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Floods Enchantment Induce the Significant Expansion of Urban Land Area in Hyderabad Metropolitan Sindh, Pakistan since 1990-2022

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ABSTRACT

The global urban land expansion enforced to the sprawl process in Hyderabad metropolitan is second major urban land in sindh. This enormous pressure of population led to extend through flood in Sindh. The flood occurrence is customary in this region since 1990.The internal migration was predominant force for population toward urban portal land area.

The Geographic Information System (GIS) and Remote Sensing elaborated the changes in land use during 1990-2022.The habitual trends of flood and rate of migration are significantly caused overpopulation in this region.

The result suggested the significant expansion during reported period toward high rate of expansion 61 percentages over the time.

Keywords: *Global, Significant, Geographic Information System, Remote Sensing, Metropolitan, Sprawl, Flood.*

INTRODUCTION

Built-up land utilize spreading out across the world which lead changes in land-use and surrounding environment (J. Liu et al., 2021). Population increased significantly in last five decades globally which has led an enormous pressure on the environmental conditions of the world (Meerow & Newell, 2019; Meerow, Newell, & Stults, 2016). Land use change is being most significant subject of the world recently due to rapidly increasing of urban areas in the entire world. World is facing rapid growth in population due to that the urban expansion are taking place at a large scale. Urban areas are facing much pressure than that of the rural area due to this population increase (Elmqvist et al., 2019).

In recent times the internal migration rate is a big issue of the world, peoples migrate from rural to urban for better facilities such as health, education and economic resources which has cased urban expansion and simultaneously it has posed raising temperature of Earth atmosphere (Grimm et al., 2008; Mishra, Ganguly, Nijssen, & Lettenmaier, 2015; Seto, Güneralp, & Hutyra, 2012) Many researchers have reported that geo-environmental conditions of the globe are changed due to the changing patterns of Land cover. Human settlements are most important issue of Land use and land cover change thus they have a strong correlation with environment and its preservation (Alexander et al., 2017). One of the single predominantly result of urbanization is its impact on regional surface temperature and local air temperature(Roberts, Dennison, Roth, Dudley, & Hulley, 2015). Nowadays approximately 56% of the global inhabitants reside inside metropolitan surroundings and the velocity of metropolitan citizens is estimated raise to 69% by 2050 (United Nation Report, 2018).

Urban population in Asia is growing faster and has never grown before with that faster rate in the history; it is projected that more than 1.1 billion people in Asia will live in urban areas by 2030 (Rauniyar & Kanbur, 2010). The intensity of increasing areas of city in Pakistan is one of the top surrounded by South Asian countries and nearer regions. Pakistan city residents grow from 6.9 million

in 1950, and in 1993 were 45.3 million, 18 eighty percentage to 34 thirty four percentage of the total inhabitants), whereas the taken as a whole inhabitants grow from 39.5 million to 136 million throughout the similar episode. City size also increased; such as Karachi grew from approximately over one million in 1951 to about 9 million in 1993, and Lahore grew from approximately little less than one million to 4.5 million during the same period (Blank, Clary, & Nichiporuk, 2014; BUTT, 1996; Jan & Iqbal, 2008). Countrywide, whereas in 1951, Pakistan had nine (09) cities with 100,000 inhabitants in urban areas. Which, one urban city was over one million, by 1993 about 39 cities were having population in excess of 100,000 of which, seven (07) were having population over one million. The urban population growth is expected to remain higher than growth of national and as well as rural population; by the year 2000, the built-up population of the country increased to 38 percent of the total national population. throughout this episode, the population and residents of Karachi and Lahore amplified to more than 12 million and 6 million respectively (Blank et al., 2014; BUTT, 1996). This would rank them 12th and 20th in terms of population of major urban centers in the developing world (Blank et al., 2014; Burki, 1973; Jan & Iqbal, 2008).

Population growth has caused rapid Urbanization globally. In South Asia, Pakistan is the most Urbanized country and its annual increase in Urban areas 3% (Kotkin & Cox, 2013). Along with natural enlargement in inhabitants, the exterior and interior relocation to urban city area is major factors in the increase in Urbanization in Pakistan. This increase in population and increase urban area are the key factors of urban heat island. During last the 3 decades, Urbanization rate has increased significantly in Pakistan also which has reached at 52.6 percent from 17.9 percent, only between the duration of 1978 to 2012, with the growth rate of 1.02 percent per year.

Sindh is the most urbanized province of Pakistan (Basit, Sajjad, Khan, Ali, & Kurshid, 2018); after mega floods 2010, majority of the cities of the province such as Karachi, Hyderabad, Sukkur, Larkana, Mirpurkhas, Dadu etc., got rapid growth. The major population was displaced due to inundation of rural areas (Basit et al., 2018). Hyderabad city sheltered hundreds of the families during floods 2010. Since Hyderabad has a very pleasant weather and is near to industrial zones of the province i.e., Kotri industrial zone, Hyderabad industrial zone and Noriabad industrial zone where people could get jobs or could create alternative income sources, therefore, most of the families settled in different parts of Hyderabad after that flood.

Background of study

Historically Hyderabad was found in 1768. Hyderabad city (the study area) is the second chief urban center in Sindh region after Karachi; its early Sindhi emperor of the vicinity commencing whom the Hyderabad study area derived its prior first name Neroon Kot. Its olden times date back to medieval historical epoch, while in the part south-east of Hyderabad barren hills known as Ganjo Takkar, close to mountainous hill area, was second-hand as a consign of adoration and worship. Situated on direction of the mainly north mound of the Ganjo Takkar culminating point, situated on eastern side of Indus mighty River, by means of an spread more than three hillock division of the mainly north hill of the Ganjo Takkar range 32 thirty two miles. Its population is increasing day by day. Previously, Hyderabad was a largest district of which was braked in 2005 and Tando Allah Yar districts, Matiari districts and Tando Mohammad Khan districts were formed. Hyderabad district is divided into five Talukas (Tehsils) Latifabad, Qasimabad, Hyderabad city, Hyderabad rural and Tando Jam. Moreover, Hyderabad is a divisional headquarters. Most of the population of the district lives in three urban talukas: Latifabad, Qasimabad and Hyderabad city. The average percentage in the population increase in Hyderabad city from 1901 to 1911 was 2.8%, from 1911 to 1921 was 6.3%, from 1921 to 1931 it was 15.6%, from 1931 to 1941 it was 14.4%, from 1941 to 1951 it was 17.6%, from 1951 to 1961 it was 44.1% (this large increase in population of Hyderabad is attributed to the migration after partition of India) and from 1961 to 2003 with the growth rate of was 1.4% whereas its increase rate from 2019 to 2020 was 1.93%. (Sahito & Memon, 2016) This fast and substantial Urbanization has intensive impacts on the environment of modern Pakistan. Although this Urbanization has offered economic resources, advance structure and enhanced industrial development but has also created many environmental issues such as

increase in temperature. Therefore, this study assesses the impact of Urbanization on Urban climate in Hyderabad Sindh.

Geography of the study area

Hyderabad is located in South of Pakistan and is the second largest city of Sindh province. Which is cover 300 Square Kilometre. Study area located on following geographical coordinates 25° 22' 0" North Latitude and 68° 22' 0" East Longitude. Indus mighty River flows by the side of the western district boundary line. Hyderabad study area is the most important manufacturing and business-related centre of the interior districts of sindh province and is glowing and well associated with other cities of the country by air, road and railway.

