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Research Article

Assessment of Karachi as an Urban Heat Island Threat through Remote Sensing and GIS Techniques

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Abstract: The present study aimed to assess the threat of transformation of Karachi into an Urban Heat Island, so, ambit was having calculated temperature, buildup areas, and normalized difference vegetation index through remote sensing and GIS techniques. The Landsat satellite data was used to differentiate the temperature in different years. These images were processed through Envi 4.7, Erdas Imagine, and ArcGIS 10.3.1. The results revealed that the maximum temperature was found up to 30.52, 35.25, 33.60, 46.73 °C; the buildup area was 23, 34, 26, 45 %; the NDVI results showed ranging from 0.224-1, 0.07-0.43, 0.201-1, 0.29-0.7 during this years. The average spatial land use temperature and buildup area increased by 1.03 and 1.9 times from 1990 to 2019. The maximum NDVI was observed during 2019, because of heavy rainfall as a result which supports promoting more greenery. With an increase in the buildup area, a significant change in the temperature of the territory was simultaneously observed. Therefore, this indicates a major task for urban developers extenuating the subsequent urban heat island occurrence. That is, for the first time it is scientifically substantiated and confirmed by the results that when creating a city development plan, it is extremely important to exclude the possibility of the urban heat island occurrence through preliminary studies. The practical value of the study lies in sound recommendations, one of which is the need for future urban development to emphasize urban plantings, including vertical forests to prevent UHI occurrence in the area of Karachi city.

Keywords: Build-up areas; land use/land cover; emissivity; satellite monitoring; temperature increase; NDVI

1. INTRODUCTION

Urbanization has significantly altered the existing scenario of land use/land cover (LU/LC), which may subsequently enhance the land surface temperature (LST) in many regions of the world [1-3]. The trend of urban development growth going to decrease the ordinary land, and vegetation covers and substitute it with new buildup landscapes like buildings, industrial hubs, streets, commercial infrastructures, etc. The urban heat island (UHI) concept is realized by various research, which confirms that it has a role in the climate change impact most likely in cities [4, 5]. It is one of the significant phenomena it requires

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more investigation to address the environmental degradation impact and climate change impact [6, 7]. The vegetated area is mostly roofed with a green cover. As it is observed that ripened trees have covered the canopy region near 50 m^2. Thus, about 50 m^2 canopy-covered area has high impending to decrease the intrusion of sun rays these green cover types absorb and expose energy in the form of long radiation waves [8, 9].

As the metropolis urban buildup observes warmer than countryside areas near about 5 to 10 degrees centigrade in surroundings [10]. The average difference in daylight temperature between urban and countryside areas was 5 to 15 centigrade as compared to night time 5 to 10 centigrade at night time considering the daytime differences in temperature [11]. Due to this UHI phenomenon is considered a model for climate change impact research. Moreover, the climate alters more due to UHI's impact on an urban buildup in the last decades of the century. Generally, UHI concentration varies hourly and season vise and it is influenced by the local topography, city size, city population density, geometry, cloud cover incoming solar radiations, development of commercial and industrial, land utilization, and land concealment (LU/LC) physiognomies and countryside regions other factors are airstream swiftness and vegetation profusion [12, 13]. The plants and exposed areas naturally control the land to a maximum rural extent. However, exposed land characteristically controls the landscape in most urban areas [14]. Throughout daylight time the buildup area in an urban hub fascinates and stocks two-fold quantity of heat than its countryside [15], buildup structural materials such as stepping-stone and steel consume complex temperature dimensions in an urban environment as compared to rural materials like dry soil and sand. All the materials, including construction materials such as plaster, wood, and glass obey the same laws of nature concerning heat transformation. In current ages, the influence of climate on gender fitness has observed a problem of an enhanced consequence, particularly since the latent influences of global heating and an augmented. UHI consequence because of urbanization [16]. In current years, the influence of weather on living beings has become a matter of enhanced consequence, particularly considering the possible influences of universal heating and an enhanced UHI influence, because of urbanization [17].

The UHI has developed one of the prime problems associated with the urban population and the automation of human civilization, as the augmented hotness related to the UHI inclines to worsen the pressures on people and might cause health hazards due to thermal stress [18]. The most common impacts during nighttime are breathing problems, overall uneasiness, temperature pains, and fatigue, a temperature-associated morality overall increase in human health problems [19]. In Pakistan, Karachi is densely populated and its urbanization is increasing rapidly. The urban heat island effect phenomenon will be bulging in Karachi. According to Pakistan statistics, it is the extremely rising city in Pakistan. Karachi is the most vulnerable to this urban heat island effect. There is a rapid rise of mass migration concerning vegetation loss and an increase in buildup area. UHI effects perspective can be understood by using RS & GIS spatial analysis methods and using the Landsat 5 and Landsat 8 images. Anthropogenic activities play a vital role to boost Urban Heat Island (UHI) and resulting cause to decrease in the vegetation cover and increases land surface temperature (LST) during the last 29 years in the regions of Karachi. Furthermore, Karachi is a megacity of Sindh province, which is the location in the southern part of Sindh, and due to the huge and multi-culture population, it was chosen in this investigation to assess the difference in surface heat, built-up areas, and greenery. The temperature of urban heat islands might be affected by different anthropogenic activities including manufacturing, transportation, economic and domestic activities. It was hypothesized that an increase in the built-up area of Karachi has been increasing the land surface temperature in different years. The aim of the present study was to assess the threat of transformation of Karachi into an urban heat island (UHI), for this, ambit we have calculated temperature, buildup areas, and normalized difference vegetation index (NDVI) in Karachi during the years 1990, 2000, 2010, and 2019 via remote sensing and GIS techniques.

