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Monitoring the Urban Areas in Urban Heat Island (UHI) and Modeling the Probable Locations for Urban Expansion: The Case Review of Karachi

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ABSTRACT

Background: Globally, urban heat island (UHI) is a common phenomenon which shows high temperature difference between urban and rural areas. The temperature difference is known to be caused by massive densely populated cities as related to rural zones.

Objectives: The main objectives of this study are to analyze UHI and modeling for Karachi. The research of the objectives sub-divided to develop a digital elevation model, slope, population density, built-up land, impervious surface and water, land surface temperature, vegetation cover, land surface temperature, soil moisture index, water body and land use/land cover. These parameters helped to extract the overall urban expansion model.

Methods: The methodology uses RS/GIS techniques and data of Landsat 8 OLI/TIRS and SRTM (DEM) satellite images. Similarly, ERDAS IMAGINE 9.2 and ArcGIS 10.3.1 softwares were used for data analysis.

Results: The results show that Urban Heat Island (UHI) is growing rapidly in the city, particularly with increasing settlements. This study also shows urban expansion potential of Karachi city.

Conclusions: The results can help in developing strategies for future urban expansion and growth of Karachi, and potential options for decreasing UHI. The results concluded that the UHI cannot be decreased without taking effective decisions and proper implementation keeping in view the rapidly increasing population.

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1. INTRODUCTION

The aspect of urban heat island (UHI) is known as a city, metropolitan or urban region, which is the topmost naturally hot in comparison to its surrounding zones causes of the distinctly human beings' activities (Shah & Ghauri, 2015). The atmosphere or surface temperature creates differences not only among the natural landscape but also the rural and the urban zones which display the lightly various diurnal and seasonal instability. The diverse modification of the earth's surface and the waste heat develop instability in the seasonal and diurnal temperature (Fan et al., 2017). A metropolitan with population of 1 million or even more where the mean annual air temperature can reach 1.0–3.0°C (1.8–5.4°F) which is warmer than rural regions. In the evenings, the temperature of core of the city temperature can rise to 12°C (22°F) which differentiates both rural and urban areas.

The temperature variations are higher in the night than day times when winds are weak along with cloudless sky (Qiao et al., 2014). Both the seasons of summer and winter on the UHI are noticeable and its

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day or night occurs in the whole year. The UHI was first elaborated by Luke Howard in the year the 1810s (Sajjad et al., 2015a). All over the globe, the UHI phenomena are common and it's related to the elevated temperature that is compared with the metropolis and its nearby fields (Ningrum, 2018). In the central cities where the densely populated settlements, different infrastructures, or built up lands of the narrow space and less greenery covers are generally situated compared to the rural zones which ultimately develops the concept of UHI (Sajjad et al., 2015a). The various sources are from heat wastes like transportations, factories, and distinct construction actions (Shah & Ghauri, 2015). The UHI is directly proportional to the population so when its increase as well as, UHI is also raised.

The UHI it is examined by two factors as external and intrinsic factors. External factors are the locations (longitude and latitude), climate (wind) and nearby water zones (as rivers or sea breeze areas). While intrinsic factors include city features (like the size of urban built up, heat releases of anthropogenic and fractions of land cover) and longtime urbanization which has been reshaped with the passage of time. The waste heats are from the factory's emissions, air conditions, buildings, and transports plus these are the man-made or the anthropogenic contributors. Hence, the population density, built-up land density, and the amount of vegetation cover are the contributors that directly and indirectly increase the formation of UHI (Sajjad et al., 2015b).

The major side effects of UHI are climate change, air pollution, the demand for energy, water stress, the cost of air conditions, heat-related diseases and fatalities and greenhouse gases emissions (Lemonsu et al., 2015). The UHI raises the heat waves risk that's displaying the stress of the cities which is quite frequent in the peak of summers. Further, is a potential threat not only for the human's health but also for ecosystems, society and economy as well (Khan & Omar, 2014).

Therefore, the objectives of the study are to explore the UHI zones in the research area as well as proposing strategies for its reduction as well as model development for future urban growth. Hence, various analysis techniques are used for the identification of UHI and its reduction strategies in the study. Further diverse methods such as urban expansion model promoted with distinct parameters are also used for UHI reduction and finally some recommendations suggested for overcoming UHI.

The urban expansion is exacerbating day by day and it is analyzed with various methods that are for the satellite data (Landsat 7/ETM+ and 8/OLI) used as well RS/GIS techniques adopted and to observe the land use and urban growth changes on the Lahore study zone (Bhatti et al., 2015). The satellite images (Landsat MSS, TM, and ETM+ sensors) on land covers changes investigated which for supervised and unsupervised classification practiced additional, it's graphically studied and NDBI through built-up land contrast analyzed on the Karachi division (Mahboob et al., 2015). The dissimilarity identified of land cover/land use, slum zones, cultivated region and settlement growth on the satellite imaginaries (Quick Bird, Landsat TM, and ETM+) with the helped of Geo-informatics system and it's through urban expansion investigated on the Karachi (Ghazal et al., 2018).

The GIS tools through the urban sprawl of diversity extracted and it's for supervised classification applied to built-up land monitored as well as, Landsat data used as ETM+, MSS and TM and Faisalabad city on researched (Bhalli et al., 2012). The Karachi civic of the contemporary Urbanism issues on the various maps developed in which involved air pollution risk, land use, urban sprawl, and physiography (Qureshi, 2010). The data acquired from OpenStreetMap, Advanced Spaceborne Thermal Emission and Reflection Radiometer, census report of Lahore, The Urban Unit, Punjab Development Statistics and Multiple Indicator Cluster Survey as well, these data through LULC changes evaluated and it's classified into biophysical, socioeconomic and infrastructure additional it's through impacts on urban expansion observed and Lahore district study region (Bhatti et al., 2015).

The urban growth with UHI increased and its interrogated from the Geospatial applications further, UHI observed with land surface temperature (LST), NDVI, NDBI, and unsupervised classification and these all process proceeded on the Landsat TM, ETM+ and Quick Bird imaginaries of the Karachi district study zone

(Khan & Omar, 2014). Landsat TM data images (28th & 27th of April 2000 and 2011) on the disparate of land use/land cover (LULC), LST, and built up land inquired with aided of GIS modes and its statistically analyzed on the Lahore district (Shah & Ghauri, 2015). The process of the linear regression through developed various designed of graphs such as mean temperature (maximum and minimum), transportation, urban population, mean annual temperature and the urban region farther, all of these on the temperature and urbanization changes on the Lahore studied (Sajjad et al., 2009b). The temperature data compiled from the solar-powered radio weather station instrument and it's through displayed UHI of the variability of the different city zones as a rural area, less dense urban, urban periphery and high dense urban as well linear regression technique through all variability is measured on the Sargodha city (Sajjad et al., 2015b).

The urban zones and atmosphere among interacted in the practiced Finite Volume Mesoscale Model (FVM) and it's through the temperature of urban fields investigated farther, map of UHI progressed and map of land use conducted from GLC 2000 on the Karachi (Sajjad et al., 2015a). The GIS system through the LST map promoted as well as various graphs observed from the surface temperature in which included surface runoff, land cover classes, and precipitation and studied on the US (Bounoua et al., 2015). The linear regression method through temperature studied and various graphs established of the temperature in which involved mean temperature (maximum and minimum) and mean annual temperature and its all of the anomalies analyzed further, the temperature data compiled from the Pakistan Meteorological Department (PMD) and Computerize Data Processing Center (CDPC) on the Karachi region (Sajjad et al., 2009a).

The UHI extending with the urbanization and it's for needs to resolve this problem so; it's for evaluated suitable locations for the future urban expansion that aids to UHI decrease and it's for diverse spatial layers merged through Geospatial methods as the distance to roads, vegetation, slope, soil productivity, distance to the central area, environmental protection fields, distance to green/open space and distance to centers of education additional, all of these layers helped to suitable zones of model flourished on the Kyrenia region (Kara & Akçit, 2018). The USGS remote sensing website from data collected of Landsat ETM and TM imaginaries as well as, these data images on the contrast of urban growth, land cover/land use classification and agriculture land monitored plus, GIS techniques through suitable zones of the model developed with divergent parameters such as proximity to centers of population, proximity to developed fields, elevation, proximity to the network of roads, land value and proximity to water zones and studied on the Penang Island (Mohammed et al., 2016).

The panchromatic SPOT 2.5 m satellite data, population data (1998) and Islamabad master plan map on Geo-informatics applications used for potentially suitable locations identified further, it's for distinct factors adopted like distance to major roads, land use/land cover, population density and distance to the population center of the Islamabad (Adeel, 2010). The data acquired from the websites of Geospatial Data Cloud and United States Geological Survey (USGS) and these data on urban development boundaries extracted which for used GIS methods additional, it's for different parameters practiced as: population density, slope, basic farmland protection field, distance to the center of the city, distance to the county road, ecological protection area, distance to the town center, distance to the airport, distance to the highway, historical relics protection area and distance to the railway as well, reviewed on the Jiayuguan City, China (Ren et al., 2020). The Geo-spatial system through the model of urban expansion suitability development flourished with the disparate factors in which involved geopolitical classification, agriculture lands, Palestinian built-up land, topography, separation wall, roads, Israeli settlement field, water sensitive and heritage zone of Palestine (Raddad, 2016).

The 1:10,000 topographic map through varieties of parameters calculated with help of GIS system such as distance to major rivers, cultural sites, coal mining subsidence region, distance to main roads, distance to built-up zone, coral resources, basic farmland, water source protection field, land use, and topography plus, these parameters through diagnosed urban construction land suitability based on vertical-horizontal methods on the Jining City, China researched area (Yan et al., 2018). The satellite data Landsat MSS, 7 ETM+, 5 TM, CARTOSAT-1 and 2 on the research analyzed and diverse criteria/parameters used for future urban growth suitability sites like elevation, geomorphology, road proximity, slope, aspect and land use/land cover as well, Parwanoo, India reviewed region (Singh et al., 2014).

