Landscape-hydrological features of the territory of the Kologrivsky Forest Nature Reserve, Russia

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Abstract. The rivers of the Kologrivsky Forest Nature Reserve are characterized by a pronounced spring flood, summer and autumn low water, which is interrupted by floods and winter low water. Depth, width and flow rate can vary both seasonally and over a short period. At the Kologriv part, there are all the most common low-protocol objects, which are significantly affected by the zoogenic factor of beaver activity. The rivers of the Manturovo part of the reserve significantly differ from the rivers of the Kologriv part both in hydrological and morphological indicators.

1. Introduction
State Nature Reserve "Kologrivsky Forest" named after M.G. Sinitsyn is located in the Kostroma region, Russian Federation. The reserve was created on January 21, 2006 in order to preserve the southern taiga natural complexes of the Russian Plain. Currently, landscapes and the hydrological network in the reserve are poorly studied. The studies that were carried out on the territory of the former nature monument and the existing reserve are fragmentary [1-4]. The study of forest landscapes, their hydrological regime was carried out by many scientists, for example, A.V. Khoroshev [5], L.A. Brujinzeel [6], K. Syrjänen [7] and others.

A significant territory of the Kologrivsky part of the reserve in the middle of the 20th century was subjected to continuous concentrated logging, which led to significant changes in the annual modulus of river flow and an increase in the volume of silt sediments. In the 1960s, a significant part of the territory of the Manturovsky part of the reserve was subjected to intensive drainage reclamation. Most of the Manturovsky part of the reserve is represented by pyrogenic pine trees, which formed on the site of burning in 1972. In the first years after the fire, massive clear-cutting was carried out here.

The aim of the study was the mapping and study of permanent watercourses in the reserve with the allocation and analysis of the main catchments.

2. Methodology
The object of research is landscapes and rivers flowing in the territory of the Kologrivsky forest reserve. The Kologrivsky Forest Reserve is located in the Kologriv, Neia, Parfenyevo, Chukhloma districts (Kologriv part) and in the Manturovo district (Manturovo part) of the Kostroma region.
According to the results of land management in 2010, the area of the Kologriv part is 48094.6 hectares, of the Manturovo area - 10845.0 hectares. The total area of the reserve is 58939.6 ha.

The relief map was compiled using materials from the Viewfinder Panoramas [8] project. The tortuosity coefficient of the channel and the river slope were calculated according to the compiled electronic map of the permanent watercourses and landforms of the reserve using QGIS. In addition, as a result of the analysis of the digital elevation model in GRASS, a map of the catchment areas of the main rivers of the reserve was compiled. All cartographic material is presented in the Pulkovo 1995 coordinate system.

3. Results and discussion
For the Kologriv part of the reserve, a relief map was compiled indicating constant watercourses (figure 1). The difference in elevation is 80-100 m. The highest elevation is characterized by the area where the source of the Vonyukh river is located (altitude 210-230 m). On this site is a key site of the reserve, represented by indigenous spruce forests of different ages. North of this point, at the confluence of the Cekha river and the Londushka River, a decrease in the relief to 100-120 m occurs.

![Figure 1. Relief and permanent watercourses of the Kologriv part.](image-url)

For the main rivers of the Kologriv part, an analysis of the catchments was carried out, which are shown on the map (figure 2). Within the reserve there are catchment basins of the following rivers: Ponga, Londushka, Vonyuh, Monza, Nelsha, Pasma, Seha, Kist. The largest catchment area is the Seha River (28% of the site area) and the Nelsha River (20%). 10-15% of the total land area is accounted for by the catchments of the Ponga, Kist, Londushka and Vonyuh rivers. In total, the catchments of the Monza and Pasma rivers account for less than 5% of the area of the Kologriv part of the reserve.
Kologriv part of the reserve includes two landscapes: Kologrivsky and Kisterechensky. Kologrivsky landscape belongs to the class of elevated end moraine plains and it is characterized by quite significant absolute heights (up to 230 m at the interfluve). This landscape consists of two areas, almost equal in area. The border of the localities runs meridionally along the right nameless tributary of the Seha River.