Map of study area

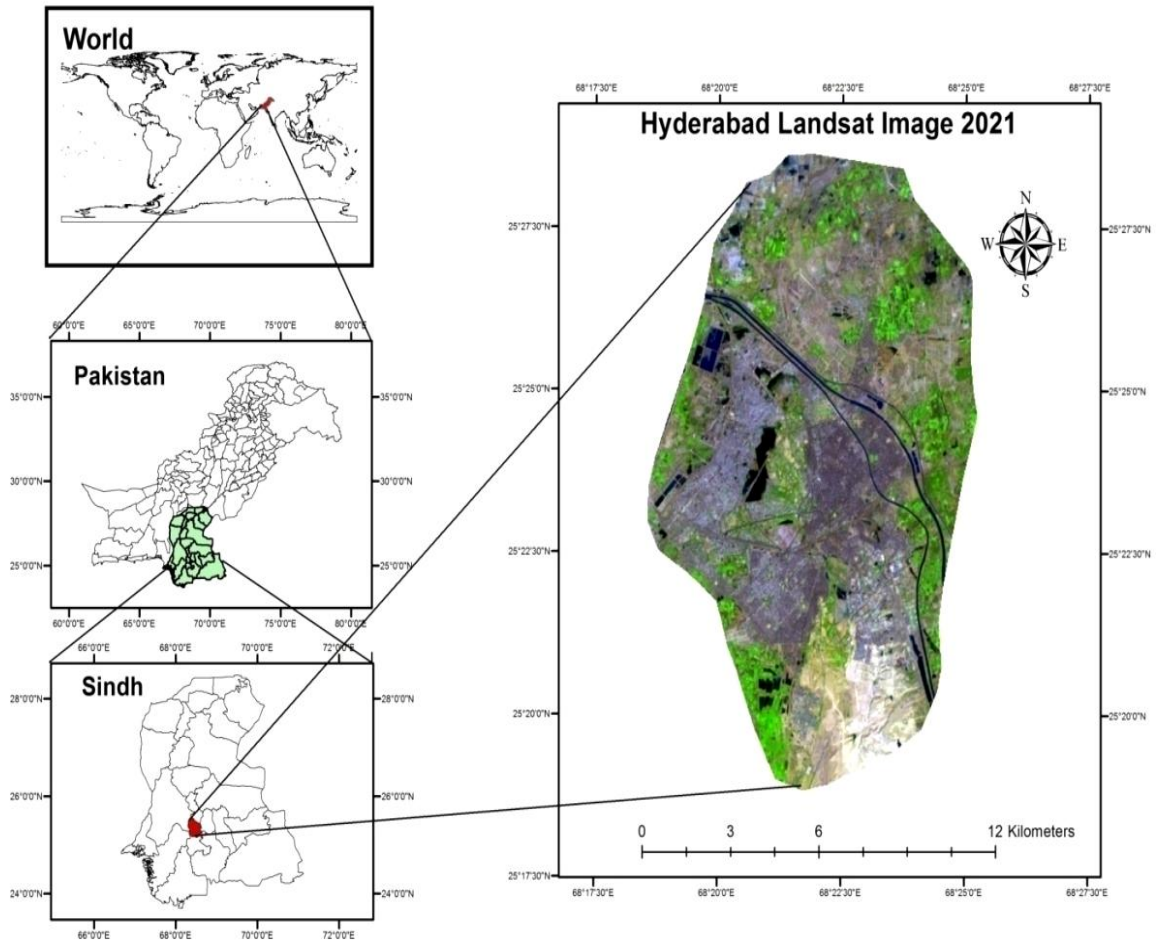

Figure. Sowing Study area inset Map (Source Survey of Pakistan and USGS.)

Aim of the research

Aim of this assessment is to discover the causes of urban sprawl of Hyderabad city and its impacts on the climatic condition of the area which is increasing rapidly due to various socio-economic activities. In order to achieve this purpose followings objective are set.

Objectives of the study

1. To investigate Spatio-temporal rate of unban expansion of Hyderabad from 1990 to 2022 due to flood.

2. To examine urban expansion and its dimensions in the study area and its impact on weather condition of the city from 1990 to 2022.

RESEARCH METHODOLOGY

In this research study assesses temporal and spatial convert, changes in land cover and land-use in Hyderabad from 1990 to 2022. To find out the causes of urban sprawl and its possible impacts on climatic elements in study area. The methodology is actual frame work of research, logical and intelligible arrangement based of views, values and belief, that given the direction of research (Kara, 2015). Remote sensing is a process to obtain data of an object without being there physically by acquiring data through Satellite, Aircraft, Drone; balloon and so on can be used to collect spatial data. Remote sensing is used to done with the help of mechanical devices known as remote sensors. These devices are improved with the time to obtain data where human cannot reach physically or to get large amount of data which is difficult and costly. Some satellites data is available on the free of cost with high quality. Over 30 Years of Image Acquisition, there's been 8 Landsat satellites from Landsat 1 which was launched in July 23, 1972 to Landsat 8 lunched on February 11, 2013 (landsat.usgs.gov/landsat-1-history). Landsat has different spectral bands sets with time the Landsat came with more bands and High spatial resolutions.

Data collection

This research study has useful different procedures and techniques to collect research data. This current research study is grouping of primary and secondary data. Following three dimension assessments will be carried out: Spatio-temporal assessment of Hyderabad city, meteorological data analysis of the study area, population change in the light of spatial expansion.

Primary data

The most important primary field data were acquired instigation through survey examination in the field. This primary data include answers to the various questions belongs to Spatio-temporal dynamics of urban land cover changes and variation in climatic elements in the study area, population change in the light of flood and spatial expansion. On the basis of preceding awareness of the study area assessment a concise questionnaire examination through the supplementary information starting from prior research related to the study area was conducted. A categorization plot was made for this purpose which incorporated urbanized area, vegetative cover, barren land, and water bodies. The categorization method prepared in this study give an extensive classification where land-cover classes were recognized through classification scheme.

Secondary data

The secondary Landsat Data will be acquired from Landsat 3 Landsat 5 Landsat 8 and Landsat 9 respectively from USGS (United State Geological Survey) website with the interval of five years 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2022. Meteorological data will be collected from Pakistan Metrological Department (PMD) from January 1990 to December 2022; the climatic data include weather elements such as Temperature and Rainfall. The population data will be collected from Pakistan Bureau of Statistics. And other basic data, including base maps, local maps, topographic maps and other ground data will be collected from local authorities.

Sources of data collection from usgs

No.	Satellite	Date	Scale/ Spatial resolution	Area/Location WRS-2
1	(TM)-Landsat 4-5 Thematic Mapper	28-04-1998	30 meters	Path: 152 Row: 42
2	(ETM+)-Landsat 7 Enhanced Thematic Mapper Plus	20-05-2004	30 meters	Path: 152 Row: 42
3	(TM)-Landsat 4-5 Thematic Mapper	23-04-2009	30 meters	Path: 152 Row: 42
4	(TIRS)-Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor	07-04-2014	30 meters	Path: 152 Row: 42
5	(OLI) -Landsat 8 Operational Land Imager and (TIRS)-Thermal Infrared Sensor	19-04-2020	30 meters	Path: 152 Row: 42

Table details of the data and the source of its collection from USGS

In this study, five (05) Landsat data were acquired, Thematic Mapper Land-sat 4-5 and Enhanced Thematic Mapper Plus Land-sat 7, for high resolution latest Operational Land Imager Landsat 8. Fairly accurate scene volume is 170 kilo-meter north-south by 183 kilo-meter east-west, 106 miles by 114 miles, (source usgs.gov.com). Table 2.1 presents the data collected from Landsat.

In this regard (07) Landsat images 1 Level-1 for the years 1990, 1995, 2000, 2005, 2010, 2015 and 2021 with interval of five years from Landsat 3 Landsat 5 Landsat 8 and Landsat 9 respectively were acquired from www.earthexplorer.usgs.gov.com Images were collected with (WRS-2) path 152 and row 42 with the resolution of 30 meters/pixel. The characteristics of Landsat are given in Table: 2.2 and Table: 2.3, Table: 2.4 The compiled information from the images is given in Table 2.1. The geo-referencing properties of all the images were the same therefore, software were used viz: such as ArcMap 10.5, Environment for visualizing images (ENVI). Moreover MS Word and Microsoft Excel were used for final finding and graphical representation.

