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City Location On the River Network Pattern and The Effect of Relief On the Distribution of Urban Buildings.

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ABSTRACT

The article analyzed the role of the five largest Black Earth cities location in relation to the river network for the process of their urban development. These cities are Voronezh, Lipetsk, Kursk, Belgorod and Tambov. It was found that the initial choice of a location for a city made and still makes an impact on the applied methods of city streets and urban planning. In most cases, the settlements were founded at the confluence of the inflow into the main river. The confluence angle of these streams allowed to form a rectangular (or a transverse) planning structure in the central part of the city only occasionally. This phenomenon is observed in Tambov, for example. The configuration of fluvial relief forms, their morphometric characteristics influence the features of buildings and various parameters of buildings and their distribution along the city territory.

Keywords: river network, Black Earth cities, urban development, relief.

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INTRODUCTION

The features of a city urban development are related to its position in a river network structure [1-4]. The location of an original settlement (from which a city develops lately) in the "figure" of rivers causes the direction of development sprawl, the expansion of its borders. Thus, it turns out that the planning and the building of a city is defined in general by the initial choice of location in relation to the network of rivers and streams, and the fluvial relief associated with this network. Some researchers traced even the fractal analogy in the structural organization of an urban area and a river network draining it [5]. The works are known, indicating the association of cities to the active faults and the zones of rock increased fracturing, along which rivers are founded usually during the early stages of river valley development [6]. In some large cities, which almost exhausted the surrounding areas suitable for development, the problem of development of floodplain and delta area development appears. Such a development is impossible without a thoughtful analysis of watercourse structure [e.g. 7]. Some publications indicate that a man's influence (and, in particular, cities) on the river systems and a relief is well studied, but the opposite effect is not understood [8].

The position of a city in a river network structure, its spatial relationship with Variable watercourses affects the different characteristics of planning and construction. They, in its turn, form the living environment of citizens with well-defined parameters of geophysical fields [9-10], geochemical flows and therefore with a certain level of living comfort. They proved the landscape confinement of urban settlements to specific locations in lowland types of landscapes in the east of the Russian Plain, in particular, within the valleys of Volga, Kama and Vyatka river [11-13].

This paper evaluates the effect of a city location in the river network structure on its development according to a number of indicators using the methods of relief digital modeling and spatial analysis. The major cities of Black Earth (the historical region as the part of Central Federal District of Russia) are taken as an example. These cities are Voronezh, Lipetsk, Kursk, Belgorod and Tambov. All studies were performed on the project Russian Science Foundation (RSF) «Geography and Geoecology of rivers and river basins of the European Russia: spatial analysis, estimation and modeling».

METHODS

We characterized the historical center place of each selected city in relation to the nearest watercourses - the order of a river in a river system [14-15], the absence/presence of tributaries and orders, the angle at which an inflow flows into a main river. The manifestations of patterns in the angles of stream merge were noted in 1802 [16]. They started to relate much later the values of acute angles of merging with the difference in river orders [17]. The figure of the river network, and, in particular, the values of the merger angles define a frame for the future development of the area around a tributary confluence. That's why the original choice of location for a city (the position of this point with respect to variable watercourses of a river system) makes an impact on the planning structure of a city.

Except for the river network figure, morphometric parameters of basic relief were determined for each structure - hypsometric position of each of the buildings, an initial slope of a surface and its exposition were analyzed.

After this the calculations of building number were performed according to "morphometric allotments". "Morphometric allotment" is the total number of the earth surface lots, characterized by the same values of such indicator pairs as "elevation-slope", "elevation-aspect", "slope-aspect". 15 diagrams were built according to these data (three for each city), characterizing the differences in morphometric conditionality of building placement. These are the schemes in the Cartesian coordinate system, where the abscissa - (slope / aspect), the ordinate - (elevation / elevation and slope), and the areas of circles show the number of buildings with location relief parameter data.

Initial data for calculations - Ecrins [18], SRTM v.4 [19], OpenStreetMap [20]. Some algorithms for the processing of digital terrain models are used in the analysis of the river network and catchment areas [21].

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DISCUSSION AND RESULTS

The considered cities were founded in the vicinity of relatively large rivers - r. Tuskar (Kursk), r. Seversky Donets (Belgorod), r. Voronezh (Voronezh and Lipetsk cities) and r. Tsna (Tambov). The order of rivers [in accordance with 14-15 and 18] makes 4 (for the river Tuskar and Seversky Donets) and 6 (for the rivers Voronezh and Tsna). But the difference of a main river and tributary orders at the confluence of which the considered cities were built are quite different (Table 1). The historic city of Voronezh was founded between two ravines which do not have permanent streams and which are opened directly into the river Voronezh valley.

