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# EVALUATING POPULATION DENSITY OF KARACHI USING GEOSPATIAL DASYMETRIC MAPPING TECHNIQUES

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## ABSTRACT

The population of the world spread unevenly, diversified by region, and rapidly growing with time. Population mapping describes the extent, density, and quantitative estimation. However, the choropleth map represents the demographic data, which combines the arbitrary area units, inaccuracies related to spatial analysis and distribution. The study aims to extract population density with the use of geospatial dasymetric mapping techniques, as well as study of correlation between population density and dasymetric population density. Landsat 8 OLI/TIRS images are utilized to acquire dasymetric mapping and to perform supervised classification. Moreover, choropleth map of population density was developed from the census data and spearman rank correlation graph progress. The results show the high dasymetric population density; around 110.609 and low upto 0, while correlation ranks between population density and dasymetric population density was perfectly positive. The study concluded that specific landuse data and GIS-based dasymetric techniques can be utilized for precise population density and accurate population distribution measurements.

**KEYWORDS:** Geospatial Techniques, demographic data, Landsat 8 OLI/TIRS, Population density, rank correlation, Karachi

## 1. INTRODUCTION

Karachi now a metropolis and economic hub of Pakistan, has grown from a fishing village. In 1947, the population was estimated to be around 0.5 million. Population in the year 1950 was (1.0 million) reached to (9.3million) in 1998, increased by 8.3 million, about 17.2% per year, similarly in the year 2011 it was (12.9 million) reached to (15.0 million) in the year 2017, an increase of 2.1 million about 35% per year. In 2018, the population was estimated to be about 15.4 million (Fig. 1), and density reached >6,000 persons per square kilometre (Safarik *et al.,* 2016). Further, its population is increasing daily.

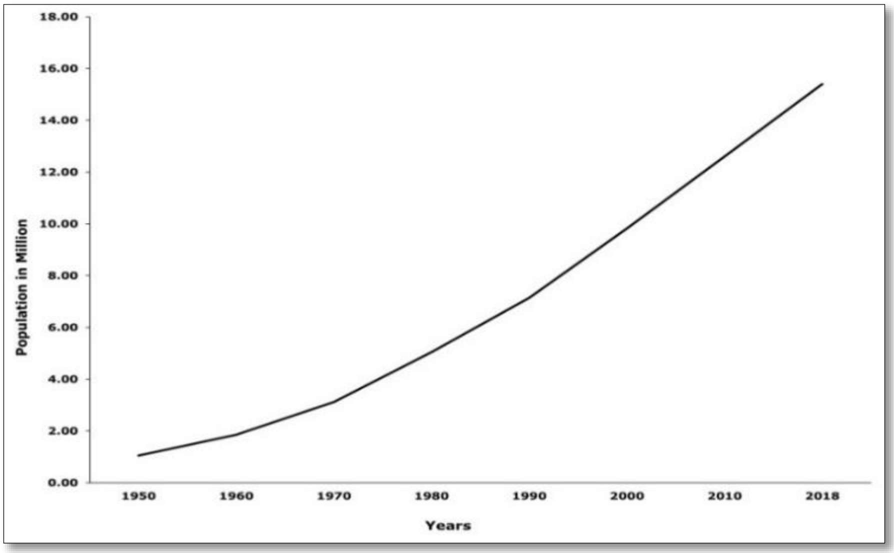


**Fig. 1 Historical Population Distribution in Karachi**

The rapid growth of population and its density estimation requires a lot of resources and time. Population mapping usually represents its extent over an area, especially to quantify the population density (Bielecka, 2005). Dasymetric mapping is an area-based cartographic technique used for mapping population density related to residential landuse, where the original administrative areas divided into smaller spatial units with the purpose of better representation of population distribution such as population density (Sleeter, 2008). This paper focuses on mapping population density of Karachi by using geospatial dasymetric mapping techniques and to procure more results rapidly through GIS analysis for population density.

