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# Loss of vegetative cover and increased land surface temperature: A case study of Islamabad, Pakistan

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A B S T R A C T

Loss of the vegetative cover becomes the paying way of accelerated carbon emissions. It leads to increase in Land Surface Temperature (LST) and resultant resulting in global warming. This study has deployed remote sensing and GIS to observe LST variations in Islamabad to study vegetative cover loss for the time span of 25 years (1992–2017). The study's findings confirmed 22% reduction in the vegetative cover from 1992 to 2000 with LST range 13–27 °C/year. It was followed by continuous reduction of the said cover up-to 27% between 2000 and 08, confirming 16–34 °C/year increase in LST. Likewise, from 2008 to 2017, alarmingly 51% vegetative cover loss contributing to 23–43 °C/year rise in LST in the study area. The results confirmed correlation between loss of vegetative cover and LST that is contributing into global warming. So, attempts to halt massive urbanization so as to reduce the polluting gateways and increasing carbon sinks efforts through afforestation and reforestation remains essential to safeguard the humanity from climatic hazards.



## 1. Introduction

The 21st century's dramatic changes in the climatic patterns became the biggest malice and severe threats to growth and development, yet alone human survival. Forests are the diverse environmental subjects, which have the capacity to adapt to the changes in the ecosystem and provide positive sustainable returns to the environment (Aljerf, 2017). But there is great threat to forest cover und the broader domain of vegetative cover on the land surface and the main source is humans. The reported adverse impacts erosion, drought and loss of biodiversity (Xie et al., 2017; Gao et al., 2017). Similarly, human-induced activities remain the main causes behind the loss of forest cover, e.g., removal of forests and/or reduction in the capacity of the forests to serve as carbon sinks (Zhang et al., 2015). The other and the most severe reason behind the loss of forest cover and there-upon massive carbon release is the rapid urbanization (Bhatt, 1990). Here, urbanization is amongst the critical factors affecting forest cover that is posing severe impacts on both regional and global environment (Lin et al., 2019).

Thus, urban settlements, amongst other major threats, are posing increasing challenge as land cover change is occurring from forested land, high coverage rate grassland etc. to bare land and massive physical infrastructure development. It therefore decreases the net decrease in the rate of grass and forest land as of growing human activities (Li et al., 2017). Thus, land use change as of conversion of forest land effects the terrestrial ecosystems and thereupon the carbon storage, thus leading to anthropogenic carbon emissions. The transfer of land to build high land infrastructures in urban settings is accounted for the large scale conversion of land and associated increased carbon emissions (Chuai et al., 2015). So, loss of forests that have the capacity to mitigate backlogged atmospheric carbon dioxide (Canadell and Raupach, 2008), are under threat. The loss to this vegetative cover on the land surface is hampering chiefly carbon sequestration by the forest and grass to attenuate global warming. This occurrence is leading to abrupt changes in the land surface temperature, further ending-up in severe disasters such as hurricanes, floods etc. and linked austere socio-economic losses. It is also established that this phenomenon contributes to regional and global climate change (Song and Zeng, 2017). The accelerate phase of climate change is by cause of forests' decay or tree's mortality that has sharply risen in response to increasing temperature and warming effect. In this debate, forest ecosystems are getting extremely vulnerable to climate change (Allen et al., 2010).

At the back of this disastrous situation lies wide spread

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landscape alterations that determine the changes in the earth's ecosystem as of wide disappearance of forested land (Haque and Basak, 2017). The die-off of vegetative cover (major junk: forest cover) is sunk of the carbon sinks and thereby release of absorbed carbon back into the environment (Bachelet et al., 2001). This release of carbon is significantly associated to rise in the LST. It leads to global warming. It all obstructs the steps to attain carbon budget as 590–1240 $GtCO_2$, thus already contributing in 2 °C rise in global mean temperature (compared with pre-industrial levels) (Rogelj et al., 2016). This marvel multiply itself when warming effect end-up in dying of microbes, found in the soil, releasing another stock of stored carbon into the open atmosphere. As a result of this feedback mechanism, the environmental crisis originates causing more warming effect (Schuur et al., 2015). The carbon emission due to changes in the land use is touching new heights. On in the year 2012, about 2.7 Gt $CO_2$-eq emissions in atmosphere which was 12.5% during 1990–2010 due to of anthropogenic change (FAO (Food and Agriculture Organization), 2012; Houghton et al., 2012).

The phenomenon of global warming is further responsible for variabilities within the precipitation events. It has been observed that for every 1 °C rise in temperature there is a 7% decrease in the water carrying capacity of air (Trenberth, 2011). The proceeding of rise in global mean temperature between the range 0.3–0.7 °C has already been confirmed by IPCC Assessment Report 5 (AR5). This range is not the result of changes within the solar irradiance or in the natural $N_2O$ or $CH_4$ levels, but the end effect of anthropogenic emissions of past, upon which the future climate of the earth will be dependent (IPCC, 2007), if the current level of vegetative cover loss and improper land usage is not curbed. In the way, the land-use intensification and drastic reduction in the vegetative cover are considered as the pervasive threats to natural environment and biodiversity, yet the rate of reduction of vegetative cover and is little known globally but it has been reported that vegetative cover and importantly the forest cover change is accelerated in the present times (Mangwale et al., 2017). Likewise, the global changes, linked to the massive rise in carbon emission and resultant atmospheric temperature rise have contributors at the micro-level (Heilman et al., 2014). This phenomenon is halting the progress towards attainment of Sustainable Development Goals (SDGs) (Aljerf and Choukaife, 2016).

Forest area of Pakistan remains approx. 1.9% of the total land area, which is decreasing at an annual rate of 42,000 ha (WB, 2017; Randhawa, 2017). This tremendous loss rate of the vegetative cover in Pakistan has been mainly concentrated in the big cities, like Karachi and Islamabad, where accelerated pace of land cover change was directly linked to urbanization. Alone, Karachi; on the Arabian Sea, is converted to hub of high rise buildings and massive urbanization due to increased population density that has declared the city amongst the most vulnerable cities that are prone to face the environmental challenges. The Land-use and housing issues have posed great threats to physical environmental quality (Qureshi, 2010). This urbanization remained across densification of urban core, i.e., high population density, especially in the newly developed sectors so resulting into building new physical environment in the open spaces. It was followed by urban sprawl, e.g., outward expansion often at the peri/urban fringe and forestland. Both without doubt adversely affected the green cover. Thus, urbanization factor here, like in other societies, found to be the single predominant cause with links to the eradication of urban green spaces (Mensah, 2014). The city that was once renowned for its green/vegetative cover has been converted into several urban strata in the past few decades (Aerts and Honnay, 2011; Shaheen et al., 2015).

It is linked to both population growth and ever increasing rural-urban migration. The loss of green spaces or ecosystem is Islamabad had not only hit the nature environment; natural parks, forests, shrubs etc. thereby damaging the recreational opportunities, but remained as the breeding source behind heat waves due to rise in temperature and poor air quality. This was reported as the main cause behind the land surface temperature rise in the capital city of Pakistan; Islamabad (Hassan et al., 2016). It is in-line with the global findings that intensive housing has much higher rate of solar radiation's absorption. It is because of the greater thermal capacity, also the conductivity, that leads to higher temperature in the urban areas than in the rural regions having higher percentage of vegetation cover (Zhou et al., 2005; Zhou, 2006). In this sense, Islamabad has also been on the brink of warming due to forest cover loss.

