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# APPROACHING DASYMETRIC TECHNIQUE IN MAPPING POPULATION DENSITY - A CASE STUDY OF THUA THIEN HUE PROVINCE

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**Abstract.** The Dasymetric mapping technique approach accurately reflects the population distribution by territory, serving as the basis for urban and living space planning, socio-economic development, and infrastructure**.** This paper approaches Dasymetric mapping techniques to create a population density map for Thua Thien Hue Province. By integrating Dasymetric mapping techniques and Geographic Information System (GIS), component maps have been developed to establish the population density map such as weighted $R_A$, total population N/ward, E-coefficient, $A_T$ total pixel/ward. The initial results show that the population distribution according to the Dasymetric mapping technique accurately reflects the people living in an administrative unit. Besides, the paper also developed a population density map by traditional density techniques of Choropleth, then compared the results obtained with Dasymetric mapping techniques. From the comparison between the two methods, it reveals that, with the Dasymetric method, the population density of Thua Thien Hue province in 2020 is reality distributed with the highest at 20.02 people per 25 m pixel (0.03 people/km$^2$), and the lowest is 0 (in places where the water surface). Meanwhile, the Choropleth method shows that the most significant population density is 0,01 people/m$^2$ (6.25 people per 625 m$^2$), the lowest is 1.28 people per 625 m$^2$, and is homogeneous for the whole commune/ward territory. Thereby, further confirmed the accuracy, visual representation of population distribution according to the population statistics space of the Dasymetric method.

**Keywords:** The Dasymectric mapping technique, population density, GIS, Thua Thien Hue

## 1 Introduction

The population is an essential part of the country's development strategy. It is a leading factor directly affecting the socio-economic country's development and significantly affects natural resource use and environmental policies [1]. Therefore, it is necessary to adjust the population trends according to the country's socio-economic situation in the development process. In other words, all socio-economic master planning and development of a country or territory must aim at people's interests and consider the population of that area.

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A population density map is a thematic cartography that portrays the extent and density of population across an area of interest and is a vital indicator of the urban development and master plan [1]. The population density is often expressed numerically in terms of the number of persons per square kilometer. From the perspective of GIS and remote sensing technology, there are many approaches for mapping population density. However, in general, it can categorize into two primary methods: (1): Traditional Choropleth mapping technique and (2): Dasymetric mapping technique [1,2, 8].

Choropleth mapping is a traditional and straightforward technique to map socio-economic variables such as population density by enumeration areas (administrative units). This simple method lacks a limited utility for detailed spatial analysis of population data [5, 6]. The choropleth map depicted the population distribution homogeneously throughout each administrative boundary unit even in the uninhabited portion of the region area as the lakes, rivers, forests, agricultural areas, bare lands, sparsely populated place and significantly affects the result of further spatial data analysis [1, 4, 6, 7]. This kind of map is often inaccurate to cast doubt on whether the analysis of census data indicates the actual number of individuals in the area or is purely a function of the administrative unit used in the analysis [6]. Many studies have proven a potential solution to this problem/limitation: to represent population data based on the surface of grid cells using the Dasymetric mapping technique [4, 6].

The Dasymetric mapping map technique was first proposed by the Russian cartographer Tian-Shanshy and has been applied to build population density maps with Russian-European sheets, scale 1: 420.000 in 1920. This technique was further developed by Wright (1936) by converting administrative units into smaller units (terrain areas, surface cover, land use) and suitable more integrated through the Dasymetric mapping technique [8]. Other authors such as Holloway et al. (1997) and Jeremy Mennis (2003) also use the mapping technique approach to build population density maps through spatial analysis, population distribution over a given territory based on the weighting of each land-use/surface cover category [5, 6, 10]. Population density data are modeled continuously without regard to any administrative zoning boundaries. Compared with the traditional method, the dasymetric method is considered the optimal method for making population density maps because of its ability to distribute population data shown on the map more accurately in geographical space. Instead of using administrative unit regions to represent population divisions, the Dasymetric mapping technique is based on standard census data of an area combined with boundaries-weighted soils [1, 6].