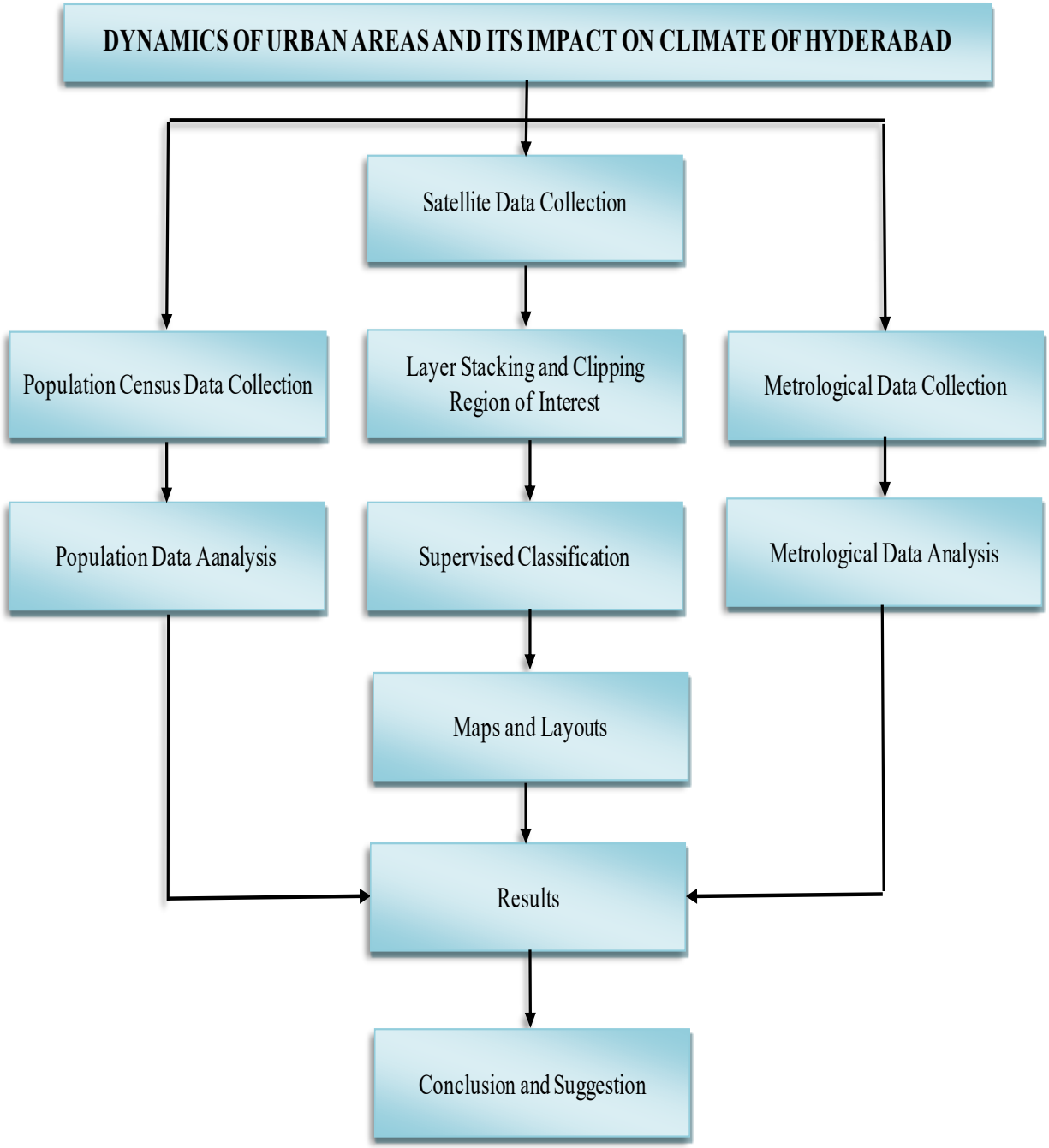

Figure Schematic Research Frameworks

Accuracy assessment

Accuracy assessment is significant part of Landsat Image classification; therefore, accuracy assessment calculation for the images of 1990, 1995, 2000, 2005, 2010, 2015, 2020 and 2022 following technique will be used. Accuracy assessment classified Landsat image compared with land cover ground data. Actual ground data will be collected with the help of Google Earth; same will be verified through GPS during field. Ground Truth Points (GTPs) used for each class to have a accurate results. User's precision communicate to slip-up of organize order. Creator come Producer precision communicate to mistake of exclusion. The Kappa index measures agreement between truth values and classification.

DATA ANALYSIS

In this assessment research data were analyzed with help of various software's, Arc GIS 10.5 and Microsoft Excel. While another source of data analysis was the social science statistical software package like SPSS. The results were displayed in the form of tables, graphics and layouts prepared in ArcGIS software and Microsoft Excel. The analysis of data in different classifications including land surface temperature as LST and normalized different pattern for scheme of classification developed main four classes as built-up, agriculture, water body and barrenland were recognized and maximum likelihood supervised classification assume and analyzed through the Arc GIS 10.5 software.

Spatio-temporal assessment

Data processing

In data processing of land-sat image through changing various bands in software for four classes for built-up as sealed surfaces, concrete buildings, metallic and un-metallic roads we mean urbanized area.

The description of undergrowth and agriculture in this assessment represent to the entire vegetation, all aroma crops in the vicinity of Hyderabad, bushes, grassland as sound as water flora found in the study area Hyderabad. In the same way all the unoccupied areas, discarded fields, space of exposed soil consider as selected as un-wrap spot. Indus mighty River, water channels and all the marshy and swampy area have been classify as Waterbody. lastly throughout categorization of all objects with spectral declaration fewer than 30 meters were excess as diverse class.

After that, usual procedures used in land cover changes and land use in four classification scheme has been adopted as a systematic manner. Land cover change and land use are visible all over the study area. The calculation and computation of the study area is obtainable in hectares and the seven land sate images in land cover types for each study period with interval of five years were identified.

Lastly, we contrasted the consequences obtain throughout spatial mold in Environment for Visualizing Image and ArcGIS 10.5. This variety of option provides a rational foundation for the assessment. Figure 2.1 presents a schematic diagram of this study.

Composing bands

The Image of Landsat were added into ArcMap Landsat Image are Multispectral each image came with one single bands can be displayed on the gray scale colors, to composing the bands into one single image we use ArcMap tool image analysis where seven bands were selected from 1-7 to composite into one image then it can be displayed with color through RGB.

Geo-referencing of the obtained image

The data of Landsat come with pre-processed corrected and geo-referenced from earthexplore.usgs.gov with format of (geo-tiff) which can store coordinates. But verifying the data samples of coordinates which were collected during the field work are used to verify geo-referenced with help of high resolution image of Google earth.

Making Shapefile for the extraction of study area

A shape-file from polygon is a trouble-free design for store and stocks the study area location and geometric position, characteristic information on the earth surface for geographic features. Geographic features like boundary represent through polygon shape file. Places through symbolization as point's shapefile, Rivers and roads railway lines represent through poly lines. (source arcgis.com). The polygon shape-file was created to form boundary of area and extraction, the process of creating shape-file. The

google-earth Pro has high declaration image with best resolution which were utilize to cover area with polygons added in Google earth then saved it into (kml format), then the kml format was converted into layers in ArcMap by using Arc Map's conversion tools (from kml to layers), then the layer data were exported into shape-file.

Extracting the areas

The image of Landsat come with large size of area to minimizing the area to closely study the area the extract by mask in ArcMap tools were used to for extraction of the area by adding shape-file which create boundary of the area then the outside of the area was removed by ArcMap tool

Combination of bands

The Landsat image acquires multispectral which divide the electromagnetic spectrum into many different bands. In the study every band were tested to analyze and to distinguish between water, settlement, vegetation and bare land, finally the Natural Color Composition and False Color Composition were used. The natural color composition was used to understand study area and was compared with high resolution images of google earth. The false color composition was used to separate vegetation from land use.

