increase in temperature is also observed. Study results from the single-factor models indicate that these influence factors can affect LST significantly. LST is strongly positively related to the BUI variable. However, a negative relationship exists between LST and NDVI. It should be pointed out that built-up increase and decrease in vegetation cover are affecting LST of area with increase and decrease respectively. Overall compared, with the OLS model, GWR model has a better ability to characterize and analyze the relationships between LST and its impact factor.

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