2. METHODS

The study design of the current research is based on the methodological framework (Figure 3).

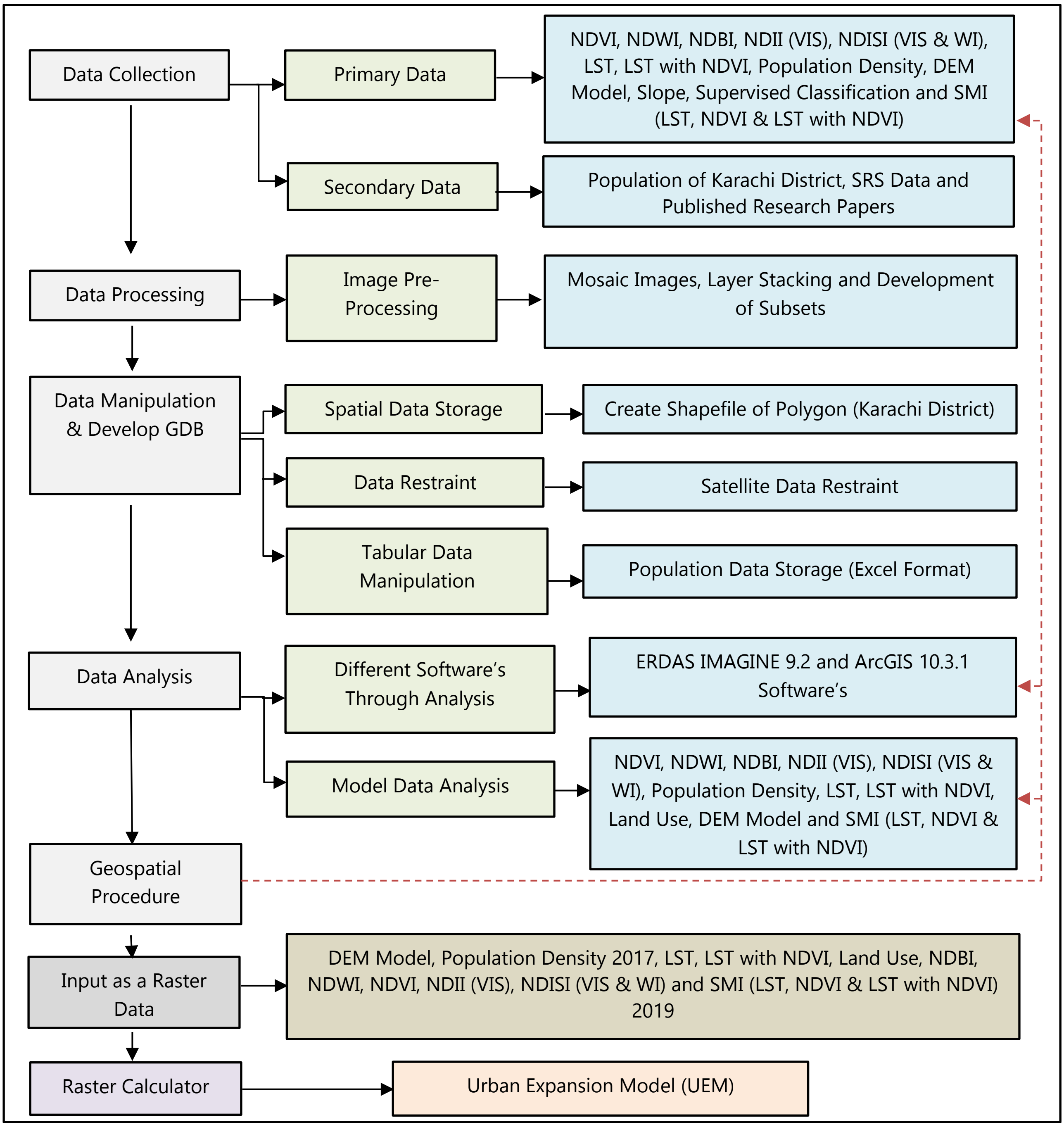

Figure 3. Methodological Framework

2.1 Setting

Karachi district, the capital of Sindh province, was chosen as the case study area (Figure 1) and the largest city of Pakistan (Ghazal et al., 2018). The city is in located the longitude of 67.0011° E and latitude of 24.8607° N (Mahboob et al., 2015). All over the world, the metropolitan is the third famous civic and its beta ranked. In the 2017 census, its population is estimated about 14.91 million which the first highest population metropolises in Pakistan. The city is the sixth rank in the highest population all over the globe. The total area of the Karachi city is approximately 3,780 Km^2. The city houses major industrial and financial centers, and generates 70% revenue of the country. The urban area is situated in the Sindh province of southern where it's around to meet the Arabian Sea of coastline (Khan & Omar, 2014).

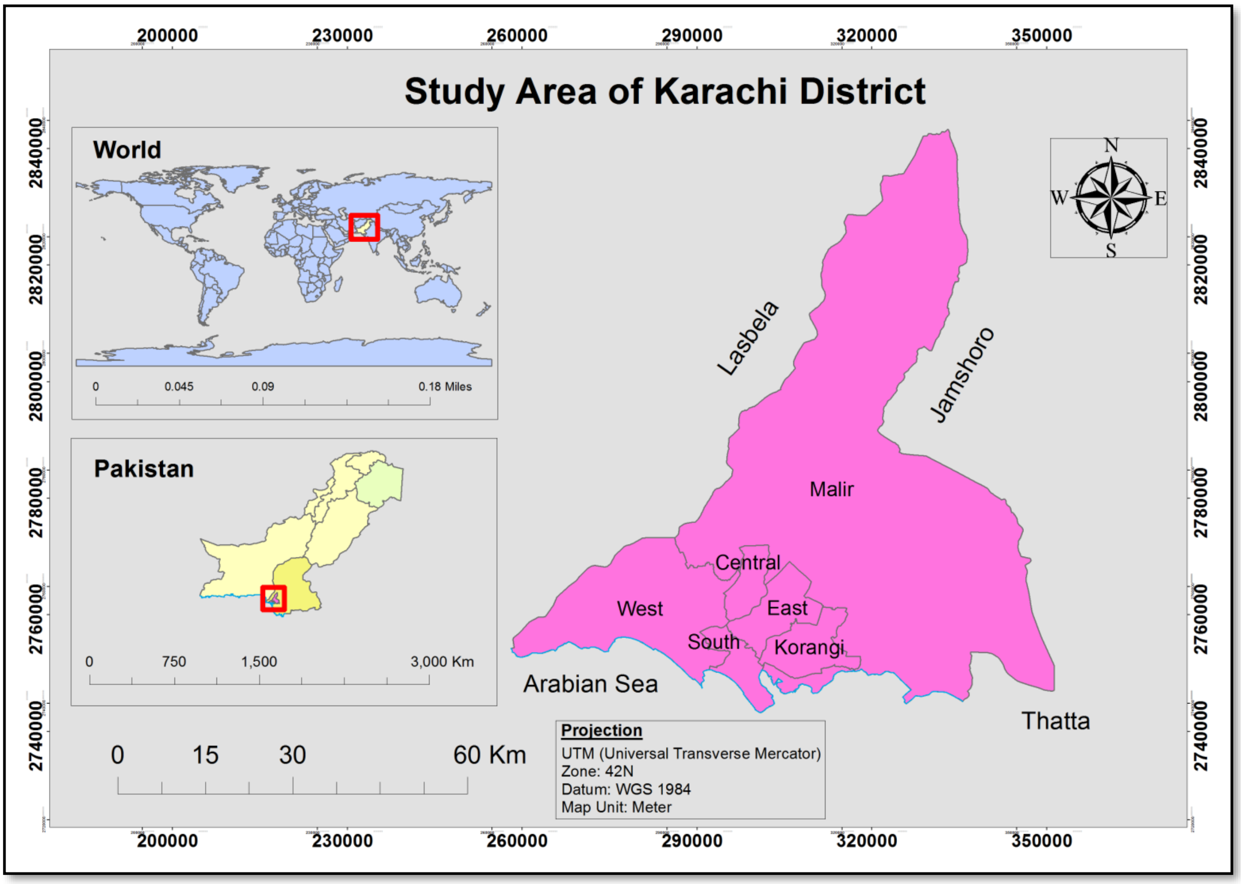

Figure 1. Study Area

The civic is in located the area of the sub-tropical zone and arid region. Karachi has the long-term summer season. The monsoon season months are July to September. The minimum annual average of precipitation estimated approximately 10 inches (250 millimeters) and maximum monthly recorded about 16.90 inches (429.3 mm). April to October is the summer season months while November to March winter season months. The highest temperature was recorded at 48 °C and the lowest at 0 °C.

Karachi district is the first rank in Pakistan by the population-wise and global in the sixth rank. The population settlement of the city Karachi varies with area, having an unevenly distribution. It is facing urban sprawl and its population is rapidly growing (Afsar et al., 2013). In the beginning or partition times in 1947's, the metropolitan of the population was estimated approximately 450,000 peoples. In the 1950s, 1981's and 1998's, the population reached about 1,055,380 persons, 5.2 million, and 9.8 million. Since in 2011, 2016, 2015 and 2017, the population settlement recorded that 21.2 million, 16.62 million, 1,111,063 and 14,910,352 people. The population reached 15,400,223 persons in 2018 (Figure 2). The city of population density has higher than 6,000 persons per square kilometers.