Landsat image classification

The Image classification is the process of assigning a pixel into different classes of land use land cover to make sets of features in maps, there are two commonly used process of classification are supervised and unsupervised, Unsupervised classification is software base analysis where common pixel characterize into classes while supervised classification is training base human analysis, where groups of pixel taken as a training samples from ground truth point, Arial imagery, high resolution imagery, and human interpretation to choose few sets of training samples then the software will apply this into whole image and to categorize into different classes, the most common algorithm is used in the supervise classification are maximum likelihood and minimum-distance classification.

In this examine study land cover and land maps were classified into four classes Settlement, bare land, vegetation, and water. By assigning training samples in the different classes, the algorithm was set maximum likelihood in the supervise classification.

Maximum Likelihood Supervised classification

The data were found in ENVI and the Arc GIS 10.5 software satellite data in 1990, 1995 2000, 2010, 2015 and 2022. In ENVI and Arc GIS, it was used in the supervised classification the process of 40 tanning sample, 40 tanning for each given variable before maximum likelihood supervised image classification (Boori, Choudhary, Kupriyanov, & Kovelskiy, 2016; Z. Liu, Zhang, & Golubchikov, 2019)

Population data analysis in the light of spatial expansion

The population is described as group of same species interbreeding and inhabited in given area. The scientific study of the population investigating individual interaction with population each to other and how the whole population interrelation within its environment (Lebreton, Burnham, Clobert, & Anderson, 1992).The same parameters were particularly important density, age structure, death rate, birth rate, population size and Sex ratio(Dodge & Commenges, 2006).

The Hyderabad estimated has been lived 1.7 million in three urban tehsils. The average percentage in the population increase in Hyderabad city from 1901 to 1911 was 2.8%, from 1911 to 1921 was 6.3%, from 1921 to 1931 it was 15.6%, from 1931 to 1941 it was 14.4%, from 1941 to 1951 it was 17.6%,

from 1951 to 1961 it was 44.1% (this large increase in population of Hyderabad is attributed to the migration after partition of India) and from 1961 to 2003 with the growth rate of was 1.4% whereas its increase rate is from 2019 to 2020 was 1.93% (Sahito & Memon, 2016).

TEHSIL	POPULATION
Hyderabad City	756,906
Latifabad	672,504
Qasimabad	304,899

Table Demonstrated the population of census 2017

(Source: Statistics Bureau of Pakistan).

CENSUS	POPULATION
1981	**751,529**
1998	1,166,894
2017	1734309

Table Shows the population of census 1981, 1998, and 2017

(Source: Statistics Bureau of Pakistan).

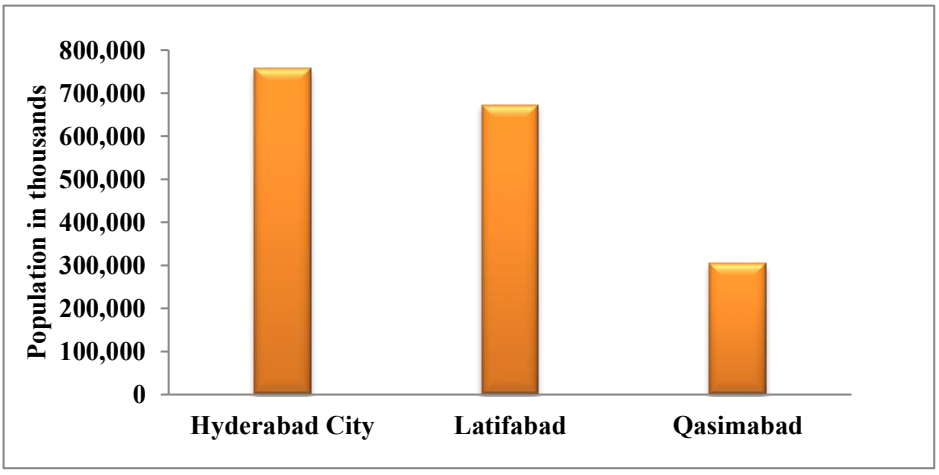

Figure Shows urban population of census 2017.

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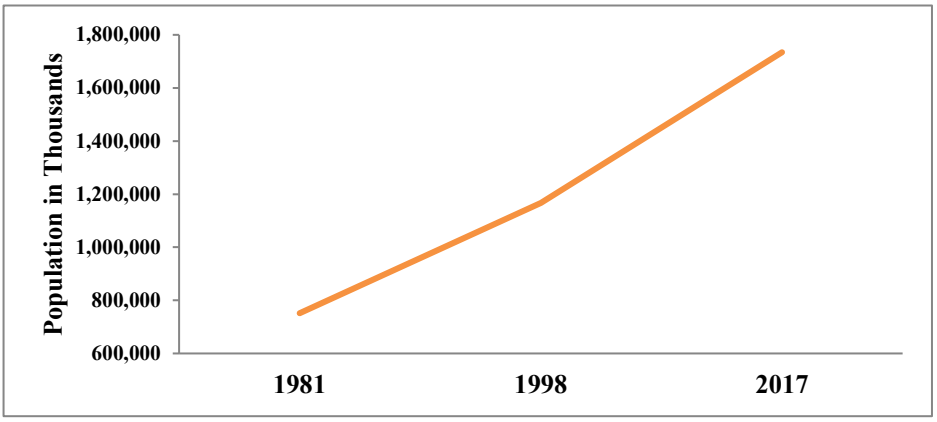

Figure shows urban population of census 1981, 1998, 2017

The figure reflected that the total urban population of Hyderabad in the 1981census was 751,529 and the census of the urban population reached 1,166,894 in census of 1998. The most recent report from 2017 showed that the total urban population was 1734309 (Figure 3.2). In census of 1998, Latifabad Tehsil had the largest population, while Qasimabad Tehsil had the lowest. According to data of 2017 Hyderabad city Tehsil had the highest population, while Qasimabad Tehsil had the lowest population. The growth rate of population decreases from 1981 to 2021 that decline from 3.36% to 1.95%.It was found that the population had been increased rapidly from census of 1981 to 2017 that has reached from 751529 to 1734309 of total urban population of three Tehsils. In census of 1998, Latifabad Tehsil had the largest population, while Qasimabad Tehsil had the lowest. According to data of 2017 Hyderabad city Tehsil had the highest population, while Qasimabad Tehsil had the lowest population (Figure 3.1 and Table 3.3).

RESULTS

Classification of land-use and land-cover changes in hyderabad

Classes	1990	1995	2000	2005	2010	2015	2021
Built-up	1402.6	1640.5	4796.4	4819.2	5696.5	8021.9	9747.1
Agriculture	5271.9	5075.4	3990.7	3861.0	3504.2	2860.8	2567.6
Waterbody	531.1	571.7	588.5	554.3	571.6	517.8	551.1
Barrenland	7221.1	7139.3	5050.7	5192.3	4654.1	3025.6	1560.8

Hyderabad city is facing rapid expansion in its built-up; the obtained and analyzed images reveals that from 1990 and 2021 different areas of the city are expanding where settlements is replacing natural habitats; the scale of this change was high during 2010 to 2021. Comparing to Hyderabad urban area with other districts of Sindh, it can be seen that this area has high rate of expansion and is still increasing rapidly than that of its surroundings towns. Land area of Hyderabad is classified into four classes (Table 4.1 and Figure4.1); the obtained data Land cover and Land use and distribution is gathered commencing each map and is discussed below.

Table Land-use and land-cover changes in Hyderabad area in Hectares.

Built-up pattern in the study area covered 9.7 percentage of the total land in 1990 which expanded to 67.6 percentages in 2021. Barrenland has decreased to 10.8% in 2021 which was 50.1% in 1990 barren. Agriculture was 36.5% of the total studied land in 1990 which decreased in 2021 and reached to 17.8%. Water body has also amplified and decreased, in 1990 water was 3.7 % of the total studied land which has increased to 3.8 % in 2021, the increase in Waterbody from 3.7% to 3.8% due to reduction in agriculture land results decline in agriculture surface water, the same vacuum cover by built-up, as fresh water reservoirs, municipal water in open area. The obtained data for 1990 shows that Hyderabad city covered 9.7% of total land (1402.60 hectares), Barrenland 10.8% (7221.10 hectares), Agriculture 36.5% (5271.90 hectares) and water bodies covered 3.7% (531.10 hectares).