Figure 2. The catchments of the main rivers of the Kologriv part.

The eastern area of the Kologrivsky landscape is a flat-undulating plain. The elevations of the interfluve reach 225 m, the depth of the river is 25 m. The river Vonyuh flows in this area. The rivers are cut deep enough, the channels are very flat - the sinuosity coefficient for the Vonyuh river within the reserve and in general for the entire watercourse is 1.7 (Table 1). The magnitude of the fall is very significant - from 2.6 m/km and in some areas can reach 5.6 m/km. The average fall is 3-4 m/km. The flow rates of all rivers, despite this, are low and average 0.2 m/s. The terrain is characterized by the largest density of the erosion network (small river tributaries and small erosion forms) in the entire area.

The western area of the Kologrivsky landscape is characterized by a slightly different character of the relief. This is a rounded summit hilly ridge plain. The absolute height of the interfluves is slightly less than 220 m. The depth of the river penetration is somewhat less - up to 20 m. The main rivers of this section are the upper reaches of the rivers Sekha and Kist. They are characterized, first of all, by the practical linearity of the channels - the tortuosity coefficient does not exceed 1.3. The magnitudes of the fall within this territory tend to decrease quite sharply - the Seha River from 6.6 at the source to 1.0 m/km at the mouth. The river flow rates here are on average 0.3 m/s. Interfluve drainage is better than in eastern areas. The density of the erosion network of this area is noticeably (1.5-2.0 times) less than in the east.
The Kisterechensky landscape of the Kologriv part of the reserve is characterized by a moraine water-glacial relief, mostly gently undulating. The largest rivers of the Kologriv part of the reserve flow here - the Ponga river, the Kist river, the Seha river in the middle and lower reaches. The maximum height of the interfluve here does not exceed 200 m, the depth of waterways incision is 20-25 m.

A distinctive feature of this territory is the development of the valleys of the most significant rivers within the valley zandras. These include the Londushka River and the Seha River, the Ponga River, the Kist River and its tributary, the Yurmanga River, formed at their confluence. The valleys formed in this case have a trough-like or crowded shape, their width reaches 1.2 km. River floodplains (up to 300 m wide) are complicated by old depressions. The sinuosity coefficient of the channels reaches 1.8-2.0. The magnitude of the fall of the main rivers does not exceed 1.5 m/km. The flow velocities in the middle course are 0.2 m/s, in the lower reaches 0.3 m/s.

| Table 1. Channel characteristics of the main rivers of the reserve. |
|---------------------------------------------------------------|
| River       | Tortuosity coefficient | River slope, m/km |
|            | Within the reserve     | All over the watercourse | Within the reserve | All over the watercourse |
| Ponga      | 3,7                     | 2,0                       | 0,3 | 0,2 |
| Seha       | 1,5                     | 1,3                       | 1,9 | 1,0 |
| Chernaya   | 1,1                     | 1,1                       | 2,9 | 2,9 |
| Londushka  | 1,6                     | 1,6                       | 2,1 | 2,1 |
| Vonyuh     | 1,7                     | 1,7                       | 3,0 | 3,4 |
| Kastovo    | 1,3                     | 1,4                       | 1,5 | 1,3 |
| Ivanchikha | 1,3                     | 1,2                       | 2,8 | 2,1 |

The largest river is the Ponga. Its valley is the widest (reaches 2 km) and is complicated by a floodplain terrace. The width of the river channel in the upper reaches is 12 m, in the lower reaches 15 m. The flow velocity is 0.3 m/s. At the same time, the channels of the smallest watercourses - tributaries of the main rivers, are straightened (the tortuosity coefficient does not exceed 1.1), the magnitude of the fall reaches 4.6 m/km. The valleys of these rivers are narrow, the shape of the valleys is U-shaped.

