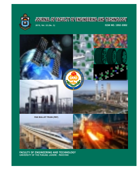
JFET 22(2) (2015) 111-121

Journal of Faculty of Engineering & Technology

journal homepage: www.pu.edu.pk/journals/index.php/jfet/index



IMPACT OF LAND USE CHANGE ON CLIMATE: A CASE STUDY OF GULBERG SCHEME, LAHORE, PAKISTAN

O. Nadeem[1]*, R. Hameed[1], A. Basheer[2], A. Azam[1], I. Ismail[2]
[1]Department of City and Regional Planning, UET, Lahore, Pakistan.
[2]Lahore Development Authority, Lahore, Pakistan.

Abstract

The whole globe is facing perilous impacts of abrupt climate changes. Due to this, climate change adaptation and mitigation has become a sizzling issue of 21st century. In Pakistan, the concept of climate change adaptation has been promoted during the last decade. Focussing on land surface temperature, this study determined the impact of commercialization on climate by considering the case of Gulberg Scheme, Lahore. The methodology included: literature review, data collection and the use of state of the art sofwares to determine the surface temperature of various land uses. The study found that change of land use was causing significant rise in temperature. There is need to give due consideration to climate change vulnerability while formulating land use reclassification schemes. Use of green infrastructure may prove to be effective in climate change adaptation.

Keywords: Climate Change, Land use Reclassification, Commercialization, Green Infrastructure, Lahore, Pakistan

1. Introduction

Climate change is an emerging issue and a potential threat for all the living creatures on the earth including the human beings [1, 2]. The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” [3]. There are many contributory causes of past climate change including ocean currents, earth's tilt, continental drift, volcanoes, greenhouse gases and their sources. Earth's climate is always changing due to natural cyclic process. But unfortunately these changes are exacerbating due to human activities. For instance, the concentration of greenhouse gases has increased the atmosphere beyond natural variations in the past century [4]. The most recent scientific assessment by the Intergovernmental Panel on Climate Change (IPCC) suggests that the earth's average

* Corresponding Author: obaidnadeem@uet.edu.pk

temperature will rise by 1 to 3.5°C (about 2 to 6°F) by the year 2100. This will also cause nearly 15 to 95 cm (about 6 to 37 inches) rise in sea level. Despite this alarming assessment, most of the governments in developed and developing countries are not giving due attention to this issue. Thus, certain climate change effects would be unavoidable in future [2, 5, 6]. Relevant literature increasing points towards the need to taking measures for the adaptation of expected climate changes [1, 7].

Pakistan is also experiencing climate changes, especially, in the intensity of precipitation and temperature rise and consequent floods. This situation is occurring despite the fact that Pakistan's contribution to the atmospheric greenhouses gases (GHG) is very small. It is producing only 135^{th} part of the total quantity of GHG being produced by other countries [8]. Thus, it seems possible to adopt necessary proactive measures by revisiting the national development policies, plans and programme and even rules. In this context, the National Climate Change Policy suggests various adaptation measures for the water, energy, agriculture, livestock and forestry sectors as well as for the coastal areas, biodiversity and vulnerable ecosystems. Furthermore, appropriate measures to address the issues pertaining to disaster preparedness, capacity building of relevant institutions, transfer of technology and international cooperation have been incorporated in the policy [9].

This situation also presents many new challenges for urban planning which may need to enter into a new regime of adaptation and mitigation measures. Review of relevant literature suggests that green infrastructure is considered as an overarching concept that provides a range of climate change adaptation measures. Green infrastructure solutions can be applied on different scales, from the house or building level to the broader landscape level. On the local level, green infrastructure practices include: rainwater harvesting, permeable pavements, green roofs, green building materials, infiltration planters, trees and tree boxes, and green modes of transport [10]. At the larger scale, the preservation and restoration of natural landscape is a critical component of green infrastructure. In this research, we mainly focussed on provision of green infrastructure at the local level.

This research attempts to determine the temperature variations in Gulberg Scheme due to land use change (mainly from residential to commercial) and the land use reclassification proposed by the Lahore Development Authority (LDA), the principal urban planning and development controlling agency in Lahore. This study is of great significance as climate change is directly or indirectly affecting the environment. As the Lahore city is growing rapidly, it is facing considerable variations in temperature. This study would not only help in cross comparing different present and past scenarios of varying land uses of Gulberg Scheme but also serve as a guideline on how to understand and estimate climate change and consider its adaptation in future urban planning endeavours particularly with respect to land use change.