In recent years, Thua Thien Hue has been considered one of the provinces with a relatively fast development speed in Vietnam [3], accompanied by a high population density and increasingly strong infrastructure development. Therefore, the study and establishment of population density maps using Dasymetric mapping techniques will be essential to support urban planning, residential areas, socio-economic development, and urban planning and

infrastructure in Thua Thien Hue Province. This paper describes the process and approach to mapping technique "Dasymetric" under the Geographic Information System (GIS) support in establishing population density map in Thua Thien Hue province in 2020.

## 2 Study area and data

### 2.1 Research area

Thua Thien Hue is a province in Central Vietnam, with an area of 5,033.20 km$^2$, accounting for 1,50% of the natural area of Vietnam. The Province organizes into nine district-level administrative units, including one city, two towns, and six districts. In 2020, the total population is 1,136,550 people, with an average population density of about 226 people/km$^2$. The Province has a favorable geographical location and plays a vital role in the socio-economic development process in the central region and the whole country. Therefore, population issues are increasingly focused on making policies, infrastructure planning, and environmental planning towards sustainable development for Thua Thien Hue province.

### 2.2 Data

The primary data used for the population distribution modeling problem include census and land use data. These data must coincide or nearly coincide because land use cover information significantly impacts population distribution. In this study, population data at the ward level in 2020 was collected from the Department of Statistics of Thua Thien Hue province. The land-use status map data in 2020 was gathered from the Department of Natural Resources and Environment. In addition, the GIS boundary data of the Province was also used to normalize the level boundaries for spatial analysis. Details of the data are shown in Table 1.

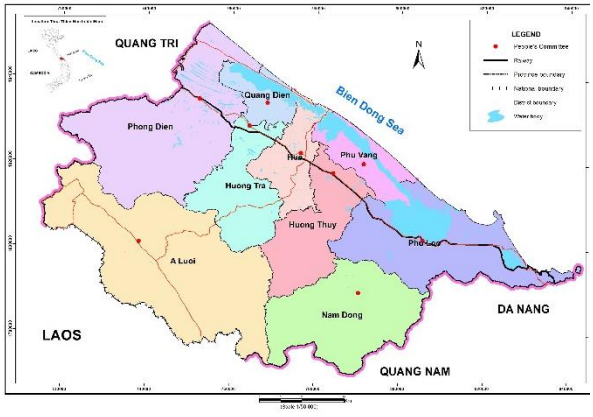


**Fig. 1.** Location of study area

**Table 1.** Data for Research

| Data | Format | Source | Scale/Scale |
|---|---|---|---|
| Land Use Status in 2020 | Converted from (*.dgn) Microstation to (*.shp) Shapefile | Department of Natural Resources and Environment | 1:50,000 |
| Census 2020 | (*.xlsx) Excel | Statistical Office of Thua Thien Hue Province | Commune/ward |
| Background data | Geodatabase | Project GISHue | 1:50,000 |

# 3 Research methodology

## 3.1 Choropleth technique mapping population density

The method represents the scattered objects in blocks and each defined boundary area on the map. To follow this method, first determine the boundaries of the regions (in this study, the administrative boundaries are taken at the ward level) and then collect the population data corresponding to the identified area. Use the GIS tool to represent the population density calculated based on this (people/area unit $km^2$).

## 3.2 Dasymetric technique mapping population density

The Dasymetric mapping technique uses region notation to classify volumetric data, allowing realistic spatial visualization, which is considered a combination of the Choropleth and Isopleth mapping. Isopleth maps simplify information about a region by showing areas with continuous distribution. Isolines are claimed to be a good choice for presenting the arrangement of the magnitude, as well as the steepness and orientation, of a surface gradient, and a dot map illustrates the geographic character of distribution more clearly than any other map type [9].

The method used to present (present what?) is based on the survey result, cadastral map, and the land-use map has converted administrative units into smaller units (topographic regions, land cover, land use). Population density is expressed through spatial analysis, population distribution over a territory based on the weights of each group of land use/surface cover types.

During the mapping process, a quantitative boundary variable is derived from the distributive characterization of the data. This form of zonal interpolation uses additional (auxiliary) data to convert population data from one set of spatial units to another.

