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Solutions for the Spatial Organization of Cropland with Increased Erosion Risk at the Regional Level: A Case Study of Belgorod Oblast, European Russia

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Abstract: Among the reasons for soil degradation, runoff-induced erosion causes the greatest damage to agriculture in European Russia. One of the effective tools for regulating soil erosion is changing the structure of sown areas and the composition of crops with a focus on soil conservation and rehabilitation land use. The aim of this paper is to present the results of the impact of the program on river-basin nature management and the adaptive landscape agriculture system (ALAS) on changes in soil losses due to storm erosion in one of the agriculturally most developed and, at the same time, most eroded administrative regions of European Russia—Belgorod Oblast. In this study, the calculation of potential soil washout was carried out for three cropland models: (1) The maximum erosion potential of the territory, expressed in terms of soil washout from bare (clean) fallow areas; (2) soil washout, considering the actual structure of sown areas over the past 10 years; and (3) soil washout, considering the full implementation of projects for the erosion-control organization of cropland within the framework of ALAS. The calculation of erosion-induced soil losses was carried out according to the USLE model adapted to regional environmental conditions, while the *C*-factor values were set separately for each model. For model 1, the average soil loss is 11.3 t/ha per year; for model 2, it is 3.5 t/ha per year; and for model 3, it is 2.2 t/ha per year. It was found that the current programs for the biologization of agriculture and the contour-reclamation organization of cropland would have a noticeable erosion-control effect. It is noteworthy that the greatest efficiency was modeled for areas with unfavorable relief conditions, with up to 40% reduction in soil losses as compared to actual ones.

Keywords: soil erosion; soil loss; USLE; *C*-factor; crop rotation; environmental management; erosion-control measures; bare fallow; land use; land cover; grassing; hollow; river basin; Central Russian Upland; East European Plain

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1. Introduction

Soil (sheet/rill) erosion by water is one of the most severe problems in agriculture in the southwestern part of European Russia. It causes significant damage to the agricultural production of the country. Cultivated lands in Russia annually lose over 500 million tons of the most fertile part of the soil due to water-erosion processes [1]; the annual damage from erosion is estimated to reach 10% of the income generated by agriculture [2].

The intensity of water erosion in agricultural landscapes on the one hand limits the possibility of sustainable agricultural production, and on the other hand, disturbs the ecological balance of geoecosystems. With a high agricultural load under the conditions of a sloping landscape, the natural process of the removal of soil particles by water runoff and their redistribution downslope represents one of the key types of soil degradation.

For European Russia, detected changes in the dynamics of agricultural erosion over the past three decades were caused by climatic and socio-economic factors. The overall intensity of erosion-induced soil losses in European Russia decreased. Of the socio-economic factors, the main ones were the reduction in cropland area and the change in the structure of sown areas. The significant reductions of cultivated land area [3] with accompanying climate change in all of the landscape zones of this region after 1991 were the main reason for the 46% reduction in the total annual soil losses in 2012–2014 as compared to 1980 [4]. This trend is also confirmed by a significant reduction in river suspended sediment loads [5,6]. Transformations in the agricultural production in Russia eventually affected the soil-protection capacity of agrocenoses, having different directions in various landscape zones [7]: on cropland of the forest zone, soil washout decreased by 43%, in the forest-steppe zone by 19%, and in the steppe zone, it even increased by 19% due to an increase of the share of row crops.

To solve the problem of regulating the rate of soil erosion, a transition to an ecologically balanced spatiotemporal organization of agricultural landscapes is necessary. With such an organization, for areas of low erosion resistance of agricultural soils, mechanisms for rehabilitation land use will be developed, taking into account soil reproduction standards [8]. Choosing an effective agricultural land management strategy can significantly reduce soil erosion rates and increase soil organic carbon stocks [9]. Proposals for site-specific best management practices to check soil losses within permissible limits should also consider the economic interests of farmers [10]. In Europe, from 2016 to 2021, within the SoilCare project, the concept of soil-improving cropping systems has been developed as a holistic approach to facilitate the adoption of soil management that is sustainable and profitable. Its results showed that, along with positive impacts on the environment and soil, there are negative impacts on economic and sociocultural dimensions [11]. The project's results underlined the need for policies that support and enable a transition to more sustainable agricultural practices in a coherent way.

In this way, a model of sustainable agriculture can be created to prevent erosion. This model should be adapted to the soil-climatic and socio-economic conditions specific to the region; however, it is based on general principles:

- Comprehensive assessment of the ecological and resource status and impact on the environment, including mathematical modeling of potential causes of soil losses;
- Development of project solutions for conservation land use, including farm types, cropping systems, and agricultural management techniques;
- Regular centralized monitoring of soil quality, including agrochemical and erosion surveys;
- Economic evaluation and detection efficiency of soil protection measures.

This paper is devoted to the experience of implementing the soil conservation strategy in the practice of farming in one of the administrative regions of Russia—Belgorod Oblast. Runoff-induced soil erosion as a leading driver in soil degradation in this region is an indicator of the effectiveness of proposals for transforming the structure of sown areas.

