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CARTOGRAPHIC MODELING OF THE POPULATION DENSITY IN THE FUNCTION OF RESEARCH OF SPATIAL–DEMOGRAPHICAL RELATIONS

Abstract: Cartographic modeling of the population density by a diagram map method (comparative way of semioscale mapping) and by a method of cartogram, enables presentation of the information about current spatial-demographical relations in a systematic, comparative, metrical, synoptic and suitable way, relevant for different aspects of specific research. Through methods of the cartographic information forms various types of population density are included: general, general agrarian, specific agrarian, agrarian-productive density and valorized agrarian population density. Chosen and applied cartographical methods, by modeling of the population density, enable to view them and express in a more apparent spatial graphical-analytical way. Applied semiometrics tends to realize the results of the numerical values of the parameters of the subject area via figures of symbols. Different types of population density are shown on the coordinate graph which enables their comparison as well as their status regarding the average values of the subject area. Cartographic modeling of the population density enables analytic and synthetic approach in researching and evaluating of the quantities and quality characteristics of the presented categories, which are functionally connected and determined, for the purpose of highlighting the typical, specific and essential. Application of the cartographic methods in modeling of the population density is shown in the example of municipalities in districts of Bor and Zajecar for 2002, where the spatial differentiation of the population density was explicit.

Key words: cartographic modeling, cartographic method, semiometrics, population density, spatial-demographical relations

Introduction

Cartographic modeling is a specific way of scientific expression and research. The system of cartographic forms of logical methods of knowledge, includes the following processes: comparison, analyses and synthesis, abstraction and generalization. Cartographic form of comparison has its own specialty. A map exists spatially in time, and temporally in space, thus enabling a cartographic

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form of the logical method of learning of the objects that can be grasped visually, but also of the phenomena and processes that do not have visual forms of existence. A map, through its language, expresses the similarities and differences, while in its more complex form, i.e. a geographic comparison, it shows the regularity in those similarities and differences for the further generalizations. Cartographic form of analyses and synthesis is characterized by spatial, temporal and structural distinctiveness in the course of research and learning of the content – of each element, of the characteristics and determination of their mutual relations, as well as its core. Cartographic form of the abstraction and generalization includes parameters of quantity and quality of the content of the subject area, their actual characteristics and relations determined by the process of chosen and adjusted to purpose, classification for the reason of highlighting the typical, specific and essential (Aslanikasvili, 1974).

Complexity of the mapped parameters is shown in the map. A map represents the source of rational information for presentation and researching (structural, causal and comparative analyses). Composition of thematic content of the map depends on its purpose. By cartographic modeling of the population density, as one of the most important quantity and quality parameters for actual geographical-demographical relations, the information is given in: a systematic, classified, generalized, comparative and synoptic form. Application of the cartographic methods (diagram map and cartogram) and of the cartographic ways of expression, enables metrical and explicit presentation of the spatial complexity of the population positioning.

Application of the cartographic methods in population density modeling

A map with the population density (as in the example of municipalities in districts Bor and Zajecar for 2002), composed by combining of a diagram map and cartogram method, enables systematic analyses in research and evaluation of the characteristics of the presented phenomena regarding their quantity and quality – essentially interfaced and determined.

The chosen application of combined methods of diagram map and cartogram method in mapping the population density enables to highlight the differences between the numerical expressions of its attributes. Characteristics of the population density, as a series of numerical values of parameters, are given in a semioscale (comparative way of mapping) in the course of cartographic modeling, by which their metrical adjusting has been done, in order to achieve more diverse and quality information.

Methodological approach is based on the presentation of the population density on real and reduced areas. Reduced areas are the parameters for production potentials of the territories depending on their natural resources. Different ways of soil exploiting can be translated to one measurement unit and calculated in relation to the reduced area[1], which gives, so called reduced density.

A graphical-analytical spatial description of population density is shown, as an example, for the municipalities of districts Bor and Zajecar according to the registration in 2002 – (total number of population, total number of the agrarian population and total number of active agrarian population). Data on the ratio between total population, total and active agrarian population regarding the total and total agrarian land of the subject municipal territory were presented as measurable numerical parameters. That is, various types of population density were included in cartographic forms of knowledge – general, general agrarian, specific agrarian and agrarian-productive density[2].