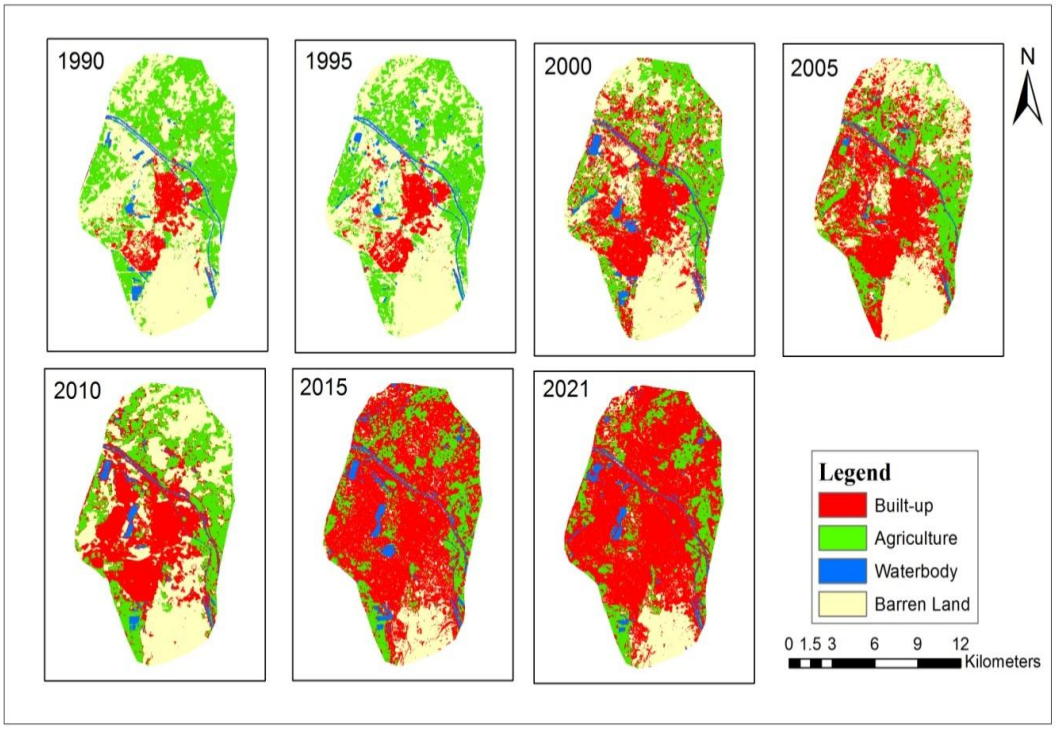

Figure Comparative Analysis of land cover and land use changes from 1990 to 2021

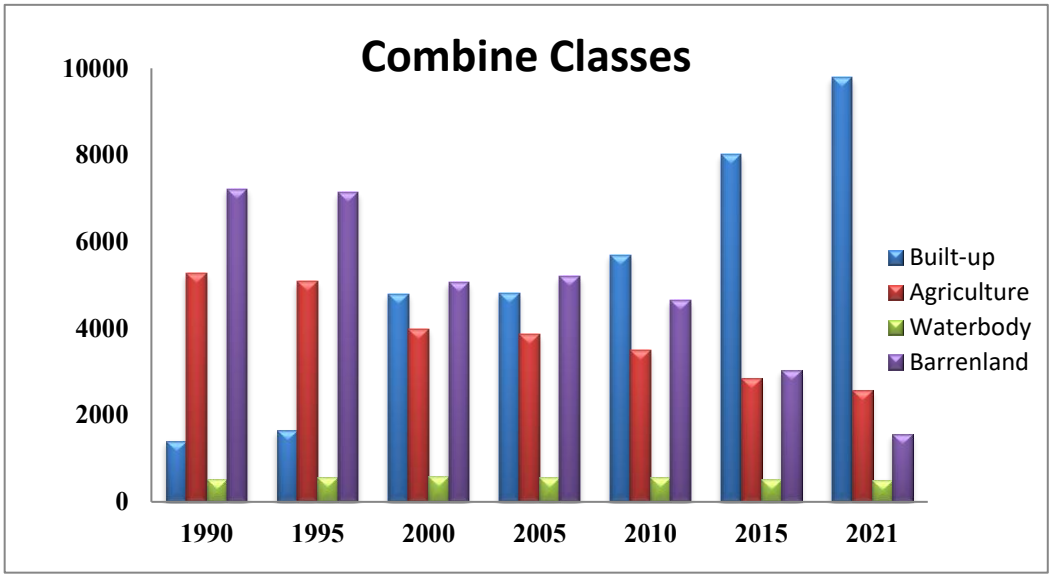

Figure Comparative graphical representations of Maximum Likelihood Supervised Classification of land-sat images 1990, 1995, 2000, 2005, 2010, 2015, 2021.

Built-up Changes in Hyderabad from 1990 to 2021

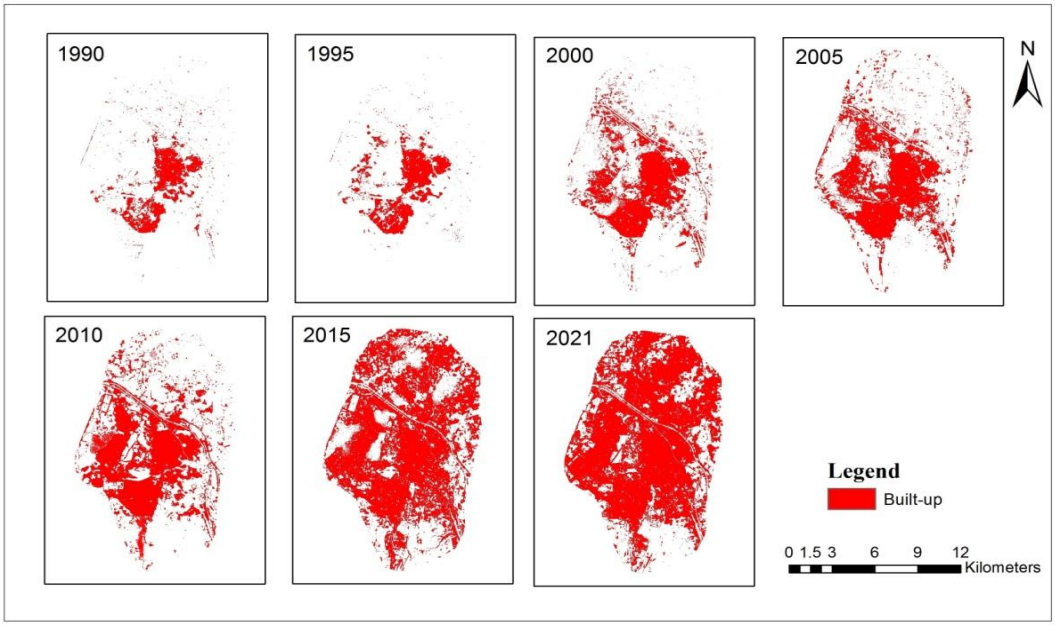

Figure Built-up changes in Hyderabad from 1990 to 2021.