Table 1: River network parameters in the areas of studied city foundations

City	The position of a city foundation in relation to the river system	The main river order (according to Straler)	The order of inflow (according to Straler)	The difference of orders	Confluence angle, °
Kursk	At the confluence of the river Kur in the r. Tuskar	4	2	2	46
Belgorod	At the confluence of the river. Vezelka into the r. Seversky Donets	4	3	1	82
Voronezh	On the right bank of the river Voronezh	6	-	-	-
Lipetsk	At the confluence of the river Lipovka in the r. Voronezh	6	3	3	96
Tambov	At the confluence of the river Studenets into the r. Tsnu	6	1	5	85

Confluence angles affect the planning not only of the historic part city but also its great neighborhood. One may look at the planning structure of the central parts in the city of Tambov and Kursk for comparison. Tambov has the angle close to a right, and Kursk differs from it most of all (Fig. 1).

Fig.1. The rectangular pattern of the historic center of Tambov (on the left) and the quasi-radial one in the center of Kursk (on the right) in connection with a river network figure

In addition to the impact on the planning, the river network makes an impact on the development distribution via the relief morphology. The analysis of the development distribution diagrams allowed to reveal some features of its relationship with the relief according to morphometric allotment.

Voronezh. All the buildings are confined to the surfaces with the marks from 85 to 175 m and a slope of no more than 11°. Two storey of building concentration are traced clearly at the altitudes of 95-115 and 150-165 m. However, they are expressed mainly on the sub-horizontal surfaces (Fig. 2). Some storeyed

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structure can also be traced on gentle slopes (2-4°). At that the elevation marks of storeys decline with steepness increase. If a slope angle is more than 7° a building is located only at the altitudes of 95-120 and 140-155 m. The decomposition of selected storeys according to surface orientation criterion demonstrates their exposure heterogeneity. The development on the slopes of all exposures is available up to 4° tilt. The development on the slope of northern exposure disappears at a greater steepness. The maximum steepness of slopes under construction is confined to the E-NE oriented slopes.

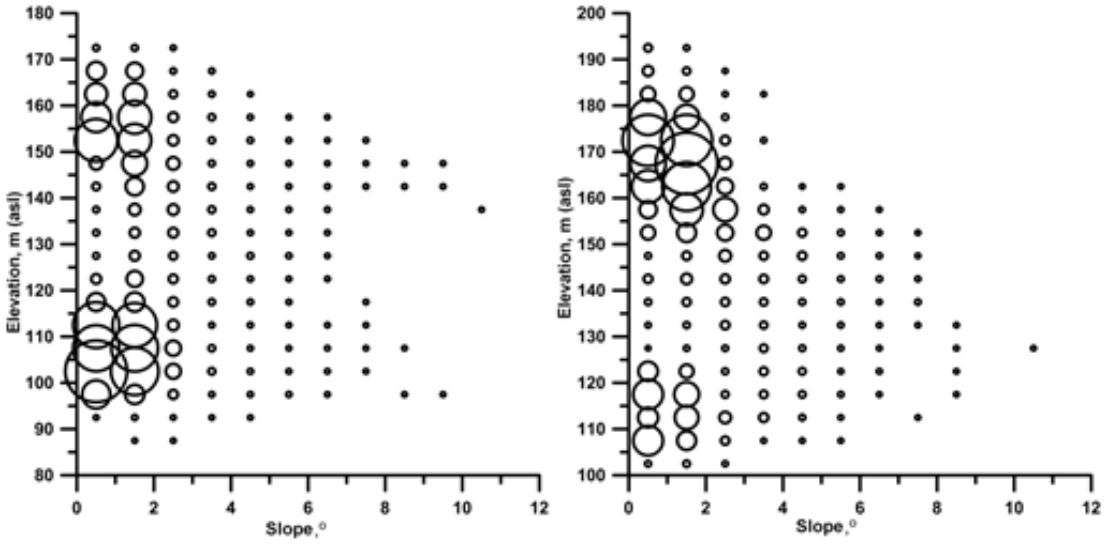

Fig.2. The distribution of construction according to the allotment "elevation-slope" for Voronezh (on the left) and Lipetsk (on the right). The number of buildings is in proportion to a circle area

Lipetsk. The buildings in Lipetsk are in hypsometric range of 100 - 195 m at the steepness of no more than 11°. Two storeys of development are clearly seen as in Voronezh. An upper storey (155-175 m), which is the main one, falls with each degree of steepness increase by 5 meters. The buildings on the slopes with the steepness up to 11° are confined only to the absolute heights of 130-135 m (Figure 2).

There is some heterogeneity in a building orientation. The concentration of buildings at the altitudes below the basic storey is noted in the sector 60-210° of the azimuth circle. The lower storey (105-125 m) is characterized by a small number of buildings on the slopes of the northern and the north-eastern exposure.