Two combined cartographic methods were intentionally chosen and applied to the subject topic: diagram map and cartogram. Diagram map method was used to show the figures: area surface (real and reduced) and population density (real

[1] Ratio between real and the same reduced area. For reducing of the real area surface the following coefficients are used: acre and garden – 1; orchard – 1.6; vineyards – 3.01; fields – 0.4 (cultivated area); pasture – 0.15; sedge land – 0 (agrarian area); wood – 0.10 (productive area); and infertile land – 0.05 (total area) (Simonovic, 1980).

[2] 1. General density
– General population density – ratio between total number of population at 100 ha of the total (real) area surface;
2. Agrarian density
– general agrarian density – ratio between total number of population at 100 ha of the total (real) agrarian surface area;
– specific agrarian density – ratio between total number of population at 100 ha of the total (real) agrarian surface area;
– agrarian-productive density – ratio between total number of active agrarian population at 100 ha of the total (real) agrarian surface area;
3. Reduced density:
– general reduced population density – ratio between total number of population at 100 ha of reduced total surface area;
– general reduced agrarian population density – ratio between total number of population at 100 ha of reduced agrarian surface area;
– specific reduced agrarian population density – ratio between total number of agrarian population at 100 ha of reduced agrarian total surface area;
– reduced agrarian-productive population density – ratio between total number of active agrarian population at 100 ha of total reduced agrarian surface area (Spasovski, 1985).

and reduced), by the coordinate graph in relation to the average values. In this way, the different components (area surface, population) were apparently compared as well as their characteristics in functional relation (population density). Cartogram method was used to show the values of valorized agrarian population density according to the given classification by raster intensity for the relevant administrative-territorial division.

Modeling of the population density determines application of the semioscale in metrical forming of the figures in a symbol form for series of diverse numerical values, which result in graphic-numerical information.

Coordinate graph of the population density enables comparison of different types of population density in administrative units (as in the example for municipalities of districts Bor and Zajecar). The graph is a rectangular coordinate system with x and y and areas they form in a certain quadrant, in a rectangular shape. Surface area is shown on the abscise (x), and population density on the ordinate (y). Values of the coordinates are sides of the rectangle which make a graphical area showing the number of population. Values on the x- axis and y- axis showing the area surface and population density are defined by a semioscale – a comparative way of mapping.

There are various types of population density shown on the graph: I quadrant – general population density and its reduced value; II quadrant – general agrarian population density and its reduced value; III quadrant – specific population density and its reduced value; IV quadrant – agrarian-productive population density and its reduced value. In order to enable comparison of the population density for each administrative unit with the average population density, they are adjusted to ratio in relation to average area population density.

It is done by defining one side of a quadrant for the average surface area of the administrative unit in that district (on x- axis) and presenting the average population density (on y- axis) as a side format of the subject quadrant. Rectangular coordinate graph can be combined in map metrics with polar coordinate system (polar radius φ as a diagonal of the rectangle and polar angle α). Therefore, a coordinate graph, especially when combined with rectangular and polar system can express structural parameters of the mapped phenomena in many values. A coefficient of the relative population density (N) represents the ratio of the population density of the administrative unit (of the chosen municipalities) according to the population density of the district. It represents the ratio between the coordinates x and y in a polar angle α, as formed by a x-axis and quadrant diagonal for the average population density. Thus, a

coordinate graph, as a combination of rectangular and polar systems, shows population density by values of a polar angle α[3] (Sretenovic, 1973).

By making a coordinate graph, a cartographic expression, graphic comparison and apparent measurability are enabled for: – population density, area surface and population for relevant administrative unit; – population density and number of population between certain administrative units of the subject district; – population density, area surface and population for administrative units with the average area surface, population density and number of population of the subject district (Sretenovic, 1973).

Applied values in the process of semioscale mapping:
– average surface area of the municipality of the relevant – chosen territory which represents the basic value of the ($G_{\varnothing}$),
$G_{\varnothing} = f_{\varnothing} = 89140$ ha,
– basic scalar (S) (is defined *ad hoc* but depending on the average, basic value of the parameter G, for the purpose of optimal dimensioning of all parameters of the subject topic),
S = 10 mm,
– reduction (T_1) for presenting of all area surfaces on *x* - axis: $T_1 = G_1 \cdot S^{-2}$,
$T_1 = 891.4$,
– average for the general population density ($A_{\varnothing} = G_2$),
$A_{\varnothing} = G_2 = 43.8$ populat./100 ha,
– reduction (T_2) for presenting of all densities on *y*- axis: $T_2 = G_2 \cdot S^{-2}$,
$T_2 = 0.438$,
– separate scalars (s) for presenting of the area surfaces $s_1 = \sqrt{f} \cdot \sqrt{T_1^{-1}}$ and for presenting of the population densities $s_2 = \sqrt{A} \cdot \sqrt{T_2^{-1}}$; (f – separate municipal area surface,
A – separate, relevant population density).
The process of metric mapping:
– is done by applying a formula $g = f = s_1^2 \bullet T_1$ and $g = A = s_2^2 \bullet T_2$.
Characteristics of the agrarian population density may be reviewed and compared more meaningfully by using the parameters – valorized agrarian population density. Valorized agrarian population density (A_v) represents a