The formula for calculating population density was developed by Holloway (1997) and modified by the United States Geological Survey (USGS) [5, 8] to estimate the population for each grid cell on the land-use status map as follows:

$$P = \frac{R_A \times P_A \times N}{A_T \times E} \quad (1)$$

Where:

**P** is the population of a given cell

**$R_A$** is the relative density of a cell with land-use type A

**$A_T$** is the total number of cells in the enumeration unit

**N** is the actual population of the administrative unit (commune/ward).

**$P_A$** resolution of the calculated raster data

**E** is the expected population of the enumeration unit calculated using the relative densities. E equals the sum of the products of relative density and the proportion of each land-use type in each administrative unit.

$$E = \sum \frac{P_{Aj}}{A_T} \times R_A \quad (2)$$

Where:

$P_{Aj}$ is the number of the cell of land-use type A of ward j

$A_T$ is the total number of cells in the enumeration unit

$R_A$ is the relative density of a cell with land-use type A

By applying the formula (1), the component map layers are prepared as input data, including weighted map RA; map of total population N/commune, ward; E coefficient map; map of the total number of pixel plots/commune, ward A.

Land-use types will be grouped according to population concentration and weighted RA. Based on the survey results of extraction by each household across the city to estimate population density number by ward, combined with the cadastral map to determine the number of people distributed according to each object (house, neighborhood) or land-use type. Holloway (1997) and J. Mennis (2003) have done surveying for several developing cities in the world and have also been validated by the United States Geological Survey in estimating the weighted RA. Holloway (1997) proposed the weighted RA of six land-use classes based on approaching the relative density proposed by including Low-density residential, high-density residential, Commerical/Industrial, Agricultural, Natural, Water/wetland corresponding to weighted RA value of 15, 65, 5, 10, 5 and 0, respectively [5 - 6].

Component maps are built-in raster format with a resolution of 25 m x 25 m corresponding to a scale of 1:50,000 according to the original maps. ArcGIS Desktop software is used to build population density maps with Dasymetric mapping technology. The research process is shown in Figure 2.