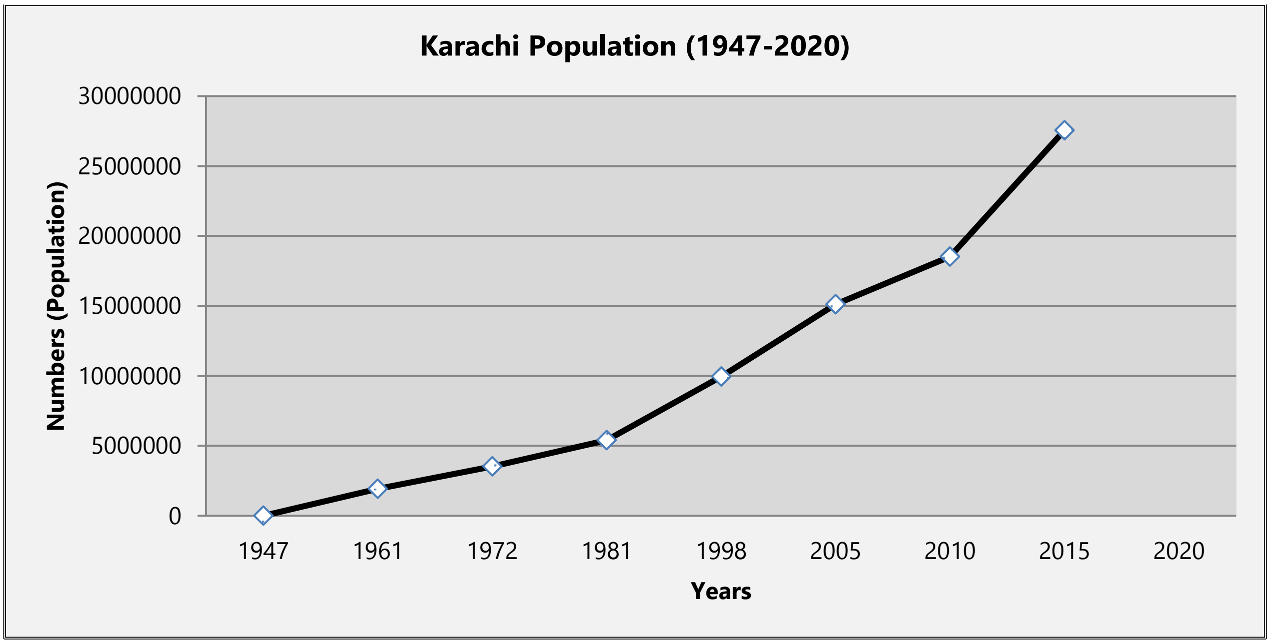

Figure 2. Population of Karachi Source: (Pakistan Bureau of Statistics, 2020).

2.2 Data sources and measurement

The study uses diverse sources for the data. Two satellite images were downloaded from the Earth Explorer website (Table 1). Different formats of data were used and their details are shown in (Table 2).

Table 1. Various Data Collection Types

Raster	Vector	Numeric
Landsat 8 OLI/TIRS C1 Level-1 image 2019 SRTM Arc-Second Global image (30 m) 2014	Karachi district shapefile	Karachi town's population census (2017)

Table 2. Distinct Parameters Types

Parameter	Spatial Resolution	Temporal Resolution	Spectral Resolution	Areal Swath	Availability	Dates	Pixel Size	Thermal Band
Landsat 8 OLI/TIRS (Operational Land Imager/ Thermal Infrared Sensor)	30 meters (band 8 = 15 meter) (band 10 & 11 = 100 meters)	16 days	10 bands	185 km	16 days	1/Feb/2019	30 m	100 m
SRTM (Shuttle Radar Topography Mission)	30 meters	11 days	1 band	225 km	11 days	23/Sept/2014	30 m	-

2.2.1 Softwares and Processing of Images

Different softwares were used for data analysis, i.e., ERDAS IMAGINE 9.2 and ArcGIS 10.3.1. Further, images were processed through these softwares for mosaicking, layer stacking, subset development, digital elevation model (DEM), slope, population density and supervised classification. The shapefile of Karachi district boundary through progressed population density map (Population Data from Pakistan Tehsil Wise for Web Census 2017) (Table 3). Different images various satellite data imaginaries were processed and analyzed (Figure 4).

Table 3. Divergent Software's Processes

S. No.	ERDAS IMAGINE 9.2 Software	ArcGIS 10.3.1 Software
1	Mosaic	Layer stacking
2	Supervised classification	Subset development
3		Digital Elevation Model (DEM)
4		Slope
5		Population density
6		Normalized Difference Vegetation Index (NDVI)
7		Land Surface Temperature (LST)
8		LST with NDVI
9		Normalized Difference Water Index (NDWI)
10		Normalized Difference Built-Up Index (NDBI)
11		Normalized Difference Impervious Index (NDII)
12		Normalized Difference Impervious Surface Index (NDISI)
13		Soil Moisture Index (SMI)
14		Urban Expansion Model (UEM)
15		All raster images of map layouts developed

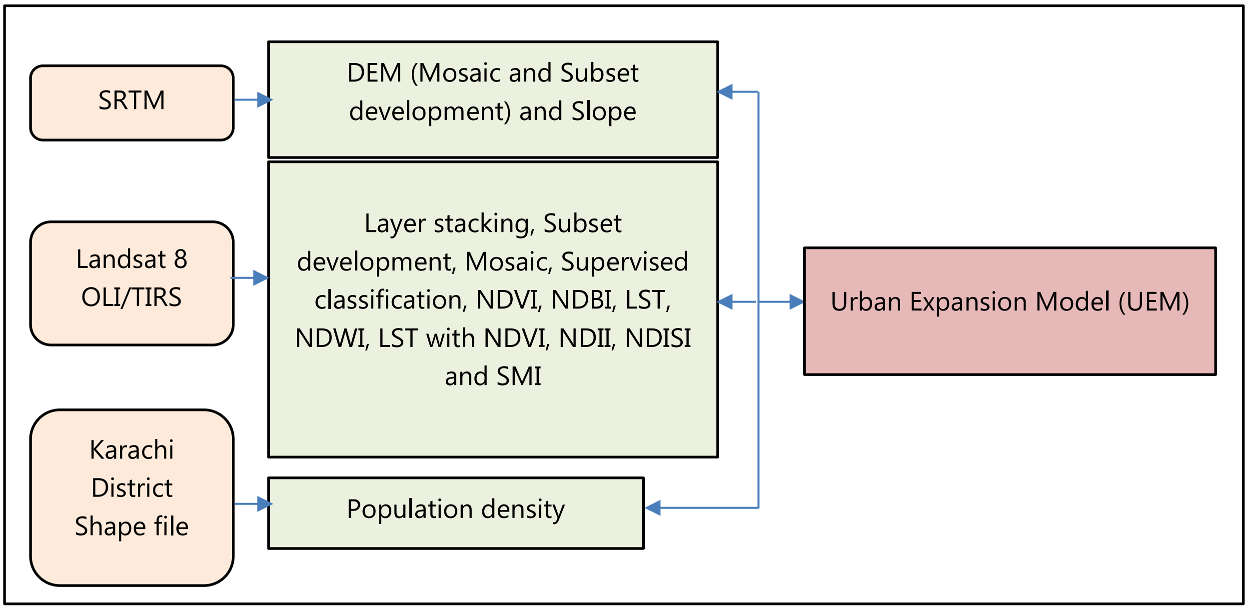

Figure 4. Flowchart of Data Processes

Further, diverse applications used on images from the distinct software's for the best results appearance and its description are followings:

2.2.2 Indexes

Different indexes were used for data analysis (Table 4). The indexes were developed for enhancing the images for different purposes. NDVI was adopted for the vegetation cover region identification, and NDWI was used for analysis of water bodies. Similarly, NDBI, NDII, NDISI, SMI were used for finding impervious, built-up land, soil quality of water and moisture in the images, respectively.

Table 4. Various Indexes Practiced

S. No.	Indexes	Formula
1	NDVI	(NIR–Red)/ (NIR+Red)
2	NDWI	(Green-NIR)/ (Green+NIR)
3	NDBI	(SWIR-NIR)/ (SWIR+NIR)
4	NDII	(VIS - TIRS)/ (VIS + TIRS)
5	NDISI	TIRS-((MNDWI+NIR+SWIR)/3)/TIRS+((MNDWI+NIR+SWIR)/3)
	MNDWI	(Green-SWIR)/ (Green+SWIR)
6	SMI	(LSTmax- LST)/ (LSTmax- LSTmin)

2.2.3 Surface Temperature (LST)

Firstly, Landsat 8 OLI/TIRS satellite image was used for measuring LST. The raster image utilized both thermal layers 10 and 11 used for preparing map, using the following formula is:

Radiance = Radiance multiplicative layer*Layer X+Radiance additive layer ...... (1)

Secondly, the same image of both layers (10 and 11) of the metadata file of constant values utilized and radiance converts into SBT (satellite brightness temperature). The LST or SBT formula is given by:

SBT=Thermal conversion constant (K2)/ ln{Thermal conversion constant (K1)/Layer X_radiance+1}-272.15 ...... (2)

On the other side, both layers (10 and 11) of SBT average extract.