## 2. Study aim & research questions

This aim of this study was to fill the literature gap by studying loss of forest or vegetative cover[1] on the land surface and increased LST, over a period of twenty-five years (1992–2017). It was hypothesized that there exists a strong correlation between the decreased vegetative cover and increased LST in the five urbanized sectors of Islamabad namely; G-13, G-15, H-10, I-16, D-12.[2]

### 2.1. Research questions

- What was the rate of vegetation cover loss in the study area from 1992 to 2017?
- What was the extent of increased LST to vegetation cover loss from 1992 to 2017?

## 3. Materials and methods

### 3.1. Study area

Islamabad is the capital city of Pakistan that has an area of 906 square km./90,650 ha. It is located at 33.738045° N and 73.084488° E (Shaheen et al., 2015). The capital city of Islamabad is divided into eight different zones or sectors i.e., administrative sector, commercial sector, educational sector, industrial sector, diplomatic enclave, rural areas, green areas and residential sectors (Butt et al., 2015). The present study was conducted in the residential sectors of Islamabad, i.e., sector G-13, G-15, H-10, I-14 and D-12. In the past decades, these sectors were filled with forest or vegetation cover, which was hampered by massive urbanization (Fig. 1).

### 3.2. Tools & techniques

For data analysis to satisfy the study's research questions, Geographic Information System (GIS) and Remote Sensing were deployed for data processing and results generation. The deployment of GIS and Remote Sensing was behind the reason that these tools assist for an easy and meaningful capturing, storing, manipulating and analyzation of the data. Furthermore, these tools have the strength to manage and present all types of geographical data to extract meaningful outcomes to answer the research questions. The utilization of the said tools was behind the reason that it helps in quality results generation and is therefore widely used in these types of researches (Goodchild, 2009; Shaheen et al., 2015). The

[1] The term vegetative cover here covered only forests cover and grassland. Whereas, only the land with vegetation canopy density more than 10% on an area of (not less than) 1 ha of land was considered in this study.

[2] The abbreviations used for different sectors constitute D = Diplomatic Sector, G = General Sector, H=Higher Education Sector and I=Industrial Sector. Whereas, sectors are synonym of an area or a region.

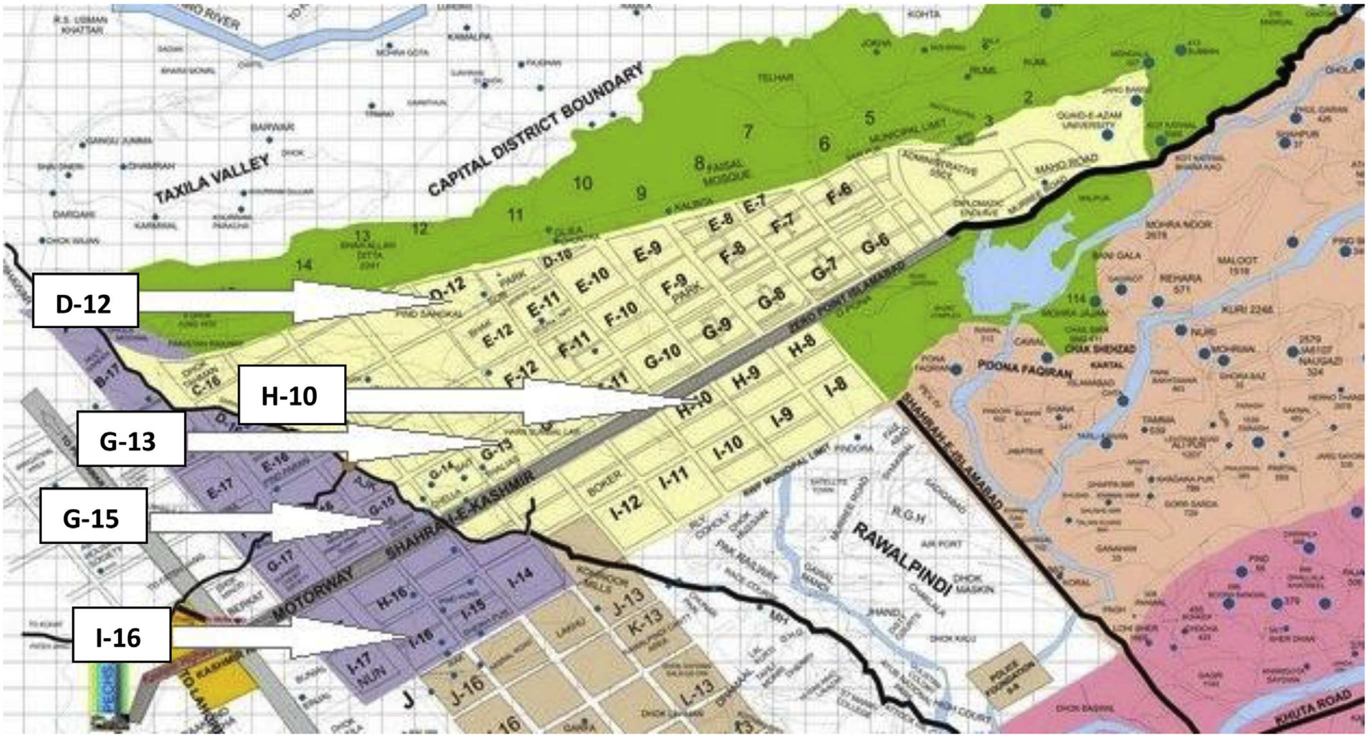


**Fig. 1.** Map depicting Studied Sectors of Islamabad (*Source:* www.google.com).

databases used in this study were assembled from different reliable sources (Table 1). For the spatiotemporal analysis through the application of Remote Sensing and GIS, four Landsat imageries were obtained from the United States Geological Survey (USGS), whereas the months of September as study point was selected for all the four study years (1992, 2000, 2008, 2017). It was done to avoid any discrepancies in LST determination and to get each imagery to observe LST variations (Table 2).

The clipped imageries (1992, 2000, 2008, 2017) of Islamabad were classified in ArcGIS in accordance with six IPCC Land Use classes. The conversion of one Land Use class into the other during all these respective study years was determined using Tabulation in ArcGIS. Thence, forestland change was calculated which was multiplied with the emission factor (for carbon emissions absorbed by tree species found in Islamabad). In this way, carbon emissions for Islamabad were calculated. Normalized Differential Vegetation Index (NDVI) was performed on all the Landsat images to identify the difference of the vegetation cover within the study area. The deployment of this index was due to its strength to show the density of vegetative cover on the land surface. NDVI has a range of values between +1 and −1. If the values are close to +1, it indicates dense vegetation, so classified as good and *vice-versa* (NASA, 2017a).

