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REDUCTION OF RIVER SYSTEMS ON THE EAST-EUROPEAN PLAIN: NATURAL AND ANTHROPOGENIC REASONS

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Introduction

Already in the middle of the XIX century the well-known Russian soil-scientist Vassiley Dokuchaev attracted public opinion to a distinct tendency observed in Russian steppes: many small rivers had completely disappeared during few decades (Dokuchaev, 1892). Wide discussion on this matter started much later – in 1980th -1990th when interest to environmental problems rose highly in Russia. Comparison of old (since the end of XVIII century) and contemporary maps for selected regions provided quantitative information about decrease of the number of rivers or change of the total length of river systems. As most steppe areas in the European part of the Russian Empire were involved into cultivation only during XVIII-XIX centuries, most researches think land cultivation to be the prime reason of river disappearance. Discussion is held only on the mechanism of this process. Two explanations are most popular, both supported by indirect data and field observations:

1) Dokuchaev idea – transformation of water balance because of destruction of natural vegetation which leads to quick run-off of snowmelt water in spring and only minor percolation and thus to lowering of ground water table in summer (Dedkov, Mozherin, 1996);

2) siltation of river sources and burial of streams by sediments because of soil erosion increase in the catchments (Golosov et al., 1992).

Meanwhile, buried channel alluvium of early and middle Holocene age found in now dry valleys (Panin et al., 1998, 1999) shows that reduction and restoration of river systems took place in the geological past without any man impact and may be attributed to climatic changes. To clarify the role of climate, in this paper new data are presented on the rates of river reduction in climatically different regions and about the changes of these rates through the time.

Methods

Several series of old maps were used for comparison: (1) 1:42000 - 1:126 000 scale maps of 1770-90s made in the context of the Ekatherine the Great land reform; (2) „The Special Map of the Western Part of Russian Empire", 1:420 000 scale, engraved under the leading of General F. Shubert in 1826-1839 (so called „Shubert Map"); (3) 1:126 000 scale maps made by the Military Topographic Corps in the middle of the XIX century; (4) 1:126 000 scale maps of the „Expedition For Investigation Of The Sources Of Main Rivers Of European Russia" under leading of A.Tillo („Tillo maps"); (5) 1:300 000 (photographically diminished 1:100 000) scale maps made in 1940-50s by the USSR Armed Forces Staff; (6) 1:100 000 - 1:200 000 scale maps made by the Russian (USSR) State Cartographic Service in 1980-90s.

To make all maps comparable, permanent streams shown on old maps were transferred onto the modern maps. On a modern map all the valley talwegs were drawn up and indexed according to the Horton-Strahler order system. All the talwegs were drawn through the middle of valley bottom with no respect to river meandering. The source point of permanent stream from a given old map was defined for each talweg and marked on a base map. All data were digitised in a GIS-package (Mapinfow 4.0-5.0). Each valley stretch was indexed with its order and codes showing the presence or absence of a stream in different time period. Basin boundaries were also digitised and stored in separate tables as polygons with a related database which contains area, landuse structure, relief features and other necessary characteristics. Overlaying basin and talweg maps makes it possible to calculate total length of streams in separate basins and to watch over its change between time layers.

The Savala River Basin: An example of river system reduction

To illustrate the phenomenon discussed above, fig.1 demonstrates the fluvial system of the Savala River (right tributary of the Hoper River, the Don River Basin) shown on maps of 1830th and 1940th yrs. The Savala River Basin is located in the north of the steppe zone, in semi-arid climate with rather hot summer (mean T_{july} +22^{0}C), cold winter (mean T_{jan} –10^{0}C) and mean precipitation 450 mm annually. Line width indicates the order of valleys (by Horton system) which were occupied by permanent streams. Dry valleys are not shown.

Table 1. River length in valleys of different order, the Savala River Basin
Таблица 1. Суммарная длина рек в долинах разного порядка, бассейн р.Савала

Valley order	Total valley length L, km	River length in 1830th		River length in 1940th	
		[km]	[% of L]	[km]	[% of L]
1	4688	146	3,1	3	0,1
2	1441	371	25,7	71	4,9
3	617	398	64,4	119	19,2
4	328	310	94,4	197	60,1
5	142	142	100,0	142	100,0
6	149	149	100,0	149	100,0
7	33	33	100,0	33	100,0