The major purposes of the study are to explore the population density using geospatial dasymetric mapping techniques in Karachi district. Additionally, the study aims to examine the dasymetric population density in relation to geographical land use and population density. The study's novelty is to scientifically validate the applicability of GIS tools used to identify ground population development. The originality of the research is to explain a new approach that includes geospatial dasymetric population density with accuracy assessment, revealing the best and most accurate results between choropleth and dasymetric population density. The research analyzed a crucial space in past studies, as its limited research investigated the Spearman rank correlation used to find the accuracy of results between choropleth population density and dasymetric population density statistically. Furthermore, the results studied the comparison of choropleth vs. dasymetric population density.

The principal objective of the research is to explore the population density using geospatial dasymetric mapping techniques in Karachi district. Furthermore, the research is divided into the following sub-objectives:

- To extract dasymetric population density using choropleth population density and land use data.
- To statistically explore the correlation between population density and dasymetric population density by using Spearman rank correlation to acquire more accurate results.
- To compare the results of choropleth vs. dasymetric population density.

## 1.1. Study Area

Karachi is situated between 24° 45’ N to 25° 37’ N and 66° 42’ E to 67° 34’ E. The city's total area is around 3,780 Km$^2$ and Pakistan's first highest populated and sixth in the world (Wareing *et al.,* 2010). The population of the city is about 14.91 million according to the 2017 census (STATISTICS, 2007) increasing rapidly with time (Wazir & Goujon, 2019). The city constituted of twenty-three municipal towns and six districts such as Karachi Central, Korangi, Karachi East, Karachi West, Karachi South and Malir (Fig. 2).

Physiographically, the city is classified into three general categories: the hilly areas, an undulating plain, and coastal areas. The Malir and Layari, seasonal streams, are the main seasonal streams; drained into Arabian Sea that mark the physical features of the city (Pithawalla*et al.,* 1946). The coastal zone of metropolitan is based on hills, marshlands, scattered rocks outcrops and distinct types of islands located in the coastal region. The dense mangroves forests are in the south east of the coastline and a small patch around the sands pit area south west of the city. The city also constituted of small hill ranges such as the Khasa hills and the Mulri hills.

The city is represented as a region having high humidity with temperate climatic conditions (Roth, 2007). The climate of the metropolis is mainly affected by the Arabian Sea. According to climate-data.org, the months from July to September are the monsoon rainfall months where annual rainfall reached around 194mm. The months from November to March and April to October represent winter and summer, respectively. The annual average temperature is mostly around 25.9°C (Fig. 3).