NDVI was performed using a model maker in Erdas Imagine 2013). Thus, greater the presence of vegetative cover in a region, the higher the value of NDVI (i.e., +1). So, satellite Landsat imagery was allowed to run through the model maker and NDVI images were obtained having values within ranges +1 to −1. Here, the NDVI value range from 0.72 to 0.92 represented 'very good' whereas NDVI value $\leq$ 0.1 represented 'no vegetation' or total barred land. The other NDVI value ranges remain: 0.42–0.72 as 'good', 0.2–0.42 as 'normal', 0.1–0.2 as poor and 0.10–0.12 as 'very poor' (Table 3). The research findings were compared to these standard NDVI values to determine how much vegetation loss has occurred in Islamabad over the period of 25 years i.e., 1992–2017.

The LST for the present study was determined using the LST model in Erdas Imagine 2013) (Fig. 2) by using single infrared channel method. The measurement of LST is actually the measurement of radiations emitted from the land surface. It is a difference of temperatures of bare soil with that of the soil covered with vegetation, measured through remote sensing technique with the aid of geostationary satellites (NASA, 2017a).

The change in LST over the years (1992–2017) was calculated using the thermal band. A thermal band is found within the Landsat imagery. In the case of Landsat 4–5 and 7, the thermal band is mostly band 6. However, in the case of Landsat 8, the thermal band is band 10. Following equations were used in the model maker:

$$L\lambda = (Lmax - Lmin) / (Qcal\ max - Qcal\ min) * (Qcal - Qcal\ min) + Lmin\lambda \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (1)$$

Where;

Raw quantized Voltage = Q, Spectral Radiance = Lλ, Spectral Radiance Scaled to Qcal min = Lminλ, Spectral Radiance Scaled to

**Table 1**
Type of data obtained for the study under consideration.

| Type of Data | Description | Source |
|---|---|---|
| Landsat Imageries | Remote Sensing and GIS Application | United States Geological Survey (USGS) |
| Shapefile Islamabad | 33.738045° N and 73.084488° E | National REDD + Office |
| Land Surface Temperature | Thermal Band | United States Geological Survey (USGS) |

**Table 2**
Dataset obtained from United States Geological Survey (USGS) for the present study.

| S. No | Imagery Type | Acquisition Year | Acquisition Date |
|---|---|---|---|
| 1. | Landsat 5 (Thematic Mapper (TM)) | 1992 | 20-09-1992 |
| 2. | Landsat 5 (Thematic Mapper (TM)) | 2000 | 26-09-2000 |
| 3. | Landsat 5 (Thematic Mapper (TM)) | 2008 | 16-09-2008 |
| 4. | Landsat 8 OLI (Operational Land Imager) | 2017 | 09-09-2017 |

**Table 3**
NDVI values along with the physical characteristics of vegetation.

| S. No | Vegetation (Physical Characteristics) | NDVI Values |
|---|---|---|
| 1. | Very Good | 0.72–0.92 |
| 2. | Good | 0.42–0.72 |
| 3. | Normal | 0.2–0.42 |
| 4. | Poor | 0.1–0.2 |
| 5. | Very Poor | −0.10–0.12 |
| 6. | No vegetation | ≤0.1 |

Qcal max = Lmaxλ, Quantized Calibrated Pixel Value (DN) = Qcal, Maximum Quantized Calibrated Pixel Value (DN = 255) = Qcal max, Minimum Quantized Calibrated Pixel Value (DN = 0) = Qcal min

Temperature = K2 / [Log (K1 / Radiance) + 1)] … … … … … … … … … … … … … … …..… … … … (2)

K1 and K2 are Land Surface Temperature coefficients. The values for K1 and K2 constants were obtained from the metadata file (MTL) found along with the Landsat imagery.

The values of K1 and K2 in case of Band 10 were: K1 = 607.76, K2 = 1260.56, The values of K1 and K2 in case of Band 6 were: K1 = 666.09, K2 = 1282.71. The values were added to the model maker along with the thermal band (Fig. 1). The model was then allowed to run and LST maps for the four study years have been obtained.

### 3.3. Primary and secondary data collection

For image classification, temporal images of the year 1992, 2000, 2008 and 2017 were classified by using Supervised Classification. Also, thirty signatures of six land use classes were taken on the Landsat images by using ArcGIS. The six IPCC land use classes are Forestland, Grassland, Settlements, Wetlands, Croplands, and Other lands (bare land, shadow region) (IPCC, 2007). The forestland change, in hectares, against all the land use classes was also

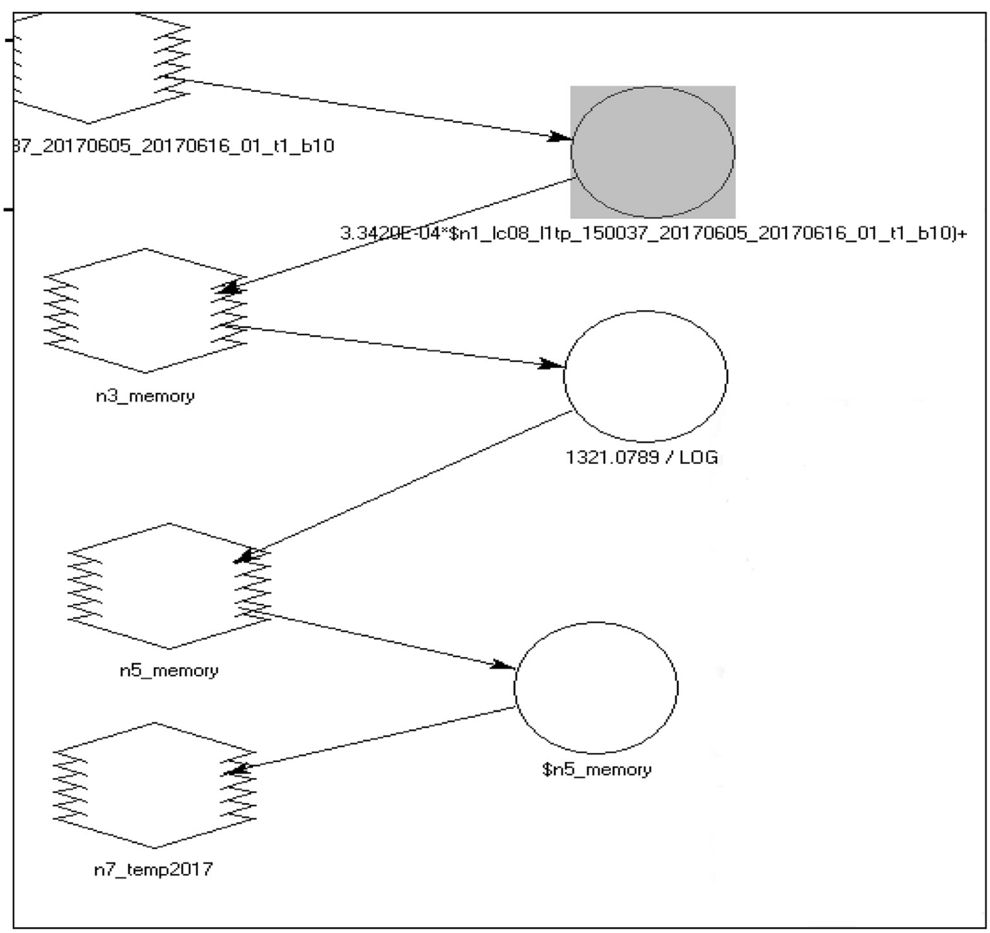


**Fig. 2.** LST determination using model maker.

analyzed over the specified years and after calculating the carbon emissions due to forestland change. Maximum Likelihood Classification was performed and classified images were obtained. Digitization was then done and study sectors were extracted from the Landsat imagery of Islamabad through masking, i.e., taking shapefiles using ArcGIS and considering google earth as the base map. Lastly, the study sectors were extracted-out by using the masking tool in the ArcGIS toolbox (Fig. 3).

