GIS-technologies application for calculation of potential soil loss of Marha River basin (Republic of Saha)

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Abstract. In the article the presentation of estimation methods of potential soil loss in the conditions of Siberia with application of geographical information systems is resulted. For the reference area of the Marha river basin, which is a part of the Lena river catchment, there was created a specialized geographic information database of potential soil erosion, with scale of 1: 1,000,000. Digital elevation model "GMTED2010" and the hydroset layer corresponding to the scale of 1: 1,000,000 are taken to calculate the soil loss values. The formation of the geobase data is considered in detail being constructed on the basis of the multiplicative structure which reflects the main parameters of the relief (slope steepness, exposition, slope length, erosion potential of the relief), soil, climatic characteristics and modern types of land cover. At the quantitative level with sufficiently high degree of spatial detail results were obtained for calculating the potential erosion of soils. The average value of potential soil loss in the basin without taking into account the factor of land cover types, was 12.6 t/ha/yr. The calculations carried out, taking into account the types of land cover obtained from remote sensing data from outer space resulted in an appreciable reduction of the soil loss values (0.04 t/ha/yr.).

1. Introduction

The territorial development of Siberia and Far East, indicated in the plans of the Russian Federation Government, predetermines the scientific substantiation of projects on economic development and prediction of anthropogenic impact. Territorial analysis of geographic features and phenomena is most conveniently carried out on the basis of the basin approach [1, 2]. This also can be applied to such a process as erosion.

The works on calculating the potential loss of soils within the basins of different order by means of GIS technologies is widely spread both abroad and in Russia. The review of publications on river basins in Siberia showed the lack of systematization of works on this topic. Some works concern the problem of determination of long-term dynamics of water balance. Soil-erosion processes are taken only in the individual basins of the rivers Selenga, Tom', Ob, Irkut [3, 4, 5, 6, 7].

The purpose of this study is to quantify the potential soil erosion in the Marha River basin. The research tasks included the choice of the design model of potential soil loss, the selection of source materials, their transfer to the geo-information database and the calculation of the potential soil loss in the basin.

2. Study area

The object of study is the basin of the Markha river (Yakutia), flowing in conditions of lowlying relief, the catchment area of 89600 km^2 [8] which falls into the Vilyuy river – left tributary of the Lena.

3. Materials and methods

Calculations were carried out on the basis of methods related to the class of hydrophysical models. The soil loss model recommended by the Laboratory of Soil Erosion and Fluvial Processes of the Moscow State University was used which is a modified version of the USLE (Universal Soil Loss Equation) for Russia (rainfall runoff) and the RSHI (Russian State Hydrological Institute) loss formula (meltwater runoff) [9].

The main formulas used in determining the potential loss of soil are [10]:

Soil loss from rainfall runoff:

$$LR = EPO \cdot ES \cdot EPR \tag{1}$$

where LR – Soil loss from rainfall runoff, t/ha/yr., EPO – Eroding potential of rainfall runoff, ES - Soil erodibility, t/ha per unit EPO, EPR - Eroding potential of relief.

Soil loss from meltwater runoff:

$$LM = f \cdot (ES \cdot h \cdot L \cdot I) \tag{2}$$

where LM – Soil loss from meltwater runoff, t/ha/yr., ES – Soil erodibility, h – Layer of surface runoff (reserves of water in snow, precipitation for during snowmelt, runoff coefficient), L – Slope length, m., I – Slope steepness.

Potential soil loss:

$$LP = LR + LM \tag{3}$$

The presented empirical dependencies, when performing calculations using GIS-tools are adapted for computer technology; a detailed description is contained in the monograph [9]. The loss model is based on the creation of a specialized geoinformation database using GIS tools composed of four blocks, i.e. multiplicative structure (table 1). All layers of thematic maps are presented in the form of point files [10].