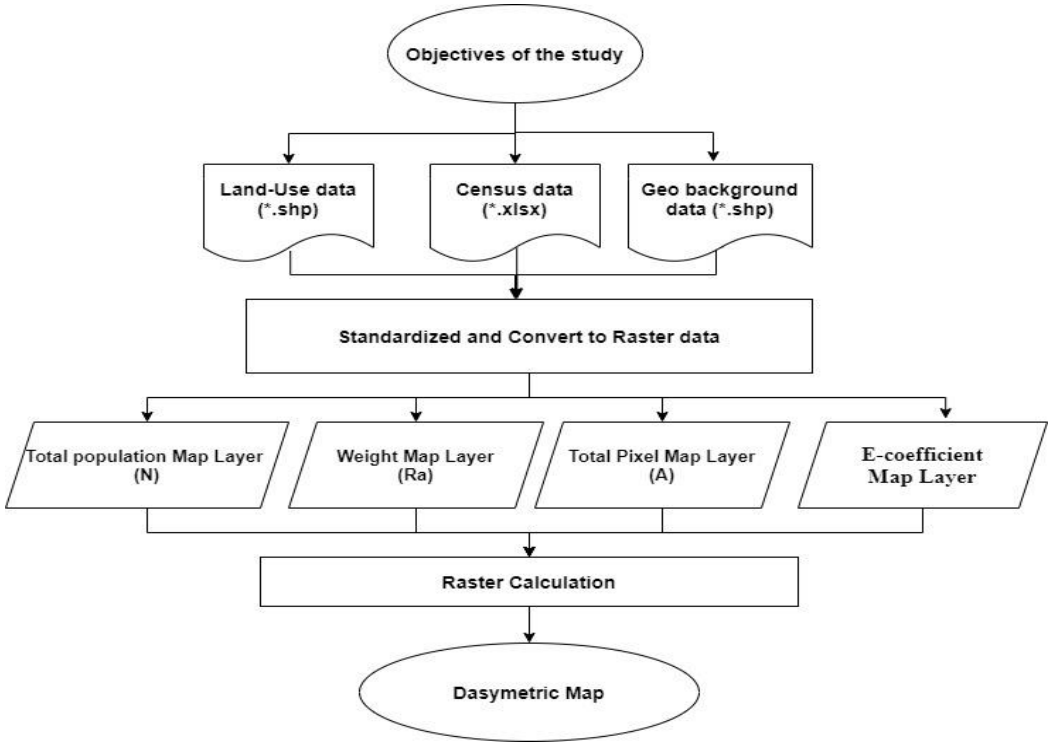


**Fig. 2.** Research process

## 4 Results and discussion

### 4.1 Constructing component maps for dasymetric mapping population density

**a. The total population by administrative unit N map**

The total population by administrative unit N map is built on the commune-level administrative boundary layer extracted from the GISHue base map project. Census data at the commune/ward level is collected from statistical data of the Department of Statistics (presented in summary by the district administrative unit in Table 2) and integrated into the spatial data of administrative maps of the Province. The output is in shapefile format, converted to raster data for the computational model (Figure 3).

**Table 2.** The population and number of administrative units at commune/ward level in Thua Thien Hue in 2020

| No. | Name of the district, town | Number of administrative units at commune/ward level | Total area (ha) | Population (person) |
|---|---|---|---|---|
| 1 | Hue city | 27 | 7,086.62 | 353,222 |
| 2 | Huong Tra Town | 15 | 51,534.78 | 115,689 |
| 3 | Huong Thuy Town | 12 | 45,605.32 | 114,623 |
| 4 | Phong Dien District | 16 | 94,747.87 | 89,105 |
| 5 | Quang Dien District | 11 | 16,401.89 | 77,635 |
| 6 | Phu Vang District | 19 | 27,828.38 | 180,309 |
| 7 | Phu Loc District | 17 | 137,738.52 | 130,415 |
| 8 | Nam Dong District | 10 | 64,742.11 | 26,196 |
| 9 | A Luoi District | 18 | 122,377.14 | 49,356 |
| | **Total** | **145** | **503,320.53** | **1,136,550** |

*Source: Thua Thien Hue Provincial Statistical Office*

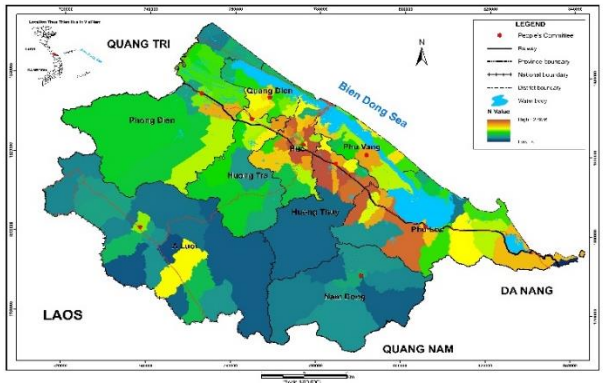


**Fig. 3.** Map of the total population by administrative unit N

### b. Weighted population distribution of land-use type $R_A$ map

Land use map of 2020 in *.shp format, with attribute data normalized. Based on the proposed weighted value Holloway (1997) and J. Mennis (2003) [5-6], combined with the actual land-use in Thua Thien Hue province, the type of land-use are grouped, and weighted density

population distribution relative to $R_A$ is shown in table 3. Class of land-use maps has weighted grouping $R_A$ is converted into raster formats for inclusion in the calculation model as shown in Figure 4.

**Table 3.** The number of population distribution type of land use

| No. | Types of land use | Symbol | Area (ha) | Weight $R_A$ |
|---|---|---|---|---|
| 1 | Housing area | DTO | 26,626.23 | 65 |
| 2 | Industrial, commercial, and service land | TMD | 9,422.91 | 10 |
| 3 | Agricultural land, Production forest | NNP | 201,470.04 | 7 |
| 4 | Protective and special-use forest land | DTG | 189,239.49 | 3 |
| 5 | Water surface land, Unused land | DTN | 37,039.98 | 0 |
| 6 | Other lands (office land, land for traffic, medical, public, etc.) | DKH | 39,521.88 | 15 |