## 4. Results and discussion

### 4.1. Vegetation coverage intensity – 1992, 2000, 2017

NDVI performed for September 1992 revealed that all the study sectors fall in 0.704,225 range. This high NDVI values confirmed the physical characteristics of vegetation in 1992 as 'very good', hence indicated the presence of dense vegetation cover in the study sectors for the study period (Fig. 4).[3] The results of vegetation coverage for September 2000 shown some initial variation in vegetation index. The NDVI value for September 2000 (for the concerned sectors) was 0.0485–0.2297. Hence, the physical characteristics of the vegetation cover was indicted as 'good to normal' in NDVI range (Fig. 5). However, the analysis confirmed NDVI values for September 2008 in the negative range, i.e., 0.12871287 to −0.375 (Fig. 6). This indicated that the vegetative cover was reduced 'form poor to very poor'. This trend was further intensified by very low NDVI value, equals to −0.0198,697, sanctioning 'no vegetation cover' for the last study period (September 2017) (Fig. 7). Conclusively, the study confirmed decreased vegetation intensity over the period of 25 years in the study sectors of Islamabad. And the major reason behind found was massive urbanization in the study areas over the past 25 years.

### 4.2. Land surface temperature (LST) – 1992, 2000, 2008

The results shown that the LST for September 1992 was of the range 13–27 °C/year (Fig. 8). Here, green zones were prominent. However, the LST started rising and it remained in the range of 16–34 °C/year for the period September 2000 (Fig. 9). The lower tempueration range increased by 3 °C/year and upper temperature increased by 7 °C/year. As a result of LST increase, the study areas which was mostly green region, started packed by yellow and red paches.[4] The range for LST for September 2008 indicated sharprise. The LST range was 19–43 °C/year (Fig. 10) that clearly demarcated another +3 °C/year in the lower and +9 °C/year in the upper limit, compared to eight years' earlier findings. Alarmingly, September 2008 results confirmed that green zones were almost removed, whereas red and yellow paches became more prominent. The alarmngly trends was followed by the results for September 2017; confirming LST range of 23–43 °C/year for September 2017 (Fig. 11). Here, although the upper limit remained the same, i.e., 43 °C/year, but the lower limit of LST rose by 4 °C/year. For the last study period, the removal of the green zones were furhter intensified, followed by increased red zones to the great extent.

Conclusively, the rise in LST in September 2000, compared to September 1992, was directly due to the loss of vegetation cover, as during this time the NDVI range remained 0.0485–0.2297 (not good or normal). It was followed by further increased of LST in September 2008, where the lower limit extended by +7 °C/year, again due to vegetation cover loss, as confirmed through decreased NDVI value i.e., 0.12871287 to −0.375 (i.e., poor to very poor). Lastly, another +4 °C/year addition was recorded September 2017 – directly linked to −0.0198,697 NDVI value, confirming conversion of all the green land to barren land. This infers that our study results are in accordance with the study hypothesis, i.e., decreased vegetative cover caused increase of LST in Islamabad, since 1992.

This loss of vegetative cover by September 2017 without doubt contributed into the global phenomenon that declared September 2017 as the warmest September amongst the past 137 years of record (NASA, 2017).

The potential sensitivity analysis for the two variables; carbon emission and rise in land surface temperature also shows positive relationship in the study area over the study time period (1992–2017 (Fig. 12). This relation can be directly connected to urbanization as of rise in population and thus the deforestation factors. The population of Islamabad was 0.8 million in 1998 that recently reached to 2 million. In order to settle the massive population, reduction in vegetation cover took place on a large scale over the years, thus 51% reduction in the vegetative cover due to settlements and croplands (as calculated using IPCC Land Use classes). This reduction in the vegetation cover means the ultimate removal of carbon sinks from the environment. This huge quantity of carbon entrapped the sunrays, thus raising the land temperature, thus leading to 13 °C rise i.e., 0.52 °C rise in land surface temperature per year from 1992 to 2017 in Islamabad and contributing to global warming, an ultimate science behind climate change.

## 5. Conclusion

It is confirmed from the study's findings that Islamabad is consistently experiencing loss of the vegetative cover, since 1992, particularly in the urbanized sectors. It is found that study area faced 22% reduction in the vegetative cover over the time period 1992–2000 that led to increase in LST between the range 13–27 °C/year. This trend is followed by another spell of continued reduction in said cover of up-to 27% between the years 2000–08, thus confirming another 16–34 °C/year increase in LST. More alarmingly, the results confirmed 51% reduction in the vegetative cover between the time period 2008–2017, contributing to 23–43 °C/year rise in LST in the study area. The results of the sensitivity analysis also confirmed that increase in carbon emissions, Land Surface Temperature for the respective study areas also increases.

Conclusively, the study confirmed for the global R&D that a strong correlation exists between loss of the vegetation cover, importantly the forest cover, and rise in LST. It is also established that rise in LST ultimately contributes to regional as well as global warming effect. It further paves the way for the creation of 'urban heat island' all around the world. The empirical evidences from Shanghai, India, USA and Amazonian also confirm that reduced forestlands and vegetated surfaces eventually turned-in warming effect at the global scale and interlinked rise LST, in the recent past (Li et al., 2016; Perugini et al., 2017). To blame is increased cross-continental urbanization patterns (Zhang et al., 2013; Mohan and Kandya, 2015; Lejeune et al., 2015). This alarming situation directs the negative effects on the local societies in the realm of massive urbanization, and majorly contributing to drastic global climatic changes. Thus, it can be established that ever increasing mass migration from 'rural to urban' areas, intercity growing urban patterns and linked loss of the vegetative cover is ending-up in sharp rise in LST. There is dire need to direct efforts through global R&D to halt the urbanization bomb through prescribing mitigation as well as long-term adaptive policies and plans to regulate the global warming. Also, simultaneously, speed-up afforestation and

[3] The red regions in Fig. 2 (also in other figures) showed water bodies, which always have a negative NDVI value.

[4] Here, yellow patch represents up-to 50% decreased thickness of the vegetation cover, whereas red patch confirms totally exposed earth's top surface having no vegetation/green cover.

