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# Urban sprawl in the regional settlement system: a case study of Belgorod and Sary Oskol-Gubkin metropolitan areas

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**Abstract.** The paper defines factors and methods of studying spatial sprawl of Belgorod and Sary Oskol-Gubkin metropolitan areas. A differentiation of population dynamics in Belgorod regional settlement system is made. Built-up areas are found to occupy larger territories and display a higher development density, while the population size in metropolitan areas does not change significantly. Growth promoting factors and growth specifics are revealed, territorial disparities of built-up metropolitan areas are analyzed; a retrospective assessment of the population density in the settlement system is provided. A study of the population distribution pattern shows that the population tends to be strongly oriented toward core areas. The territories under study were mapped with ArcGIS 10.5. tools.

## 1. Introduction

Single cities are no longer key players [1] in population distribution and territorial structure of the economy. Instead, urban agglomerations are becoming a more typical pattern of settlement. Their absolute and relative role in the spatial organization of territories has increased. Due to the socio-economic, political, financial and demographic potentials concentrated in it, a city develops into the core of respective area, that is, a metropolis, thus forming a metropolitan area (agglomeration).

An intensive development of metropolitan areas [2, 3], new territories drawn into their 'orbits', more population concentrated in metropolises, suburban development, shuttle migration, urban lifestyle gaining popularity in rural communities have resulted in the emergence of Belgorod and Sary Oskol-Gubkin metropolitan areas in the Belgorod region.

The research object is the population distribution pattern in Belgorod region.

The research objectives include the following: determining the methodological approaches, developing methods, calculations and analysis of the factors contributing to the urban sprawl of Belgorod and Sary Oskol-Gubkin metropolises in the 21st century; revealing the differentiation of the population dynamics in urban and rural areas within the regional system of population distribution; establishing the spatial changes in built-up sectors of metropolitan areas and emerging challenges; a retrospective assessment of population density in the population distribution pattern of Belgorod region; mapping the results obtained.

## 2. Materials and Methods

For the purposes of this research, we have determined and used a systemic approach, regional network analysis methods, statistical methods, with an increased focus on geo-informational mapping. Official



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statistical data provided by the Russian Federal Service of State Statistics [4, 5] have been used as the data source.

In our earlier works [6], we described the delimitation of Belgorod and Stary Oskol-Gubkin metropolises and their areas, based on the spatial data of 2019.

Map charts have been made with ArcGIS 10.5 software which allows geodata to be input, processed, analyzed, simulated and compiled. Information available at data.nextgis.com (providing data on 2018-2019) has been used as the basis for making vector maps. The attributes tables have been verified and population size statistics have been added (as of 1<sup>st</sup> January 2010 and 1<sup>st</sup> January 2018). Boundaries of built-up areas and the road network referring to different time periods have been ascertained using the open access DigitalGlobe satellite images of 2008-2012 and 2016-2019 with the spatial resolution equal to 2.4 m and higher. The images cover the territory of Belgorod region and are loaded with the help of the ArcGIS Server.

In order to calculate the areas of built-up territories within the boundaries of human settlements, the Analyst tools have been used (with Intersect applied for the “settlement” feature layer and Frequency used for settlement names).

We would like to stress that the boundaries of regional metropolitan areas are identical to those of agglomerations [5]; network analysis of determining the “service area” (metropolis) in the Time impedance is basic to the method we suggest. The “default boundaries” have been identified for a large and a big city (Belgorod and Stary Oskol, respectively) with the isochron equal to 60 minutes, and for a medium one (Gubkin) with the isochron equal to 30 minutes.

### 3. Results and Discussion

The existence of two metropolitan areas is a characteristic feature of Belgorod region. Belgorod metropolis is the capital one, while Stary Oskol metropolis evolved due to the 20th century nationwide project to develop the so-called Kursk magnetic anomaly (iron ore deposits). In the late 20th century, metropolises became core areas for agglomerations, or speaking in the innovative terms of the Russian language [7], for “metropolitan areas”: Belgorod and Stary Oskol-Gubkin. As they developed, the historical evolution of traditional urban and rural settlement patterns was replaced by group forms of a high concentration population distribution. This settlement trend emerged as residential areas were located in close proximity to each other and had strong interrelations. Among the factors contributing to the formation of metropolitan areas were urbanization processes – shuttle migration, as well as the extension of suburbs, also known as suburbanization and resulting in urban sprawl. Initially, a classical type of suburbanization took place. After the emergence of the secondary and tertiary sector enterprises, elements of a structural suburbanization began to unfold [8]. As a result, we can no longer divide the suburban population into urban and rural. Instead, there is metropolitan population (located within the metropolis influence zone) and non-metropolitan (the remaining area) [1], or peripheral one (within the “centre-periphery” gradient). Due to the interpenetration of urban and rural patterns of settlement, application of labour, lifestyles and values, the dichotomy between rural and urban areas has disappeared to be replaced by a “rural and urban continuum”.