2. MATERIALS AND METHODS

Urban heat Island effects can be estimated with environmental and meteorological properties viz., air temperature, humidity, and greenhouse gas emission. The map site of the study area is indicated in (Figure 1). The source of data was the USGS online website, and we downloaded the following satellite imaginaries data sets. 1990 LANDSAT 5; 2000 LANDSAT 5; 2010 LANDSAT 5 and 2019 LANDSAT 8 and processed the imaginary data sets through various important software such as Arc GIS 10.3.1, ERDAS Imagine, and ENVI 4.7. In the initial process, Landsat 5 and 8 satellite imagery requires preprocessing such as layer stacking to show the natural color of the imagery and geo-referencing according to our region.

In the first step Satellite image of Landsat 5 and 8 of two slots of time from 1990, 2000, 2010, and 2019 are geo-referenced using Envi 4.7 in the UTM/WGS84/42N coordinate system. In the second step, all the images of the following years (1990, 2000, 2010, and 2019) are stacked using the Envi 4.7 software layer Stack tool. While in the third step, the satellite image was subset using the subset tool of the Arc GIS10.3.1 software. In the fourth step, we will calculate the Normalized Difference vegetation index of subset images by using Envi 4.7. It calculates the wholesome vegetation cover of the area. It uses the ratio between the (NIR) near-infrared (Band 4) besides the red band (Band

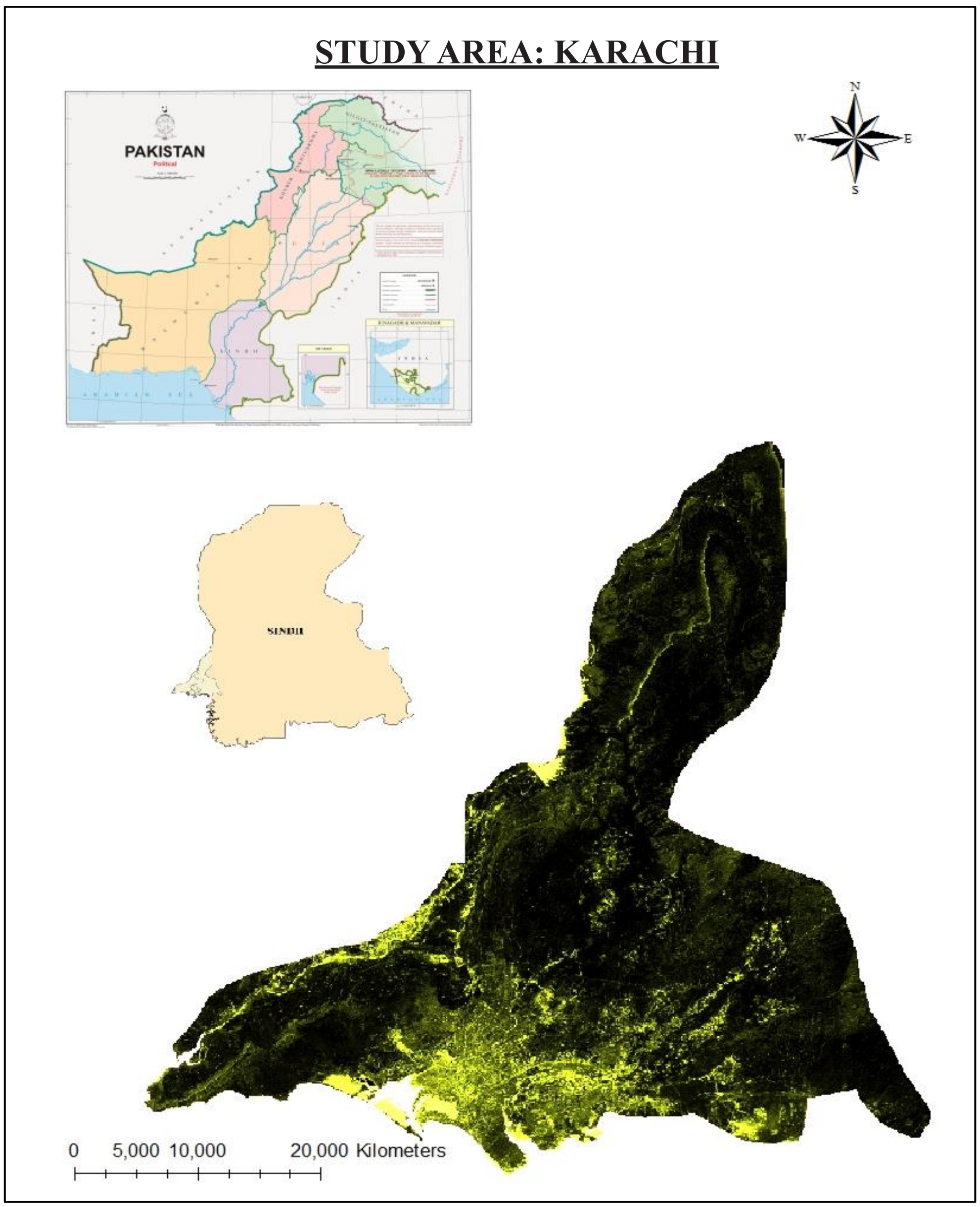

Fig. 1. Map of the study area

3). Both these bands contain information on the vegetation index. In the final step, radiance values are calculated using the Erdas imagine 10.2 DN value tool, further the DN value for transformed into the inverse of the Planck which gives out the temperature value. Additionally, the radiance value converted into the Kelvin represents the precise spatial distribution of temperature. The flow diagram of the study area is indicated in (Figure 2).

2.1. Extraction of Satellite Imaginary Data

In order to obtain the LST, LULC, and NDVI of the study area Landsat ETM 5 and 8 Images are transferred from the United States Geological Survey website of the years 1990, 2000, 2010, and 2019.