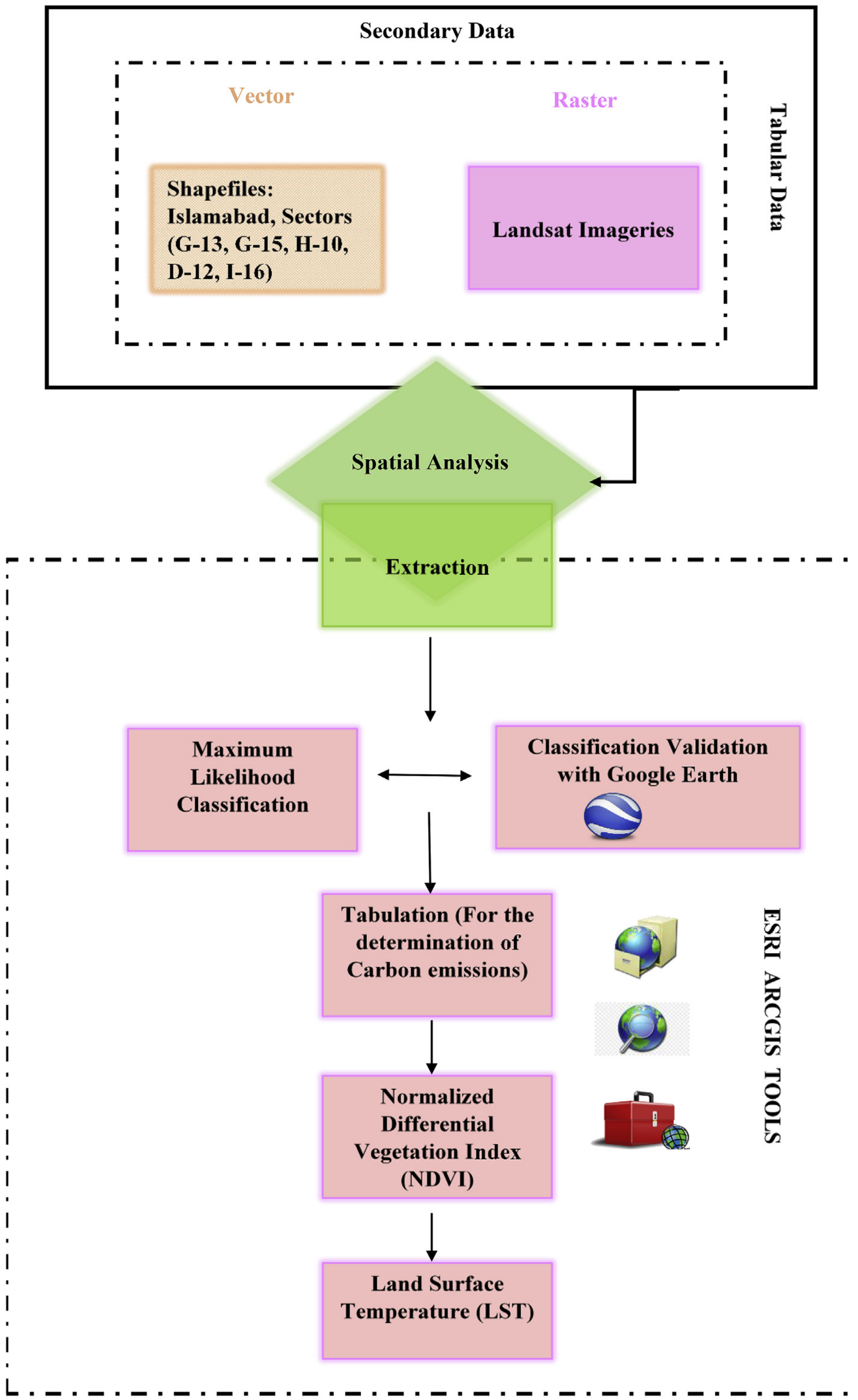


**Fig. 3.** Data collection process.

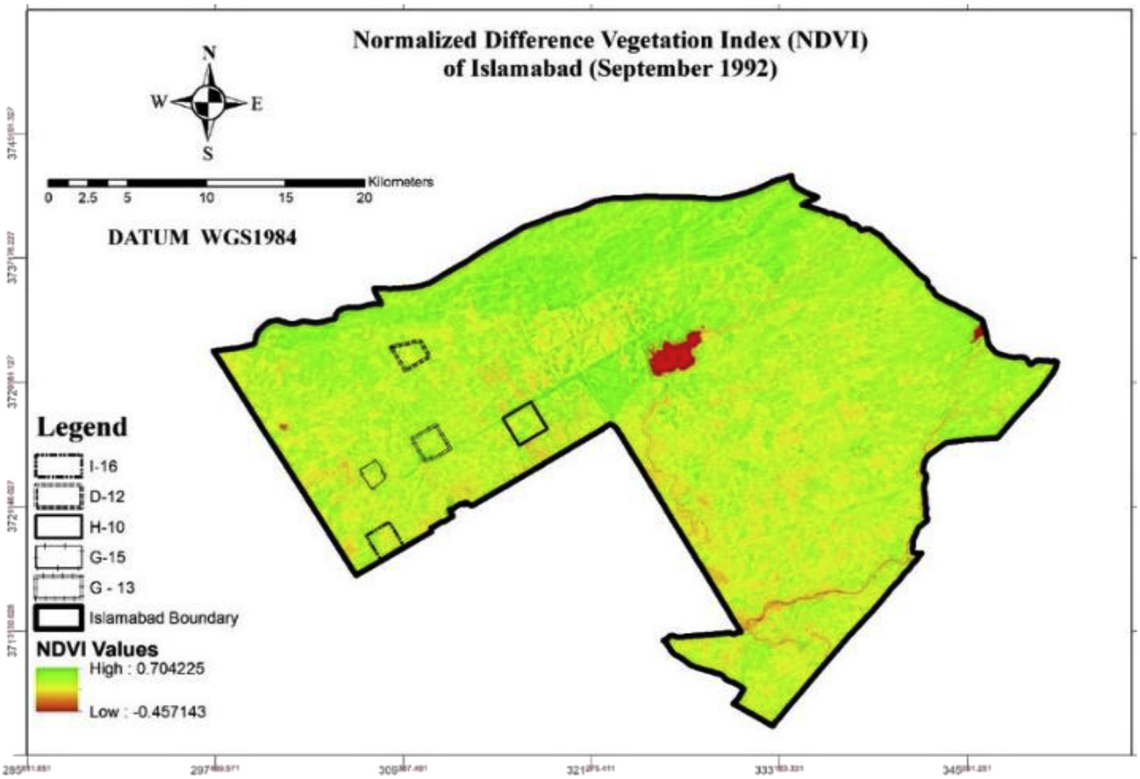


**Fig. 4.** NDVI map of Islamabad (September 1992).

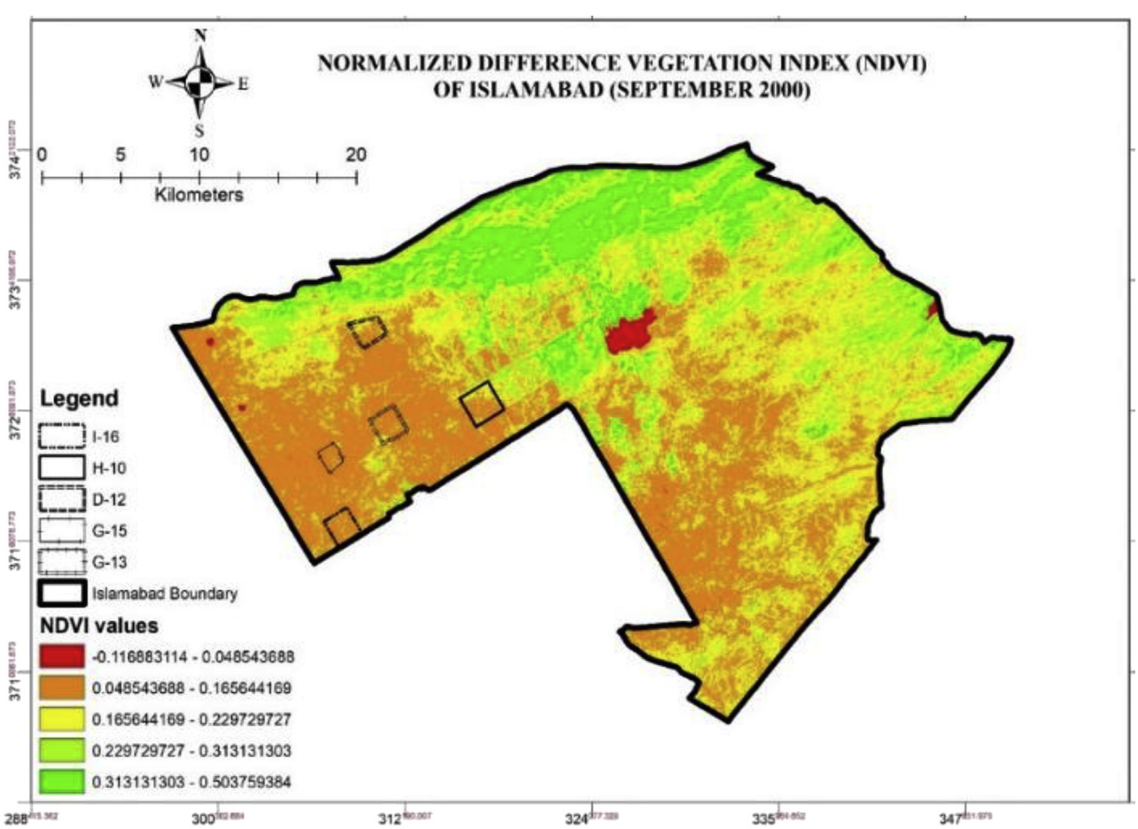


