Soil Erosion and Small River Aggradation in Russia

Valentin Golosov

Laboratory for Soil Erosion and Fluvial Processes, Department of Geography,
Moscow State University, Russia
E-mail: golosov@river.geogr.msu.su

Abstract: Intensive soil erosion lead to transformation of sediment redistribution within river basin, because of increase of sediment input from slope to the river channel. Cultivation of interfluve and valley slopes within temperate climatic zone promotes to development sheet, rill and gully erosion. Intensive growth of cultivation area in Russia began from the southern part of forest zone and the northern part of forest-steppe zone in XVII century. Than area of intensive cultivation expanded in south and south-east directions and the rest of forest-steppe zone and steppe zone were ploughed during XVIII—XIX century. As a rule both rill and gully erosion rates increased dramatically immediately after cultivation, because of growth of surface runoff. From the other hand part of underground water decreased, that influenced on the summer water discharges of small rivers. Both these tendencies in connection with possible climatic fluctuations of precipitation across the agricultural part of Russia resulted in small river aggradation. Dynamic of small river aggradation were studied for different parts of agricultural zone of Russia using method of comparison of topographical maps composed for different time intervals. In addition the detail study of soil redistribution within small basins was undertaken for few key sites located in different landscape zone. Different methods and approaches were used for quantitative assessment the erosion and deposition rates and calculation of sediment budgets.

The river net length decreases from 20%—30% in the northern part of forest-steppe zone up to 50%—70% in some parts of steppe zone. Moment of the most intensive disappearance of small rivers was observed immediately after quick increase of arable land area within the river basins. Addition increase in river aggradation was observed after cultivation of valley sides. It was established that the intensive river aggradation started when the area of arable lands exceeded 35% from the total area of river basin. However correlation between area of arable lands within basin and intensity of river aggradation do not exist. The key factors are the location of arable lands relatively river channels, intensity of soil erosion and trap effectiveness of dry creek bottoms along the pathways from cultivated field till the river channel.

Keywords: soil erosion, deposition, river aggradation

1 Introduction

The southern half of the Russian Plain is the main agricultural region of Russia, where the most part of arable lands is located. Intensive cultivation of the Russian Plain began in XVII century from the area around Moscow, which belong to the south part of the forest landscape zone. Then forest-steppe zone was cultivated from the XVIII century. The maximum of the arable lands was reached in the end of XIX century. Area of arable lands became increase in the steppe zone only in the second half of XIX century. Hence the essential differences are observed between temporal changes of the arable lands area within different landscape zones of the Russia Plain (Fig.1).

Land cultivation leads to increase of the sheet, rill and gully erosion within drainage basins. That promoted to deliver the large volume of sediment to the small river bottoms. The most part of sediment stored within river bottoms and buried their channels. It is possible to evaluate the relationships between the river aggradation processes, deposition rates and erosion intensity in the different landscape zones of the Russian Plain.

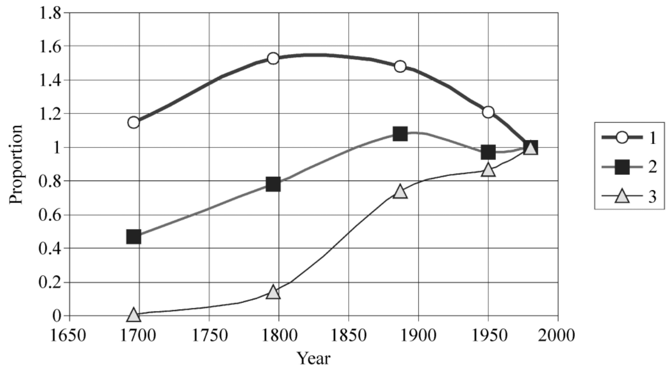

Fig. 1 The temporal dynamic of the arable land area in the different landscape zone of the Russian Plain (1 – present-day area of cultivation for each zone)Key: 1 – south of the forest zone; 2 – forest-steppe zone; 3 – steppe zone

2 Methods

The complex approach was used for evaluation of the landform changes during period of intensive agriculture within the large river basin (Fig.2).