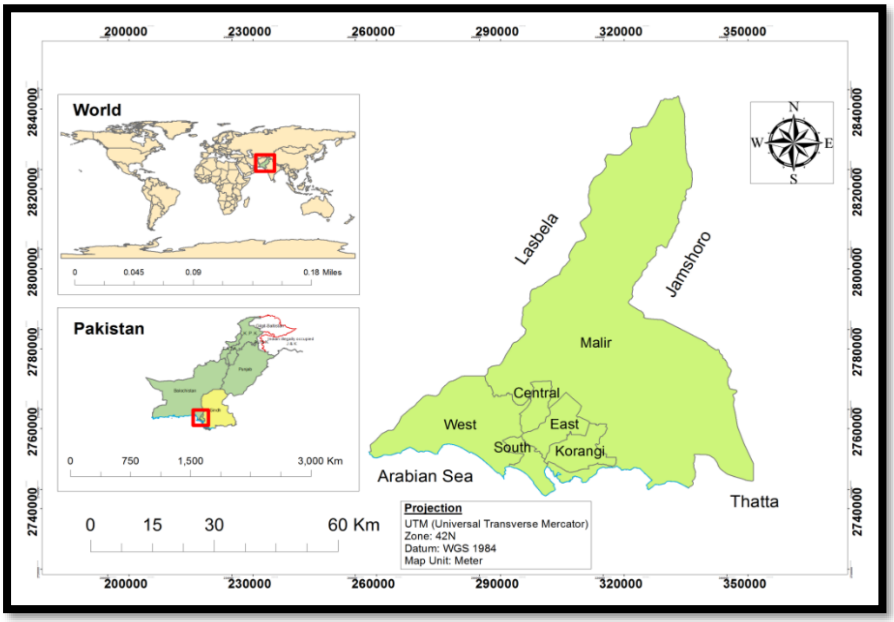


**Fig. 2 Study Area**

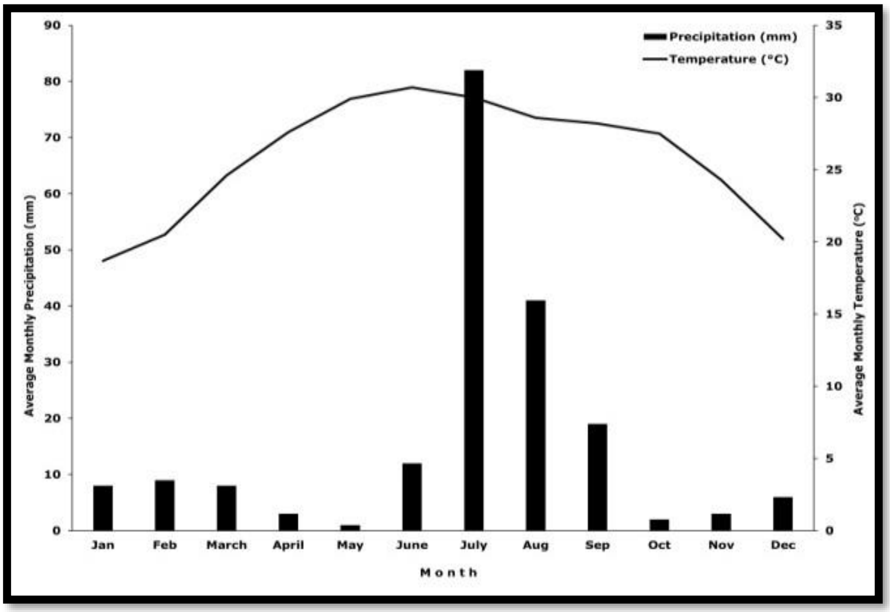


**Fig. 3 Average Monthly Rainfall and Temperature**

Karachi is now major industrial and financial hub as well as the principal seaport of Pakistan. Consequently, the people are migrating from different parts of Pakistan in search of bread earning means and to enhance their standard of living – which is a major reason for its rapid population growth.

## 2. MATERIAL AND MEATHODS

### 2.1. Satellite Images and Ancillary Data

The satellite image of Landsat 8 was acquired from the USGS portal. The population data was collected from the 2017 Pakistan census. The administrative boundaries acquired from the concerned authorities (Table 1). In the study, various kinds of data formats were utilized (Table 2), and the properties of Landsat 8 OLI/TIRS (2019) satellite data were described (Table 3). (Fig. 4) elaborates the related methodological framework of the study.

**Table 1: Different datasets of data sources of study zone**

| Dataset | Source |
| --- | --- |
| **Landsat 8 OLI/TIRS C1 Level-1 image 2019** | https://earthexplorer.usgs.gov/ |
| **Karachi District boundary** | https://data.humdata.org/dataset/pakistan-administrative-level-0-1-2-and-3-boundary-polygons-lines-and-central-places |
| **Karachi town's population census (2017)** | https://www.pbs.gov.pk/content/city-district-karachi-glance |
| **Postal Codes** | http://www.kmc.gos.pk/Contents.aspx?id=13 |

**Table 2: Various Kinds of Data Formats Utilize**

| Raster | Vector | Numeric |
| --- | --- | --- |
| **Landsat 8 OLI/TIRS C1 Level-1 image 2019** | Karachi district shapefile | Karachi town's population census (2017) |
| | | Postal codes of Karachi district |

**Table 3: Properties of Satellite Data**

| Parameter | Spatial Resolution | Temporal Resolution | Spectral Resolution | Areal Swath | Availability | Dates | Pixel Size | Thermal Band |
|---|---|---|---|---|---|---|---|---|
| **Landsat 8 OLI/TIRS** | 30 meters (band 8 = 15 meter) (band 10 & 11 = 100 meters) | 16 days | 10 bands | 185 km | 16 days | 2019 | 30 m | 100 m |