**Fig. 5.** NDVI map of Islamabad (September 2000).

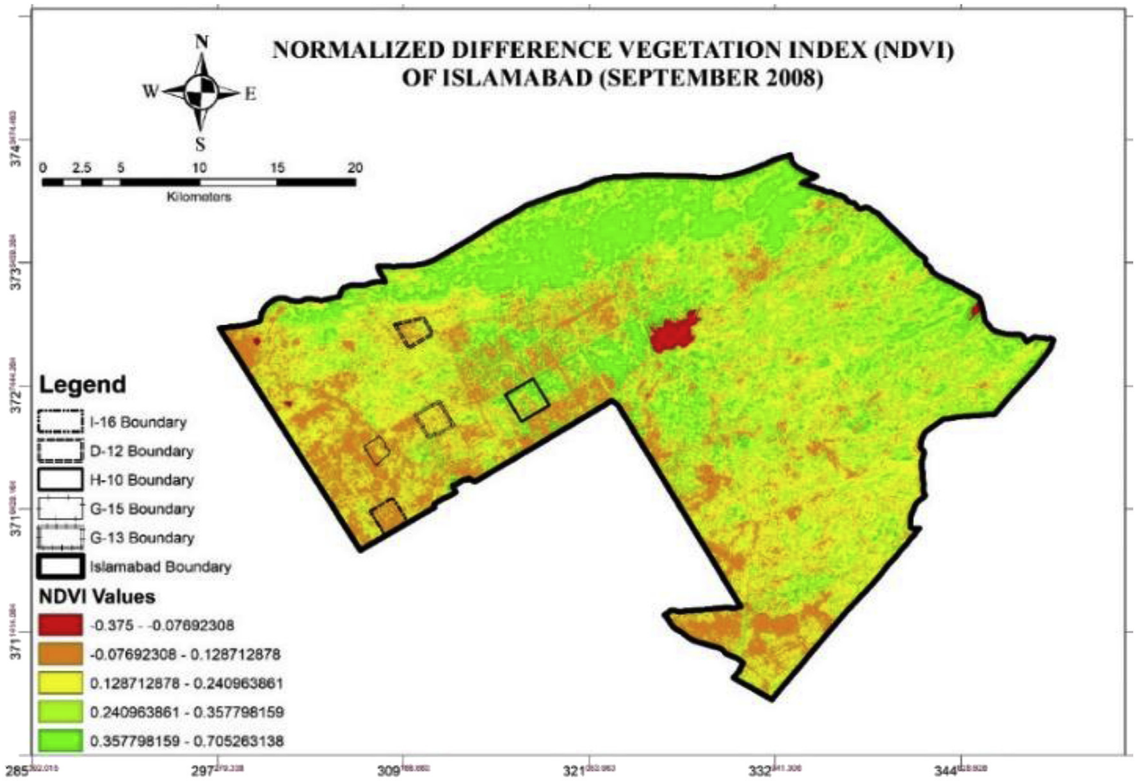


**Fig. 6.** NDVI map of Islamabad (September 2008).

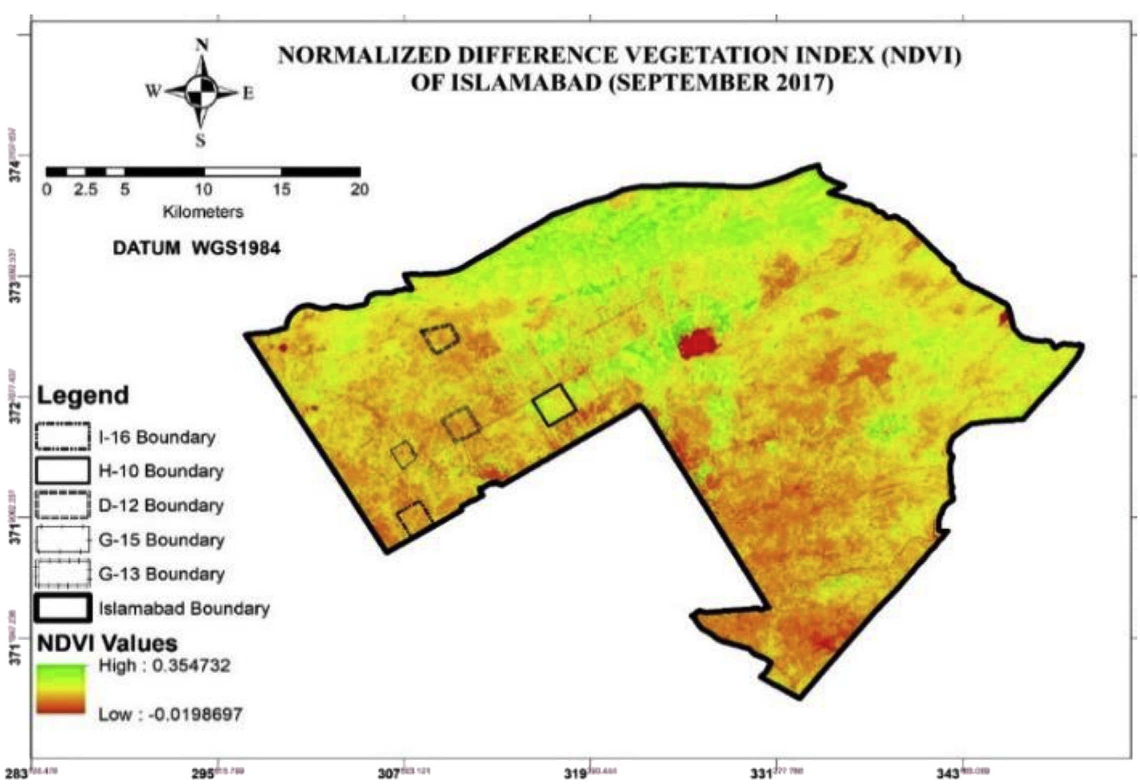