2. Introduction to the Case Study Area

Lahore is the capital city of Punjab province and the second largest metropolitan area in the country. Gulberg Scheme, as shown in Figure 1, spread over an approximate area of 2034 acres, was initially planned as a housing project in 1958. It is bordered by the main Lahore-Karachi Railway line and Cantonment area to its east, Garden Town and Model Town to its west, the Aitchison College campus and Shadman along its north and Cantonment area and Chungi Amar Sadhu along south direction. This Scheme is known for its high class commercial centres, modern restaurants and a major sports complex. It is also known as the hub of the contemporary fashion and cuisine industry in Pakistan. The LDA has proposed this Scheme as a new commercial hub of Lahore.

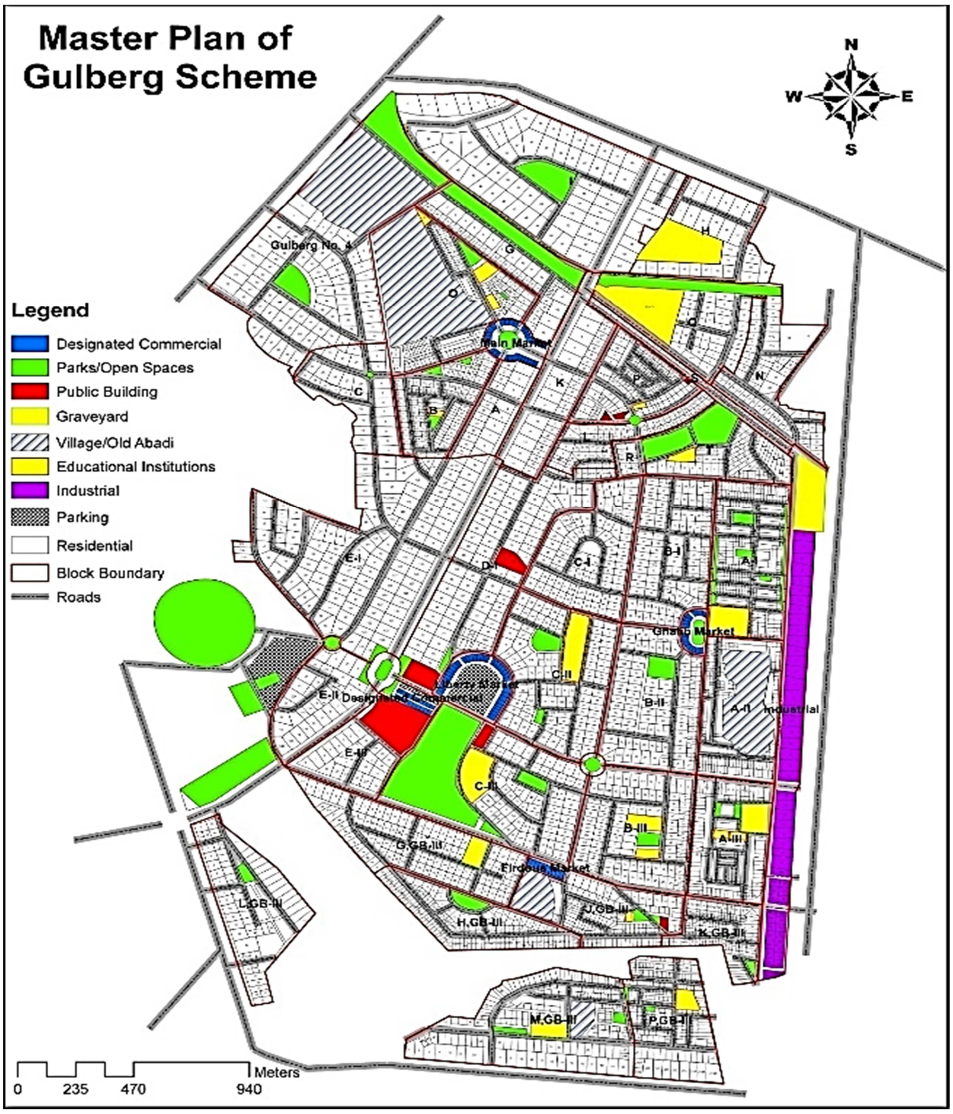


Figure 1. Master Plan of Gulberg Scheme

Source: LDA, 2014

3. Methods and Data

To establish theoretical context of the study, current situation and status of climate change and its adaptation at the international and national levels were critically reviewed. The land use maps of the Gulberg Scheme for 2002 and 2011 and the reclassification map of 2013 were obtained from the