2.2. Pre-processing of Satellite Images

All Landsat 5 and 8 images were downloaded under a criteria set of 0 to 10 % cloud cover. No atmospheric correction was employed on these images. The USGS has already reprocessed for geometric distortions and radiometric correction. All the images are geometrically modified and geo-referenced through the USGS under Universal Transverse Mercator (UTM) zone 42 N to organize the system and the WGS1984 datum.

2.3. Pre-processing for Land Use Classification

The shape file of Karachi city was downloaded from open map tiles that depict the Karachi city area. The vector file is already rectified under the WGS 1984 datum, UTM zone 42. The shape file was used to extract the studied area from the satellite image by using the spatial analyst tool extracted by mask (Figure 2).

In a second step, the extracted image was processed for the supervised classification method by using the maximum likelihood technique in Arc GIS10.3.1. The signature file was generated with a spatial analyst that is utilized for the further image processing step (Table 1). The method for a composite band for land use classification is indicated in (Figure 3).

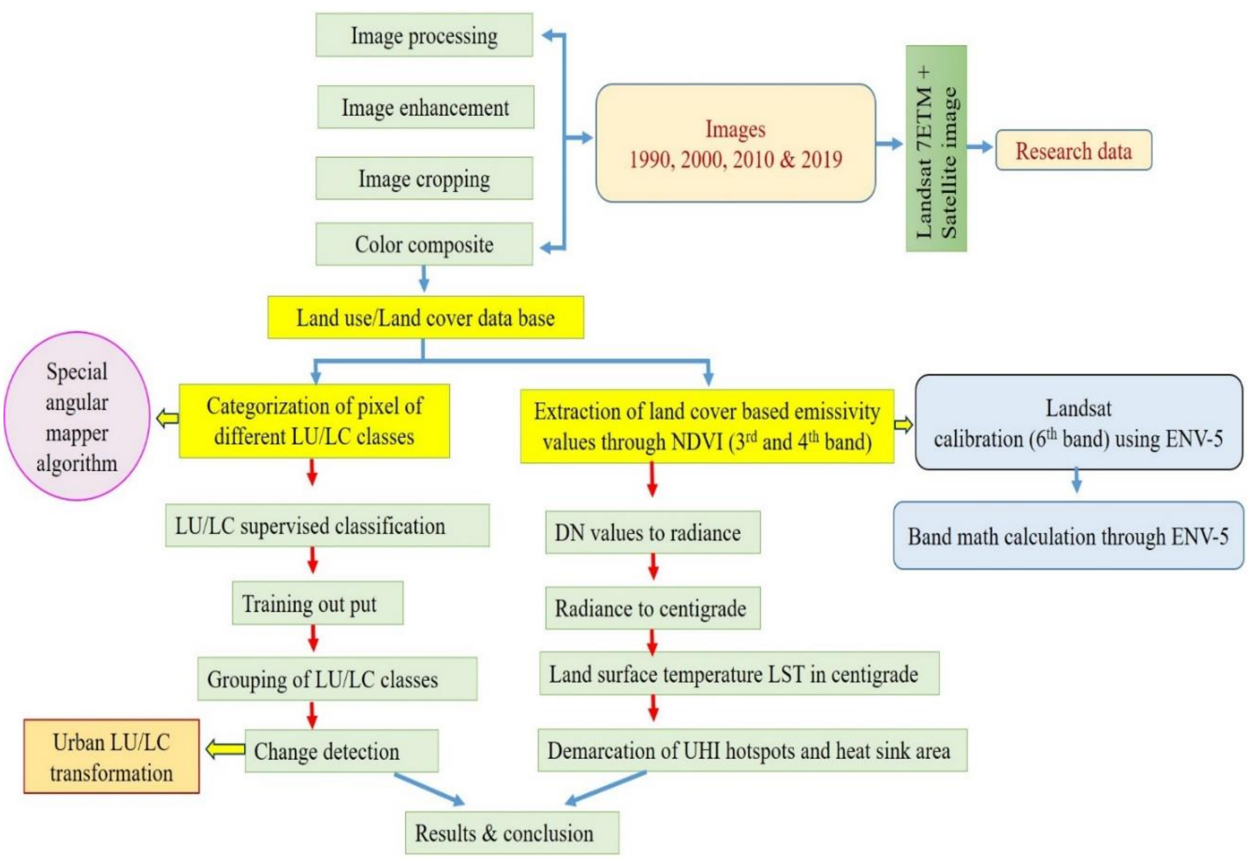

Fig. 2. Research methodology

Table 1. Shows the distribution of classes according to visual-spatial analysis

The classes color	Representation of color as
Yellow	Open surface or Barren ground.
Green	Vegetation Sparse or dense vegetation and Parks.
Blue	Water bodies ditch ponds and stagnant water, river Dam water.
Dark Yellow	Build up areas, buildings, roads houses, and other concrete structures.