[3] Polar angle α for the average population density is 45° or a coefficient of the relative population density $45^{\circ} = 1.0$; administrative units with lower population density than average have a coefficient less than 1.0, and administrative units with higher population density than average have a coefficient more than 1.0. This makes population density of the administrative units more metric and comparable with the average population density of the district (Sretenovic, 1973).

conditional numerical relation between the number of agrarian population and valorized agrarian area surface with the average national income in agriculture at the municipalities. By comparison of the general agrarian population density (A) and valorized agrarian population density (A_v), municipalities with the agrarian population density can be defined: deficit, surplus and optimal population density.[4]

Population density in the function of research of spatial–demographical relations

In the course of research of the settlements revitalization issue, especially regarding regional and rural development, it is necessary to include content and relevance of all the significant parameters that are functionally connected and determined. When pointing out the quality measurable parameters of a certain area, population density is one of the basic within the research of regional and rural development.

Apart from the territorial, socio-economic organization of the village population within the municipalities, has different forms which have been changing during time. Agriculture was traditionally a basic activity of the rural population. Nowadays, it is quite neglected, and needs to be revitalized and improved. General trends of demographic development of the total rural population had a negative effect on the agrarian, especially the active population. Decrease in number of the total rural and, within it of the agrarian population, makes the revitalization more difficult. Population resources are in a different correlation with natural resources vital for the revitalization and development of the agriculture and villages in most of the Serbian municipalities.[5]

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[4] Valorized agrarian population density (A_v):

$$A_v = \frac{P^2 \cdot D}{f\,d \cdot P} = \frac{p \cdot A \cdot D}{d \cdot P}$$

P – agrarian population in Serbia,
p – agrarian population in the municipality,
f – agrarian area surface of the municipality,
D – national income in agriculture in Serbia,
d – national income in the municipality,
A – population density in the municipality (Sretenovic, 1986).

[5] More details on this subject can be found in the essay by Todorovic (2003): Agrarian population in the process of regionalization, Demographic principles of the regionalization in Serbia, book 54, GI "Jovan Cvijic" SANU, Belgrade, p. 201-248.

Territorial demographic resources, which agrarian production depends on, especially in rural parts of the less developed municipalities, are viewed through a population density as a numerical indexes for the population positioning regarding the total and agrarian area. Changes in numerical migrations of the total, and especially total and agrarian population, had negative effects on the recent development of the agriculture and villages in most of the Serbian municipalities.

Ratio between real and reduced area surfaces shows the potential land resources vital for the development of the agriculture in villages of the subject municipalities. Population resources, especially those engaged in the agriculture, significantly determine the problem of agrarian revitalization.

Population density is a relevant parameter of the settlements revitalization, and thus, its cartographic modeling provides the information for analytic and synthetic approach in research and solving of the problem of regional and rural development. That is, global cartographic presentation of the general and agrarian density and their geographic complexity is vital for various forms of specific researches, especially in advanced researches, for instance in the research of the agriculture and village revitalization in certain municipalities within regional planning.

By comparison of the general and agrarian density (real, reduced and valorized agrarian), the general (total population) and real demographic resources (total and active agrarian population) become evident, as well as their relation regarding certain categories of agrarian areas. Thus, population density shows population resources engaged in agriculture, which are important factors in changes regarding agrarian activities. (Spasovski, 1985).
Municipalities in districts of Bor and Zajecar (set as the examples for density mapping) are characterized by different values of the population density (general and reduced). Differences in population density are shown by the ratio between values of the population density and real general density. All municipalities have higher reduced general density than the real one. Natural resources and possibilities for development of agriculture and village revitalization are followed by low population resources, esp. engaged in the agriculture. Population resources are in different correlation with natural resources, as indicated by ratio between real and reduced general agrarian and specific agrarian density. All municipalities have higher reduced general agrarian and specific agrarian density than the real ones (table 1 and 2).