The main number of buildings is confined to subhorizontal surfaces. Mostly these are the surfaces of the south (at the slope of less than 1°) and the south-east (at 1-2°) exposure. This south-east-oriented "cluster" is traced on the slopes and in the end it "develops" into the graph peak. At the slopes oriented by the azimuth of 120-150° the construction is marked up the slope of 9°. The second peak of the graph is provided by the rare development of W-SW exposure on the slopes up to 11° of steepness, but the subhorizontal surfaces of this orientation are not characterized by building concentration increase.

Kursk. The development is confined by the heights of 150-255 m at the slope up to 14° (Figure 3). One "lower" level of development concentration is traced in a clear form. The implicit form is presented by a fragmented upper level along the slopes of different orientation. The interval of the lower level makes 150-175 m. Some unevenness is presented by the reduction of building number on the north-oriented surfaces. At the exposure of 300-330° the development concentration is confined to some higher level (160-185 m). The upper level consists of two concentration areas - a complex area in the NE-E-SE oriented surfaces at the heights of 205-245 m. The second area of concentration is clearly highlighted on the surfaces with the orientation of 180-270° at the altitudes from 205-230 to 250 m.

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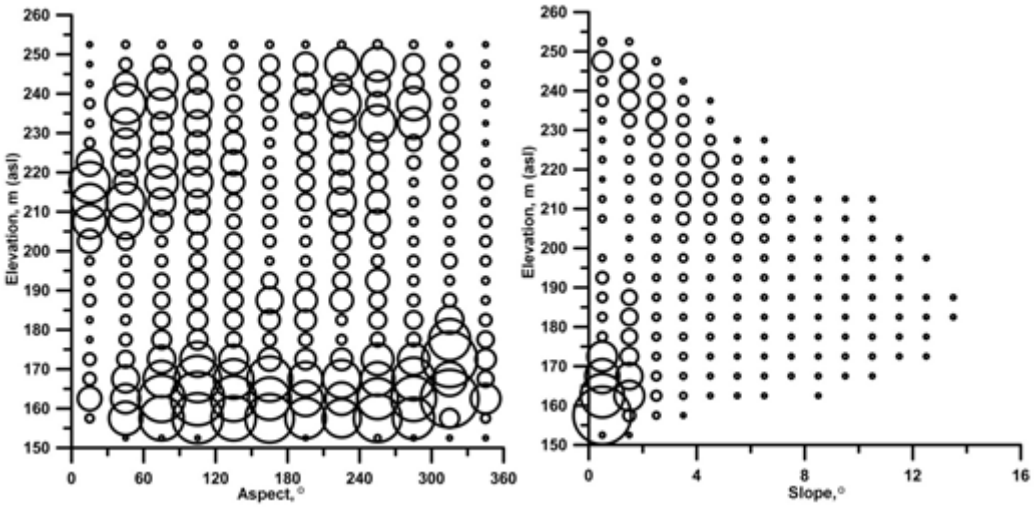

Fig. 3. The distribution of Kursk development according to "elevation-aspect" and "elevation-slope" morphometric allotments

At the classification of the fragmented upper storey according to heights and tilt angles, both areas merge into a single storey which declines gradually up to the altitudes of 200-205 m on the slopes with the steepness up to 7° from sub-horizontal surfaces at the heights of 230-250 m. The lower storey is arranged easier: the area of building concentration is on the altitudes up to 175 m at the steepness up to 1°. Above 175 m the development "crawls" on very flat surfaces, which are not slopes formally, but, apparently, they represent some ledged forms. At the altitudes of 180-190 m the construction of slopes is noted with the steepness up to 14°.

Minimum number of buildings is observed on the slopes of the northern exposure. At 0-30° orientation some burst of concentration is revealed on the slopes with the steepness of 5-7°. There is a uniform distribution in the basic storey on sub-horizontal surfaces. There is a significant heterogeneity on the slopes. Explicit peaks of building number at the exposure of 30-120°, smaller peak in terms of building volumes make 210-270°. Repeating the volumes of building, the extreme parameters of slopes developed by buildings are the maximum ones for the same exposures (up to 14° for greater first peak and up to 11° for the second one less by volume).

Belgorod. All development of Belgorod was confined to the surfaces in the range of 110-225 m with the slope up to 13°. The main level is located within the heights of 115-135 m. The concentration of development is the maximum one on the western slopes. The pronounced peaks are absent. Only the southern and the south-western slopes demonstrate an implicit peak. The northern slopes differ by a small number of buildings. The upper storey is insignificant at the altitudes from 200 to 215 m and only on the slopes in the sector of 150-270°. Clearly, this suggests a local manifestation of this storey. The field between storeys is relatively homogeneous.