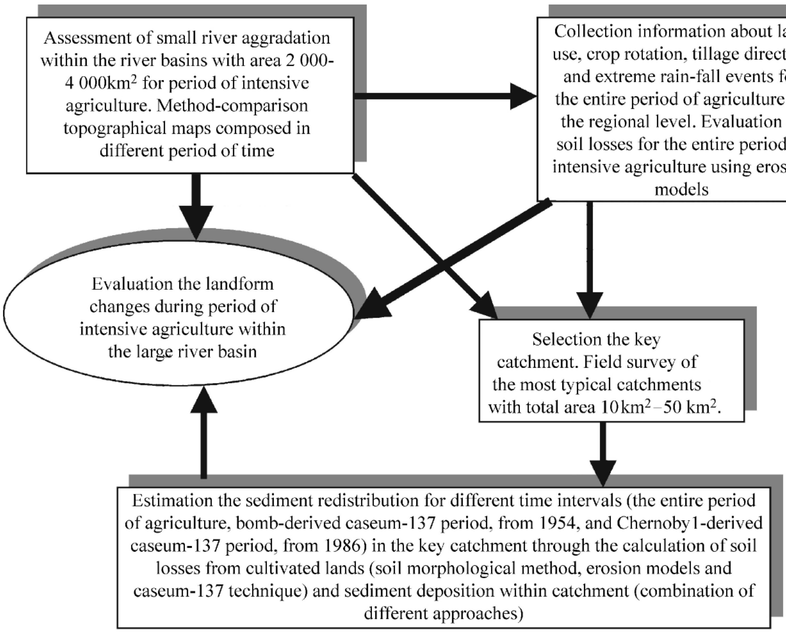

Fig. 2 An integrated approach to the assessment of landforms transformation within river basin due to slope erosion intensification

The similar approach was used for each landscape zone. Detail description of methods and models, which were used for evaluation, can be found elsewhere (Golosov, 1996a,b, 1998; Golosov *et al.*, 1992; Sidorchuk & Golosov, 1995; Panin *et al.*, 1997).

3 Results

Evaluation of river net structure changes allows to receive the preliminary assessment of river aggradation for the period 1825—1945 for the area which included the most part of the Don river basin and the Upper Oka river basin (Fig.3). It was found that river net is relatively stable within the south of the forest zone during the studied period of time. Three suggestions can be applied for explanation of this result. Firstly, dynamic of tillage area decreased during XIX—XX century in this area (Fig.1), so the sediment input from watershed areas decreased too. Secondly, cultivation area in absolute values only in some basins exceeded 60% even in the beginning of XIX. So it is likely, that the most part of the sediment eroded from tillage redeposited within interfluve area. Calculation of the mean annual soil losses shows (Table 1), that maximum intensity of erosion was observed during XIX century. This suggestion is supported the results of monitoring in several slope catchments, located in the middle reach of the Protva river. They demonstrate that recently only 7% of field sediment delivered to the river channels (Golosov, 1989). Thirdly, annual precipitation volume exceeds evaporation for the forest landscape zone. So the constant flow may exist in some valley bottoms even after channel aggadation.

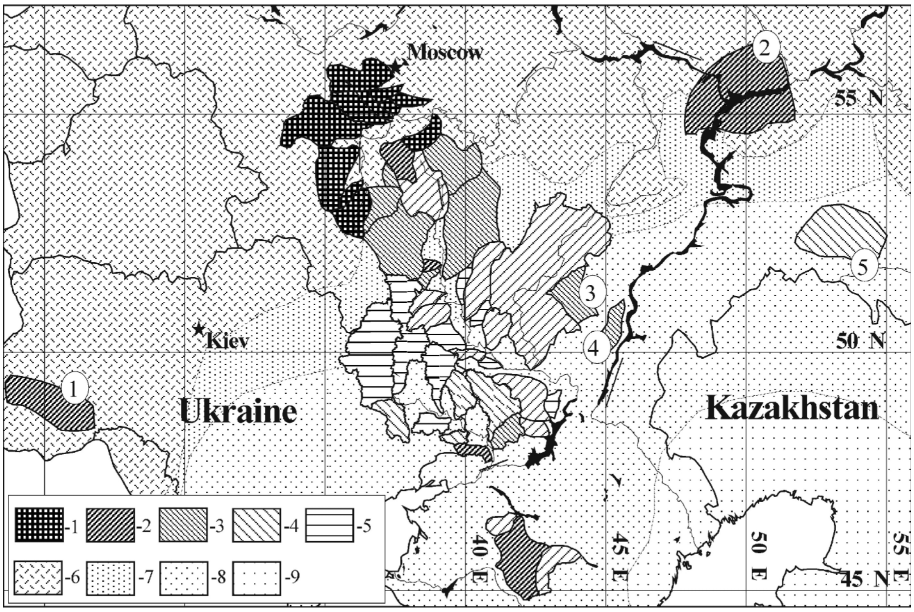

Fig.3 Change of the total river length in a number of river basins in the 1940—50th in comparison with 1820—30th (river length in 1820—30th is 100%) in %. Key: 1– 90%—110%; 2– 75%—90%; 3– 60%—75%; 4– 45%—60%; 5– 25%—45%. Landscape zones: 6 – forest; 7 – forest-steppe; 8 – steppe; 9 – desert.
Circled numbers: 1 – Western Podolia, 1855—1955 (Kovalchuk & Shtoiko, 1992); 2 – Western Tatarstan , 1876—1976 (Boiko *et al.*, 1993); 3 – Tersa river basin 1825—1960th (Golosov & Ivanova, 1993); 4 – Upper Ilovlya river basin (Golosov & Ivanova, 1993); 5 – Upper Samara river basin (Golosov & Ivanova, 1993)

However in some areas of the forest zone river (Western Tatarstan) aggadation was happen mostly because of changes in relationship between surface and underground water flow. In the result small rivers lose permanent water flow and transform into dry creek with temporary flow.