Significant parameters for more precise view of the recent and future development of the agriculture and villages are valorized agrarian population densities. By comparison of the agrarian population density and valorized agrarian population density, municipalities Majdanpek and Sokobanja are distinguished with higher valorized agrarian population density, whereas other municipalities have lower density regarding the general agrarian density. Values of the valorized agrarian population densities in municipalities Kladovo, Negotin, Boljevac, Zajecar i Knjazevac show the deficit in their population density. Parameter for this comparison is a coefficient of relative agrarian population density: Bor = 1.04; Kladovo = 1.29; Majdanpek = 0.59; Negotin = 1.16; Boljevac = 1.08, Zajecar = 1.57; Knjazevac = 2.75 and Sokobanja = 0.76.

Table 1. Population density in municipalities of Bor and Zajecar district in 2002

Municipality	General density	General agrarian density	Specific agrarian density	Agrarian - production density	Valorized density
Bor	66.7	137.5	5.1	5.4	131.6
Kladovo	49.6	105.7	7.1	4.9	81.7
Majdanpek	26.9	122.8	10.4	5.7	206.9
Negotin	52.7	79.9	13.7	9.4	69.1
Boljevac	20.9	43.7	7.0	5.2	40.3
Zajecar	64.8	98.8	7.0	5.2	62.8
Knjazevac	31.6	55.1	3.2	2.5	20.0
Sokobanja	37.2	62.2	14.4	10.4	82.1

Municipalities that make higher national income per capita in agriculture have lower valorized agrarian density, and vice versa, if the municipalities have lower national income per capita in agriculture they have higher valorized agrarian population density. This means that if two municipalities with similar number of agrarian population and similar agrarian area are compared, the municipality with lower average national income in agriculture has higher valorized agrarian population density, and the other way around. (Sretenovic, 1986).

Table 2. Reduced population density in municipalities of Bor and Zajecar district in 2002

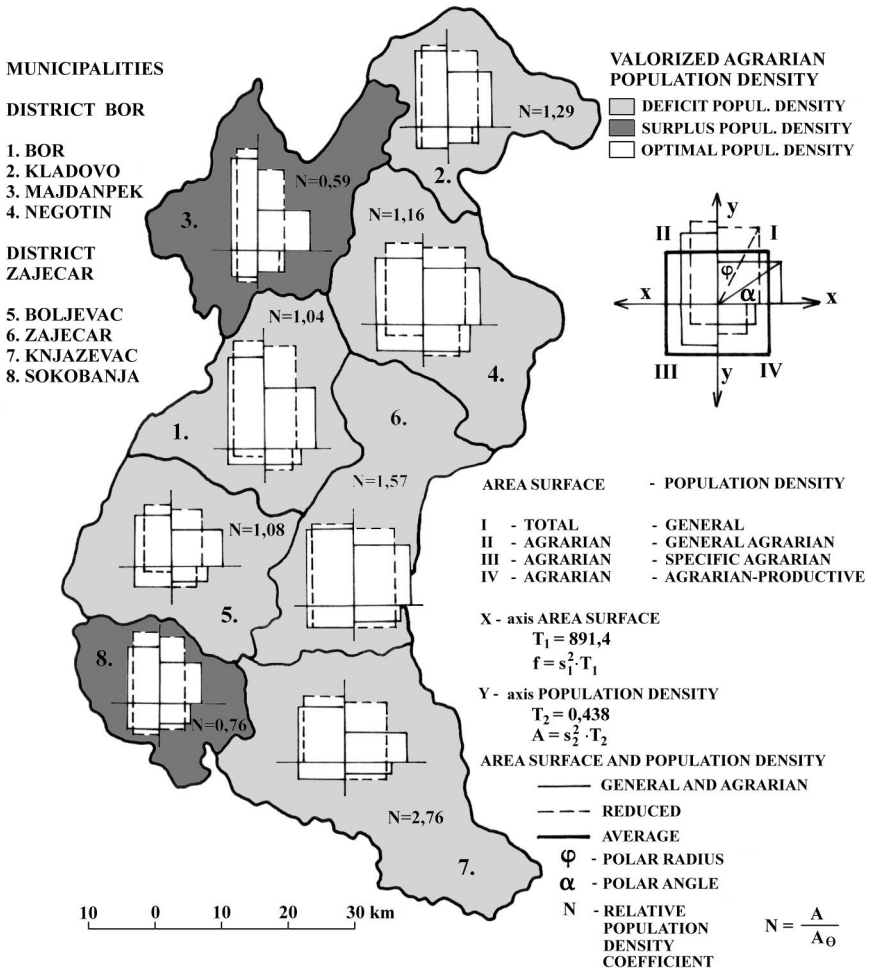
Municipality	General density	General agrarian density	Specific agrarian density	Agrarian - production density
Bor	173.9	197.8	7.3	6.1
Kladovo	105.8	118.2	8.0	5.4
Majdanpek	119.3	177.4	15.1	8.2
Negotin	98.7	117.3	19.6	13.8
Boljevac	53.6	63.2	10.1	7.6
Zajecar	100.1	109.6	7.8	5.8
Knjazevac	61.6	74.4	4.4	3.4
Sokobanja	85.8	97.8	22.6	16.4