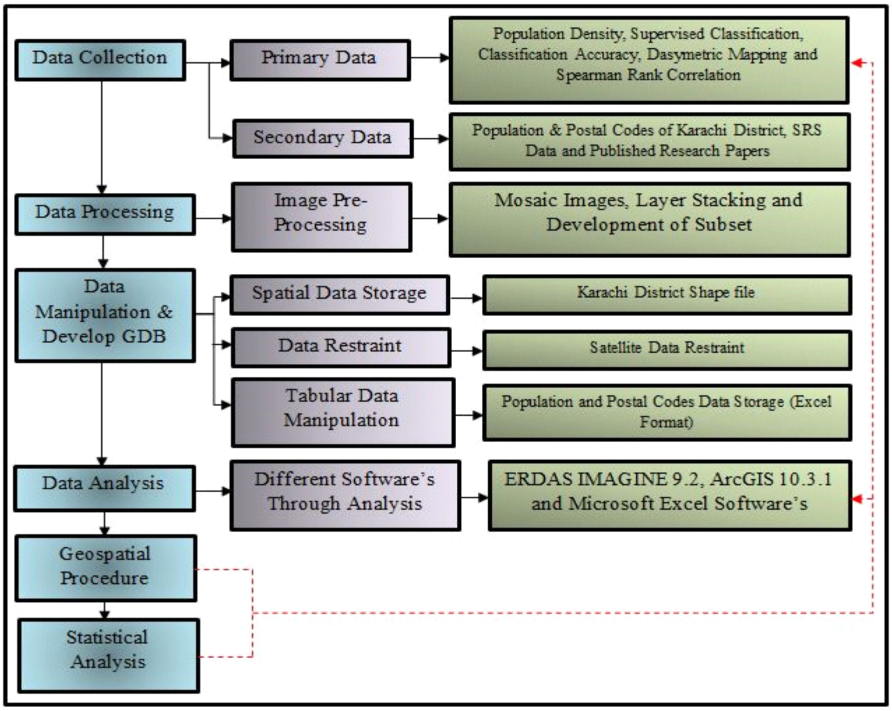


**Fig. 4 Methodological Framework of the Study**

In this research, geospatial analysis of the results was conducted using different software tools, including ERDAS IMAGINE 9.2, ArcGIS 10.3.1, and Microsoft Excel.

## 2.2. Processing of Satellite Images and Ancillary Data

The basic image processing techniques performed are layer stacking, mosaicking, and subset development to further calculate population density, dasymetric mapping, supervised classification, classification accuracy, areas calculation and spearman rank correlation.

## 2.3. Dasymetric Determination

The basic procedure applied in this study is mostly related with the binary dasymetric method (Fisher & Langford, 1996; Langford & Unwin, 1994). A dasymetric map: generally used in population mapping, describes quantitative data using boundaries which divide the area into zones of relative homogeneity with best portrayal of the inherent statistical surface (Eicher & Brewer, 2001; Goerlich & Cantarino, 2013; Maantay *et al.,* 2007; Mennis, 2003; Thompson & Hubbard, 2014). Recently, dasymetric population maps are proved to be the most common type of maps. The zonal limits in dasymetric maps consist of sharp changes in the statistical surface. The individual dasymetric zones are developed based on internal homogeneity. The population data used as input data and land use/land cover served as source zone in the dasymetric method and rearranges the population to a set of target zones made from the intersection of the source and ancillary zones.

# 3. RESULTS AND DISCUSSION

## 3.1. Population Density

The population density was calculated on the basis of published data by using ArcGIS spatial analysis tool. The spatial distribution map showed high density in Central District that accounts for 109556 Persons/Km$^2$ (Persons per square kilometre), while low density in Malir District that accounts for 30 Persons/Km$^2$ (Fig. 5).

## 3.2. Land use/Land cover

The land use/Land cover classification was acquired through the supervised classification including general class categories such as open land, built-up land, semi built-up land, mangrove forest, vegetation, and water classes. The classes were also extracted by applying different indexes mentioned in the section 2. The result showed that the water class counted 0.65%, Mangrove Forest counted 0.50%, Vegetation counted 4.7%, built-up land counted 16%, semi built-up land counted 1.65% and open land counted 76.5% of the study area (Fig. 6).