Both peaks of a steep-side building are confined apparently to the heights of 125-145 m, i.e. to the lower storey of a building concentration in fact. At that the building is creeping from this level on overlying slopes. An upper "underdeveloped" storey is similar to the same storeys for other cities. The exception is the maximum number of buildings with the steepness of 1-2°, and then the storey crawls down the slopes, however, without the traces at the slopes of more than 4°. The maximum steepness of slopes, to which a building is confined makes 13°. Only NE and NW oriented slopes are developed among all slopes. The slopes of the southern exposure are mastered by the development up to 9° steepness.

Tambov. Buildings are located on the heights of 110-180 m up to 9°. There are two storeys. The upper (implicit one) demonstrates the shift of development on the slopes of interfluves only up to 3° of steepness. Then this pattern is not observed visually. The maximum values of built-up slopes are confined to the altitudes of 120-125 meters above sea level (Figure 4).

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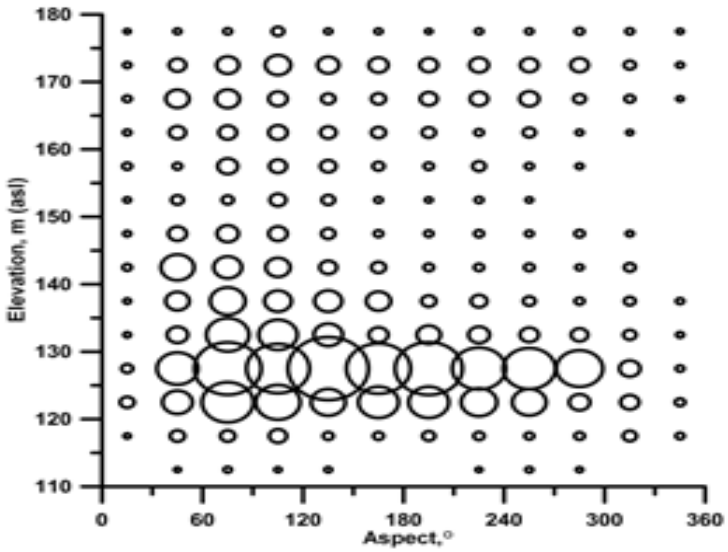

Fig. 4. Tambov development distribution according to "elevation-aspect" allotments

One storey is expressed clearly with the average marks of 125-130 m already in this "five-meter" interval which provides 27.6% of the entire building on 12% of the city area. It is characterized by an extremely harsh exposure differentiation. There are very few buildings on the slopes and sub-horizontal surfaces of the northern exposure: only 2.6% of development is confined to the surfaces with the orientation of 330-360(0)-30°, which make the sixth part of an azimuth circle.

An upper (implicit) storey is confined to the heights of 165-175 m. The field between storeys is not a uniform one: the development on the heights of 150-155 m within the sector "west-north" is absent completely. There is no development in the sector of 330-360° at the altitudes from 140 to 165 m. At that there is a large number of structures in the sector of 30-120°. In terms of building volume this "bridge" connecting two storeys is comparable, at least, with the upper storey. An absolute maximum of buildings is confined to the surfaces with the steepness less than 1°. The exposition differentiation of development is manifested on the surfaces of 1° - 2°, the maximum number of structures is confined to the sector of 60-90°.

SUMMARY

Thus, the article provides the characteristic of the impact that an initial position of the city provides in relation to the river network and the attendant relief on urban planning and development.

Briefly this influence can be summarized as follows:

- The selection of a place for a future city at the confluence of the main river inflow made a decisive influence on the used planning techniques and on the planning configuration in general. The angle of inflow into the main river did not contribute to the use of the most convenient rectangular street planning.
- The cities confined to the border areas of large, structurally conditioned relief forms clearly show this in two storey development. Voronezh and Lipetsk are among the key cities of this study, located in the transition zone between Central Russian Upland and Oka-Don lowland. The storeys are clearly expressed only on sub-horizontal surfaces, a storeyed structure can also be seen on gentle slopes (up to 4°). Steeper surfaces do not have an elevated concentration of buildings, but this development is often absent on the slopes of more than 4° beyond hypsometric ranges. At that the upper storey has a tendency to lowering (the decrease of height marks at steepness increase), the lower one to the ascent.
- An exposure differentiation of the development is expressed in general according to the number of buildings, and their nature. There is a few buildings on the northern exposure slopes, however, the surfaces of the southern orientation are not the leading ones according to this indicator. Often the

peaks of development concentration are confined to the surfaces of the north-east and north-west orientation.

- The less diverse the relief of built-up areas and the smaller the area of a city, the more pronounced the unevenness of development distribution according to morphometric allotments. This is due to the fact that there are several equivalent arrays built on different morphological relief in the cases of large urban areas. In Tambov, for example, one storey, concentrating the vast number of buildings, is confined to the similar surfaces of monotonous relief on right bank of the river Tsna.

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