Comparison of these two maps reveals obvious disappearance of a large number of rivers especially in low-order valleys. Total length of valleys of 1-7 order is 2710 km. In 1830th total length of rivers (more exactly, the length of valley stretches occupied by rivers) in the basin equalled 1402 km, i.e. more than a half (52%) of total valley length was occupied by permanent streams. By the middle of the XX century it had become twice less (total river length 710 km, 26% of valley length). The majority of the 1st order valleys were dry already in 1830th , so river disappearance concerned mostly the 2-4 order valleys

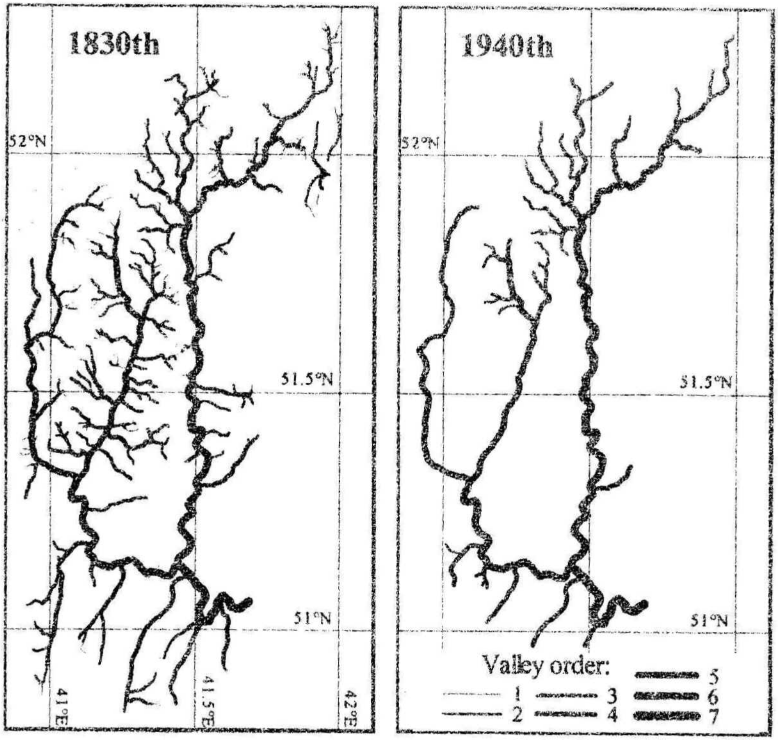

Fig. 1. River net in the Savala River Basin in 1830th and 1940th
Рис. 1. Речная сеть в бассейне р. Савалы в 1830-х и 1940-х гг.

Geographical difference in river length change

Maps from the beginning of XIX and the middle of the XX centuries were compared for 45 river basins (total area 350 000 km^2) each more than 1500 km^2 in area. The selected basins are located in a transect from Moscow to Northern Caucasus. The transect crosses different landscape zones from mixed forests in the north to dry steppes in the south and thus promotes comparisons of the rates of river disappearance in different climates. For each basin the total length of rivers in 1830th is taken as 100%. River length in 1940-50th is expressed in percent of that of in 1830th. The results are shown on fig.2.

Values of river length change show rather distinct difference in humid and semi-arid regions. In humid conditions (the forest zone, basins of the Moskva, Protva, Ugra, upper Oka, Zhizdra Rivers, etc.) both slight shrinkage and growth of river systems is detected, but the variations (±5%) lie within the limits of reliability of the cartographic method. In forested steppes and steppes (semi-arid climate) each basin demonstrates decrease of total river length. It varies from 15% (the Sosna and Zusha River Basins) to more than 50% (basins of

Chernaya Kalitva, Chir, Kalaus Rivers, etc.). So in humid conditions river systems have not undergone any outstanding changes meanwhile in semi-arid territories they have suffered from large-scale shortening.

Fig. 2. Length of river net in a number of river basins in the middle of the XX century in % to that of the beginning of the XIX century:
1 – 90-110%; 2 – 75-90%; 3 – 60-75%; 4 – 45-60%; 5 – 25-45%. Landscape zones: 6 – forest; 7 – forested steppes; 8 – steppes; 9 – deserts

Рис. 2. Протяженность речной сети в ряде бассейнов Восточно-Европейской равнины в середи-не XX в. в %) к первой половине XIX в.:
1 – 90-110%; 2 – 75-90%; 3 – 60-75%; 4 – 45-60%; 5 – 25-45%. Природные зоны: 6 – смешан-ные леса; 7 – лесостепь; 8 – степь; 9 – пустыни и полупустыни

Change of fluvial systems in time

Data on total river length in five river basins in different time moments collected by the authors and taken from literature are shown on fig.3. The basins are located in different climatic conditions and thus give an opportunity to compare fluvial system dynamics in humid and semi-arid environments.