## 3.3. Dasymetric Map

The dasymetric map elaborated the population density with the land use areas in diverse population cluster zones. The raster layers of population density and land use are used to develop dasymetric population map by using ArcGIS software (Fig. 7). The result showed that the density range up to 110.609 and low counted 0.

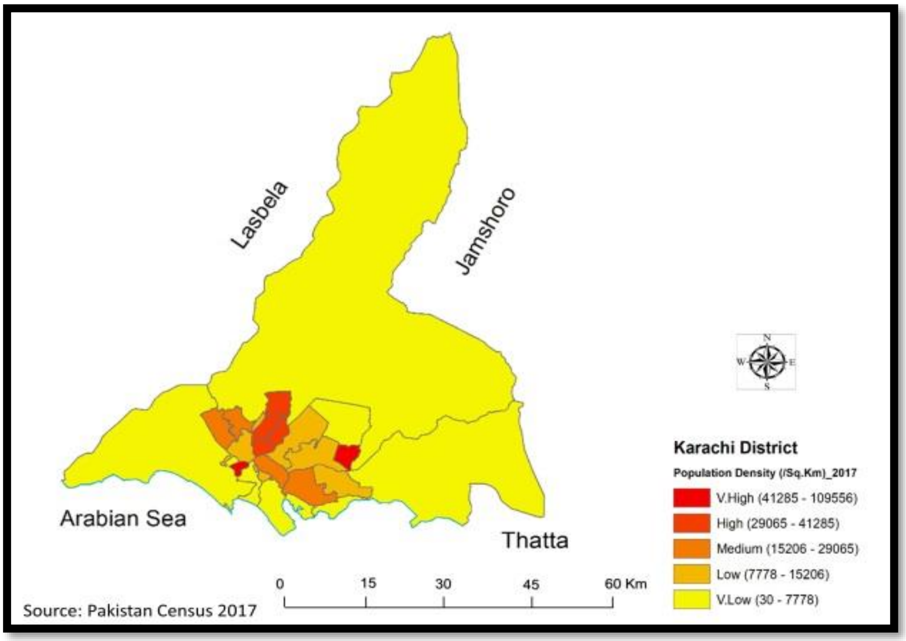


**Fig. 5 Choropleth Population Density Based on 2017 Census of Study Area**

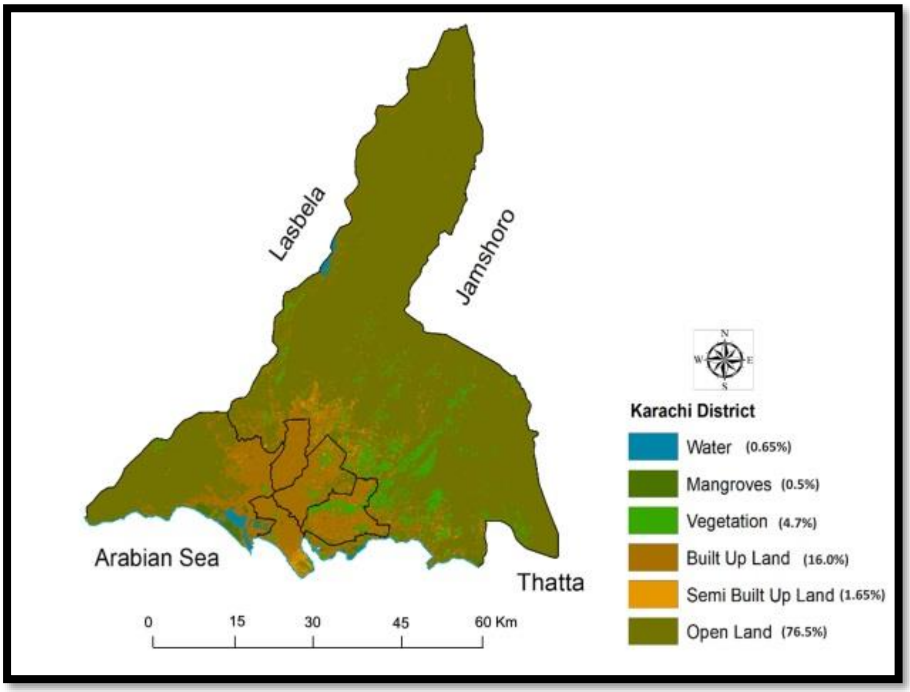


**Fig. 6 Land use/Land cover Classification of Study Zone**

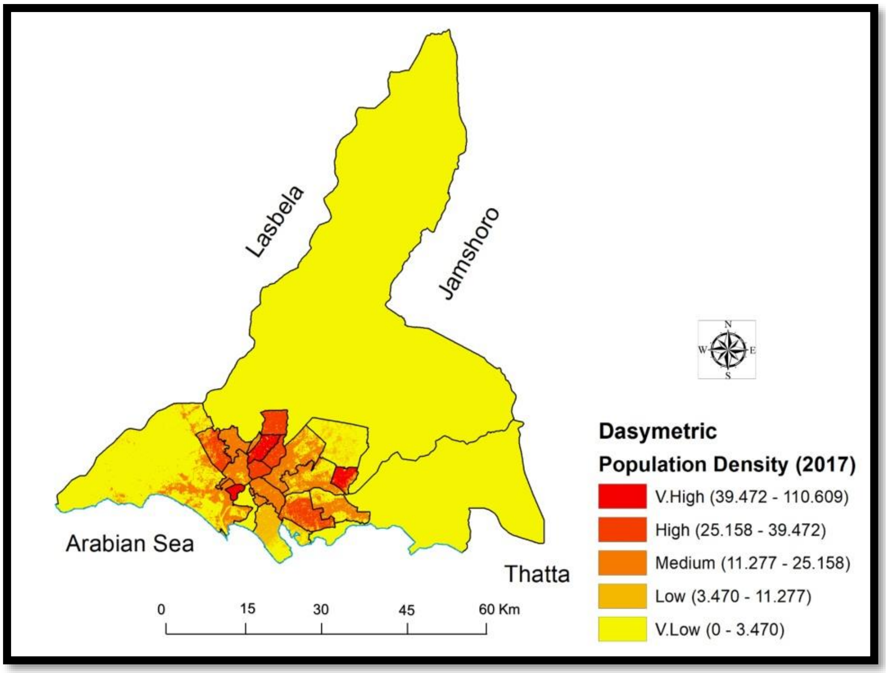


**Fig. 7 Dasymetric Population Density Based on 2017 Census**

### 3.4. Accuracy Assessment

Accuracy assessment is an inherent challenge for dasymetric mapping therefore, the summary statistics method for accuracy assessment was utilized because this method is widely used to assess the accuracy of dasymetric mapping. For dasymetric approach which is not volume preserving, target-level estimates can be aggregated to the zone level and compared to the true values using correlation coefficient. Therefore, the spearman rank correlation was reviewed and analyzed on the population density and dasymetric population density (Fig. 8). The results graphically described the perfect positive correlation between ranks respectively.