**Fig. 7.** NDVI map of Islamabad (September 2017).

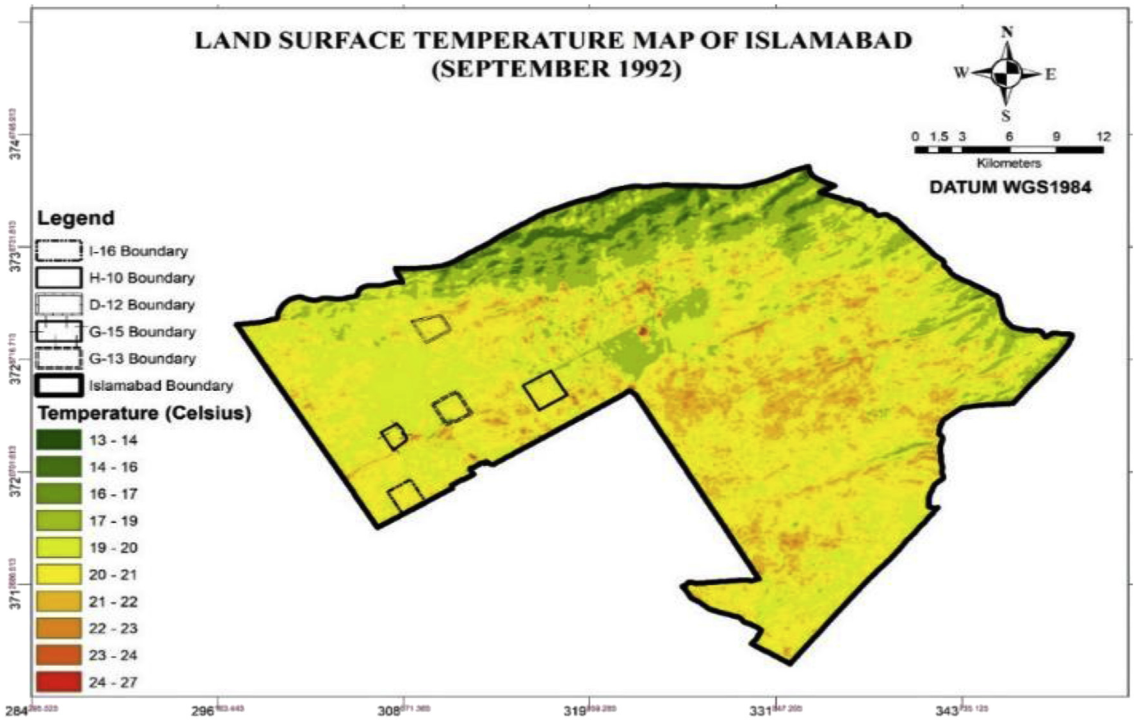


Fig. 8. LST map of Islamabad (September 1992).

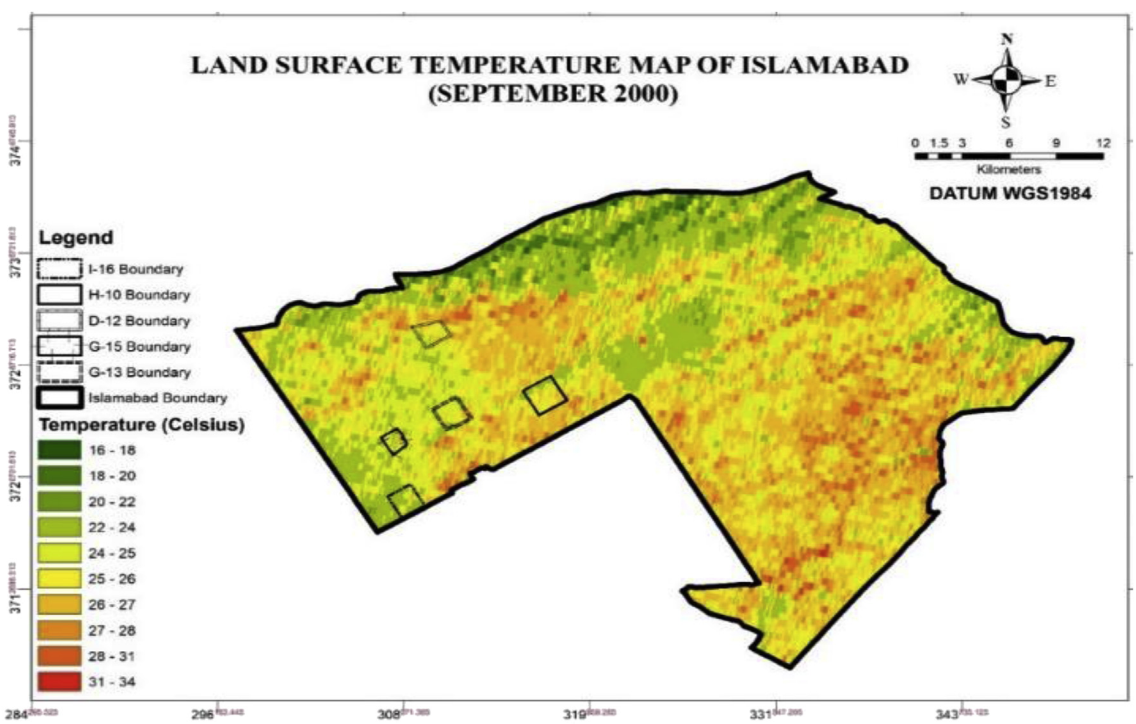


Fig. 9. LST map of Islamabad (September 2000).