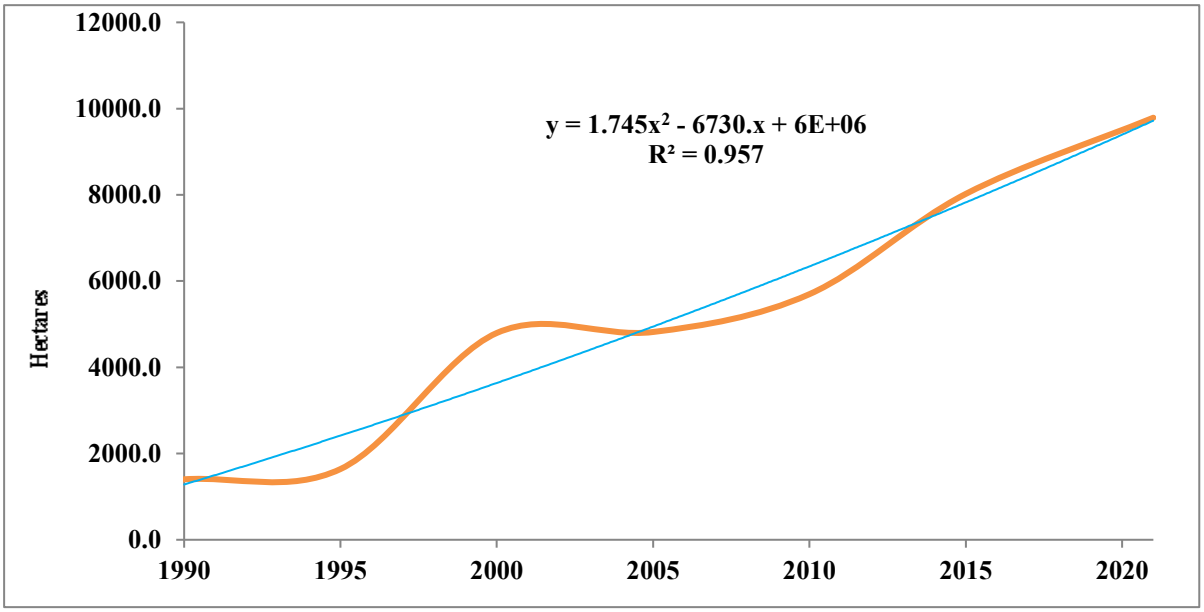

Figure graphical representations of Built-up changes in study area from 1990 to 2021.

The obtained data shows that the area under built-up was 1640.5 hectares in 1995 and it reached to 4819.20 hectares in 2005, in 2015 it has reached to 8021.90 hectares and reached to 9747.10 hectares in 2021. The most interesting point here is that the area under Built-up has increased rapidly after 2010. The R^2 value of polynomial regression is 0.957 of the data for all the studied years (Figure). This was also deep-rooted in field questionnaire survey to compare the obtained data from land-sat satellite images. The interviews were taken from the old residents of Hyderabad three urban Taluka's who also said that the Built-up has increased in this area rapidly after the mega floods 2010 and 2012. Since the weather in this part of the province is pleasant. Moreover, the rate of residential Plots around the city is cheaper as compared to other surrounding areas which have attracted peoples to come and settle at this part. The nearness of industrial zones and major educational public sectors is another cause of this rapid increase due to pull factor migration in this part of Hyderabad.

Agriculture Changes in Hyderabad from 1990 to 2021

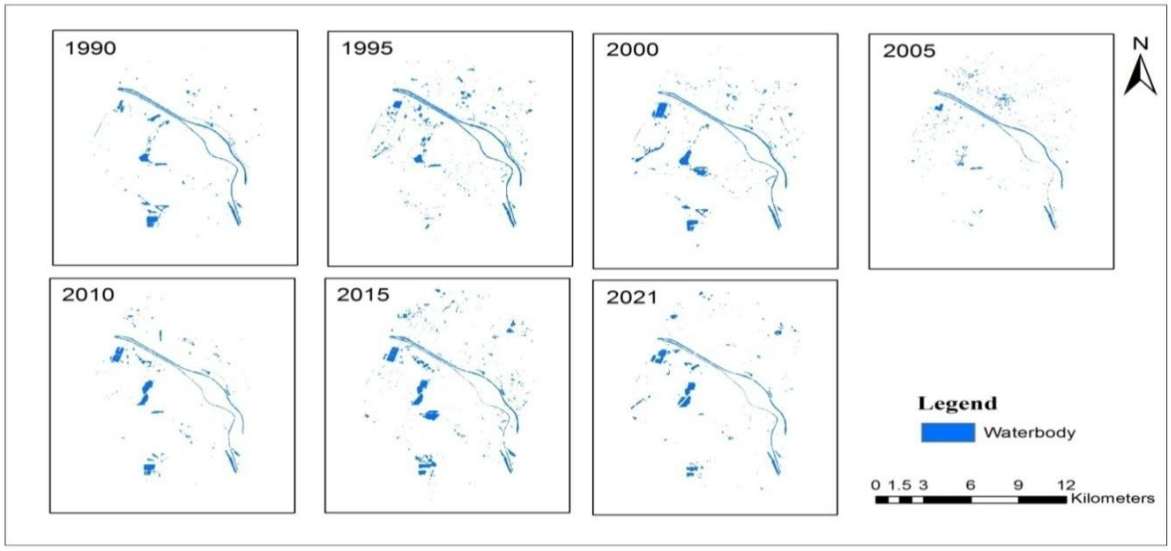

Figure Agriculture changes in Hyderabad from 1990 to 2021

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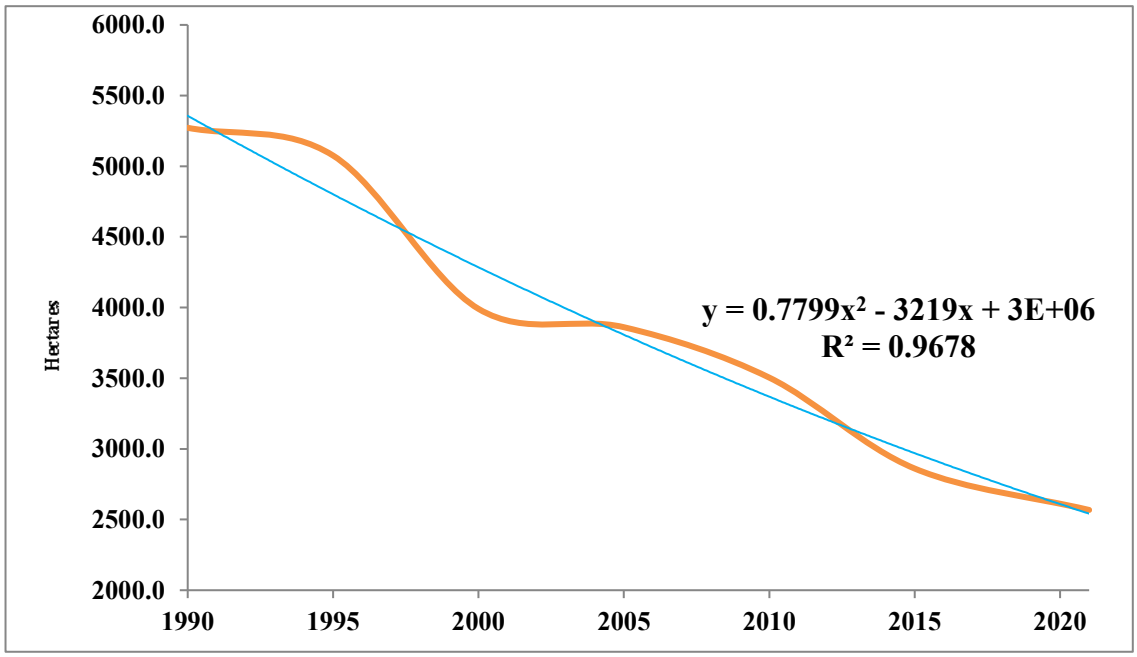