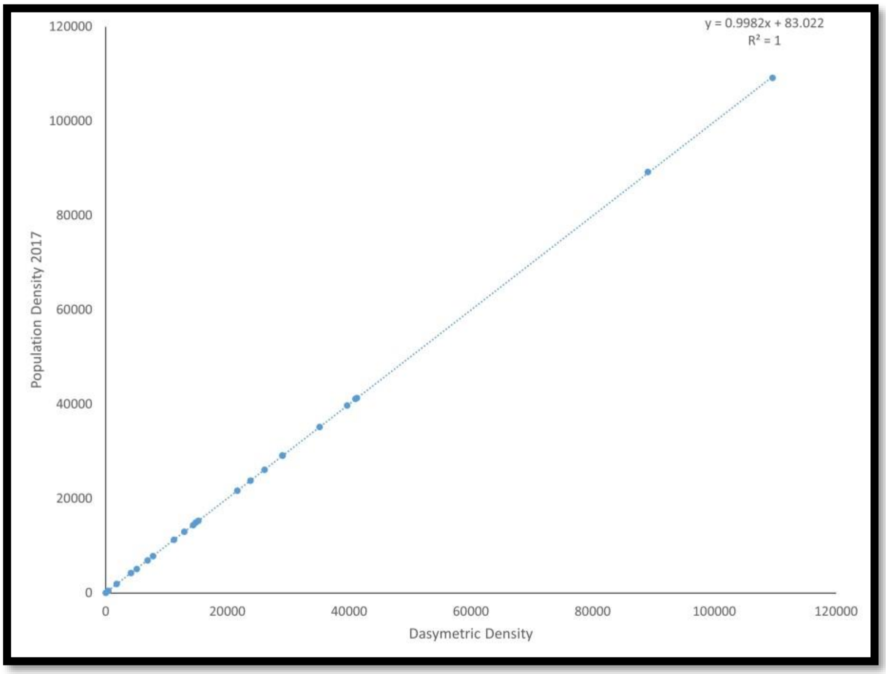


**Fig. 8 Correlations between Choropleth Population Density Vs Dasymetric Population Density Statistical Graph**

The dasymetric mapping accurately presented people within a given zone. Therefore, to test the precision of dasymetric map distribution, the census zone total were evaluated as an indicator of how well the population is distributed. In all 23 towns of Karachi, the census parcel-level dasymetrically informed the densities of population exceeded, as compared to the population densities calculated with the choropleth method (Table 4). The distinct results showed by the dasymetric technique (Fig. 7) and choropleth techniques (Fig. 5). The data assigned into five classes in both maps using the natural break (Jenks) methods. A comparison of the two maps promptly shows differences in the outer towns. Specially, all censuses in Gadap, Kiamari, Bin Qasim, Saddar towns hold the smallest population density class in the choropleth map, proposing wide homogeneity of population density across the outer sub-urban periphery. Nevertheless, the dasymetric population densities for the similar towns depicts with higher density within Kiamari town. These generally represent an area of new, higher-density housing subdivision. Consequently, the dasymetric map delineates areas with higher and lower population densities, more accurately, within towns. However, the population density according to the census report (Fig. 5) and calculated through the dasymetric techniques (Fig. 7) are well correlated (Fig. 8). It can be assumed that the land use categories played an important role in dasymetric calculation.

**Table 4: Comparison of Choropleth population density vs Dasymetric population density (Statistics of Karachi Towns)**

| S.No. | Karachi Towns | Population | Area $Km^2$ | Population Density | | Difference % |
|---|---|---|---|---|---|---|
| | | | | 2017-Choropleth | Dasymetric | |
| 1. | Gulberg Town | 495892 | 14.10 | 35150.6 | 35198.97 | 0.14 |
| 2. | North Nazimabad Town | 708583 | 17.26 | 41045.11 | 41125.85 | 0.20 |
| 3. | Liaquatabad Town | 448484 | 11.30 | 39673.14 | 39736.85 | 0.16 |
| 4. | New Karachi Town | 871232 | 21.10 | 41284.67 | 41317.04 | 0.08 |
| 5. | Layari Town | 662816 | 6.05 | 109555.1 | 109174.8 | -0.35 |
| 6. | Saddar Town | 36366 | 20.00 | 1817.813 | 1959.125 | 7.77 |
| 7. | Malir Town | 1500771 | 16.85 | 89078.48 | 89222.59 | 0.16 |
| 8. | Korangi Town | 1071560 | 45.03 | 23792.62 | 23827.27 | 0.15 |
| 9. | Jamshed Town | 471830 | 21.78 | 21654.39 | 21697.69 | 0.20 |
| 10. | S.I.T.E. Town | 404757 | 27.31 | 14817.42 | 14937.93 | 0.81 |
| 11. | Kiamari Town | 2156623 | 423.31 | 5094.565 | 5110.936 | 0.32 |
| 12. | Baldia Town | 832768 | 28.65 | 29064.24 | 29083.33 | 0.07 |
| 13. | Gulshan-e-Iqbal Town | 644362 | 57.48 | 11209.47 | 11266.82 | 0.51 |
| 14. | Shah Faisal Town | 744462 | 48.95 | 15205.6 | 15290.32 | 0.56 |
| 15. | Landhi Town | 553665 | 42.78 | 12941.57 | 12979.23 | 0.29 |
| 16. | Clifton Cantonment | 305938 | 44.36 | 6895.843 | 6923.752 | 0.40 |
| 17. | Manora Cantonment | 5874 | 0.75 | 7777.928 | 7797.79 | 0.26 |
| 18. | Orangi Town | 520609 | 19.95 | 26090.88 | 26149.61 | 0.23 |
| 19. | Gadap Town | 64192 | 2127.96 | 30.16595 | 32.59833 | 8.06 |
| 20. | Korangi Creek Cantonment | 57745 | 13.84 | 4172.327 | 4224.16 | 1.24 |
| 21. | Bin Qasim Town | 247141 | 548.26 | 450.7697 | 454.7692 | 0.89 |
| 22. | Malir Cantonment | 139052 | 71.94 | 29017.36 | 29147.04 | 0.45 |
| 23. | Karachi Cantonment | 68877 | 4.79 | 14373.25 | 14403.8 | 0.21 |