LDA. For temperature variation, different Landsat images were downloaded from an online search tool for satellite data i.e. GloVis (USGS Global Visualization Viewer during April 2014). The satellite acquired these images during July 2002 and June 2011 around 7:25 pm, as per the Pakistan Standard Time. Moreover, ERDAS Imagine (geospatial data authoring software) and Geographic Information System software were used for extracting area of interest (AOI). Each extracted image of AOI was then converted by adding it to ENVI 4.7-the software that helps in analysing imageries and identification of regions of interest. The radiance data layer was generated through calibration of AOI in ENVI by assigning all the specific details of the image obtained from MTL file available with Landsat data. This was followed by the application of Spectral Radiance Scaling Method to measure the quantity of radiation that was passing through or emitting from surface of the AOI and determine varied temperature ranges of land uses in the case study area in the years 2002 and 2011 (Figure 2 a & b).

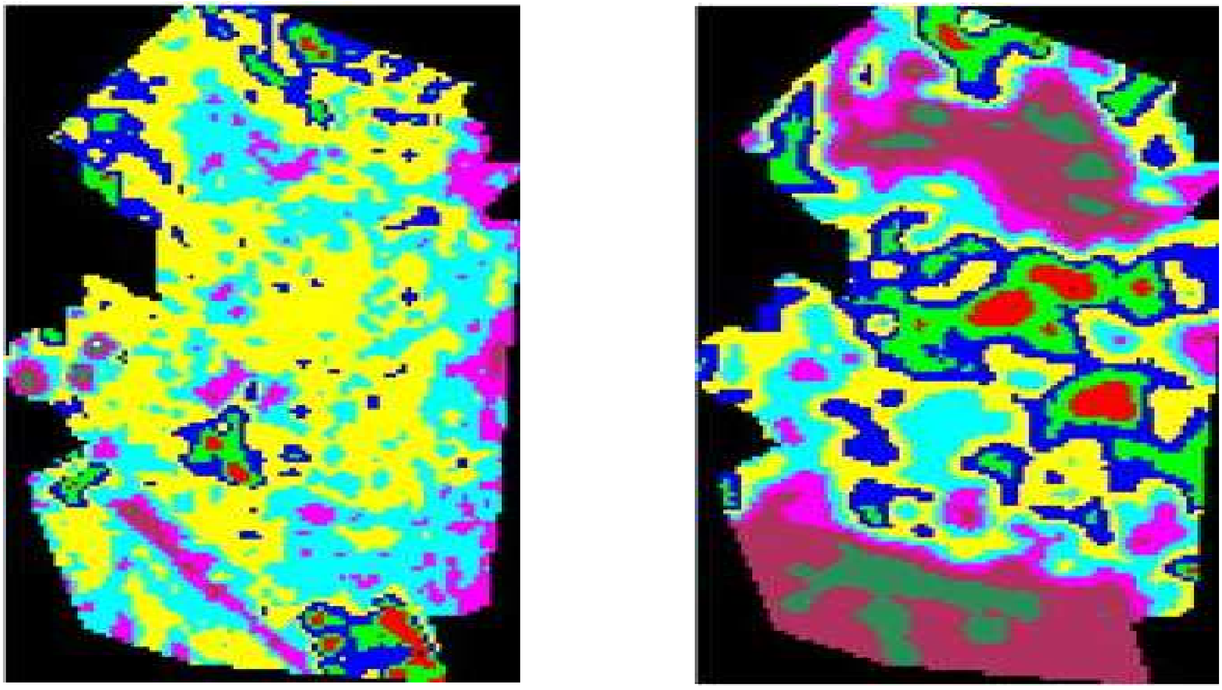


Figure 2 (a) & (b). Plot of Land Surface Temperature of Gulberg Scheme for 2002 and 2011