2.2.4 LST with NDVI

The proportion of vegetation (Pv) values observed on the Landsat 8 OLI/TIRS image of NDVI and it's for the formula is:

$$Pv = (NDVI\text{-}NDVImin/\ NDVImax\text{-}NDVImin)^2 \quad \text{....... (3)}$$

Similarly, land surface emissivity (e) calculated that is the formula:

$$e = 0.004*Pv+0.986$$

Finally, the average LST or SBT of the Landsat 8 OLI/TIRS image layer used in the formula of LST with NDVI. The formula in which applies average thermal layers (10 and 11) and the formula is:

LST with NDVI = SBT/ 1+ Layers*(SBT/ 14380)*ln(e) ....(4)

2.2.5 Urban Expansion Model (UEM)

The model develops with diverse parameters (Table 5). Various parameters were used to obtain results for UEM and identify future urban growth potential. NDVI was used for observing vegetation covers which were decreasing over time. Similarly, water bodies were monitored through NDWI, and can be seen as reason of future urban growth due to accessibility of water. NDBI was used for identifying impervious zones for urban expansion in new areas. Additionally, no accuracy or error developed was UEM done. The model pattern used in the study is shown in (Figure 5). Further, UEM of the formula used in the ArcGIS 10.3.1 software of the raster calculator application:

Urban Expansion Model (UEM)= (0.06*Reclass slop) + (0.06*Reclass feature to raster)+(0.06*LST)+(0.05*LST with NDVI)+(0.06*NDISI (Water))+(0.05*NDISI (Red))+(0.05*NDISI (Green))+(0.05*NDISI (Blue)) + (0.05*NDII (Red)) + (0.05*NDII (Green)) + (0.05*NDII (Blue)) + (0.05*NDVI) + (0.06*NDWI) + (0.06*NDBI) + (0.06*SMI (LST)) + (0.06*SMI (NDVI)) + (0.06*SMI (LST with NDVI)) + (0.06*Supervised classification)

Table 5. Parameters for Model development

S. No.	Parameters
1	NDVI
2	NDWI
3	NDBI
4	NDII with VIS (Blue, Green, and Red)
5	NDISI with WI and VIS
6	SMI (LST, NDVI, and LST with NDVI)
7	LST
8	LST with NDVI
9	DEM Raster Image (Slope)
10	Population Density
11	Land Use/Land Cover

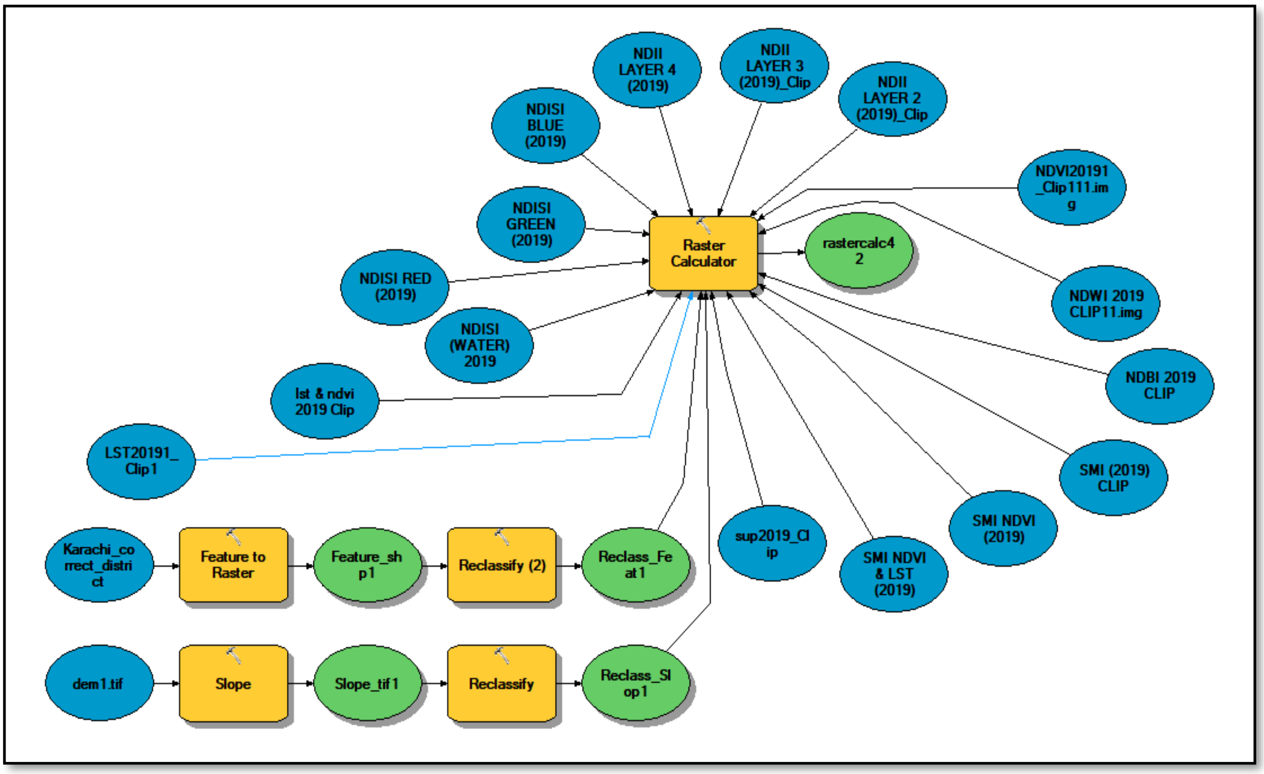

Figure 5. Model Development Pattern

3. RESULTS

The purpose of the study was to investigate the urban heat island (UHI). Firstly, digital elevation model (DEM) was prepared to show elevations on the earth's surface (Figure 6). The model was developed on the ArcGIS 10.3.1. The map of DEM shows plain or very low zones (-25 - 63 meter) in mostly the south area, while very high elevation (311.00 – 534 meter) in the north side of Karachi. So, its direct impacts on the urban growth causes of the most population preference to plain areas for living purpose reasons of the accessibility (such as transportation, markets, water, jobs, etc.).

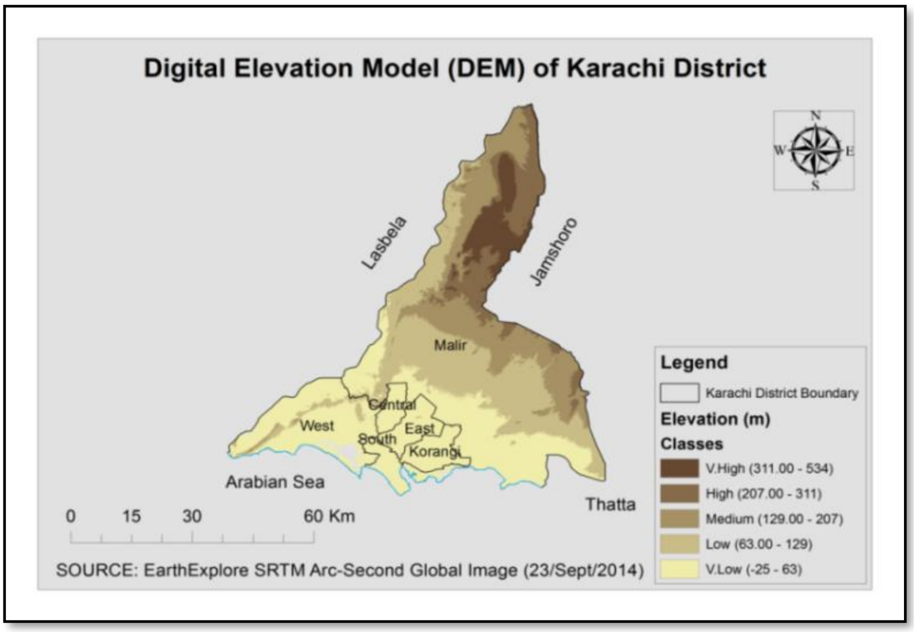

Figure 6. Digital Elevation Model (DEM)

Secondly, slope, the physical terrain of the land surface, was prepared (Figure 7). Slope described the plain and highland regions where the population can live. The south area represents the low slope (0°-1.88°) that's comfortable for population settlement because of its plain region, while the north and some the west zone high slope (39.76° - 68.50°) zones showed and this is not suitable for settlement causes of its highland zone. The slope analyzed through GIS tools on the original DEM (SRTM) satellite image.

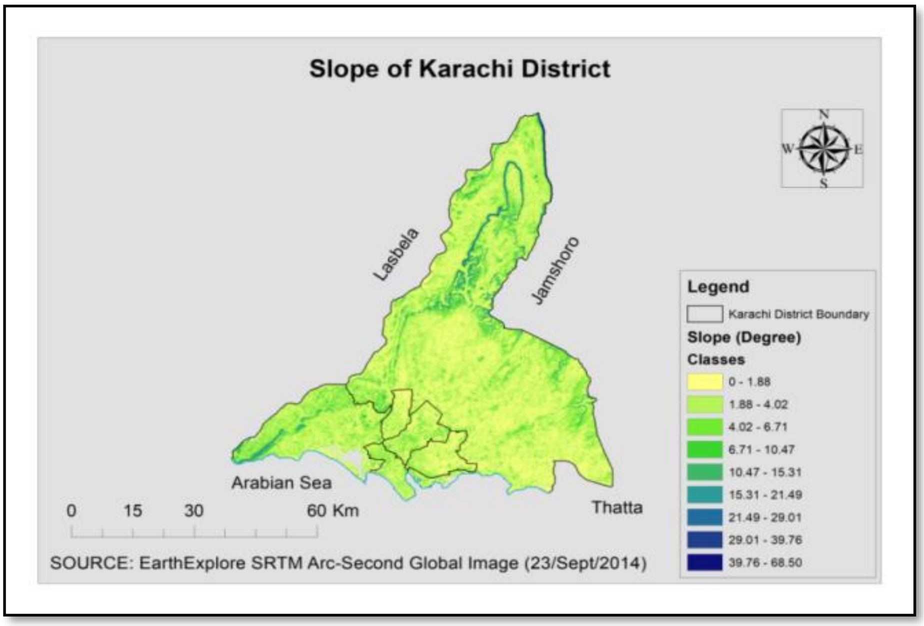

Figure 7. Slope

Thirdly, population density indicates settlements areas of the population on the earth sphere (Figure 8). The district boundaries of geospatial data on the population 2017 data were added from the census report of the Pakistan, and processed in the ArcGIS 10.3.1 software. The very high (1.57-5.26 P.D/sq.km) population displayed in the west district of Karachi city and very low (0.09 P.D/sq.km) in the Malir district.