The entire territory of the Manturovo part of the reserve belongs to the basin of the Kastovo River, a left tributary of the 1st order of the Unzha River. The total length of permanent watercourses in the territory of this section of the reserve is 61.6 km. The largest watercourses are the Kastovo River and the Ivanchikha River. The channels of all rivers are slightly tortuous, as indicated by the coefficient of tortuosity. For example, for the Castovo River within the reserve, the tortuosity coefficient is 1.3, and 1.4 over the entire watercourse. For the Ivanchikha River, within the boundaries of the reserve, 1.3, and throughout the watercourse, 1.2.

Figure 3 shows the longitudinal profile of the relief of the Manturovo part from the northwest corner (latitude 44.60721, longitude 58.07350) to the southeast (latitude 44.75543, longitude 57.96298). When moving towards the floodplain of the Unzha River (from southeast to northwest), a decrease in elevations from 150 m to 115 (slope of 2.3 m/km) is observed, which is shown by the red line in the figure 3. The largest slope is characterized by the Ivanchikha River - 2.8 m/km within the reserve and 2.1 m/km throughout the watercourse. For the Kastovo River, the slope is 2 times smaller and within the reserve is 1.5 m/km, and 1.3 m/km throughout the watercourse.

The uppermost level of the relief of the territory of the Manturovo part of the reserve, located above 145 m in absolute height, belongs to the flat-wavy interfluve water-glacial plain of the Dnieper age, composed of thick sands. The interfluve of this landscape is weakly affected by erosion. Separating the hills of the saddle under conditions of difficult outflow of moisture, they are quite swampy in the upper and transitional type. The gentle slopes of the plain are complicated by ancient
hollows of the melt of glacial waters, which are currently swampy. Modern erosion forms (valleys of small rivers and small erosion forms - hollows and hollows of the girder type) for the most part inherit these ancient incisions, which explains their considerable width. Due to the cutting of thick sand strata, the shape of the valleys is predominantly U-shaped. The floodplains of rivers and bottoms of small erosive forms are mostly boggy. The riverbeds are slightly winding (the meander coefficient is on average 1.2). The magnitude of the fall reaches 3.0 m/km.

![Figure 3. The relief profile of the Manturovo part.](image)

The next two large steps are formed by the valleys of the zandra surfaces. They form drive-separated terraced surfaces, with the spread of marshy ancient glacial forms. Their slopes are quite long and steeper than in the landscape described above. The inheritance of the valleys determines their significant depletion. The U-shaped form of the valleys is preserved here. The width of the floodplains reaches 50 m, the floodplain is complicated. The channels become meandering with segmented and sometimes loop-like bends (the tortuosity coefficient reaches 1.5-1.6). The magnitude of the fall is an average of 1.2 m/km. The channels of the smallest rivers are much more straightened. Small erosion forms formed here — flattened troughs practically do not inherit the ancient forms.

In the west of the site is an ancient alluvial plain (third floodplain terrace of the Unzha River), where the river valleys become even wider. The floodplain reaches a width of 70-80 m. The riverbed is intensively meandering (the tortuosity coefficient reaches 1.8-2.0), the shape of the bends in the plan approaches the loop-like ones. The magnitude of the fall does not exceed 1 m/km. In the lower reaches, river valleys are complicated by an undivided complex of floodplain terraces, the surfaces of which (up to 200 m wide) are significantly boggy. The surface of the ancient alluvial plain is flat and also quite boggy.

4. Conclusions
As a result of the study, for the first time, maps of the relief, permanent watercourses and catchments of the main rivers of the Kologrivsky Forest Nature Reserve were compiled. The revealed features of constant watercourses and the landscape structure of the studied areas supplement the previously obtained information on the functioning of natural complexes in the southern taiga.

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