Source: Authors, 2014

Legend of 2002 LST in ^{0}C
29.08 - 30.04
30.05 - 30.99
31.00 - 31.94
31.95 - 32.90
32.91 - 33.85
33.86 - 34.81
34.82 - 35.76
35.77 - 36.72

Legend of 2011 LST in ^{0}C
31.04 - 32.56
32.57 - 34.07
34.08 - 35.59
35.60 - 37.10
37.11 - 38.61
38.62 - 40.13
40.14 - 41.64
41.65 - 43.15

This Land Surface Temperature (LST) is in fact the skin temperature of land. It is determined by the land surface energy balance by applying the following formula:

$$S_t = \frac{T}{1 + (\lambda \times T/\rho)\ln \varepsilon}$$

T= Brightness Temperature

E= Emissivity (ρ) = 0.0144 (Constant)

λ = 0.000011(Constant)

In this equation, brightness temperature is a measure of microwave radiation traveling upward from the top of earth's atmosphere. It was calculated by applying the following formula:

$$T = K2/ \ln (K1/L+ 1)$$

Where, T is Effective at-satellite temperature in Kelvin, K1 and K2 are constant measured in watts/meter, L is spectral radiance in watts/(meter squared * ster * µm) [11, 12]. Values of K1 and K2 are different for Landsat 5 and 7. For Landsat 5, K1= 607.76, K2= 1260.56 and for Landsat 7, K1= 666.09, K2= 1282.71.

"The emissivity of a material (usually written ε or e) is the relative ability of its surface to emit energy by radiation. It is the ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature. It is a measure of a material's ability to radiate absorbed energy. A true black body would have a value of ε =1 while any real object would have ε < 1. Emissivity is a dimension less quantity with no units" [13]. Emissivity depends on factors such as temperature, emission angle, and wavelength. It was calculated by applying the following formula:

$$\text{Emissivity (E)} = 0.004PV + 0.986$$

The unit of temperature is in Kelvin scale. The pattern temperature variation as it appears in the Figure 2 a & b cannot be explained without relating it with the specific land use parcels. Detailed explanation has been provided in the maps of area of interest shown in Figure 6 and 7 while relating the land surface temperature variation with the change in the distribution of various land uses.

As far as the limitations of this study are concerned, 2% of error is expected because of the limitation associated with data processing, selection of method for temperature calculation and non-availability of temperature data for individual land parcels. However, non-availability of updated land use map restricted our work only onto two years with a gap of nine years in between them. Change of land use not only contributes toward temperature variation but also affects ground water recharge, precipitation level and other aspects of climate. Analysis of these aspects is beyond the scope of this study.

4. Results and Discussion

The results and discussion are presented in the following sub-sections:

4.1 Distribution of land uses

Table 1 and Figure 3 respectively show the percentages of different land uses and their distribution pattern within the Gulberg Scheme in 2002. Major land use was residential (58%). Commercial area (5%) was also present but either in the form of planned markets or scattered along various roads. Furthermore, a separate industrial lane also existed at 2% of the total area.

Table 1. Distribution of land uses in Gulberg Scheme Source: LDA, 2014

Land use/ Year	2002	2011	2013 (Proposed)
Commercial	5%	21%	30%
Education	2%	5%	4%
Graveyards	1%	1%	1%
Industries	2%	3%	3%
Parks/Open Spaces	10%	8%	8%
Parking	1%	1%	1%
Public Buildings	1%	2%	2%
Residential	58%	41%	31%
Roads	20%	20%	20%
Total	100%	100%	100%