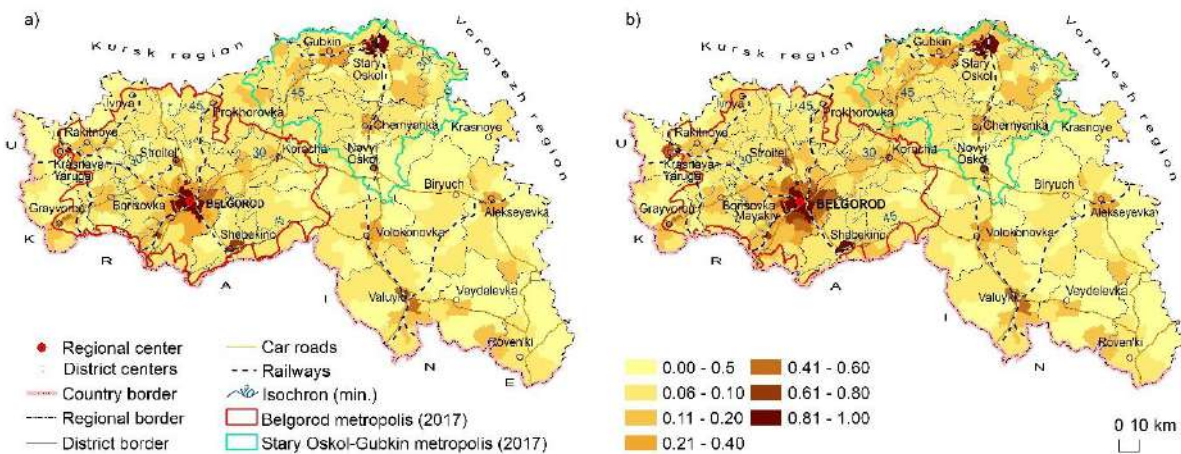
Major driving forces of the sustainable trend toward suburbanization growth in Belgorod region included land development, changes in land management patterns, more people having their own cars, the availability of good transport infrastructure and the implementation of private housing projects. The study shows that residential areas – built-up lands – grow much faster than the population size. From 2010 to 2017 only, the area of Belgorod metropolis expanded by 4%, built-up areas grew by 25%, while the population increased by as little as 0.5%. In Stary Oskol-Gubkin metropolis, these numbers equaled to 6%, 24% and 0.3%, respectively (see the table 1).

The expansion of built-up areas has resulted in the sprawl of metropolises and metropolitan areas, as well as in further changes of land management patterns, withdrawal of agricultural lands and protected areas. This practice contradicts the fundamental principle of contemporary urban development, which is based on maximum energy efficiency [9] of the city planning system.

**Table 1.** The structure of metropolitan areas in Belgorod region.

Composition	Belgorod			Stary Oskol and Gubkin		
	2010	2017	Growth index (2017 compared to 2010, %)	2010	2017	Growth index (2017 compared to 2010, %)
Metropolitan area, km <sup>2</sup>	7,778	8,113	104.3	4,881	5,169	105.9
Built-up area, km <sup>2</sup>	949	1,184	124.8	492	608	123.6
Population size	773,801	777,980	100.5	447,147	448,695	100.3

From 2010 to 2020, built-up areas in Belgorod region expanded by 3% [10], that is, from 70.9 to 73.1 thousand hectares. Figures 1 and 2 demonstrate this sprawl in metropolitan areas (figure 1).

**Figure 1.** Built-up area density: a) in 2010; b) in 2017.

Built-up density has increased as well, from 0.12 to 0.15 km/km<sup>2</sup> in Belgorod metropolitan area, from 0.08 to 0.10 km/km<sup>2</sup> in Stary Oskol-Gubkin metropolitan area, and in the region's capital, due to the newly built micro-districts. The built-up density is especially noticeable in areas within 30-minutes' drive from the core cities.

In compliance with the individual housing program, 124 thousand residential houses have been commissioned. About 85% of all the residential buildings commissioned in the region are represented by individual housing [11], but they are mainly erected in metropolitan areas. In remote non-metropolitan municipal territories, individual housing construction has stopped. The average volume of the housing constructed amounts to 0.4 m<sup>2</sup> per capita in Veidelevka district, Rovenki district (the south-east of the region), Ivnya district (the north-west of the region) and Chernyanka district (the centre of Belgorod region) [5, p. 19]. Locals explain their refusal from building houses with a strong attractive power of cities, young people's reluctance to remain rural or town dwellers. Many parents do not expect their children to return to their penates.