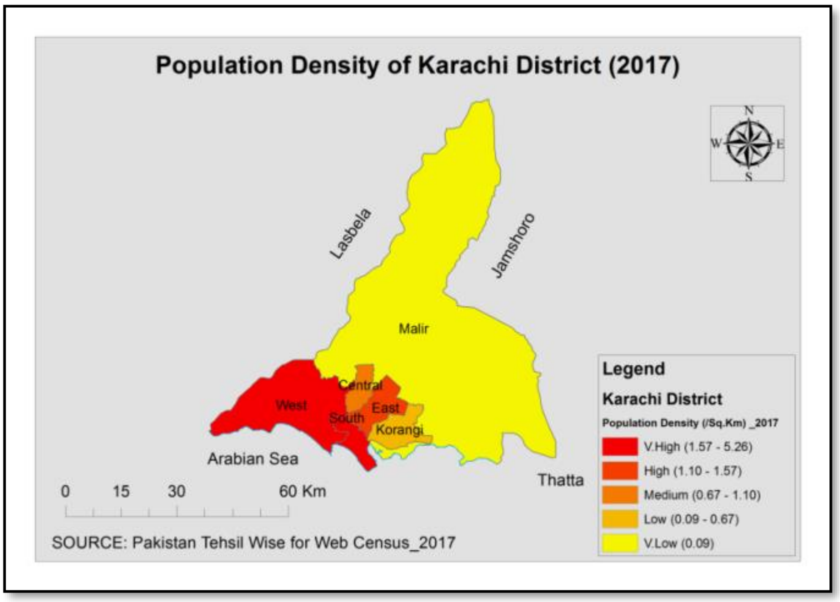

Figure 8. Population Density

Fourthly, built-up land defines those zones where the population settlement lived on the land (Figure 9). The map expresses the impervious areas that refer to populated regions. The population fields cover with pavement materials like cement, steel, concrete, dark hue roofs, etc. Further, its areas quickly absorbed solar energy and reflect different bandwidths. These zones impact to the development of the UHI. The map was made with the help of geospatial procedures and Landsat 8 OLI/TIRS image. The built-up land map was divided into two classes as the impervious and non-impervious. Mostly the impervious zone covered of the south area of Karachi. While the rest of the area represented the non-impervious that's not suitable for population settlement.

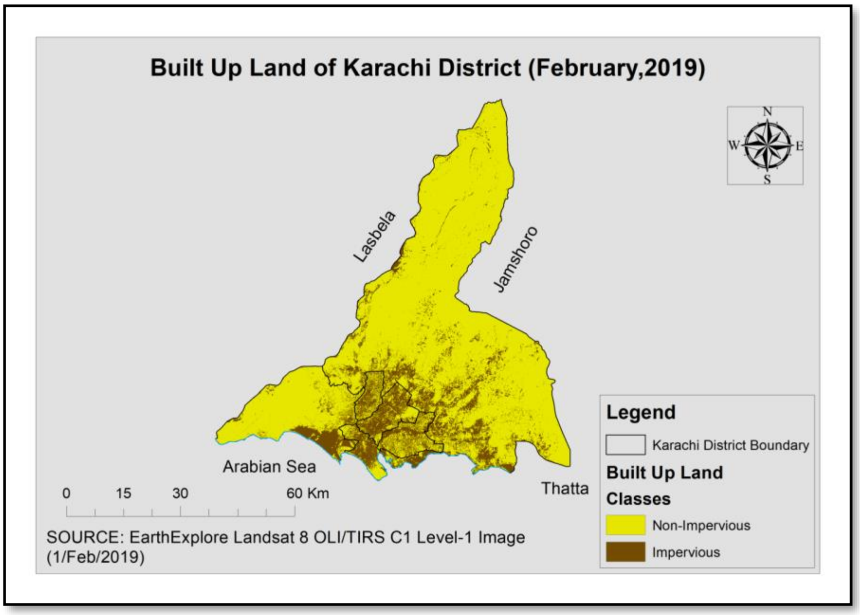

Figure 9. Built-up Land

Fifth, the impervious index with visible bands (VIS) map progressed with the support of GIS techniques on the Landsat 8 OLI/TIRS satellite image (Figure 10). The map disclosed the settlement areas on the image. The map of the impervious index with VIS in was classified in two classes such as: non-impervious and impervious. Further, the impervious index with VIS in which three bands used like blue, red, and green and all of the bands have various results related to the impervious and non-impervious areas covered. The results of the impervious index with VIS map show that all impervious areas are in the south region, because of the plain location while the most north zone showed the non-impervious zone causes of this zone covered with plateaus or highlands.

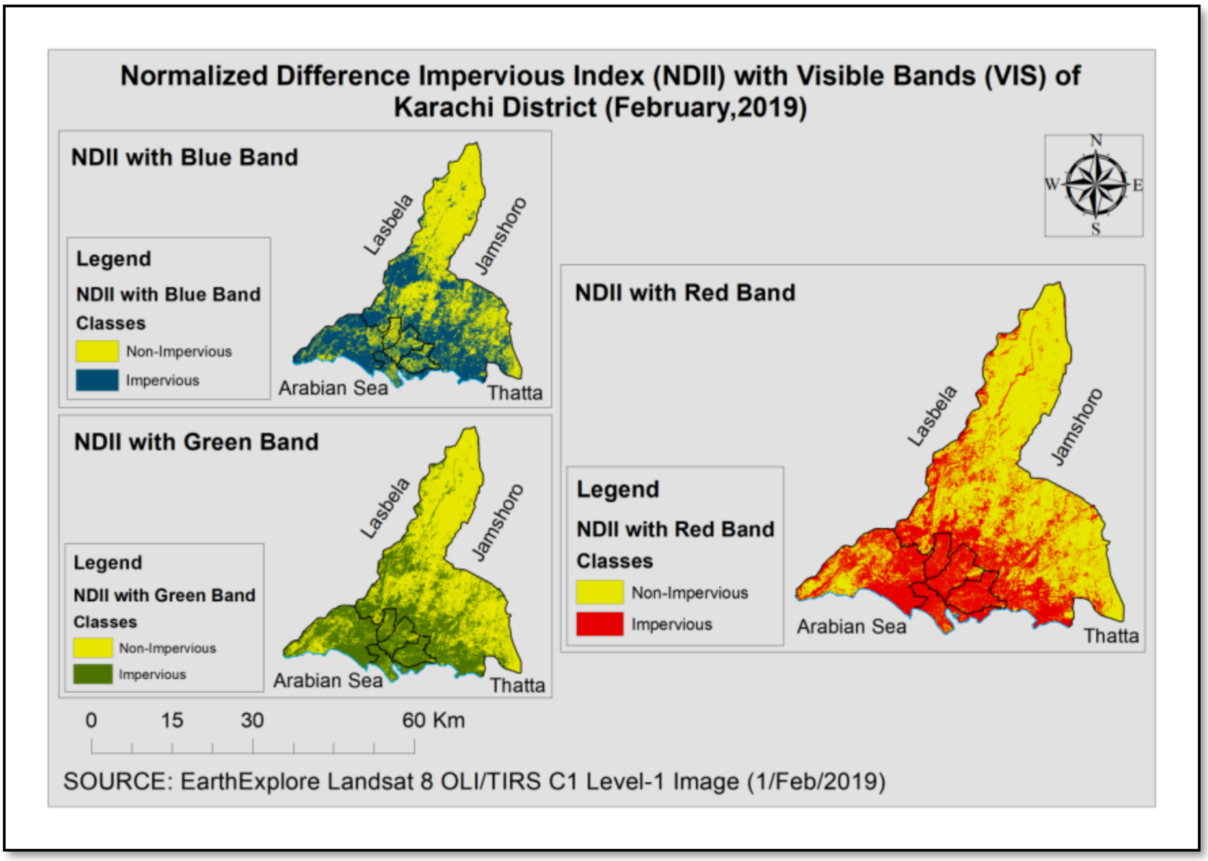

Figure 10. Impervious Index with Visible Bands

Sixth, impervious surface index with visible bands (VIS) and water index (WI) shows various terrain surfaces (Figure 11). The map was made with the aid of GIS and satellite data Landsat 8 OLI/TIRS image. The map of the impervious surface index with VIS and WI adopted three bands as blue, red, and green while, water index used and these all-expressed population settlements zones. Hence, the map divided into two classes of categories like impervious and non-impervious; and impervious situated in the south area (causes of the plain zone) while, the non-impervious covered mostly the north region (because of the mountainous area).

Seventh, the environment of land surface temperature (LST) monitored and it's for use thermal sensor (Figure 12). LST map promoted with the support of GIS analysis on the Landsat 8 OLI/TIRS image. In the layout expressed the small map that referred LST without IDW while the main map showed LST with IDW (inverse distance weighted) process, through contours developed which LST with contours high and low (Figure 8, 9, 10 and 11). Maps show that high population settled in the south location, while less in the north.