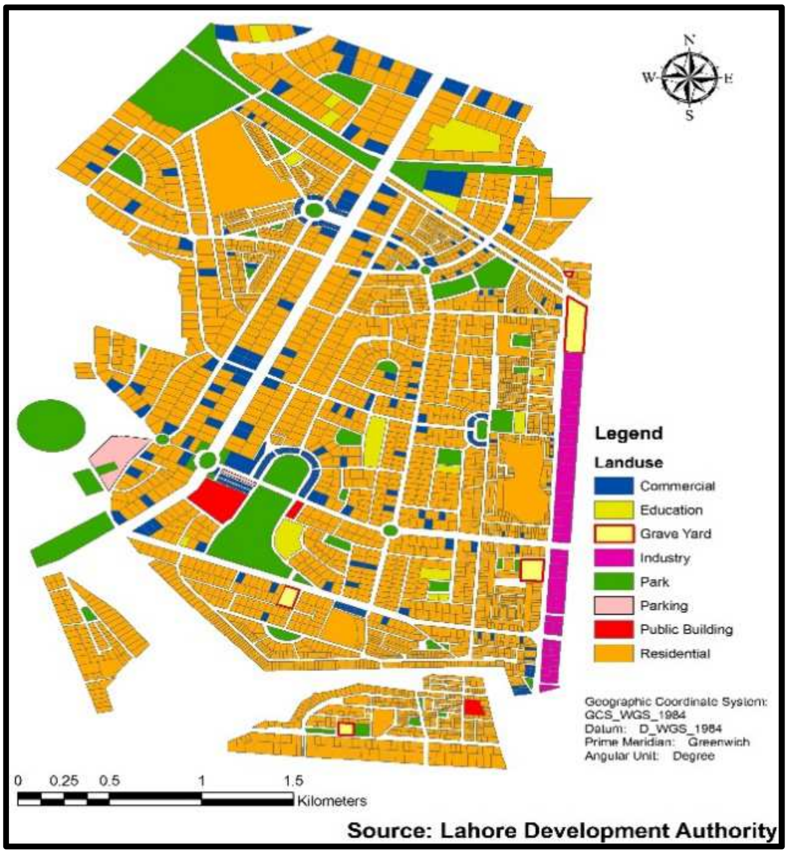


Figure 3. Land use Map of Gulberg Scheme 2002

In 2011, the residential area was decreased to 41%, whereas the commercial area increased to 21%. Some (2%) of the open spaces were converted into parking lots and plaza (Figure 4).

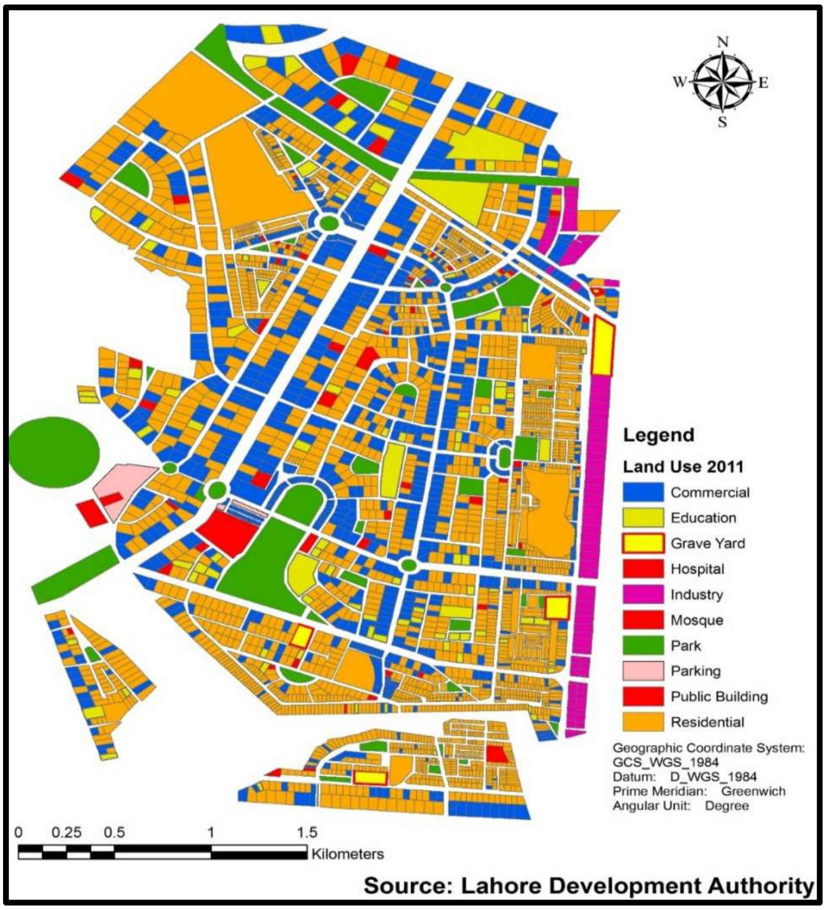


Figure 4. Land use Map of Gulberg Scheme 2011

In 2013, the LDA reclassified Gulberg Scheme under the Sub-Rule-38 of its Land Use (Classification, Re-Classification and Redevelopment) Rules, 2009 [14]. Resultantly, 10 major roads/sections of roads falling in the Scheme were reclassified as commercial (see Box 1). Figure 5 shows the location of these roads and sections of roads in blue colour. If this reclassification is implemented, this will cause six times increase in the commercial area from 5% to 30%, whilst the residential area will decrease to 31% from 58% (as compared to that existing in 2002).