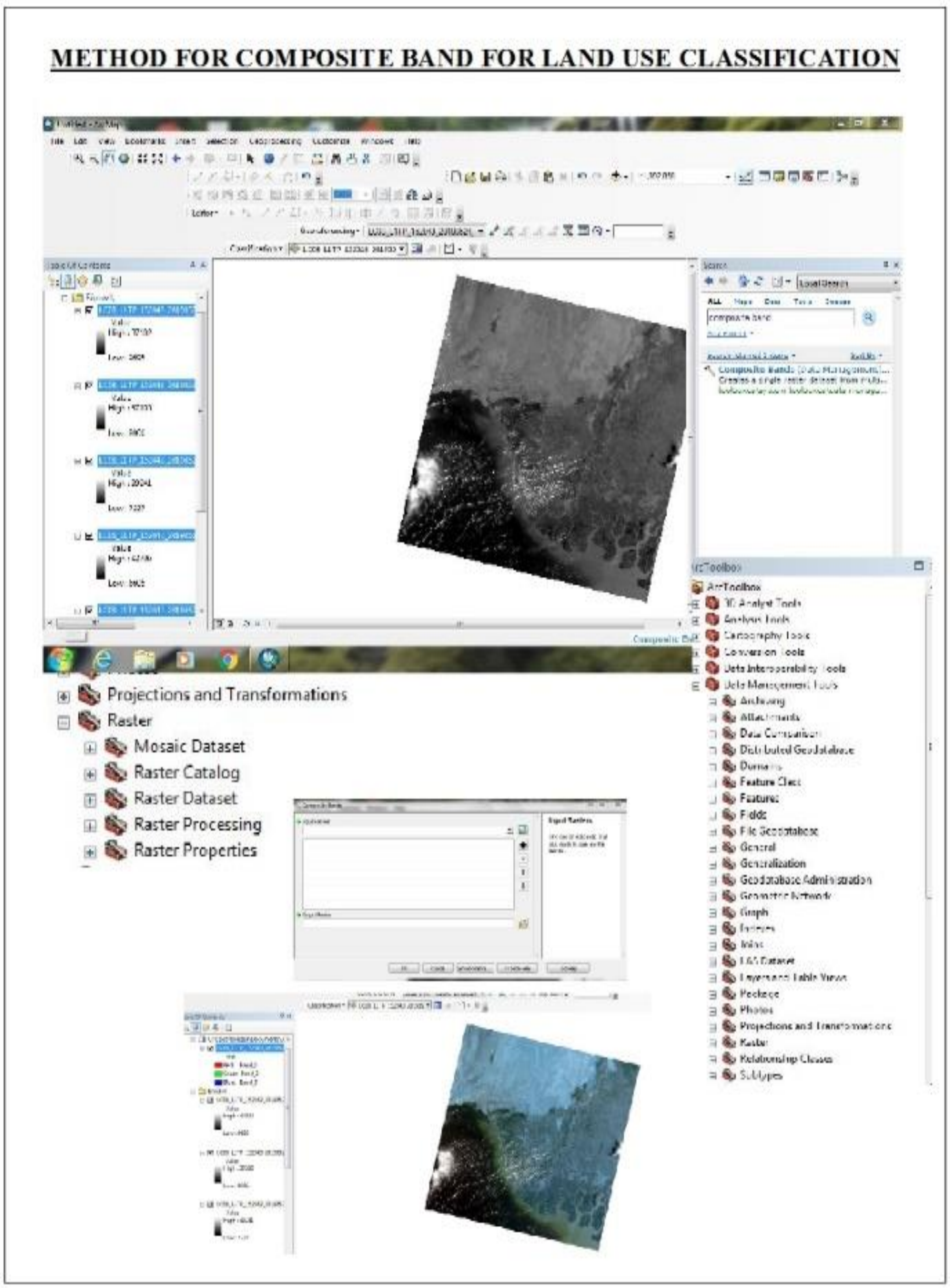

Fig. 3. Method for the composite band regarding land use classification

2.4. Data processing for land surface temperature, derivation of LST from the satellite image

The thermal band (10.4-12.5 µm) of the May Landsat 5ETM+ sensor with 30 m resolution was used to extract the LSTs over the selected area of Karachi (1990, 2000, 2010, and 2019).

2.5. DN means digital number converted into SR (Spectral Radiance)

By using Equation (1), the DNs of a thermal band from the Landsat 5 ETM+ image captured in May were first converted to spectral radiance (1990, 2000, 2010, and 2019).

$$L= (Lmax-Lmin)/(Qcalmax-Qcalmin)* *(Qcal-Qcalmin) +Lmin \quad (1)$$

Where L is the Spectral radiance of band 6 ETM Landsat 5; Lmax – Radiance maximum of band 6 ETM Landsat5; Lmin – Radiance minimum of Band 6 ETM Landsat5; Qcal max – QUANTIZE calculated maximum reflectance; Qcalmin – QUANTIZE calculated minimum reflectance; Qcal =L – Calculated radiance of band6 ETM Landsat 7.

2.6. Conversion of SR into RST (Radiance Surface Temperature)

Equation (1) is charity to adapt the spectral radiance value of the thermal band into radiant superficial heat. The conversion is carried out with the statement of Uniform emissivity by using the pre-launch calibration constant. The Uniform emissivity means that all the calculated radiant surface temperature was referenced with a blackbody A black body is a surface that absorbs all the incidents of electromagnetic radiation. It neither transmits nor reflects the radiation. The following equation is used.

$$TB= K2/ (\ln (K1/ L\lambda+1) \quad (2)$$

Where,

K1 – calibration constant 1 (666.09 $Wm^{-2}sr^{-1}$ μm^{-1}); K2 – calibration constant 2 (1282.71 K); L_λ – the spectral radiance at the sensor in $Wm^{-2}sr^{-1}$ μm^{-1}; T_B: radiant surface temperature (in Kelvin) brightness temperature at the satellite.

Conversion of kelvin radiant surface temperature into the centigrade

$$C=K-273.15 \quad (3)$$

The above equation is commonly used to convert the radiant surface temperature in Kelvin to Centigrade.

C – Centigrade Temperature; K: Kelvin Temperature calculated from radiance 273.15 – Constant for converting Kelvin into the Centigrade temperature. Calculation of the Normalized Difference Vegetation Index. NDVI was cumulated followed by reflectance value for the near-infrared and red band

$$NDVI = (\rho_{nir} - \rho_{red})/ (\rho_{nir}+\rho_{red}) \quad (4)$$

Chlorophyll contains green, highly absorbs blue (0.4 µm-0.5 µm) and red (0.6 µm-0.7 µm) spectrum, and reflects green (0.5 µm-0.6 µm). Highly reflectance NIR (Near-infrared) (0.7 µm-1.3 µm).