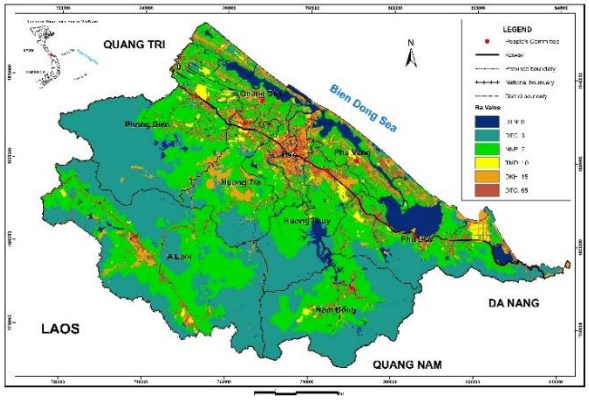


**Fig. 4.** Weighted map of the population distribution of land-use type $R_A$

### c. The pixel plots of land-use types by ward $A_T$ map

**$A_T$** map layer is calculated based on the statistical analysis between the administrative boundary raster layer containing the code of the commune/ward (CodeBlock2020) and the grouped land use raster layer (Landuse2020). **$A_T$** map calculated as the sum of pixel grid plots of land-use types per administrative unit (Figure 5).

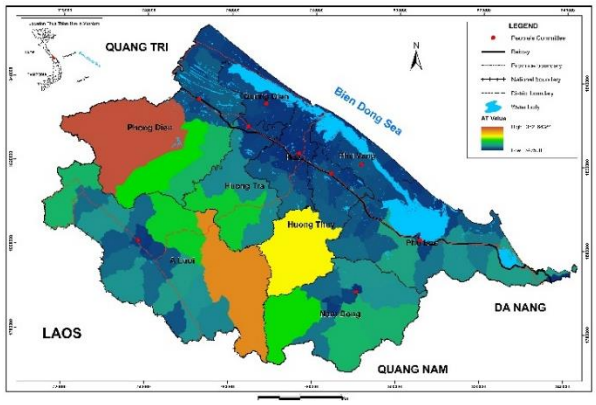


**Fig. 5.** Map of pixel plots of land use types by ward **A**T

### d. The expected population of the enumeration unit - E-coefficient map

The layer is calculated as the anticipated population per commune/ward-level administrative unit. The E value equals the sum of the products of relative density and the proportion of each land-cover type in each enumeration unit. The calculated E-coefficient map is clearly shown in Figure 6.

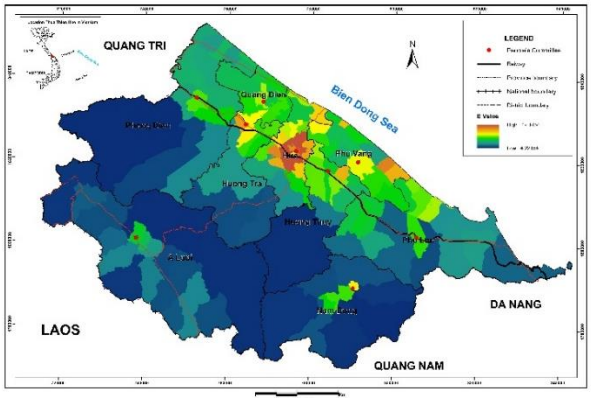


**Fig. 6.** E- coefficient map

## 4.2 Population density mapping by Dasymetric and Choropleth technique

From the results of building component map layers, the Dasymetric population density map per 25 x 25 m pixel unit is calculated based on the Raster Calculator tool according to the formula (1) is shown in Figure 7.

These demonstration maps show that in 2020, the population density of Thua Thien Hue is the highest at 20.02 people per 25 m pixel, and the lowest is 0, the mean value is 0.14. The population has a concentrated distribution in the wards of Hue city, the central area of the Province, with the characteristics of a large population and a small area of communities. Hence,

the finding output is pretty accurate compared to reality. Areas with moderate population concentration are distributed in the towns of the remaining districts such as A Luoi town, Khe Tre town, Phu Loc town, or locations in the surroundings of Hue city. Sparse areas are distributed in regions where forest land and agricultural land account for most of the Province.