- Tariq Road Link M. M Alam Road Gulberg from Property No. 75 & 86 Block C-II Gulberg-III
- Link M. M Alam Road T-Block From property No. 9-T Gulberg-II 14-T Gulberg-II
- Main Boulevard Gulberg from Jail Road Gulberg Ferozepur Road.
- Hali Road Gulberg (Segment) Property No.136 & 64 Block E-I Gulberg- III to 114 & 73 E-I Gulberg-III.
- Stadium Road Gulberg-III (Shahrah-e-Noor Jehan)
- Road behind Liberty Market Gulberg (outer circle) 19/B Block D-I Gulberg-III to 89-C-II Gulberg-III.
- Firdous Market Road from Property No. 1 Block J Gulberg-III to Property No. 37 Block J Gulberg-III.
- College Road Gulberg (Segment-I) From Main Boulevard Gulberg Property No. 9-K & 10-K Gulberg-II to Mini Market Round About (Property No. 15-L Gulberg-II & Mini Market area).
- College Road Gulberg (Segment-II) From Mini Market Round About Property No. 16-L & 167-P Gulberg-II to Gurumanget road crossing Property No. 1-Q , 32-Q & 290-L Gulberg-II.
- Link Main Market (Auriga side) Property No. 11-F & 37-G Gulberg-II to Property No. 12 Block G & 44/D Block G Gulberg-II.
- Link Main Market Gulberg (Shezan side) 12-F Gulberg-II to 42-F Gulberg-II.
- Park Road (Ali Zaib Avenue) Gulberg. From Jinnah Bridge (Property No. 14 J and 25 B-III Gulberg III to Graveyard Intersection (Property No. 21-G Gulberg-III