Relevance of the cartographic modeling of the population density

Cartographic modeling of the population density by a diagram map (comparative way of semioscale mapping) and by a cartogram method enables presentation of spatial information in a systematic, comparative, adjusted, synoptic and suitable way.

The process of cartographic modeling of population density has enabled: a) *taxonomy grouping* of the features regarding their quality by grouping of the issues with similar taxonomy and classification relations and b) *quantity grouping*, which provides a view on the size of grouped (by type) issues. A map provides a perspective of the mutual relationship and correlation between various elements using quantity synthetic parameters.

By direct presentation of the relations between parameters of population density (general and reduced), the causality of their relation, their functional determination and significance is established. So, by this modeling information is presented in a systematic, classified, generalized and, for cartography, synoptic way. A map with population density (as in the example of municipalities in districts Bor and Zajecar for 2002.), made by combining the diagram map and cartogram method, enables systematic analyses in research and evaluation of quantity and quality features of presented categories – essentially correlated and determined.



Map 1. Population density in the municipalities of districts Bor and Zajecar for 2002.

Integral presentation of the characteristics of the different population positioning regarding the area surface within their territorial units enables appropriate guided research as a part of an advanced research (for ex. regarding revitalization of the agriculture and villages for certain municipalities in regional planning). Population density map (as in the example of municipalities in district

Bor and Zajecar for 2002) includes elements regarding size, comparison of many forms of densities simultaneously appeared at one territory, the influence of certain components of the presented issues (density), i.e. regional review and character of the presented elements of the subject area.

Applied cartographic methods and instruments of cartographic presentation enable (map 1.) complex presentation of the spatial complexity of the mapped subject for various types of research. Mapping of the population densities provides information for analytic and synthetic approach in evaluation, for different purposes: scientific and practical (planning and perspective of the development of certain regions). Also, mapping of the population densities for the sake of comparison, analyses and synthetic generalization is especially relevant in complex atlases (population, industry…). Complex regional atlases include this kind of maps, as a functional form of the applied cartographic information for evaluation and prospects of the development, projecting and planning. A thematic map of this content, in sequence with other mutually connected thematic maps, enables systematic research of spatial complexes with different composition and rang, with their internal and external relations. It is important to establish the character of relations and their differences. Systematic mathematical and cartographic presentation, geographical interpretation and spatial-temporal analyses enable differentiation of the territory according to the type of parameters relevant for the research.

Summary

Cartographic modeling of population density, as in the example for municipalities in districts of Bor and Zajecar in 2002, has stipulated the necessity of using a semioscale in metric constitution of sign figures in forms of sign series with different numerical values, which results in exposed and deductive information, i.e. numerical information and nomo information. By semioscale mapping and its comparative form, separate figures in sign forms are dimensioned according to the relevant serials of numerical values of different parameters, in the process of cartographic modeling.

Combination of the two cartographic methods - a diagram map and a cartogram - have been intentionally chosen and applied for the subject topic. Diagram map method was used to show the figures: area surface (real and reduced) and population density (real and reduced), by the coordinate graph in relation to the average values. In this way, the different components (area surface, population) were apparently compared as well as their characteristics in functional relation

(population density). Cartogram method was used to show, in a very explicit way, the values of valorized agrarian population density according to the given classification by raster intensity for the relevant administrative-territorial division.

The process of cartographic modeling of population density has enabled taxonomy grouping of the features regarding their quality and a quantity grouping regarding their type. Mapping of the population densities is a functional way of applied cartographic information. A map provides with the overview of the relationship and correlation between various elements using quantity synthetic parameters. Also, the map includes the elements for size evaluation, for comparison of numerous density forms simultaneously present at the same territory, as well as for the impact of certain components of the presented densities.

Population density is a relevant parameter of the village revitalization, therefore its cartographic modeling provides the information for the analytic and synthetic approach in researching and solving the problem of regional and rural development.

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