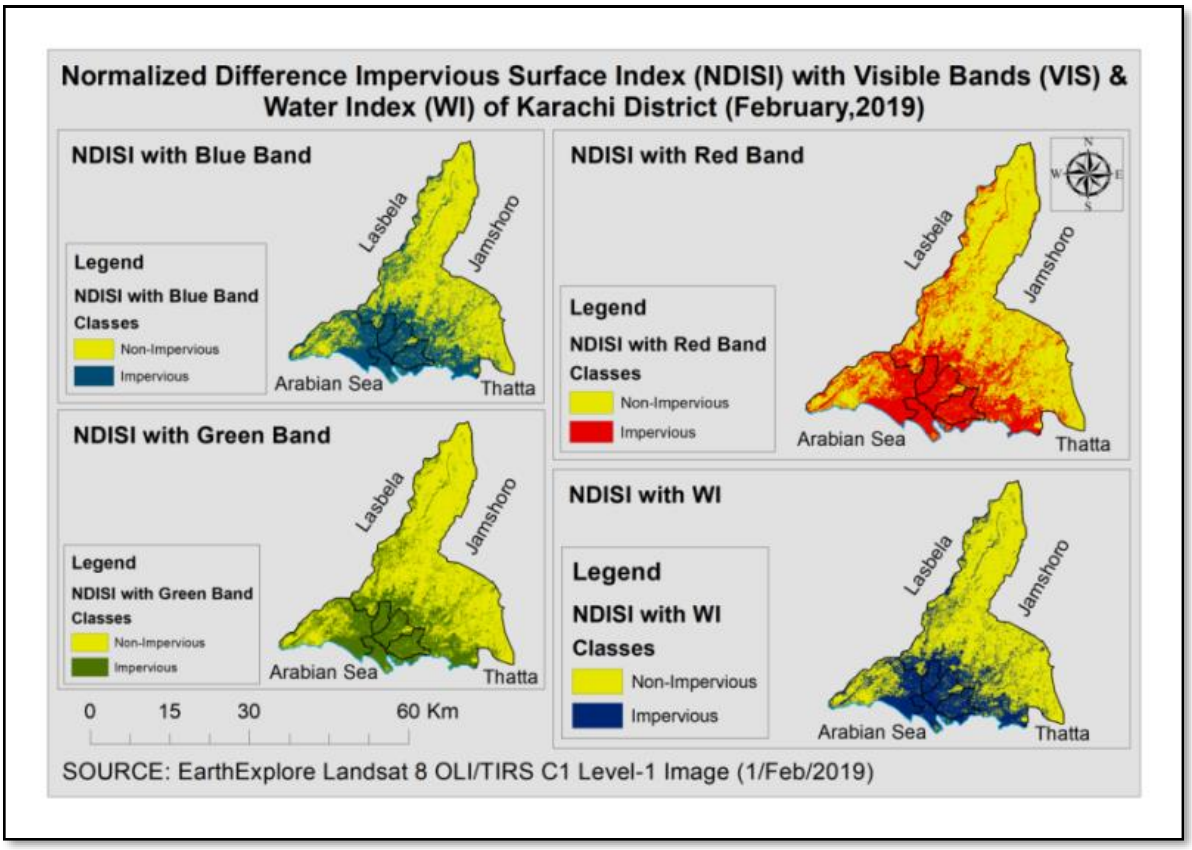

Figure 11. Impervious Surface Index with Visible Bands & Water Index

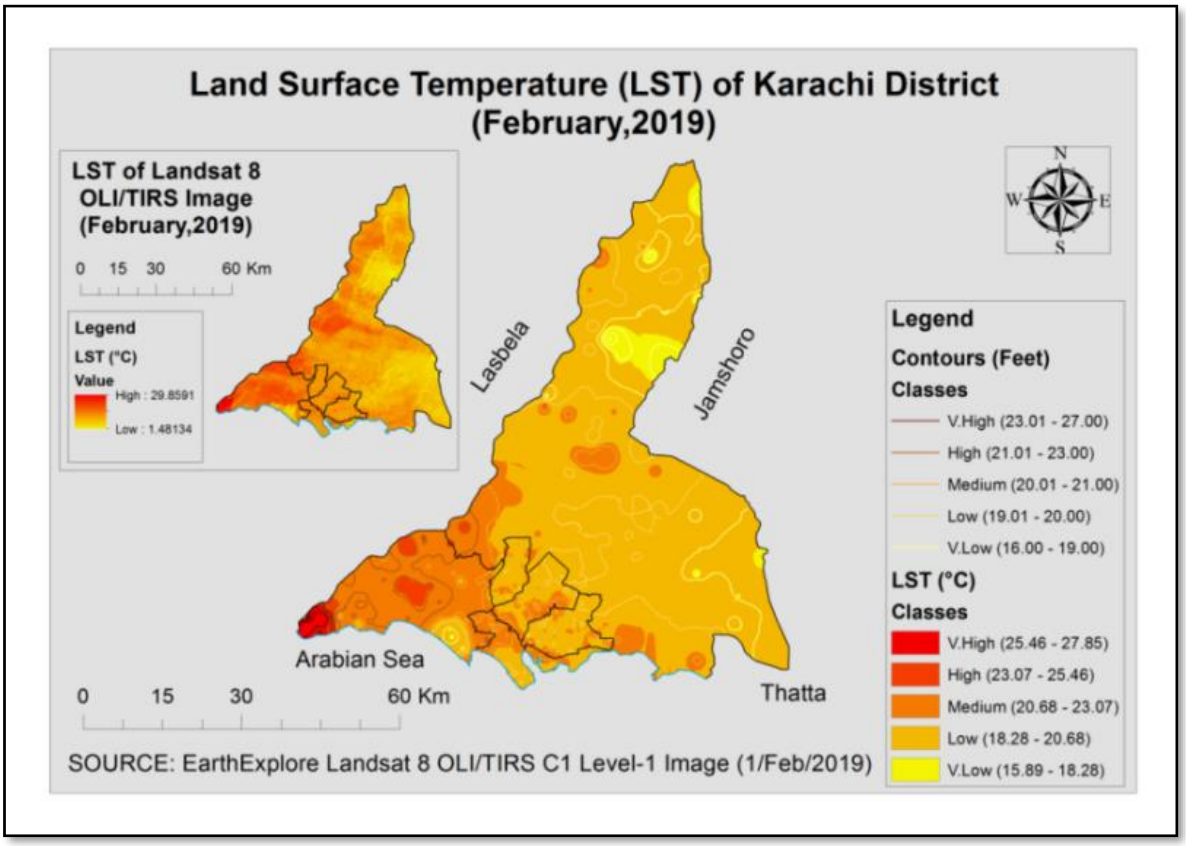

Figure 12. Land Surface Temperature (LST)

Eight, map of vegetation cover defines the natural flora regions on the diverse terrain (Figure 13). The vegetation cover described both human planted and natural grow greeneries. The analysis performed with the practice of the geospatial system on the image of Landsat 8 OLI/TIRS. The map represented the high vegetation (0.20 - 0.45) and low (0.06 - 0.10) that's described the high vegetation is fewer areas covered while low elaborated that it decreased more with the passage of time. Further, the vegetation is an important component to maintain the temperature and directly influenced the UHI.

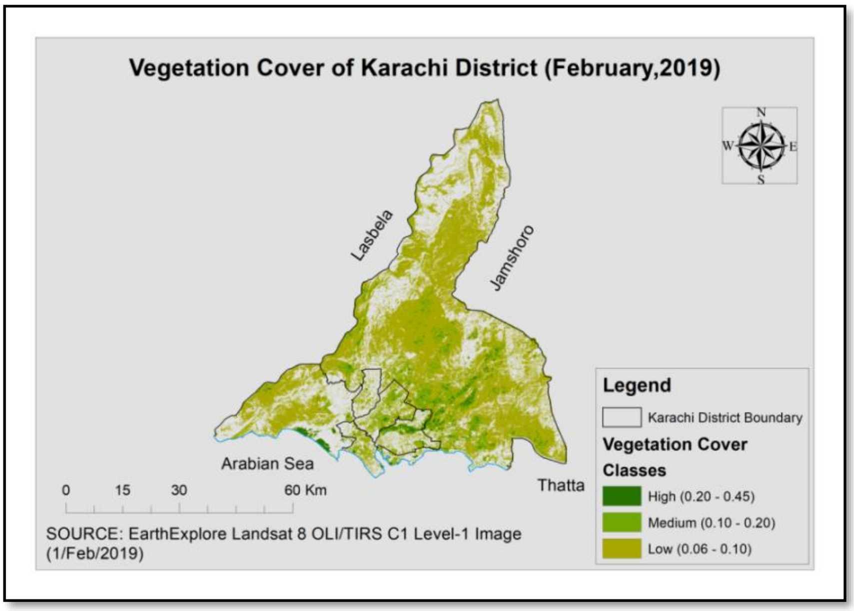

Figure 13. Vegetation Cover

Ninth, the land surface temperature with vegetation cover was examined (Figure 14). The map evaluated through the thermal sensor of LST, through IDW method. Further, the map developed with NDVI and all processes for used to GIS tools as well as, image data of Landsat 8 OLI/TIRS adopted. The map expressed that high-temperature zone covered mostly the southwest region, while low referred the east area. It is diagnosed that high-temperature areas were less or not existing greenery in the region (these areas on high population settlement situated) as compared to the low-temperature location on the high vegetation cover (these regions on less or not exist urban growth).

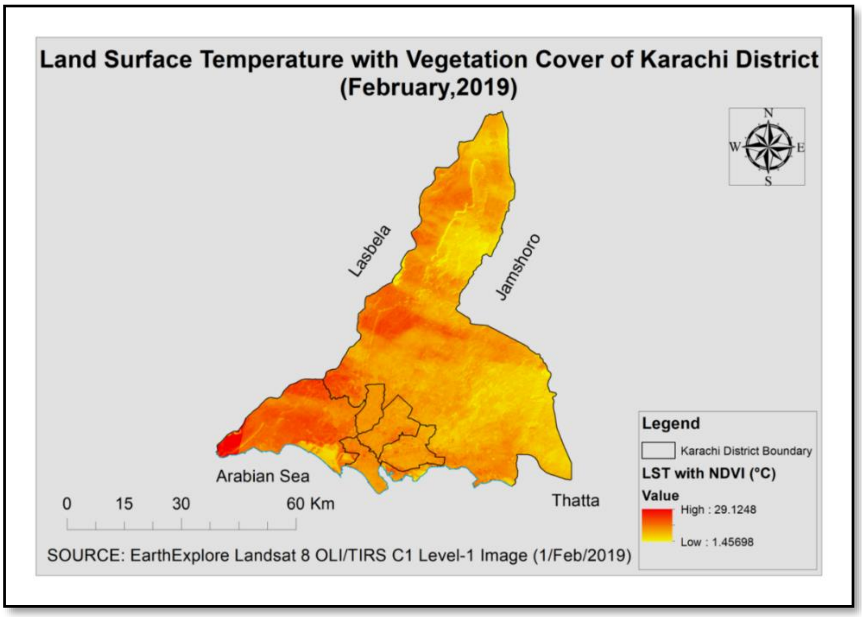

Figure 14. Land Surface Temperature with Vegetation Cover

Tenth, soil moisture index (SMI) was made with the assistance of LST, NDVI, and LST with NDVI of the raster layers (Figure 15). SMI describes the water content or moisture quality in the soil. So, SMI with LST determined the temperature of the soil. Similarly, SMI with NDVI elaborated vegetation covers zones of soil quality. SMI with LST and NDVI through found soil areas of vegetation cover of temperature, using the Landsat 8 OLI/TIRS image. The map explained different classes as high, low, and medium and all of the various results enhanced related to the SMI. The SMI is an important factor for the ground level of water investigation and it's necessary for human life survival. So, the results explained the water level was high (0.06 - 0.18) where the population did not exist (such as the east area on less or not presence settlement) while, the other zones in a low (-0.00 – 0.05) (as southwest zone high populated area). Similarly, SMI with NDVI showed that vegetation lies these zones on high (0.61 – 1.00) water level, while other areas on less (-0.00 – 0.47). SMI with LST and NDVI represented that's the high (0.35 – 1.00) groundwater level on the eastern areas, whereas less or no population in high vegetation lies, and also low (0.00 – 0.28) water level on the west zone where the large amount the population exist and less or not the presence of greenery covers. All SMI studied through observed that are the populated areas decreased water level and vegetation helped to maintain water level so, the population settlements are harmful to the water table as well its increased UHI.