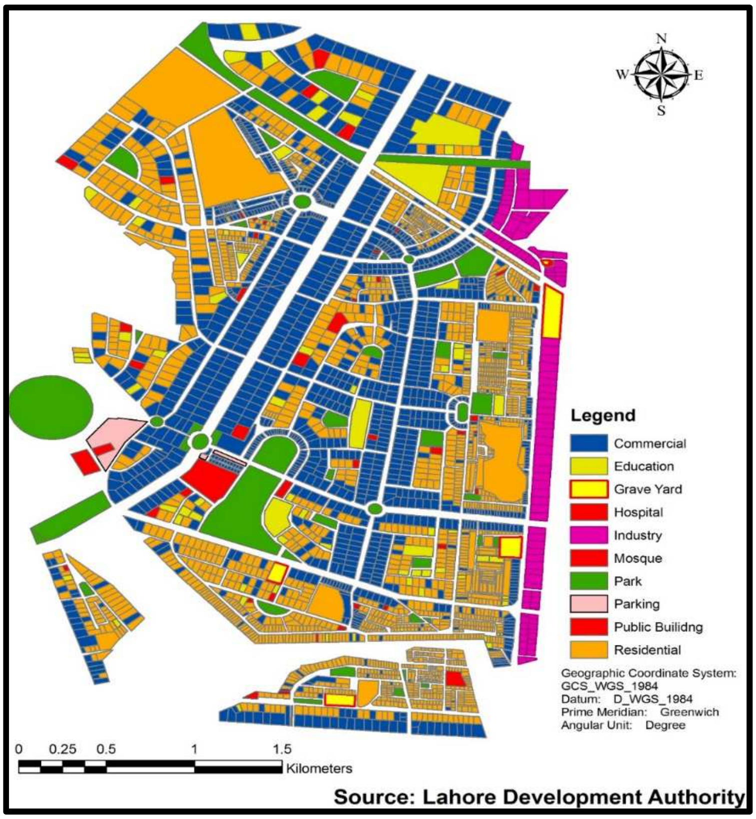


Figure 5. Reclassification Map of Gulberg Scheme 2013

4.2 Land surface temperature

The maximum LST of various land uses in the years 2002 and 2011 is shown in Table 2. It shows that the LST of industrial land use was maximum (38.55^{0}C) in 2002 and slightly increased by the year 2011. The LST of roads, however, increased significantly (from 34.22^{0}C to 41.39^{0}C) during these years due to change of residential use to commercial. The temperature of graveyards, despite having sufficient greenery, got higher (38.95^{0}C) due to their location near the industrial area. The calculated value of LST also presents an interesting situation, that there is no significant increase in the temperature of commercial land use as compared to that of the other land uses. The LST of parks/open spaces and parking areas as well as other uses also increased up to 5^{0}C. The commercial land use has increased by 16 percent over the years from 2002 to 2011. This is because, the public uses are situated near main roads and the commercial land uses have penetrated in to residential streets.

Table 2. Maximum LST of various land uses in 2002 and 2011

Land Use	**Land Use 2002 (%)**	**Land Use 2011 (%)**	**Land Use Difference (%)**	**LSTMax 2002 (^{0}C)**	**LSTMax 2011 (^{0}C)**	**Difference (^{0}C)**	**Per Year Temperature Change (^{0}C)**
Commercial	5	21	16	33.05	37.7	4.65	0.52
Education	2	5	3	33.09	37.52	4.43	0.49
Graveyards	1	1	0	33.32	38.95	5.62	0.62
Industries	2	3	1	34.39	38.55	4.16	0.46
Parks/ Open spaces	10	8	-2	33.19	38.45	5.25	0.58
Parking	1	1	0	33.31	38.00	4.68	0.52
Public Buildings	1	2	1	32.42	37.55	5.13	0.57
Residential	58	41	-17	33.19	38.37	5.19	0.58
Roads	20	20	0	34.22	41.39	7.17	0.80

Source: Authors, 2014

The distribution pattern of maximum LST in various parts of the Gulberg Scheme in 2002 and in 2011 are shown in Figure 6 and 7 respectively. The increased volume of traffic due to commercialization possibly caused this rise in temperature. If this trend of change in land use from residential to commercial continues in accordance with the proposed reclassification scheme, the temperature of Gulberg will further increase during the years to come. It is therefore necessary to review the land use reclassification of Gulberg in light of possible climate change impacts. While reviewing the reclassification scheme, it would be pertinent to consider the expected increase in traffic due to further commercialization. While planning new housing schemes in future, the green spaces should be evenly distributed in overall area instead of focusing on only some area as these spaces are major absorber of temperature and can decrease the temperature of neighbouring land uses as well.

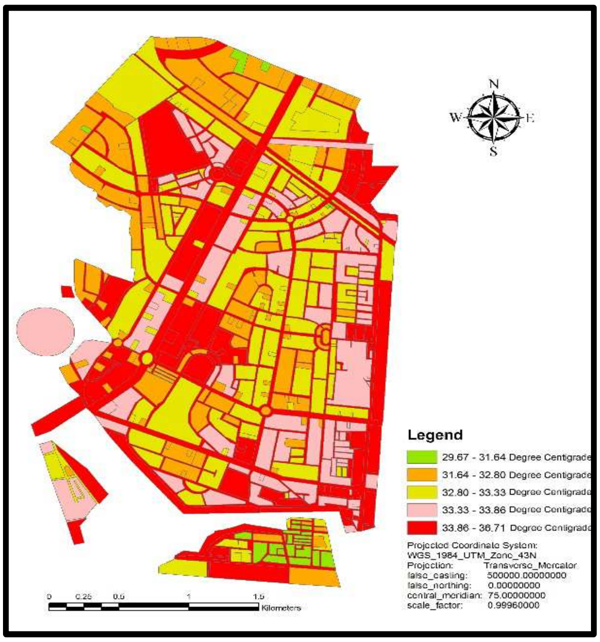


Figure 6. Distribution Pattern of Maximum LST of Gulberg Scheme in 2002
Source: Authors, 2014