The formula for NDVI Calculation in Landsat 5 and Landsat 7 is the same:

NDVI=(Band4-Band3)/(Band4+Band3).

The formula for NDVI Calculation Landsat 8 is:

NDVI=(Band5-Band4)/ (Band5+Band 4)

3. RESULTS

3.1. Land Surface Temperature

The data in Figure 4a showed that the minimum spatial land use temperature of the year 1990 was observed at 22.8 °C in northern areas of Karachi, while the maximum spatial land use temperature was observed at 30.6 °C in the west-south parts of Karachi city. As shown in (Figure 4b), the minimum spatial land use temperature of the year 2000 was found up to 30.6 °C in the Northeast, Northwest, and Southeast parts of China, but the maximum spatial land use temperature of the year 2000 was noted by 26 °C in the West south parts of the Karachi. As shown in (Figure 4c) the minimum spatial land use temperature during the year 2010 was observed as 33.7 °C in the Northeast, Northwest, and East southern parts of Karachi, whereas the maximum spatial land use temperature during the year 2010 was noted as 35.2 °C in the West southern parts of Karachi. Furthermore, the lowest spatial land use temperature during the year 2019 was found nearly 25.7 °C in the Eastern, Northwest, and southeastern regions of Karachi, whereas the highest spatial land use temperature during the year 2019 was found about 46.8 °C in the Northwest and west southern parts of Karachi (Figure 4d). Overall, it is assumed that the average highest spatial land use temperature significantly increased 1.03 times from 1990-2019.

3.2. Build-up Areas Satellite Images

The data in Figure 5a indicated that the water

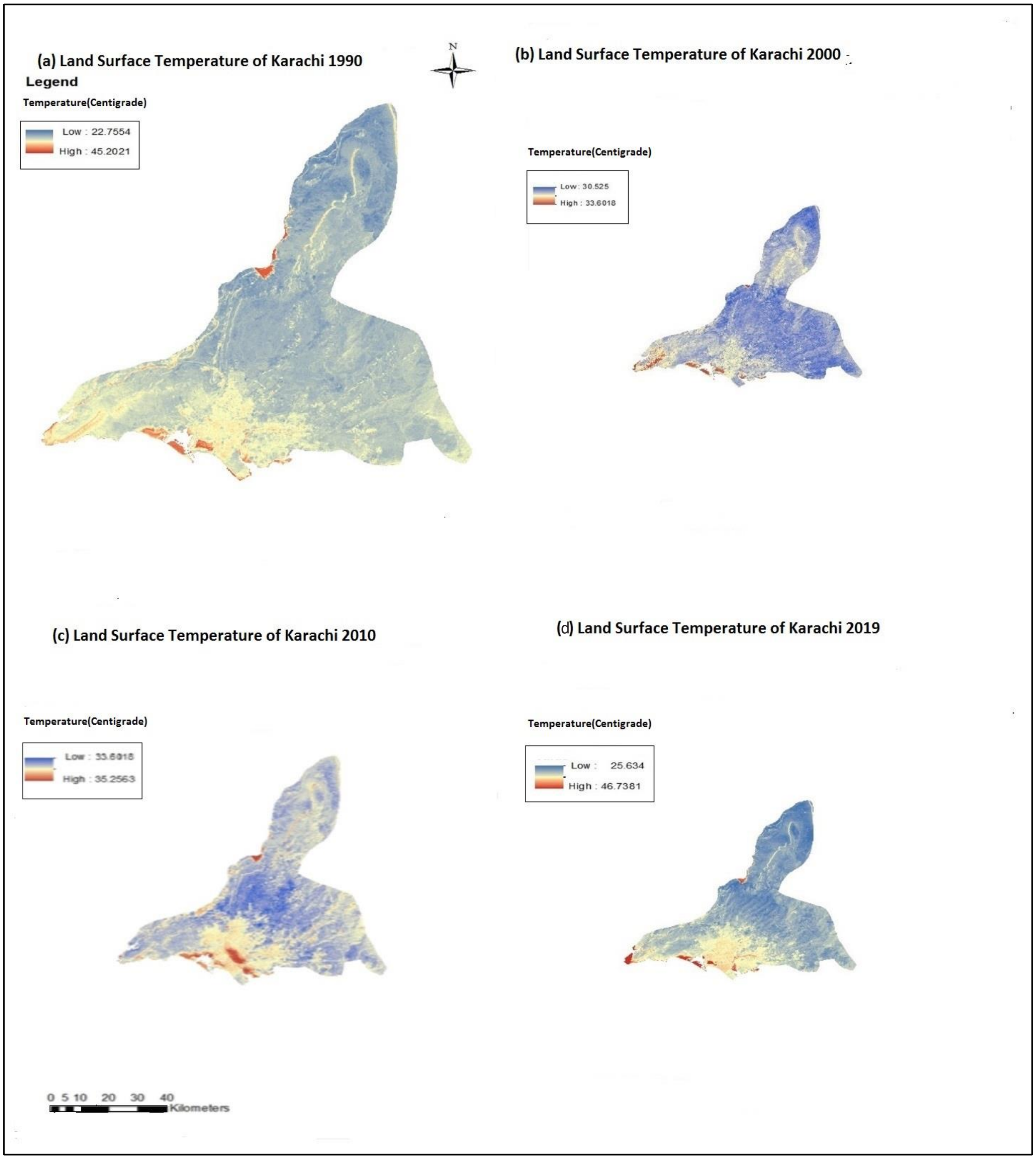

Fig. 4. Spatial distribution of land surface temperature in Karachi in the years (a) 1990, (b) 2000, (c) 2010 and (d) 2019 classification

content in this study area was observed by 10 % in the northwest and southern parts of Karachi during the year 1990. While the maximum constructed build-up areas were observed by 23 % in the Southern parts of Karachi city during the year 1990. Furthermore, the open land was 29 % in most parts of the study areas during the year 1990. Besides, the dominant rugged terrain area was observed by 38 % in most areas of Karachi, while the greatest rugged terrain area was found in the Northeast and central areas of Karachi during the year 1990. The data in Figure 5b indicated that the average water content in the study area was 10 %, while minimum water content was observed in the western part and maximum water contents were noted in east-west parts of Karachi during the year 2000. In addition, the total buildup areas during the year 2000 accounted for up to 34 % in the west southern parts of the megacity Karachi. Besides, the rugged terrain areas observed 35 % in the northeast and