During last 150-200 years river length in humid conditions (no.1, 2 on fig.3) varied not more than ±30% from that of in the middle of the XX century. XIX and the first half of the XX century were characterised by slight and uniform decrease of river length. In Tatarstan it lasted till 1970th and then changed to slight increase. In steppes and forested steppes (no. 3-5 on fig.3) river systems were shortened by 1,5-2 and more times. Decrease of river length was sharp and lasted during the end of XVIII – XIX century. By the beginning of the XX century river systems stabilised and remained stable during the whole century with a slight tendency to increase during last decades.

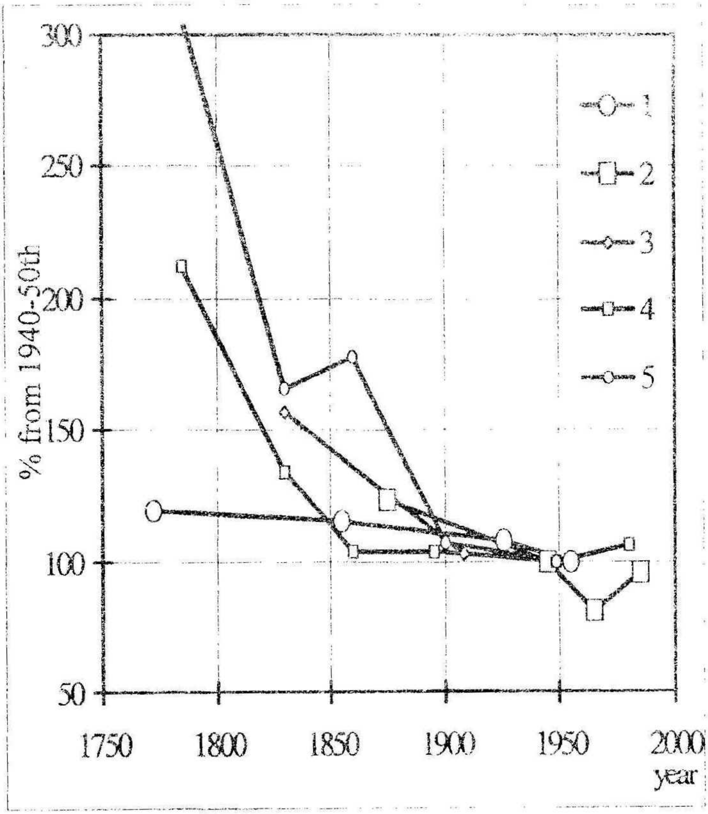

Fig. 3. Change of total river length in a number of river basins in different landscape zones: forests (1, 2), forested steppes (3, 4) and steppes (5), in % of 1940-50[th]:
1 – Western Ukraine (after Kovalchuk, Shtoiko, 1992); 2 – Western Tatarstan (after Kurbanova, Butakov, 1996); 3 – the Plava River Basin (after Golosov, Panin, 1995); 4 – upper Don River Basin (after Panin et al., 1997); 5 – the Savala River Basin (this paper)

Рис. 3. Изменение протяженности речной сети в ряде районов юга лесной (1,2), лесостепной (3, 4) и степной (5) зон, в % от 1940-50-х гг:
1 – Западная Подолия, Украина (Ковальчук, Штойко, 1992); 2 – Зап. Татарстан (Курбанова, Бутаков, 1996); 3 – верх. Плава, басс. верхней Оки (Голосов, Панин, 1995); 4 – верховья Дона и Кр.Мечи (Панин и др., 1997); 5 – бассейн р. Савала (эта статья)

In the upper Don River Basin in 1780[th] permanent flows occupied half of the total valley length (Panin et al., 1997). Period of river disappearance had been finished here by the middle of the XIX century (fig.3). If this tendency was extrapolated back in time, then at the end of the XVII century the total length of rivers would have exceeded the total length of valleys. Obviously, this is impossible, so disappearance of rivers started not earlier than at the beginning (in the middle?) of the XVIII century. Meanwhile, the north of forested steppes, especially the Tula Region where the upper Don Basin locates, has a rather long history of agriculture. Already at the end of the XVII century arable lands occupied 64% of the area of the Tula Region (Tsvetkov, 1957). Later the area of arable lands did not increase and even decreased during the XX century. So, rapid disappearance of rivers in the upper Don Basin took place much later after the onset of land cultivation.