About half of the river was completely filled in the forest-steppe zone (Fig.3). Intensive growth of arable land areas and intensification of soil losses (Table 1) are the main reasons of intensive aggradation in given zone (Fig.1). However it is not possible to find good correlation between river aggradation and tillage area for river basins. Both type of relief and location tillage within interfluve area influence more essentially. It was found in the result of detail study of sediment redistribution within the key small basin, that the maximum sediment input from cultivated area to the river bottom corresponded with period of gully growth followed after cultivation of valley banks (Ivanova *et al.*, 1998).

Maximum river net transformation is observed in the southern part of forest-steppe and the northern part of steppe zones within uplands (Fig.3). This area was characterized the essential transformation of water flow in combination with maximum area of cultivation, because of chernozem soils in the second half of XIX century. So huge volume of sediment was transported from tillage to the valley bottoms. Towards south east the process of river aggradation decreases because of squeezing of tillage area and more short period of cultivation (Fig.1). One other reason is the construction of small dams in the upper reaches of dry valleys immediately after beginning of cultivation. They trapped the most part of sediment washed out from cultivated slope. It is more typical situation for Stavropol upland and Kubanskaya lowland

Fig. 4 shows the river length dynamic for five key areas (Fig.3) during last two centuries. The results confirm that river aggradation in the some areas of the south of forest and forest-steppe zones continued up to the end of XIX century (Fig.4). Later on they became almost stable because of preliminary balance between sediment input from cultivated slope and sediment deposition in the dry creek bottoms.

Table 1 Dynamic of soil losses for different parts of landscape zones within the Russian Plain and mean layer of sediment deposition in valley bottoms for ^{137}Cs period

Landscape zone	Evaluation period	Calculated soil loss, mm year^{-1}	Mean annual deposition rate in valley bottoms of 2—3 order for ^{137}Cs period, 1954—1986, mm year^{-1}
South of forest zone and north of forest-steppe zone	1696—1796	0.63	
	1796—1887	0.76	
	1887—1980	0.35	
	1950—1980	0.39	8.5
South of forest-steppe zone and north of steppe zone	1696—1796	0.24	
	1796—1887	0.46	
	1887—1980	0.28	
	1950—1980	0.29	12
Center of steppe zone	1696—1796	0.01	
	1796—1887	0.03	
	1887—1980	0.14	
	1950—1980	0.17	17
South of steppe zone	1696—1796	0	
	1796—1887	0.01	
	1887—1980	0.44	
	1950—1980	0.68	45
South-east of steppe zone	1696—1796	0.02	
	1796—1887	0.1	
	1887—1980	0.15	
	1950—1980	0.16	17

Evaluation of deposition rate for the few decades of the second half of XX century within valley bottoms of dry creek allows to understand the relationship between erosion at the cultivated slopes and deposition in different parts of the Russian Plain (Table 1). Intensity of deposition does not correspond directly with calculated soil losses for the same period of time for different zones. Maximum is observed in the south part of the steppe zone, which is the area with maximum of soil losses. This part of the Russian Plain was cultivated only during XX century, so it is likely, that ephemeral gully and rill erosion were more intensive, if compare with other regions. The lowest deposition rate was measured in the southern part of forest zone despite of the relatively high soil losses. Sediment re-deposition within cultivated and uncultivated slopes is the main reason of such differences between erosion and deposition. This is confirmed by the results of field long-term study at the several slope catchments in the middle reach of the Protva river basin (Golosov, 1989).

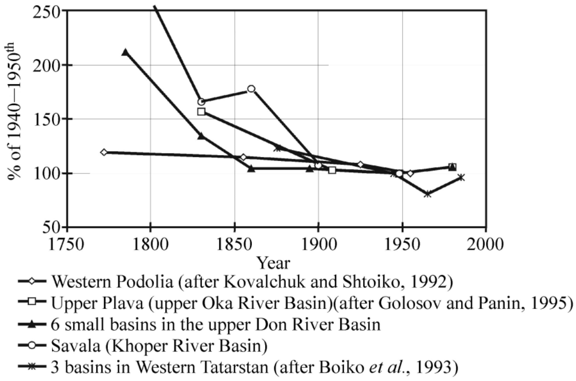

Fig. 4 Change of the total river length in selected basins at the Russian Plain (value for 1940—1950th is taken as 100%)

It is likely, that equilibrium balance between erosion from watershed slopes and deposition within bottom parts of cultivated and uncultivated slopes and dry valley bottoms is existed recently.

Similar processes are observed in the other parts of Russia with intensive agriculture, such as Ural-Tobol Upland in Western Siberia, uplands of the Upper Ob river.

4 Conclusion

Intensive cultivation of basin slope during last centuries promoted to increase in sediment input in the small river channel of different agricultural zone of the Russian Plain. As a rule, maximum erosion rate was observed immediately after vast cultivation of region. Essential reduction of the river net was observed in the result of cultivation, which led to essential changes in relationship between surface and underground flows and growth of surface erosion.

Acknowledgements

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