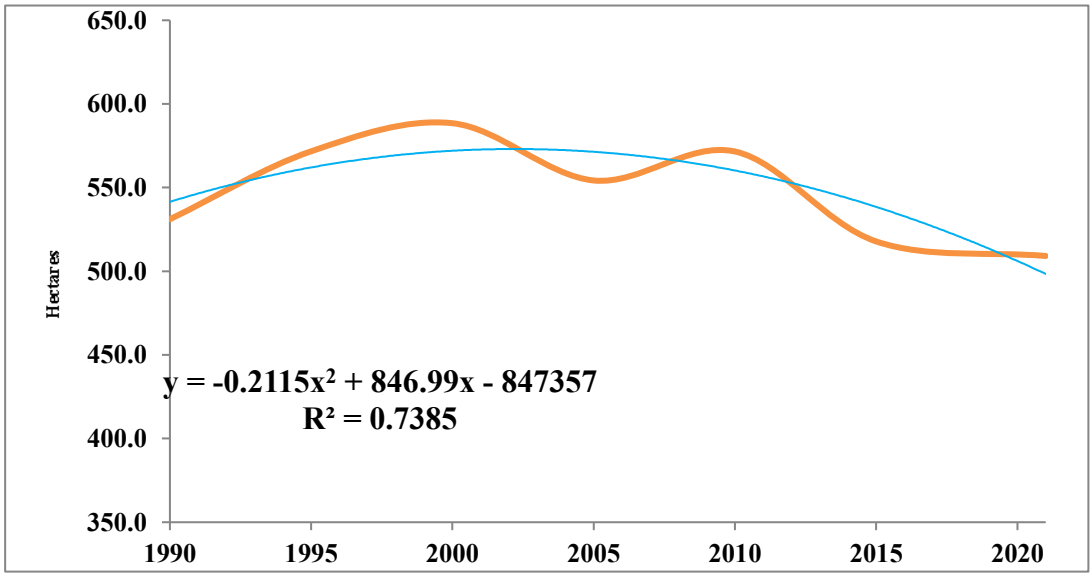
Figure A graphical representations of Agriculture changes in study area from 1990 to 2021

The obtained data for the assessment of Agriculture change in different years is presented graphically in figures and is given in Table The obtained data reveals that the Agriculture in the Hyderabad area has also decreased with the passage of time. It was 5271.9 hectares in 1990, 3990.7 Hectares in 2000, 3504.2 hectares in 2010, and 2860.8 hectares in 2015. it has again decreased and has reached to 2567.6 hectares in 2021 (figure, Table). It is suggested that the land area for agriculture is decreased significant which led to shortage for food security. The R^2 vale of polynomial regression model is 0.967 of the data of all the studied years (figure).

Waterbody Changes in Hyderabad from 1990 to 2021

Figure Waterbody changes in Hyderabad from 1990 to 2021

Figure A graphical representations of Waterbody changes in study area from 1990 to 2021.



The obtained data for Waterbody changes assessment in the study area is given in Table and is also presented graphically in Figure 4.8. The obtained data reveals that the area under Waterbody body is fluctuating in Hyderabad with the passage of years. In 1990 total area under water bodies in the study area were 531.1 hectares, 571.7-hectares in 1995; in 2000 it enlarged and reached to 588 hectares. The increase trend of water bodies in 2000 can be attributed to the heavy rains of 1999, actually the image for this year was of November 1999 and it is considered as 2000. Because images for 2000 from January to July were not clear so we used this image for 2000. More ever, 554.3 hectares in 2005 and 571.6 hectares in 2010, 517.8 hectares in 2015, 551.1 hectares in 2021 (Figure and Table). The reasons of this fluctuation are some rainy years and the discharge of domestic or municipal wastewater in the open areas and depression of the area. Since the command was given to assess Waterbody only and it characterizations was not assessed during the analysis. The R^2 vale of polynomial regression is 1 of the data of all the studied years (figure).

Barren Land Changes in Hyderabad from 1990 to 2021

Figure Barrenland changes in Hyderabad from 1990 to 2021

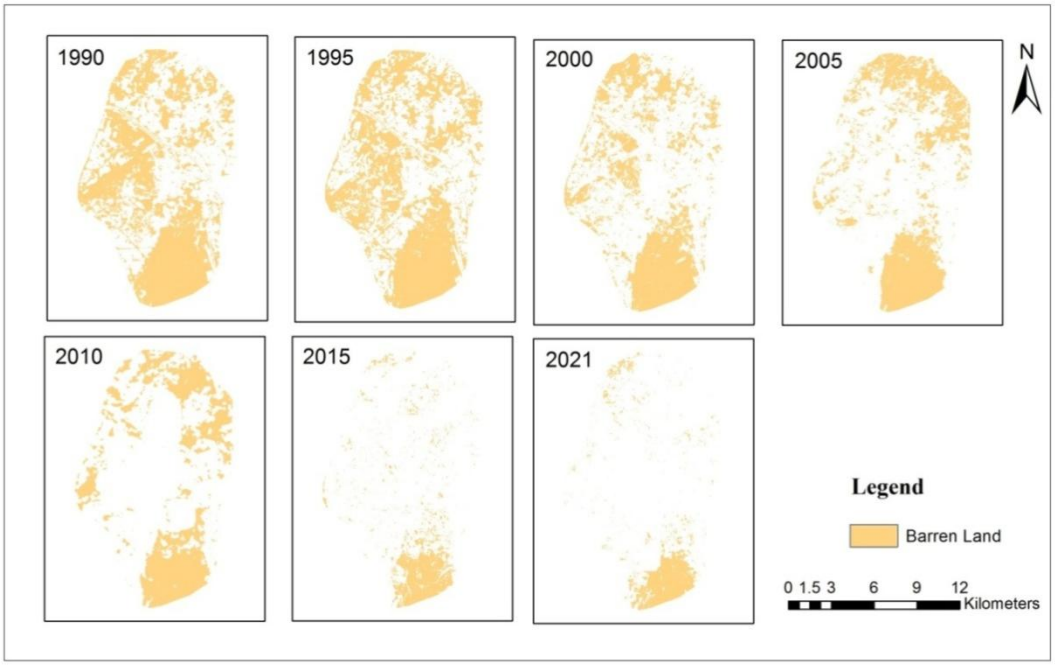
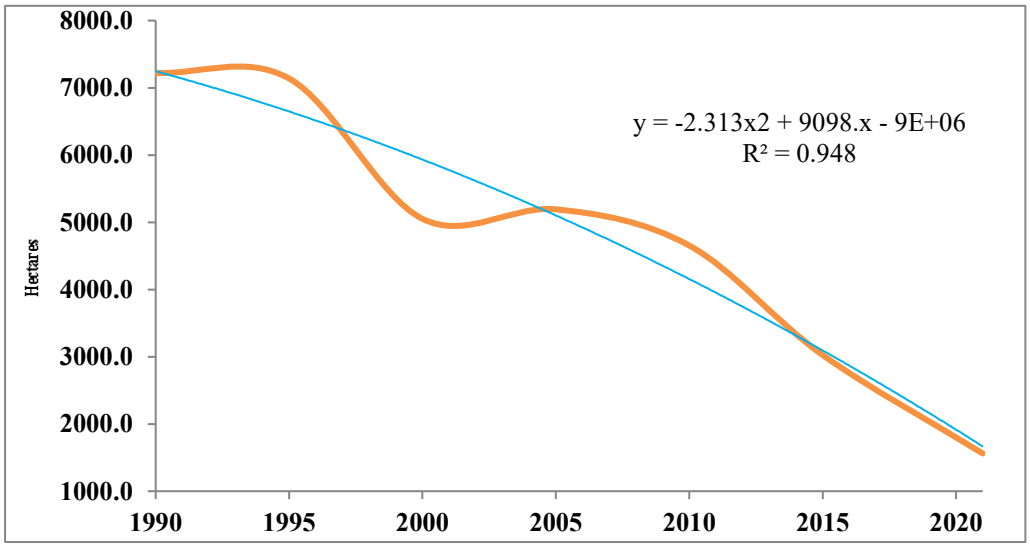


Figure A graphical representations of Waterbody changes in study area from 1990 to 2021.



The barren land change in Hyderabad is assessed from 1990 to 2021. The obtained data reveals that it was 7221.1 hectares of total studied land in 1990 and surprisingly, it is decreasing constantly and has reached to 1560.8 hectares in 2021. The R^2 vale of liner regression model is 0.948 of the data of all the studied years (Figure).