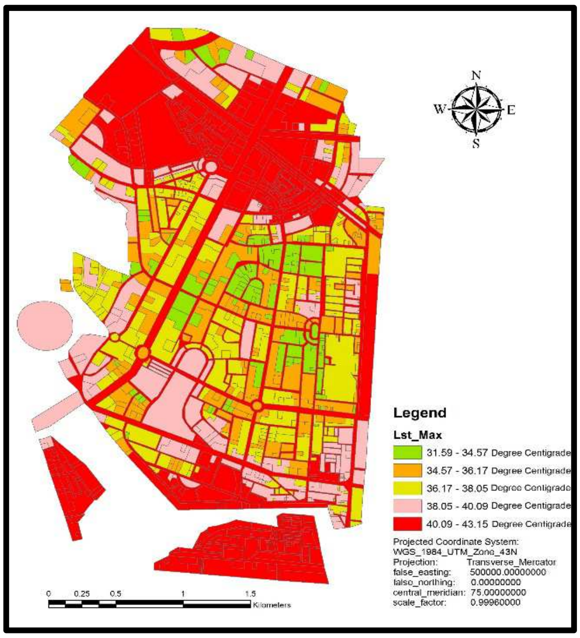


Figure 7. Distribution Pattern of Maximum LST of Gulberg Scheme in 2011
Source: Authors, 2014

5. Conclusion

Major cities of the world are experiencing climate related changes resulting from modern development. In this context, several measures including green roofing, solar cars and bus rapid transit systems have been taken to minimize the possible impacts. In the case of Gulberg Scheme in Lahore, this research has demonstrated that there was no significant variations in LST of different land uses within the Scheme in 2002. But in 2011, the commercial development not only increased but also penetrated into the residential streets. This conversion not only attracted more traffic and resultantly affected the temperature of commercial land use but also took the other uses into this effect causing significant rise in their temperature, particularly that of roads/streets. Green spaces decreased in these years thus putting extra pressure on the existing ones to accommodate this change which ultimately raised their temperature too. If the land use reclassification done by LDA is implemented, this would cause further increase in LST. Thus, there is a need to re-consider the reclassification and take certain measures to minimize traffic load and resultant emissions. Maximizing green spaces perhaps by encouraging green roofing may also contribute towards minimizing the impacts of rise in temperature.

Acknowledgements

The authors are thankful to the concerned officials of LDA for providing invaluable maps and data. This article is based on a research project undertaken at the Department of City & Regional Planning, UET, Lahore. A conducive research environment provided by the department is also acknowledged.

References

[1] R. Garnaut, The Garnaut Climate Change Review-Final Report (Melbourne: Cambridge University Press, 2008), 23, 363.

[2] IPCC, Climate Change 2007: Synthesis Report (Geneva: IPCC, 2008), 64-67.

[3] UN, United Nations Framework Convention on Climate Change (Washington: United Nations, 1992), 7.

[4] A.J. McMichael, Climate Change and Human Health-Risks and Responses (Geneva: World Health Organization, 2003), 18-40.

[5] J. Rockström, "A safe operating space for humanity", Nature, 461 (7276) (2009), 472-475.

[6] E.L.F. Schipper, "Climate Change Adaptation and Development: Exploring the Linkages" (Working Paper 107, Tyndall Centre for Climate Change Research, Norwich UK, 2007).

[7] N. Stern, Stern Review Report on the Economics of Climate Change (London: HM Treasury, 2006), 573.

[8] PC/GoP, Task Force on Climate Change-Final Report (Islamabad: Planning Commission, Government of Pakistan, 2010), 4.

[9] GoP. National Climate Change Policy (Islamabad: Ministry of Climate Change, Government of Pakistan, 2012), 1-38.

[10] R. Hameed, "Improving the Energy Efficiency of Existing Commercial Buildings in Lahore Through Retrofitting Technique", Journal of Faculty of Engineering & Technology, 21 (2) (2014), 95-104.

[11] USGS. Landsat 7 Science Data User's Handbook, (2001). Available at: http://landsathandbook.gsfc.nasa.gov/

[12] N.D. Yildiz, "Thermal Band Analysis of Different Land Uses in Urban Spaces and its Effects" (Paper presented at the Third International Conference on Counter measures to Urban Heat Island, Venice, 13-15 October 2014), 550.

[13] M. Mauer, "Composite Fillers and their Influence on Emissivity", Journal of Physics and Chemistry of Solids, 73 (12) (2012), 1550.

[14] LDA. "The Lahore Development Authority Land Use (Classification, Reclassification and Redevelopment) Rules 2009" (Lahore: Lahore Development Authority, 2009).