Table 1. Input datasets used for the estimation of soil loss factors for Marha River catchment

Thematic factor	Parameter	Input datasets	Spatial resolution
Morphometric analysis of relief	Slope length Slope steepness Exposition	DEM GMTED2010	250x250 м
Morphological-genetic properties of soils	Soil number and name Humus content Class by structure Water permeability class Coefficient of stony Fraction of particles 0.1-0.05 mm from fraction content of 0.25-0.05 mm. Mechanical composition of soils	Soil maps in vector format; The Unified State Register of Soil Resources of Russia	1:2,500,000
Climatic characteristics	Erosion potential of rainfall (EPO) EPO Zone Reserves of water in snow	Data from Roshydromet meteorological stations FSBO "RIHMI-WDC"; Map-scheme "Regionalization of the North of Eurasia for the Interannual Distribution of the Erosion Potential of Precipitation"	250x250 м
Soil protection factor of cover and management	Types of land use	Map of land cover types	230x230 м

Morphometric analysis of relief. Digital relief models (DEM) can be divided into two categories: open access and distributed on a commercial basis. We used only open sources of data including DEM. Among them, the most qualitative global DEM for the region under study is GMTED2010 (Global Multi-Resolution Terrain Elevation Data 2010) [11]. The preparation of model of the relief is given in sufficient detail in a number of publications [11, 12, 13, 14]. On the basis of the used model of relief GMTED2010, raster layers of the morphometric characteristics of relief have been prepared: slope length and steepness, exposition.

Morphological-genetic properties of soils. As basic data the "Soil Map of Russia" which is in open access was attracted. It is created in a vector format, in scale of 1:2,500,000 by Soil institute of V.V. Dokuchayev. On this map, all polygonal objects are digitized contours of the RSFSR soil map [15, 16, 17]. The description of this map was obtained from the Unified State Register of Soil Resources of Russia (USRSR RF) [18]. Each polygon corresponds to the soil profile, to which data on the soil cover and soil-forming rocks are attached, there are altogether more than 240 soil parameters.

The database of potential soil loss contains the column "Soil Index" where to each index there corresponds the soil profile information which is filled in a separate form no. 2, presented in methodical instructions [10] and contains 13 parameters: soil name, humus content, class of a structure, waterpermeability, stoniness, granulometric composition, proportion of sand, losses norm and so forth. According to Soil map in Marha River basin there are 25 soils subtypes. Subsequently, a number of them were excluded from loss calculation due to the actual absence of erosion due to the spatial position in the basin. Areas relating not to soil formations are excluded from the soil map. These subtypes of soils and not soil formations subsequently were excluded from the map of Marha River basin.

Climatic characteristics. For definition of climatic indicators data of "RIHMI-WDC" are used: coordinates of meteorological stations [19]; air temperature and amount of precipitation (daily data) [20]. As additional materials for loss calculation the published cartographic materials were also attracted (erosive potential of rainfall, intra annual distribution (zones) EPO [9] and the manuscript map of water reserves in snow which was kindly provided by employees of Laboratory of Soil Erosion and Fluvial Processes. These cards have been digitized in the MapInfo software product with the subsequent rasterization, creation of dot files in the GIS-environment ArcMap.

Soil protection factor of cover. Types of a terrestrial cover need to be considered from a position of their influence on soil loss. Types of a vegetable cover allow to correct soil loss towards reduction, and such types as water objects, rocks, the urbanized territories etc., are excluded in general, during calculation.

The geodatabase on land cover types was created on the basis of materials of Space research Institute [21]. Values of factors vary from 0 (the protected soils) to 1 (open soils) [22]. Maps of erosive danger of lands are the results of modeling for the studied Lena River basin (figure 1). In our calculations, factor C (land use type) is used since factor P implies the consideration of an agrofon (borders of farms, pastures, etc.), which is practically absent in the basin. Details of the procedure are given in the work of Panagos et al [23].