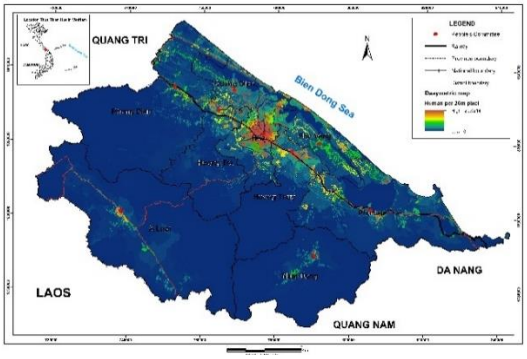


**Fig. 7.** Population density map produced by Dasymetric mapping technique

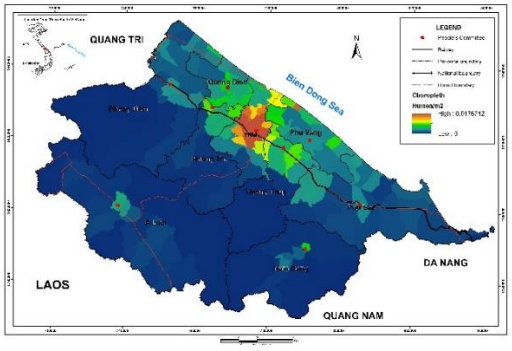


**Fig. 8.** Population density map produced by Choropleth mapping technique.

Compare and contrast the results of population density maps built using the Dasymetric mapping technique (Figure 7) with the Choropleth mapping technique (Figure 8; there is a difference in population distribution according to the two approaches. According to the Choropleth mapping technique, the population is uniformly distributed within the commune/ward boundary for population density. The maps in those areas still show uniform density values throughout the analyzed commune/ward in the areas where rivers and streams are uninhabited. Meanwhile, the population on the Dasymetric one has a clear and realistic division within the commune/ward boundaries based on the distribution of the current land use. Thus, based on comparative visualization, the Dasymetric mapping technique approach accurately reflects the population distribution than the conventional method. Because, in reality, the wetlands will be uninhabited. Through the data, in 2020, the practice of solving the graph gives us the result that the most significant population density is 0.01 people/$m^2$ (6 people per 25 m Pixel). The lowest is 0 (actually 0.02, cause there is a ward without statistics, the default is 0), while for the Dasymetric mapping method, it is 20.02 and 0.

For better analysis, the hypothesis is that the density map population built by the Dasymetric mapping technique more accurately shows where people live in 1 administrative unit. To test the accuracy of the Dasymetric population distribution, the total statistical population by commune/ward is evaluated as an indicator of the extent to which the population is distributed within an administrative unit. Density map mapped Pixel Dasymetric including 25 m x 25 m (625 $m^2$) respectively in the form of points; each point would show that the total population of Pixel. The total points on the Dasymetric map for each commune/ward were extracted for comparison using the Convert raster to point tool. For example, according to the

2020 population statistics, the Hue city area's analysis is 353,222 people with a population density of 3.11 people per 25 m pixel. According to the surrounding administrative boundaries, the Choropleth population density is homogeneous on each ward (Figure 9a).

Meanwhile, the population distribution in the Dasymetric mapping technique is differentiated according to the land-use model. The population is concentrated in a specific area and has a clear differentiation (Figure 9b). According to the land-use model, the ward's total population is distributed in the commune/ward, with a 1-pixel plot corresponding to 900 $m^2$ representing one corresponding population value (Figure 9c). The total value of pixels within the ward boundary will be equal to the entire census population of that area.

(a) (b) (c)

**Fig. 9.** Population density of wards in Hue city and surrounding areas: (a) Choropleth mapping technique, (b) Dasymetric mapping technique, and (c) The value of each point is similar Population distribution on administrative units

## 5 Conclusion

The paper has shown that Dasymetric mapping is a feasible approach to determining the spatial data's primary statistical surface. The solution mapping method can be effective for territories with a small area and a uniformly distributed population, especially for urban core areas. However, the Dasymetric map shows the population distribution more intuitive and informative for large administrative units and prominent people if the numbers are not uniformly or sparsely distributed. The study applied the Dasymetric mapping technique with GIS to classify population density for each region's inhabited areas. This efficient method is low cost and can quickly provide up-to-date information on recent changes in population distribution. Based on the visual comparison, the Dasymetric mapping technique approach accurately reflects the population distribution than the conventional method. The findings of this study will be used as the basis for urban spatial development planning, infrastructure, disease control, and ecological assessment studies in the context of climate change challenges in Thua Thien Hue province.

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