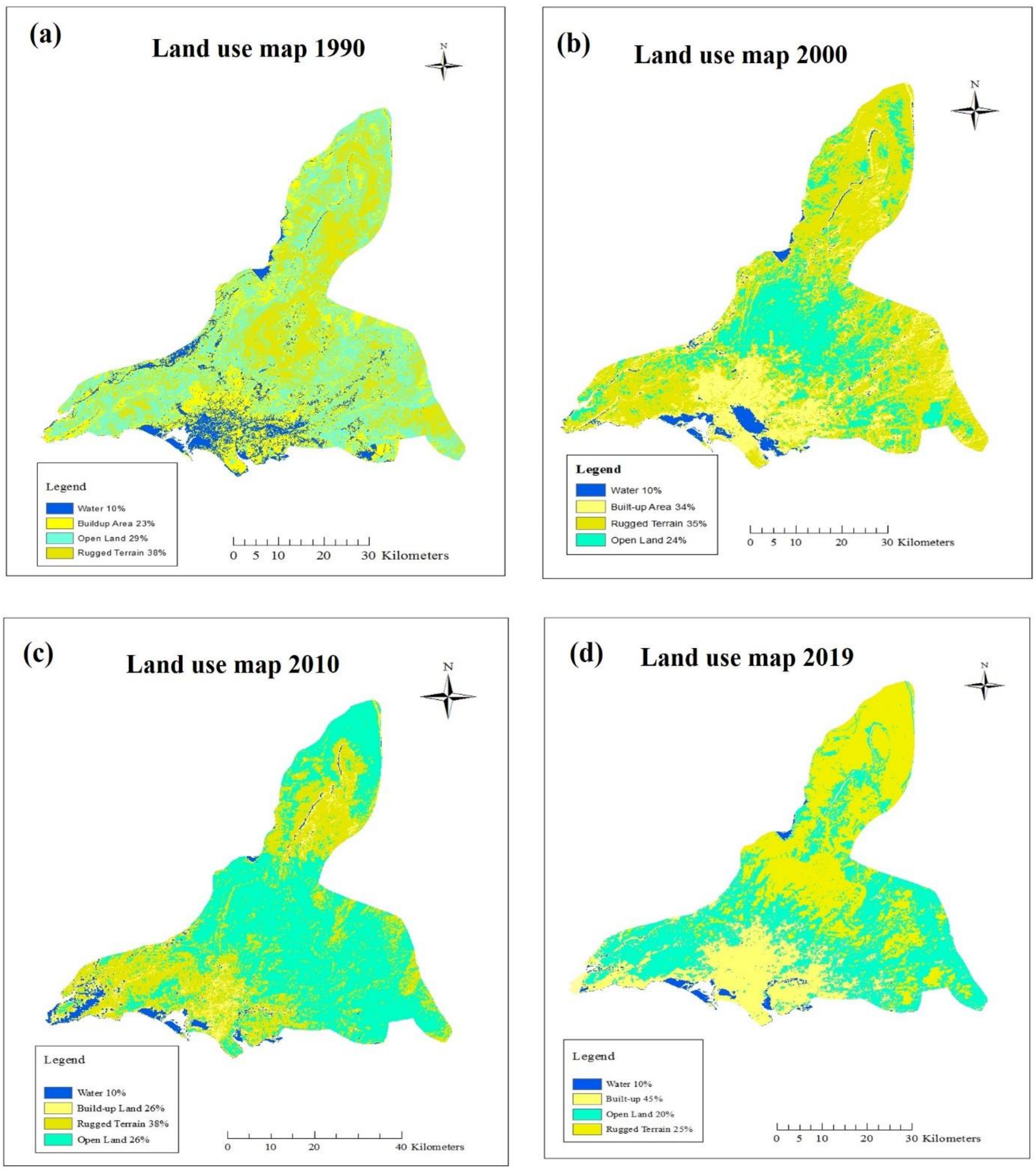

Fig. 5. Spatial distribution of land-use area of Karachi in the years (a) 1990, (b) 2000, (c) 2010, and (d) 2019

west northern parts of Karachi city during the year 2000. The maximum open land was observed by 24 % in the central parts of Karachi during the year 2000. The water content in the western and southern parts of the study area was 10 % during the year 2010. Furthermore, the average buildup area in the year 2010 was found up to 26 % in the west southern areas of Karachi. Furthermore, the average rugged terrain areas were 38 % in the eastern and northern parts of Karachi during 2010. Besides, the maximum open land areas were covered by 26 % in the central areas of Karachi during the year 2010 Figure 5c. The data in Figure 5d represented that the average proportion of water was observed by 10 % in the study area of Karachi during the year 2019. In the case of the buildup area, the maximum area was noted by 45 % in the southern parts of the megacity Karachi during the year 2019. Likewise, the open land was found to be 20 % in the southern parts of Karachi during the year 2019. Meanwhile, the rugged terrain areas were noted by to 25 % in the northern parts of Karachi during the year 2019. The above results indicated that the buildup area increased significantly by 1.9 times, respectively, from the year 1990 to 2019.