## 4. CONCLUSION

The study explored the population density using geo-spatial dasymetric mapping techniques. Moreover, review of the evaluated correlation between choropleth population density and dasymetric population density is presented. All the investigations were based on the Landsat 8 OLI/TIRS satellite image and numeric data. The population density, land use, dasymetric population density were performed for achieving precise results. Further, Spearman rank correlation showed significant results between choropleth population density and dasymetric population density, i.e. the perfect positive correlation between ranks. It suggests GIS and indexes-based dasymetric techniques can be utilized for quick analysis and precise population distribution, which is not allowed in other population mapping techniques.

## REFERENCES

Bielecka, E. (2005). A dasymetric population density map of Poland. *Proceedings of the 22nd International Cartographic Conference* (p. 15): Citeseer

Eicher, C.L., & Brewer, C.A. (2001). Dasymetric mapping and areal interpolation: Implementation and evaluation. *Cartography and Geographic Information Science,* 28, 125-138

Fisher, P.F., & Langford, M. (1996). Modeling sensitivity to accuracy in classified imagery: A study of areal interpolation by dasymetric mapping. *The Professional Geographer,* 48, 299-309

Goerlich, F.J., &Cantarino, I. (2013). A population density grid for Spain. *International Journal of Geographical Information Science,* 27, 2247-2263

Langford, M., & Unwin, D.J. (1994). Generating and mapping population density surfaces within a geographical information system. *The Cartographic Journal,* 31, 21-26

Maantay, J.A., Maroko, A.R., & Herrmann, C. (2007). Mapping population distribution in the urban environment: The cadastral-based expert dasymetric system (CEDS). *Cartography and Geographic Information Science,* 34, 77-102

Mennis, J. (2003). Generating surface models of population using dasymetric mapping. *The Professional Geographer,* 55, 31-42

Pithawalla MB, Kaye PM, & DN, W. (1946). Geology and geography of Karachi and its neighbourhood. In, *Daily Gazette Press, Karachi* (pp. 18-30)

Roth, M.J.I.J.o.C. (2007). Review of urban climate research in (sub) tropical regions. *A Journal of the Royal Meteorological Society,* 27, 1859-1873

Safarik, D., Ursini, S., & Wood, A. (2016). Megacities: Setting the scene. *CTBUH Journal*, 30-39

Sleeter, R. (2008). A new method for mapping population distribution. In: Geological Survey (US)

STATISTICS, F.B.O.J.C. (2007). Government of Pakistan.

Thompson, A.L., & Hubbard, B.E. (2014). A Comprehensive Population Dataset for Afghanistan Constructed Using GIS-Based Dasymetric Mapping Methods. In: US Geological Survey

Wareing, M., Cavas, K.S.J., Theiss, M., Winkle, ZV., Zuckerman, T. (2010). Pakistan: Urbanization, sustainability, & poverty. Humanitarian Library.

Wazir, M.A., &Goujon, A. (2019). Assessing the 2017 census of Pakistan using demographic analysis: A sub-national perspective. In: Vienna Institute of Demography Working Papers