We believe the trend toward constructing single-family houses in the vicinity of core cities of Belgorod region will remain prevalent and may even intensify. The Covid-19 pandemic will also contribute to the urban sprawl.

The territorial expansion of built-up areas (suburbanized ones) accompanied with insignificant population growth is connected with a number of reasons, namely: the need to improve the housing



conditions, the prestige of suburban accommodation (in a single-family house) for the middle class; improvement of the living conditions in small towns and villages.

Thus, we have found that built-up areas in the suburbs have expanded, single-family houses and mansions have been constructed. Still, what social amenities are available in the new micro-districts?

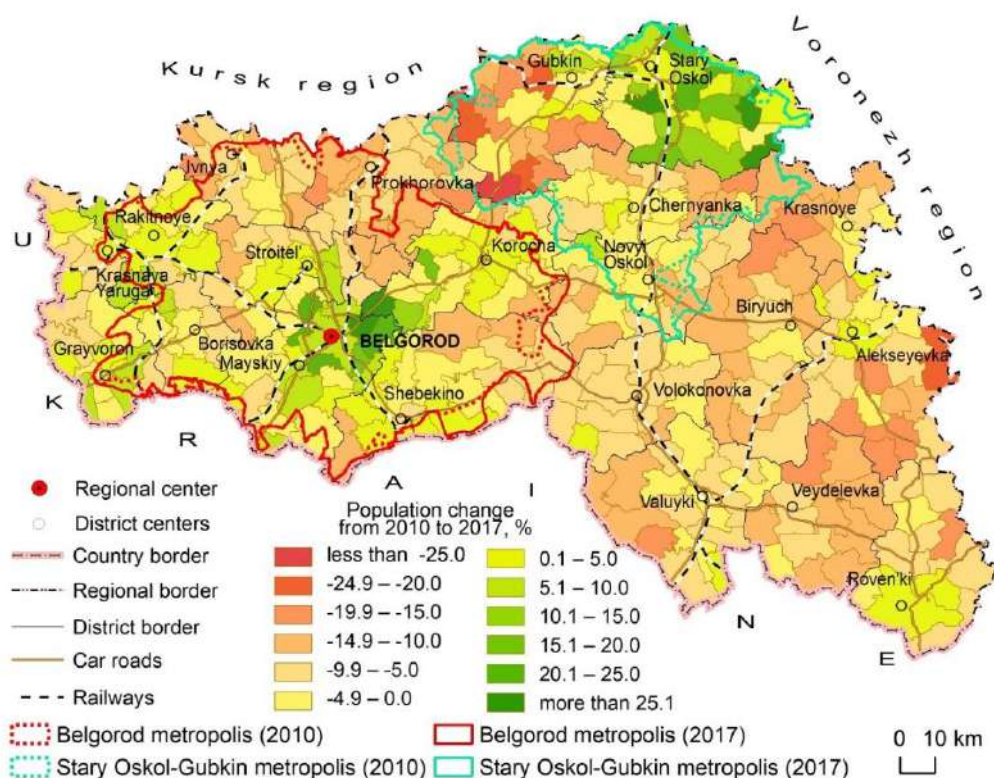
We have to stress that as early as in 2009 we argued that “new residential areas lack a systemic approach to planning the spatial organization of socio-economic development: establishments of social infrastructure are not provided, no territories are allocated for new enterprises that would meet the XXI century challenges, and no jobs are planned” [12, p. 120]. We brought up the question: “Where will the children study, where will the suburban residents work and spend their free time?” [ibid, p. 121]. Adequate forecasting of these processes will enable the society to distribute resources correctly and to save them.

Papers by a number of scholars make us conclude that the above issues have not been solved. Moreover, they have intensified. Available individual housing in the newly built micro-districts will soon cease to be attractive for the people of Belgorod region, as they lack vital infrastructure, partially or completely [11], namely, schools and hospitals, shops and cafes, as well as public transportation.

Without any doubt, the challenges described above are crucial and require a special research.

Among the reasons for the significant expansion of individual housing micro-districts is the increase of the vehicle-to-population ratio and the construction of belt highways around cities. In 2010, the length of hard-surface roads equaled to 6,569.4 km, while by 2017 this figure reached 12,995 km (calculated based on [13]), which resulted in increased traffic capacity, travelling speed, shuttle migration opportunities in the presence of a systemic rural unemployment, and eventually became an additional driver of the urban sprawl.