3.3. NDVI Imagery Interpretation

The data in Figure 6a indicated the spatial distribution of NDVI of Karachi during the year 1990. Hence, the barren rocks and land were observed in the western and southern parts of Karachi due to low rainfall and air and semi-arid climatic conditions. Furthermore, less NDVI in the study area was observed ranging from 0.076-0.224 in the western and southern parts of Karachi. While very, less dense vegetation in the study areas was observed ranging from 0.224-1 in southern parts of Karachi during the year 2019. As shown in Figure 6b revealed that the barren rocks and land contents in the study areas were observed in the eastern and northwestern parts of Karachi during the year 2000. While the low NDVI population was observed ranging from -0.02-0.07 in the east and southern parts of Karachi, the high NDVI population was noted ranging from 0.07-0.43 in the southern parts of Karachi during the year 2000.

The NDVI data in Figure 6c showed that the barren rock and land were noticed in most parts of the study area. Besides, the low vegetation including shrubs and grasslands was observed ranging from 0.051-0.201 in the central and southern parts of Karachi during 2010. However, the high vegetation including shrubs and grasslands was observed ranging from 0.201-1 in the western and southern parts of Karachi during the year 2010. The NDVI results in Figure 6d highlighted that the water contents in this area were observed ranging from -1-0.01 in the western and northern parts of Karachi during the year 2019 might be due to rainfall. The low vegetation index such as shrubs and grassland in the southern parts of the study area seemed to range from 0.19-0.29 in Karachi city, but the high vegetation index was ranging from 0.29-0.7 in the east, west, and northern parts of Karachi during 2019. The above NDVI data indicated that the lower NDVI in the selected years were observed during 1990, 2000, and 2010 as compared to 2019.

4. DISCUSSION

In Karachi city, there was an expansion in yearly least temperature during the time of 1990-2019 (especially in the last piece of the period 2010-2019 contrasted with the periods 1990-2000). The yearly least temperature pattern increases by 0.2 °C per year. The consequences of the recent work indicated that the maximum variation in spatial land surface temperature distribution in Karachi was observed by 30, 33.7, 35.2, and 46.8 °C from 1990, 2000, 2010, and 2019. On the other hand, the average proportion of buildup areas gradually increases to 23, 26, 31, and 45 % in the years 1990, 2000, 2010, and 2019. The results indicated that the spatial LST distribution and the average proportion of buildup areas increased significantly due to anthropogenic activities.

The highest air temperature in the city compared to the rural areas was obvious, because of the emissivity estimation of each LU/LC, backward connections between vegetation plenitude and LST were seen all in the examination region which is consistent with the results of a similar study conducted in China [14]. It was obvious from the visual translation of NDVI and LST that the LU/LC type vegetative stops and houses with frontal nurseries show a virus spot on the picture because of the bounty of foliage. In any case, the mechanical zone and the household's lack of gardens; no vegetation, and the development of high-rise