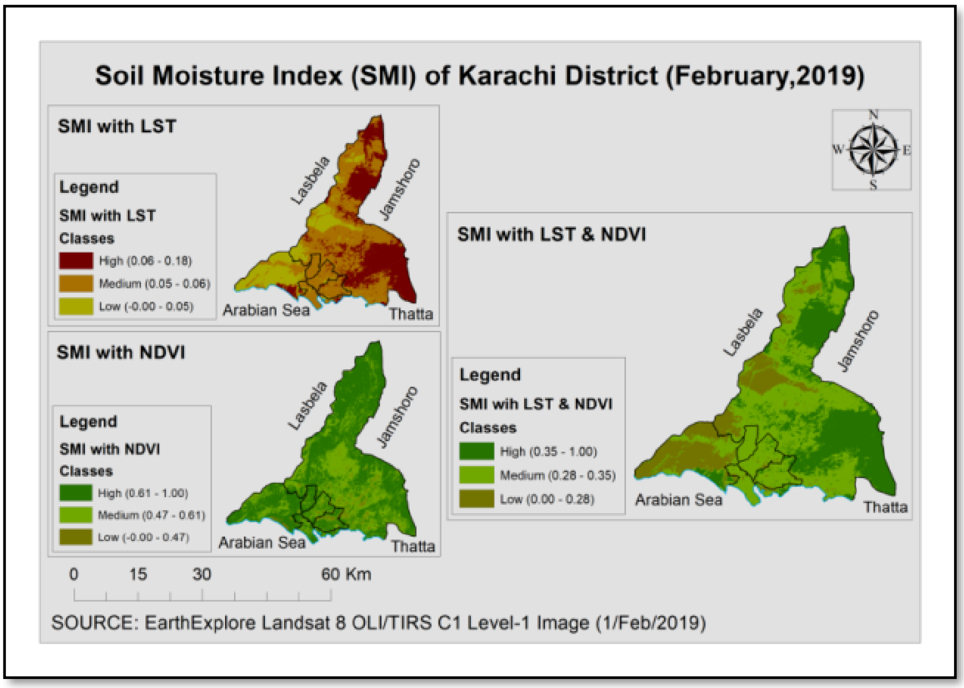

Figure 15. Soil Moisture Index (SMI)

Eleventh, the water body explains the water or moisture amount zones on the earth's exterior (Figure 16). The water body investigated with the relief of GIS approaches on the satellite data of Landsat 8 OLI/TIRS. The water body map was divided into different classes of categories as high, medium and low. The high (0.13 – 0.20) water quantity in the upper side (northwest zone) was Hub Dam area, while the mostly low (0.02 – 0.07) in the south area that's around the Sandspit location. However, all of the areas were surrounded with large population settlements, because of water accessibility and food, which might impact the UHI.

Finally, the map of land use/land cover represented the human-made and natural terrain areas (Figure 17). The terrain regions of land cover showed water, vegetation, mangroves, built up land, and open land. The map was prepared through supervised classification process on the Landsat 8 OLI/TIRS data image. The highest built-up land in the south zone causes of water accessibility, food, and plain fields and this region on high UHI. Further, the open land mostly the north area covered reasons of the hilly zone (not able for population settlement) and water body displayed on the Hub Dam, whereas mangroves situated in the south area.

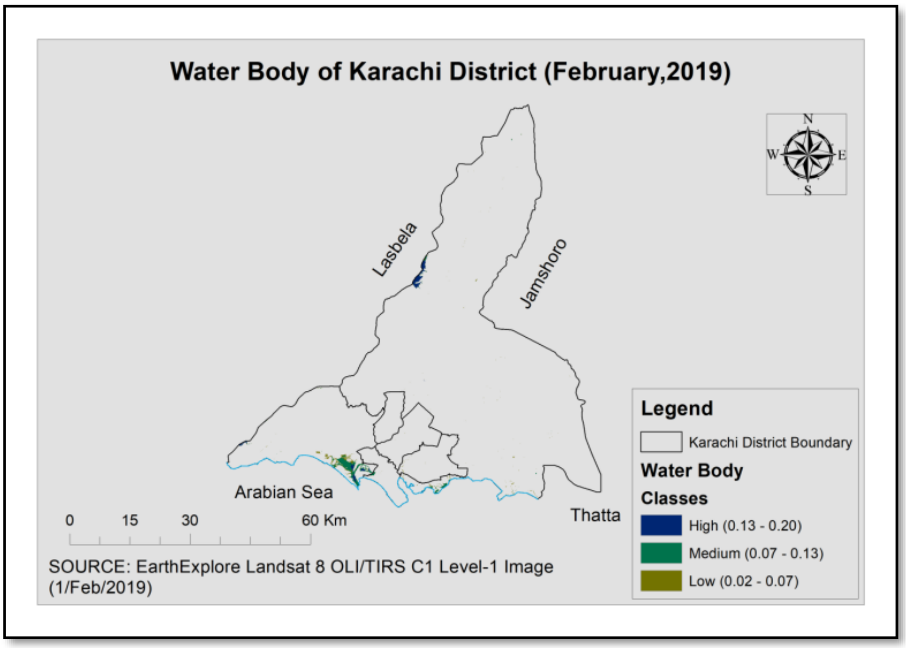

Figure 16. Water Body

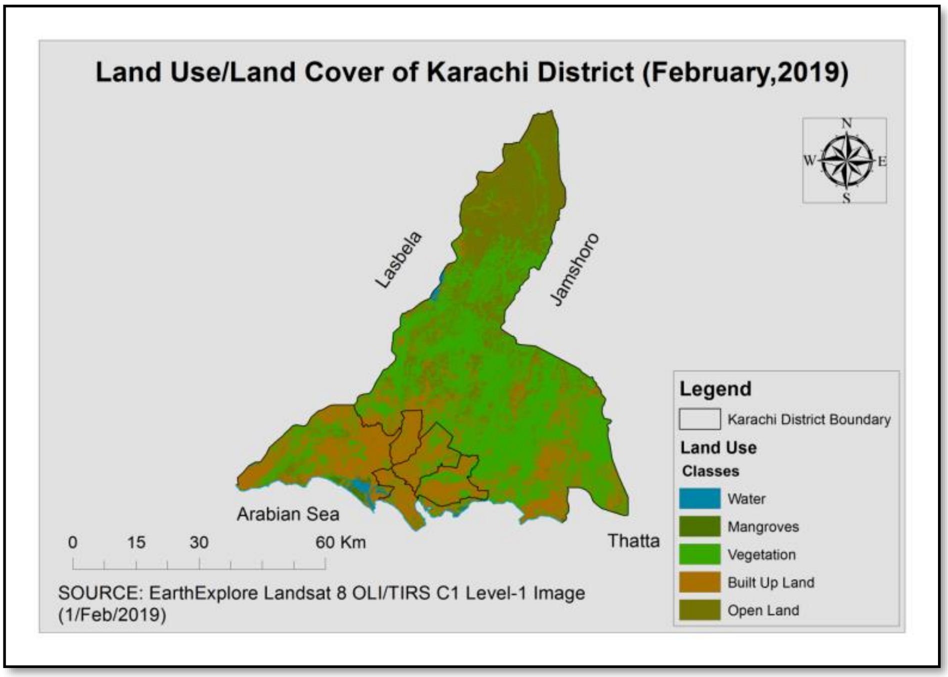

Figure 17. Land Use/Land Cover

Research has investigated the urban expansion model (UEM) (Figure 18). The model map expressed possible appropriate locations that applicable for future urban growth. The model constructed with the helped of Landsat 8 OLI/TIRS and SRTM (DEM) satellite imaginaries (all results data images used) and all processes proceeded through the GIS tools. Hence, the map for all above the parameters of the results adopted for its best consequences in which involved as slope, NDVI, LST, NDII, NDBI, LST with NDVI, NDISI, land use/land cover, water body, population density, and SMI.

Further, no replicating/multiplying results used in the study affected the UEM results. The very high (3.82 – 4.66) potential zone is the southwest field reasons of the water availability high, seafood (causes of the area near to the Arabian Sea), plain zone and various other types of accessibility (such as markets, transportation, occupations, urban area, etc.) more in the plain area compared to the hilly region as well, this zone on the less vegetation occupied that's from the greenery covers less destroyed and it's through the UHI overcome. However, very low (1.45 – 3.22) site covered the study region of the eastern region because of this location on situated the rigid and plateaus plus, high vegetation cover zone, and less accessibility area. The map helps to reduce UHI causes to its give choices for the excellent places of settlement in the vast regions.