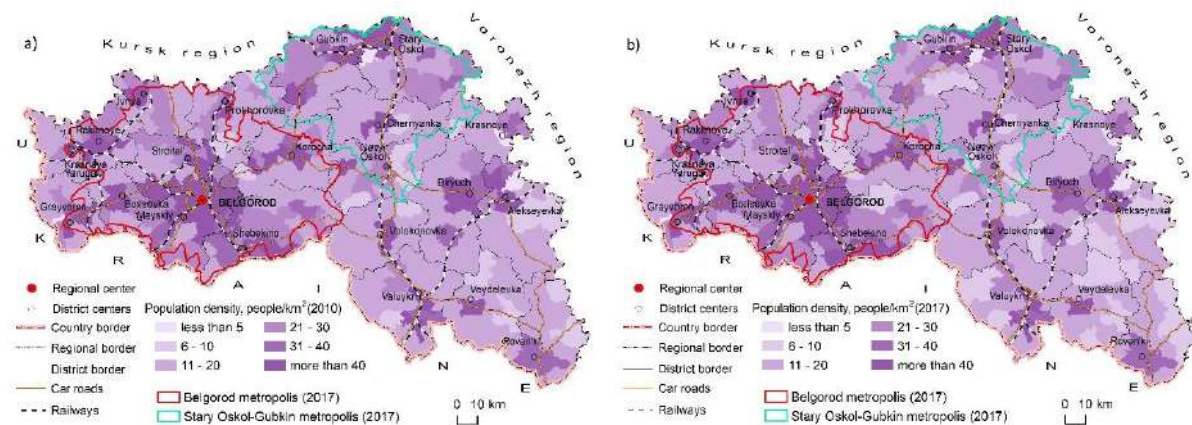
Due to the combination of the above factors, population has been drawn into metropolitan areas, and non-metropolitan territories now suffer from the socio-demographic “desertification” (figure 2).



**Figure 2.** Population size changes. Belgorod region, 2010-2017.

In a number of non-metropolitan areas in the east of Belgorod region, the population size dropped by a quarter from 2010 to 2019, while in Belgorod and Stary Oskol influence zones it rose to achieve 30% in some residential districts. The most significant population growth is typical of the first suburban area within 30 km from the metropolises: a 29% increase in Dubovoye (rural area) and a 29% increase in Razumnoye (urban area) [2].

As communities tend to be concentrated around metropolises and the few exo-metropolises [9], the region's population gravitates toward a focal pattern, with an evident dominance of high-density inhabited localities and population in the region's capital, Belgorod metropolis (figure 3).



**Figure 3.** Population density 2010: a) in 2010; b) in 2017.

Given the isochrone of the metropolitan area boundaries equal to 60 minutes both in 2010 and in 2017, high population density noticeably increased in 2017 around Belgorod and Stary Oskol. Between metropolises, population density reduced, with a more significant reduction revealed in the east of Belgorod region. Apart from causing the “agglomeration effect”, such shifts result in inequality and polarization in the region's development.

#### 4. Conclusion

The study confirms the urban sprawl taking place in Belgorod and Stary Oskol-Gubkin metropolitan areas in Belgorod regional population distribution pattern.

Factors contributing to the rapid growth of built-up areas in metropolises and suburbs include urbanization processes, transfer to the suburbanization phase driven by changes in land management patterns; a higher vehicle-to-population ratio and development of transport infrastructure; a high demand for improving housing conditions, and the middle class prestige of living in a single-family house in the suburbs.

The implementation of individual housing programs in Belgorod region has added to the expansion of urban areas significantly.

Built-up areas in Belgorod and Stary Oskol-Gubkin metropolises grow a dozen times faster than the population. At the same time, in many non-metropolitan territories of the region no housing projects are now under way. The urban and suburban sprawl changes the land management patterns and contradicts the fundamental principle of contemporary city planning, that is, maximum energy efficiency. The newly built residential districts lack a systemic approach to planning the spatial organization of the socio-economic development.

As metropolitan areas are highly attractive, people tend to gravitate toward them, resulting in metropolitan population growth and a socio-demographic desertification of other territories.

Due to the concentration of population around metropolises and the few exo-metropolises, a focal settlement pattern dominates in the region, with high density population prevailing in Belgorod, the region's capital, and the urban sprawl is now occurring.

Progressive urbanization processes create persistent problems which require adequate city-planning policies for the urbanized distribution of the population.

### Funding

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