Discussion

The above information leads to thinking over the role of natural reasons of the observed shrinking of river systems, i.e. the role of climate changes. Unfortunately, meteorological and hydrological observation data for the southern half of the East-European Plain cover rather short time period. Information on humidity changes during last centuries may be obtained from some indirect sources. One of such sources is the level of the Caspian Sea which is the indicator of water balance in the centre and south of the East-European Plain. The highest for the last millennium Caspian Sea level was indicated in the interval 1780-1810yrs, and later lowered down until the end of 1970th (Rychagov, 1993). Tendencies of the Caspian Sea level behaviour correlate well with the changes of total river length in the upper Don River Basin (Panin et al., 1997). Higher than today precipitation in steppe regions of European Russia at the XVIII – XIX century transition is reconstructed by palinological data (Klimanov, 1996). At the same period the Volga River was characterised by higher flood levels than nowadays (Reshetnikov, 1994). River runoff calculated from statistics on climatic anomalies in historical sources shows noticeable decrease since the end of XVIII till the end of XIX century (Klige et al., 1993).

These indirect data prove that at the XVIII-XIX-century border (the end of the Little Ice Age) climatic conditions in the southern part of the East-European Plain were more humid than later. The same absolute values of decrease of humidity should have different relative role in humid and semi-arid regions. In humid regions the decrease of humidity seems to have been too small to have any effect on fluvial systems, but in semi-arid regions it was high enough to result in considerable lowering of ground water levels and consequent retreat of river sources down the valleys. That fits well to the regional scheme of river net shortening (fig. 2) which shows that the climatically established southern border of the forest zone serves also as a division between regions with stable river systems and regions with high values of river disappearance during the last two centuries.

Most probably (and geologically proved) that such transformations of fluvial systems took place also before the onset of cultivation as a result of changing climatic conditions. From the other hand, such a wide-scale river disappearance in recent times could have been stimulated by anthropogenic factors discussed in the introduction to this paper. The strongest influence of cultivation was probably characteristic for steppes and forested steppes where the amount of underground water sources is small, and the effect of lowering of ground water levels was increased by siltation of river sources because of accelerated soil erosion in the fields. So excessive sediment accumulation had been superimposed over natural aridization and probably accelerated river shortening. If contemporary climatic tendencies (increase of humidity) preserve in the nearest future, river restoration may be impeded because of rather thick sediment layers stored in valley bottoms during last centuries. In any case increase in humidity may cause these sediments to move downstream resulting in a new set of environmental problems.

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СОКРАЩЕНИЕ РЕЧНЫХ СИСТЕМ НА ВОСТОЧНО-ЕВРОПЕЙСКОЙ РАВНИНЕ: ЕСТЕСТВЕННЫЕ И АНТРОПОГЕННЫЕ ПРИЧИНЫ

Резюме

Статья посвящена исследованию проблемы деградации малых рек на Русской равнине. Проведено сопоставление серии архивных карт (начиная с конца XVIII века) на территорию, охватывающую меридиональный трансект от Москвы до Северного Кавказа. Выявлено, что в гумидных условиях (юг лесной зоны) сокращения длины постоянных водотоков за два столетия не наблюдается или оно незначительно. В семиаридных районах (лесостепь, степь) с начала XIX по середину XX века суммарная длина рек в бассейнах площадью более 1500 км^2 сократилась на величины до 40-50%. Наиболее быстрое исчезновение рек в степи и лесостепи

приходится на рубеж XVIII-XIX века и заканчивается в середине-конце XIX века. В течение XX столетия длина гидросети практически не изменялась, а в его последней трети намечается слабая тенденция к ее восстановлению. Обсуждаются возможные причины деградации малых рек. В качестве таковых могут выступать понижение уровня грунтовых вод в результате изменения гидрологического режима водосборов при сведении естественной растительности и погребение водотоков под наносами, поступающими в результате ускоренной эрозии. Однако, отмечено, что в ряде районов пик деградации рек существенно запаздывает относительно пика распашки территории. В то же время, хронология процесса исчезновения рек хорошо коррелирует по времени с изменениями увлажненности в южной части Русской равнины. Сделан вывод, что исчезновение водотоков в верхних звеньях гидросети за последние 200-250 лет является результатом наложения последствий сельскохозяйственной деятельности на естественные климатические тенденции.