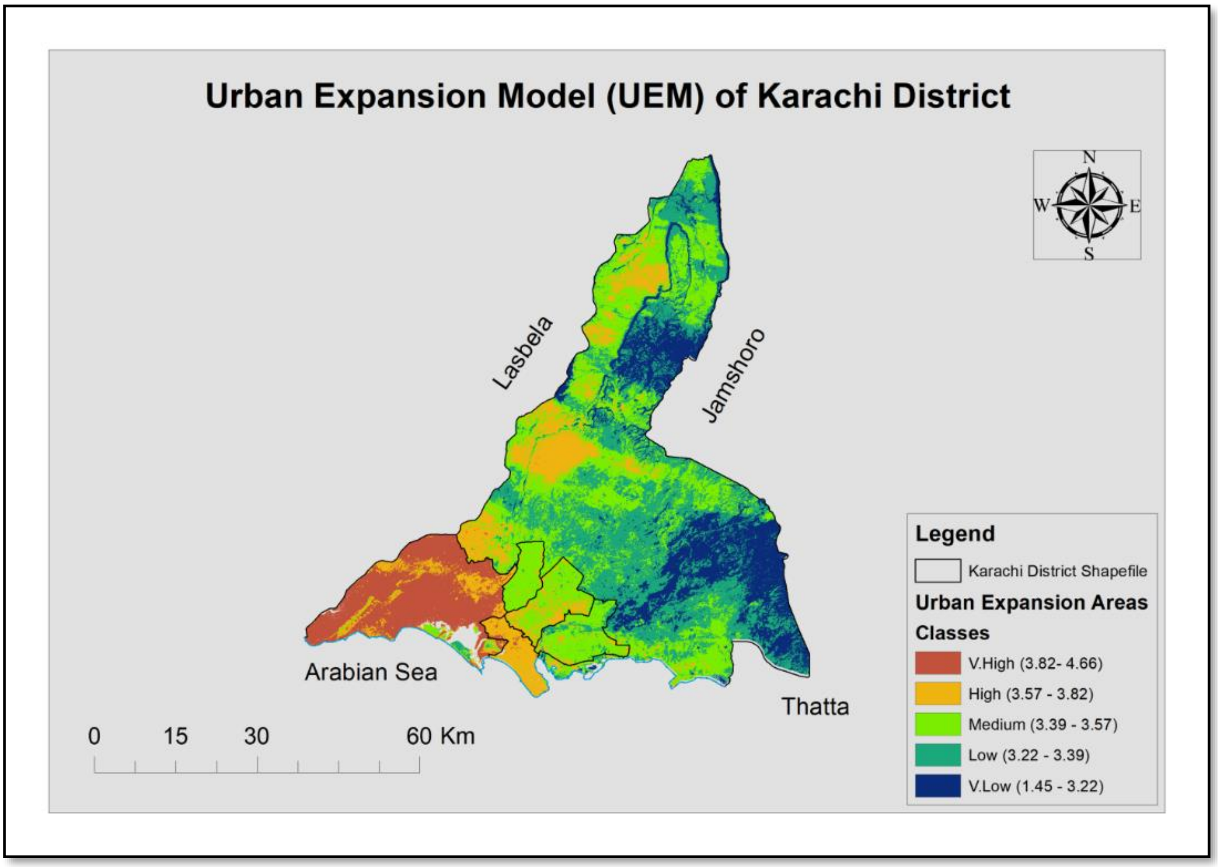

Figure 18. Urban Expansion Model (UEM)

4. DISCUSSION

The urban heat island (UHI) is the largest problem of urban areas across the globe. This problem is directly connected with the magnitude of population. An increase in the population has highest impacts on UHI. This study elaborated different results with the prospective of UHI in the study zone. The results were obtained through the digital elevation model (DEM), population density, slope, built-up land, vegetation cover, land surface temperature (LST), impervious index with visible bands (VIS), land use/land cover, water body, soil moisture index (SMI), impervious surface index with visible bands (VIS) and water index (WI) and land surface temperature with vegetation cover. Thus, these results were obtained with helped of RS/GIS techniques.

The results explained the population density, impervious index with visible bands (blue, green, and red bands), impervious surface index with VIS and WI, and built-up land. Similarly, the UHI was calculated from the distinct techniques as LST and LST with vegetation cover. The soil moisture was evaluated through SMI with LST, SMI with NDVI, and SMI with LST and NDVI. The results of DEM, water body, land use/land cover, vegetation cover, and slope revealed the conditions of natural landscape in the study area. These findings can be used for identifying the possible places of future population settlements. The results of the current study highlighted some new insights that are also explored by previous research studies related to UHI. The new results explored by this research include soil moisture index detected with NDVI and LST with NDVI plus LST measured in a way of LST with NDVI. Furthermore, new study can use urban expansion model (UEM), that contains 11th parameters, for the future growth of the best locations.

The results of this study are interconnected with each other. This study has displayed the factors related to the population settlement like DEM descripted the land surface of the diverse elevations through diagnosis of the plain and hilly regions. Additionally, results also help in identifying the most suitable plains for settlement of population on the earth's surface that could provide more accessibility (as occupation, water, transportation, etc.). Moreover, the hilly areas with low accessibility have less life survival. Furthermore, the most population was settled in the southern zones of the study area constituted of plain fields whereas in the north, the highlands lie. Similarly, the slope analysis has highlighted the plain as well as highland zones along with the population distribution in the researched area. In addition, the population density described the population settlement zones in which plain areas (in the southern region) had high density of population. However, the built-up land, the impervious index with VIS and the impervious surface index with VIS and WI explained the impervious regions that have been covered with pavement materials. Furthermore, these impervious regions lie on the same plain fields with high population density (but in some cases the results related to the population area-wise are different to each other because of the divergent indexes for the different methods adopted).

The LST described the UHI and LST are high in the plain fields of southern zone where population density was high. Similarly, the population also had impacts on the vegetation cover zones as that's the greenery high where settlements were less comparatively. Similarly, the LST with vegetation cover described the vegetation areas in comparison with temperature which was high where population situated with low or even no greenery at all. Moreover, the SMI demonstrated the water content in the soil which was high in less populated settlements. Moreover, the water body explains the moisture or water volume areas on the earth's sphere and its areas around the high population settlement situated because of the water accessibility and seafood (causes of near the Arabian Sea located) easily gained. Hence, the land use/land cover in the various categories were classified as water, built up land, mangroves, vegetation and open land. Furthermore, the built-up land covered in the south zones which is the plain region and high vegetation situated on the less built-up land areas around the water bodies.

However, all the above results indicated that the southern area of the study region is higher UHI zone, because high population settlement in the plain area has wide range of aspects to contribute to UHI (as water, transportation, urban area, seafood, markets, occupation, etc.). The UEM, constructed from all the parameters, explained that Southwest area is very suitable site due to the plain location and the diverse accessibilities (like seafood, water, jobs, transportation, urban area, markets, etc.). As the Southwest region is less vegetated area, thus the least greenery will be destroyed which will ultimately reduce UHI.

5. CONCLUSION

The target of analysis to examine the Urban Heat Island (UHI) that is rapidly increasing with increasing settlements. Further, impervious or built-up lands on the study area were also observed that causes the development of UHI. For the purpose, the satellite images of Landsat 8 OLI/TIRs and SRTM (DEM) images were used. Overall, RS and GIS techniques were used in the whole investigation. Broadly speaking, the UHI cannot be decreased without taking effective decisions and proper implementation while keeping in view the rapidly increasing population. So initially, population sprawl is to be controlled along with selection of most suitable sites for future population growth as explained in UEM analysis in this study. Therefore, to overcome the UHI and to mitigate its severe impacts, following strategies are recommended:

i. Development, management and monitoring of the environment-friendly ecosystem including substantial increase in the vegetation cover which will not only decrease the UHI effect but also will help in pollution reduction. Further, vegetation covers on the building roofs can be encouraged and facilitated to control UHI. Moreover, selection of type of plants for vegetation is quite essential as many species are environment friendly such as Neem while some have side effects as Corynocarpus tree can cause asthma and other pulmonary diseases due to the pollen grains. Most importantly, government should ban illegal cutting of trees.
ii. As infrastructure material of the study region isn't much suitable because of its dark colour which absorb sunlight rays in huge amount which ultimately causes significant increase in the temperature. Therefore, public must try to use lighter or white hue material and white colour paint specially on the top of the building's roof which reflect rays of sunlight and cool the temperature of the ecosystem.
iii. The urban planning structure is to be revised as presently the study area build-up is characterized by closely spaced tall and multi-stories buildings in narrow streets which the heat ultimately gets trapped and does not escape easily. Therefore, it is much essential to formulate and implement a comprehensive and effective infrastructure plan keeping in view aspect of ventilation as well as inter building spaces.
iv. So as to counter the growing population sprawl, the effective measures are to be taken for the development of new urban centers for future keeping sustainable development measures in mind.
v. The solar panels should be used on the rooftops of buildings its help to UHI effects overcome the reasons of buildings absorb fewer sunlight rays.
vi. As urban build-up area is mostly paved and impervious, the heat traps quickly, so the permeable and light-coloured materials must be used which will not absorb heat ultimately reducing heat effects.
vii. The government must take serious steps about the introduction and promotion of ecosystem friendly vehicles which cause less pollution. Moreover, the public transportation should be promoted as well as facilitated by the government and further private vehicle should be demoted to decrease the pollution release in environment.
viii. Some serious measures are to be taken about solid waste management for domestic waste as well as industrial waste. Moreover, recycling can be an effective solution for waste management rather than dumping or burning.
ix. As most of the public has no knowledge about UHI, its causes and severe impacts, therefore, the government along with the collaboration of various organizations can conduct workshops, conferences, seminars about the awareness of UHI. Furthermore, media platforms such as newspapers, FM radios as well as social media can also play a huge rule in spreading awareness about the phenomena.

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