Rainfall

Figure A Annual Mean Rainfall Trend from (1990 -2021)

Figure B Annual Mean Residual Rainfall Trend from (1990-2021)

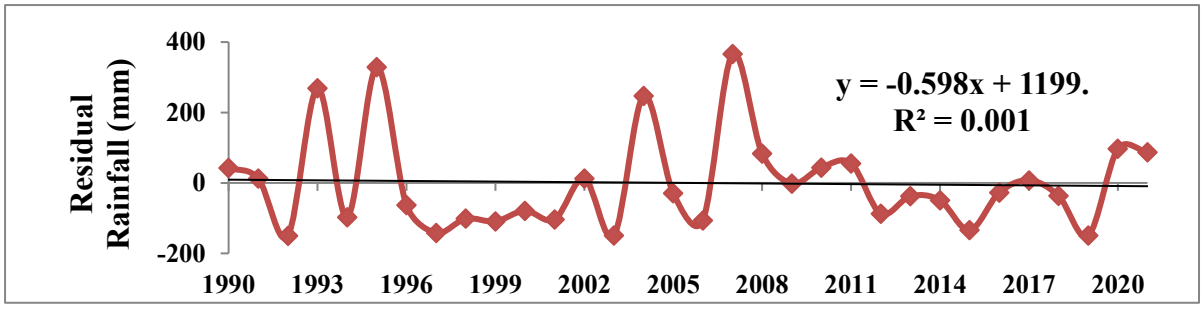


Figure (A) shows rainfall variation. From 1990 to 2000 rainfall recorded 50mm in 1992 and 500mm in it is interesting phenomena 450mm almost increase in rainfall. After this period trend of rainfall from 2000 to 2011 increase to 550mm in 2008. Furthermore from 2012 to 2021 in rainfall fluctuation recorded almost below 150mm till 2018. Moreover after 2020 rainfall Moreover after 2020 an interesting phenomena can we seen rainfall pattern increase to above 250mm. Figure (B) shows Residual rainfall of the same period, the calculated Residual rainfall recorded in 1990 is 45mm and it fluctuate to -150mm in 1993. Furthermore in 1995 rise to almost 350mm. after 1996 residual rainfall oscillate. An interesting phenomena can we seen in residual rainfall pattern increase in 2008 it is around above 400mm. Moreover, from 2011 to 2021 residual precipitation almost between -50 mm to 100 mm.

Population Growth

Figure Shows Population in thousands and growth rate in percentage (1990-2021)

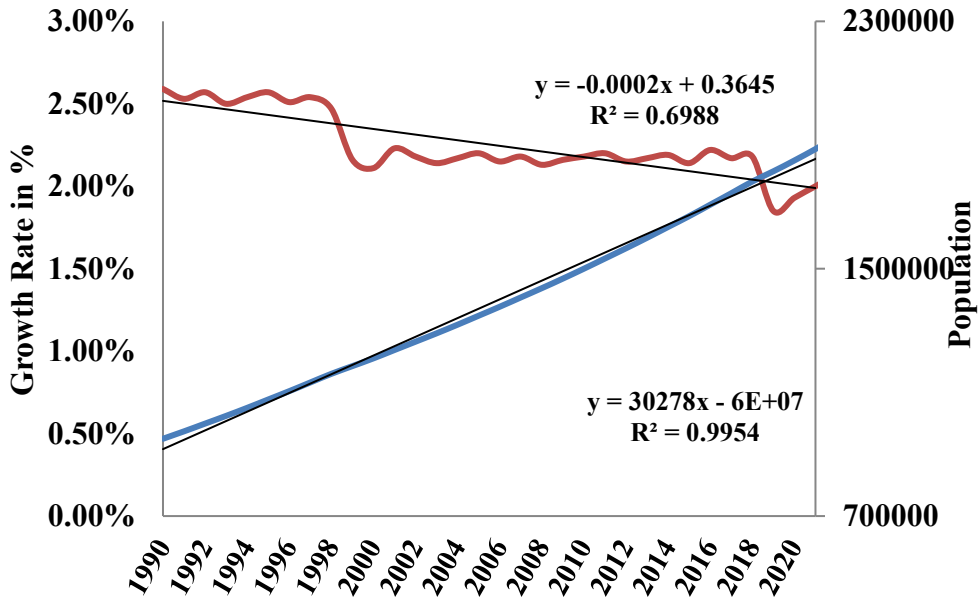


Figure shows population growth and increase in number of people in the Hyderabad urban area. In 1990 population of Hyderabad was 950,000 people and the calculated growth rate was 2.59%. And it is interesting phenomena has seen in growth rate decline with population increasing. In 1995 population of Hyderabad was 1077000 populations and the growth rate was 2.57%. In 2005 almost 1348000 increase in Hyderabad population. After this period trend of population increase rapidly from 2010 to 2015 due to mega flood in surrounding districts and interior of Sindh region. In 2010 almost growth

rate 2.18% and population 1500000 and 1670000 population and growth rate 2.14% in 2015. Furthermore from 2016 to 2021population increase and growth rate decrease. In 2021 population was1887000 and growth rate almost 2% (Figure). The R^2 value of liner regression model is 0.698 for population growth and 0.995 population increase of the data of all the studied years (Figure).

relationship between population and urban extension

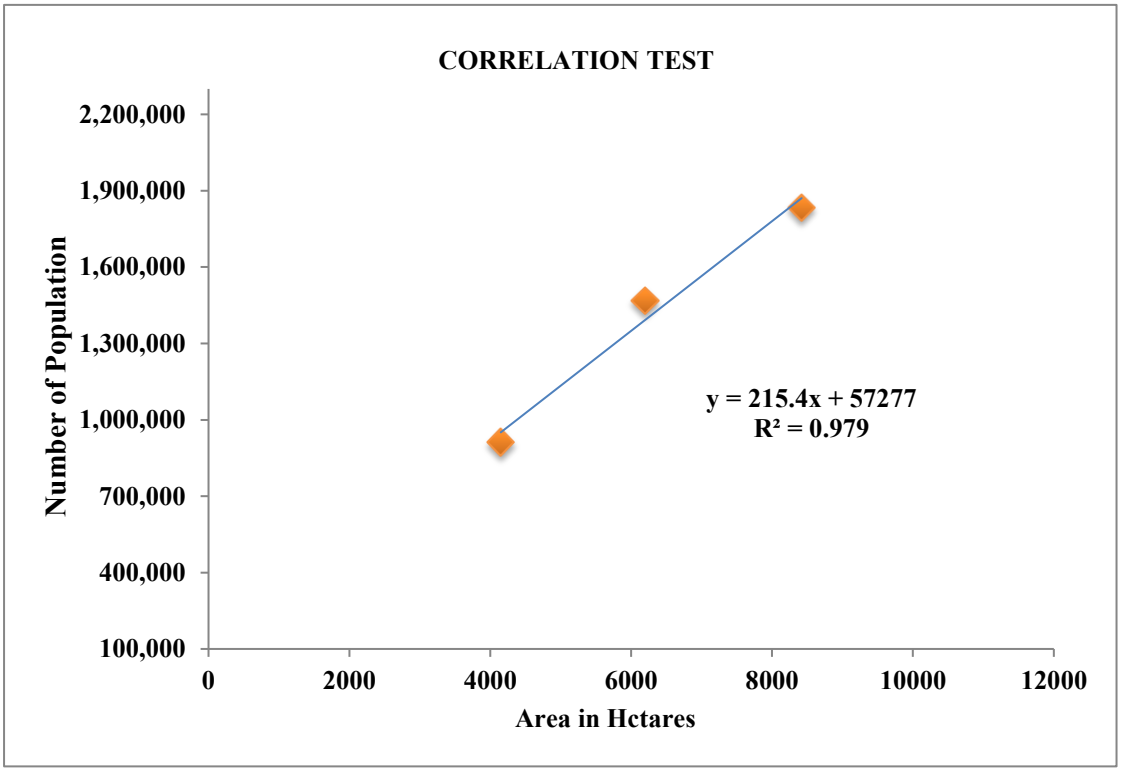


Figure Correlation test between urban expansion and population

This figure shows that strong positive association between population growth and urban expansion of Hyderabad. The figure showed that increase of one parameter also increase another they are to directly proportional to each other. The R^2 value of liner regression model is 0.979 of the data of all the studied years (Figure).

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