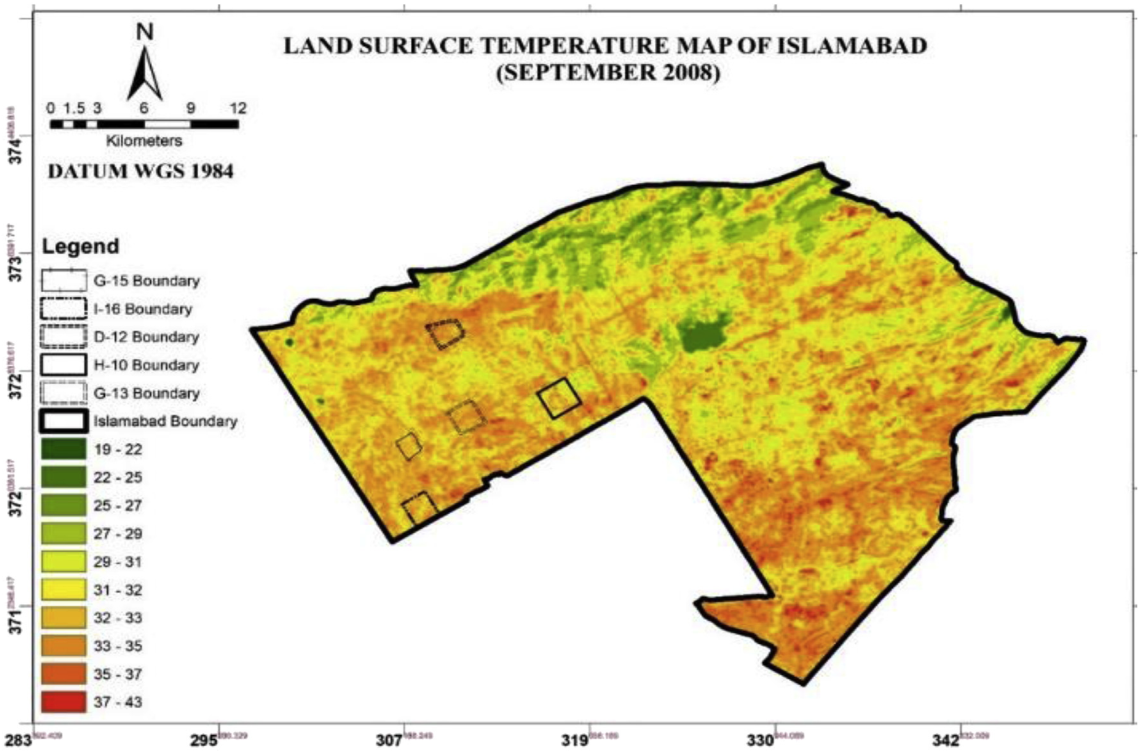


**Fig. 10.** LST map of Islamabad (September 2008).

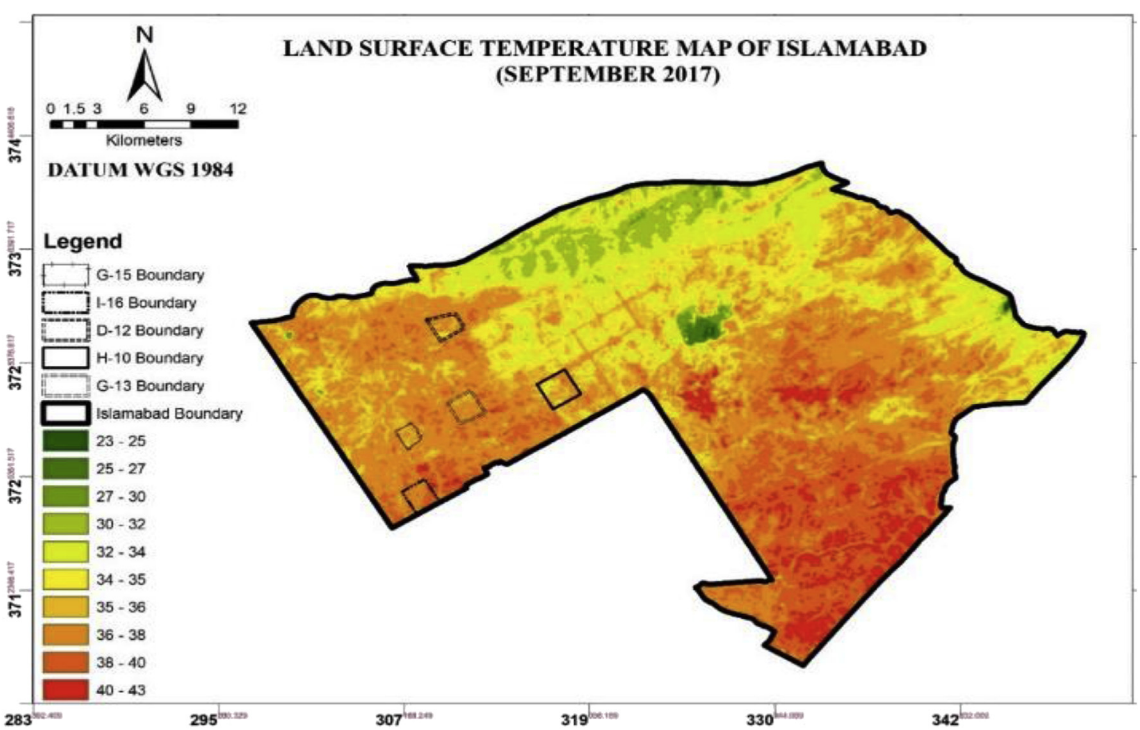


**Fig. 11.** LST map of Islamabad (September 2017).

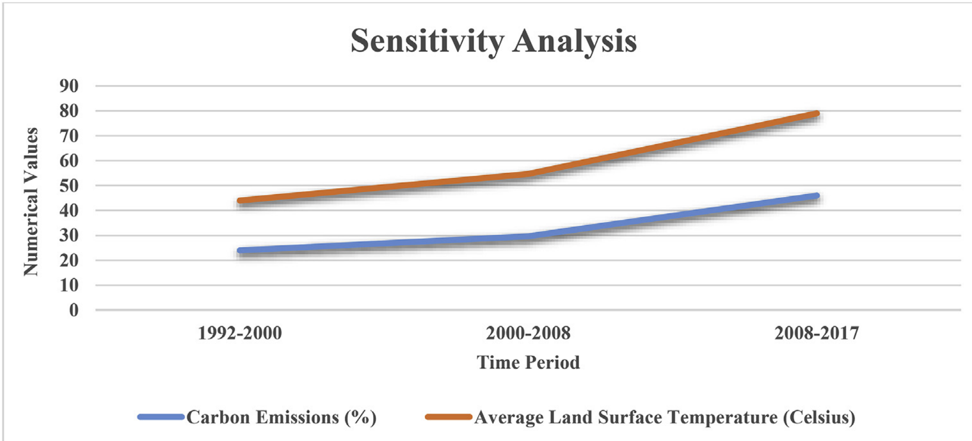


**Fig. 12.** Sensitivity analysis.

reforestation efforts that are assumed to reduce LST (Alkama and Cescatti, 2016). Such intentions aim to innovation and application of cleaner production and sustainability of the forest and grass land. Thus, curbing the global warming effect through halting massive physical infrastructure development and increasing carbon sinks remains *sine qua non* to safe the global societies futuristic climatic disasters.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.06.228.

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