4. Results
The created geoinformation database formed the basis of calculation of potential soil losses in a Lena river basin on earlier given formulas (1-3). Calculations are carried out in two steps: at first, potential soil loss is determined without a real picture of distribution of a vegetable cover, secondly – taking into account the types of land cover (table 2).
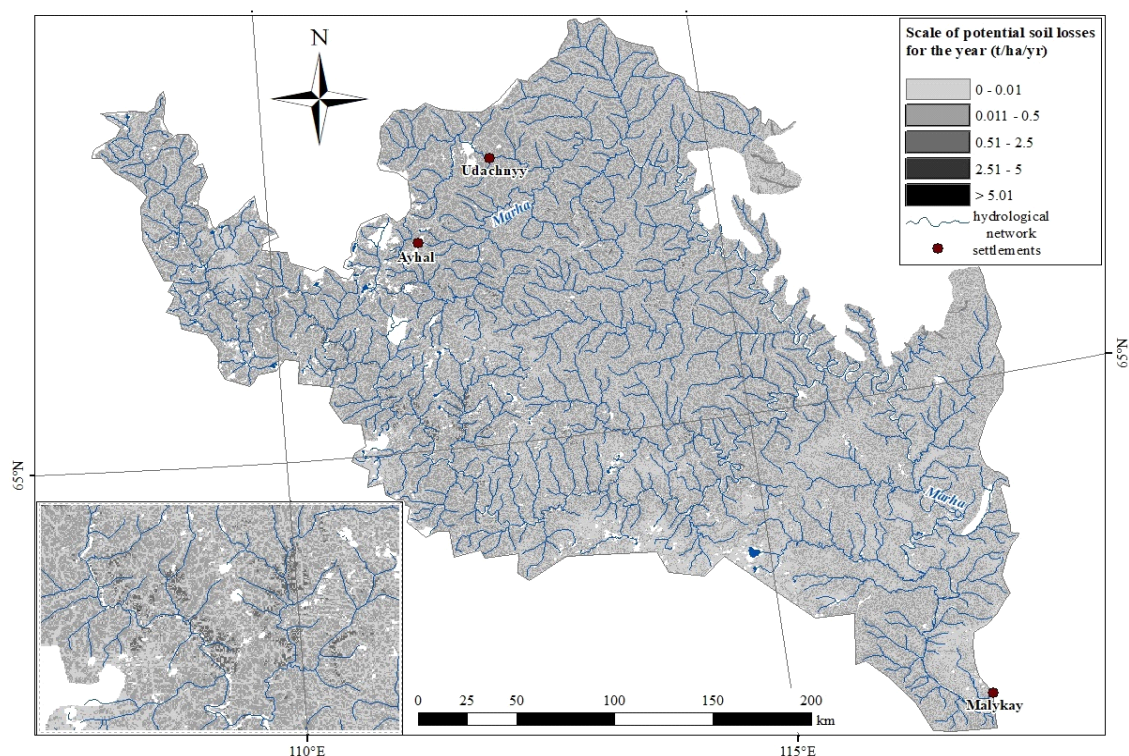
Figure 1. Lena River basin potential soil loss map.

Table 2. Lena river basin distribution by gradations of potential soil erosion.

Soil loss rates, t/ha/yr.	Soil loss (without considering the types of land cover)		Soil loss (taking into account the types of land cover)	
	Area, км^2	% of total area	Area, км^2	% of total area
0-0.01	36417	45.2	39053.4	49,9
0.01-0.5	109.06	0.1	38517.6	49,2
0.5-2.5	3018.4	3.7	733.8	0,9
2.5-5	4987.4	6.2	7.1	0 (0.01)
5-10	8668.3	10.8	0.6	0 (0.0008)
10-50	22596.3	28.1	-	-
50-100	3772.1	4.7	-	-
100-1000	944.4	1.2	-	-
>1000	0.6	0 (0.0007)	-	-
Total	80513.6	100	78312.5	100

5. Conclusions

Specialized cartographical geoinformation database of the Arctic catchment basins of an Asian part of Russia is created for the first time. As part of the database, the quantitative indexes of the parameters influencing soil erodibility are grouped according to thematic blocks (morphometric analysis of the relief, morphological and genetic properties of soils, climatic indices). Calculations of potential soil loss of the catchment basin of the Marha River were carried out based on the application of the model recommended by the Laboratory of Soil Erosion and Fluvial Processes. Based on the calculations performed, it was found that average soil loss rate per Marha river basin is 12.6 t/ha/yr, the greatest 1314.7 t/ha/yr., which corresponds to the maximum possible scenario of erosion. After calibrating the factors of model, taking into account the types of land cover, average soil loss rate per study area was

0.04 t/ha/yr., the maximum 7.8 t/ha/yr. Considering landscape and geographical features of the Lena river basin these values more correspond to realities.

Acknowledgments

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