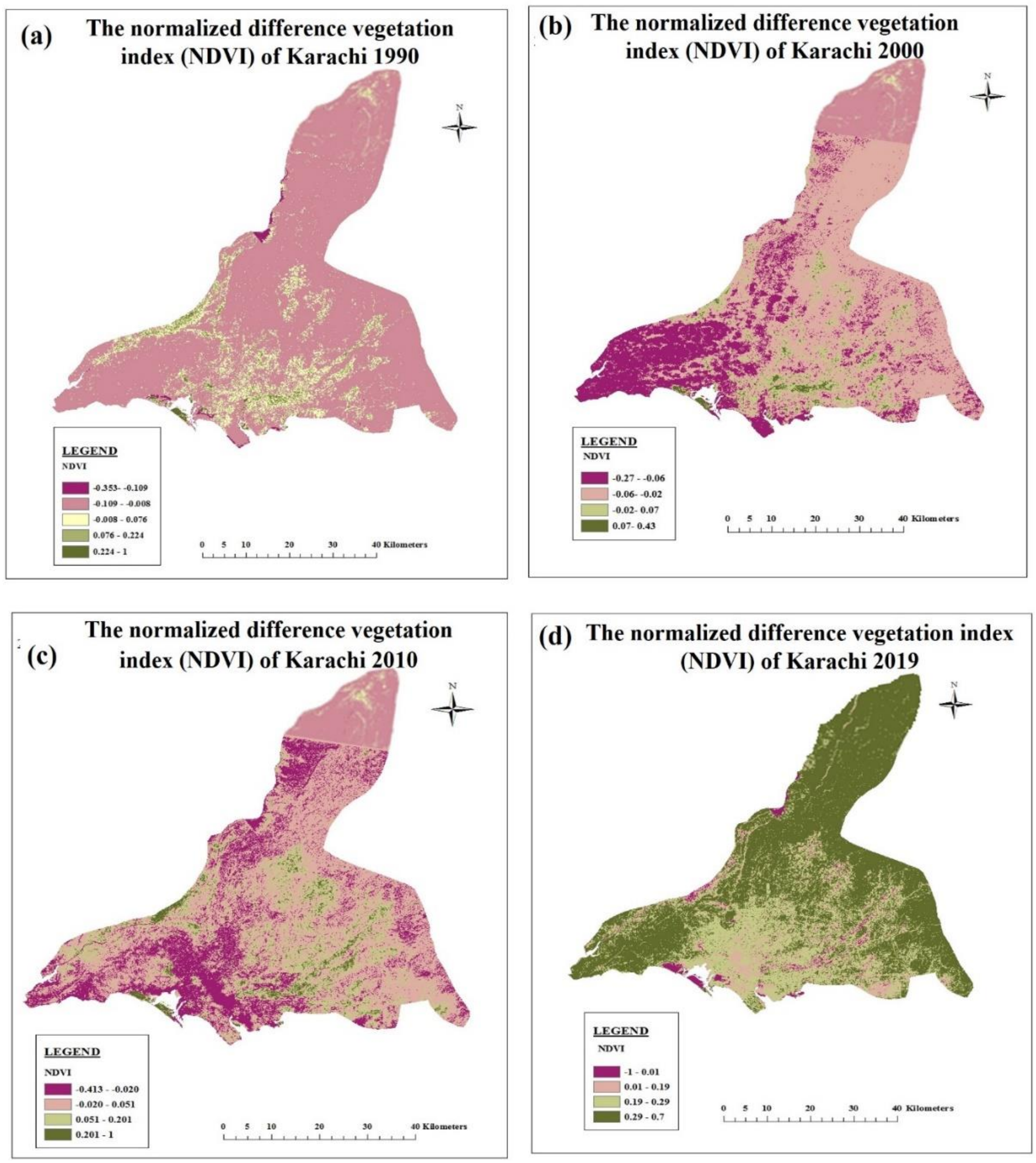

Fig. 6. Spatial distribution of normalized difference vegetation index of Karachi in the years (a)1990, (b) 2000, (c) 2010 and (d) 2019

buildings are directly or indirectly responsible for rising temperatures in Karachi city. In addition, the less vegetation these territories contain and the current of no nursery homes may influence the surface temperature. As private LU/LC now involves huge parts of the city the warm attributes of such LU/LC could probably considerably affect Karachi's warm climate. It is along these lines vital for strategy producers to decide which kinds of private houses could be generally useful to be fabricated. The area of the mechanical region ought to be taken into thought in the event that we need to diminish the general warm impression of the city. The warm reflection decrease may either be by suggesting arrangements for a broad ranch in the zone or move it out of the city [20]. The association among the spatial range of UHI and built-up features, like city size, progress area, water quantity and mean NDVI [21]. The periodic difference in the development of UHI with the assistance of Landsat TM data is observed by [22, 23]. Although, Chen *et al*. [24] reported that Landsat TM and ETM+ images from 1990 to 2000 in the PRD were designated to recover the intensity of temperatures and type of land use and /or land cover. Li *et al*. [25] observed the seasonal outline of the urban heat island for Shanghai about surface temperature conditions and the fractional vegetation index.

Considering the importance of the analysis of urban heat island and NDVI, with veneration to its effect in defining the microclimate and health in built-up areas, it comes to be an imperative part of the research. Thus, the current study goals at investigating LU/LC changes, their impact on UHIs patterns, and their spatial relationship with respective LSTs in Karachi. In imperative to understand the UHI problem in Karachi. The most common and useful technique of remote sensing has been utilized in this study and results of the study have similar conclusions to studies by other methods [8, 26]. The satellite images are processed for the spatial analysis techniques by using the RS (Remote Sensing) and GIS software [27]. It is assumed that the maximum creation of hot spots was identified in constructed buildup regions, where the urban heat island was formed, while the vegetation cover shows the minimum temperature. For this study, Envi4.7, ERDAS imagine 10.2, and Arc GIS 10.3.1 have been used in this investigation. Satellite images might be processed for the (NDVI) Normalized Difference Vegetation Index for the constructed area Index aimed at understanding the urbanization of Karachi further; Spectral radiance might be estimated by using the thermal band of the satellite image for the temperature calibration of the region, for the UHI impact. This analysis will elaborate on the effects of UHI and assess the influences of the UHI. Moreover, UHI is responsible for producing environmental impacts Such as increases in the consumption of energy, elevated emission of greenhouse gases, and adverse effect on human health like heat stroke.

5. CONCLUSION

It was concluded that the LST and land use changes are very important as both facilitate crucial information for urban planners and country policymakers for natural resources. The recent study was carried out with a detailed interpretation of LST and LU/LC changes in the Karachi region. We elaborate on the influence of UHI on Karachi areas from 1990, 2000, 2010, and 2019 by using RS and GIS practices. The anthropogenic activities play a vital role to boost UHI and to cause to decrease the vegetation cover and increases LST during the last 3 decades in the region of Karachi. There are different kinds of modes of transfer of heat through various materials like conduction, convection, and radiation or we can say infrared. Radiation is the initial mode of conduction and convection takes place. All the materials, including construction materials such as plaster, wood, and glass obey the same laws of nature concerning heat transformation. This study has been deciphered through spatial analysis with the help of Land use classification, meteorological data interpretation, and land surface temperature. After the detailed review and interpretation of the above data, it shows that temperature and urban buildup are reciprocal to each other as buildup increases also temperature increases. The obtained data revealed that the temperature has gradually increased with the construction of a high-raised building in the years 1990, 2000, 2010, and 2019. The changes in NDVI results were observed in the studies years 1990, 2000, 2010, and 2019, but the maximum greenery was observed during 2019 as compared to other studied years. It could be due to heavy monsoon rain in 2019. The overall results will help the urban planner and policymakers to well plan the city with minimum utilization of natural resources to overcome these land-use changes, LST, and UHI influences in the future.

6. RECOMMENDATIONS

The substitution of vegetation and open land by metropolitan scenes land use changes and anthropogenic action will in general be the primary elements liable for the identified variations in the atmosphere examples and hotness increment of Karachi City. The investigation incorporated the clarification of the land use changes, consequences for the neighborhood atmosphere of Karachi City dependent on satellite images. Future studies should be focused on districtwide distribution temperature, build-up area, and vegetation. In addition, low-absorbent construction material must be used in high-rise buildings and a new vertical forest system should be adopted in urban areas. It was assumed that the vertical forest has some demerits like the breeding of mosquitoes, insects, pests, and deep root destruction of buildings, so these factors should be taken into account to design a green roof/ vertical forest plan. Future studies must be carried out to investigate the urban heat island in Karachi based on district-wise and NDMI aiming to reduce the temperature of a densely polluted area by using RS and GIS techniques.

7. CONFLICT OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

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