2. Materials and Methods

2.1. Study Area

Belgorod Oblast (27,100 km^2; over 1.53 million inhabitants (2022) or 56.6 people per km^2) is one of the administrative regions of European Russia, located within the Central Russian Upland of the East European Plain (Figure 1). It is one of the agriculturally most developed administrative regions of the Russian Federation (cropland occupies 61% of the area of this region). Holding 67th place in terms of area, Belgorod Oblast is ranked at 12th place in terms of gross grain harvest (≈3 million tons in 2021). The soils of this region have great natural fertility: About 80% of the total area of the region and approximately 90% of the total area of cropland are chernozems. At the same time, it is one of the most erosion-prone administrative regions of the country.

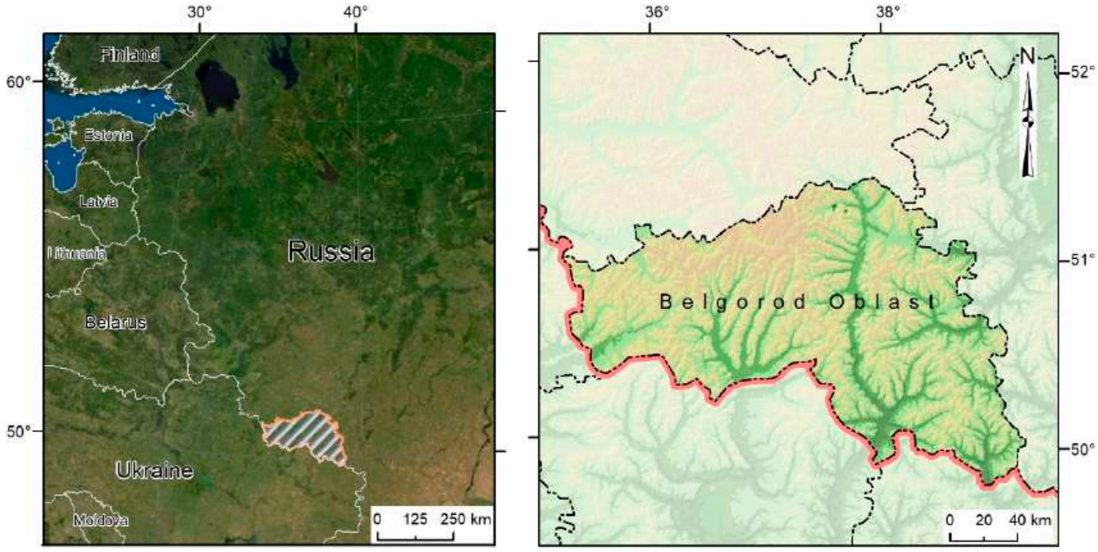

Figure 1. Location of the study area (Belgorod Oblast) in the East European Plain.

Belgorod Oblast, being located within the Central Russian Upland, is characterized by a highly dissected relief (up to 1.5 km/km^2); the depth of vertical dissection of the Earth's surface varies there from 20 to 110 m. Under these conditions, processes of both sheet and linear water erosion of soils and grounds (mainly weathered rocks) are actively proceeding. The relief of this administrative region is an elevated hilly plain with a range of altitude of 68–277 m a.s.l. The share of sloping land is 72%. The overwhelming majority of cropland (76%) is located on slopes steeper than 1° (Figure 2).

Figure 2. Cropland on the hilly slopes in Belgorod Oblast (Alekseyevsky district).

The long history of agriculture in the study region (since the end of the 16th century; however, the active phase of plowing began in the second half of the 18th century) has resulted in the degradation of all components of geosystems [12], primarily the soil cover. According to a large-scale soil survey in the 1980s, the proportion of eroded cropland was 49.9%. Moreover, eroded areas continued to increase, by 6% by 2010 [13]. The affected soils of Belgorod Oblast have lost about 130 million tons of humus, which is why they are experiencing a decrease in agricultural productivity—the annual shortage of products in terms of grain is 1.22 million tons [14]. For the environmental conditions of the forest-steppe zone, it was found in [15] that after reaching areas of cropland in river basins > 60%, the volume of eroded sediments entering small river channels exceeded the transport capacities of the permanent watercourses. As a result, the riverbeds in many cases became silted up.

The current conditions of risk farming served as the basis for the adoption of the course of the agricultural policy of the region towards the protection and reproduction of soil fertility. Therefore, since 2012, a unique experience for the country in scientifically based greening of agriculture has been implemented in Belgorod Oblast, which is regulated by the following programs:

- Program for the introduction of a biological farming system in Belgorod Oblast for 2012–2018 (approved by the Decree of the Government of Belgorod Oblast; 29 August 2011, No. 324-ПП);
- The concept of river-basin nature management in Belgorod Oblast (approved by the order of the Government of Belgorod Oblast; 27 February 2012, No. 116-рП);
- Regulations on the project of an adaptive landscape agriculture system (ALAS) and soil protection (approved by the Decree of the Governor of Belgorod Oblast of 4 February 2014 No. 9, and the Decree of the Government of Belgorod Oblast of 25 April 2022, No. 249-ПП).

These programs are united by a common idea of organizing integrated environmental management in river basins with a focus on an integrated approach to the restoration of soil and water resources. More than 100 projects for soil–water protection in the catchments of 63 river basins were developed as part of these programs. Each project includes improvements to the organization of crop rotation on biological farming system, the transfer of degraded cropland for conservation, and the creation of contour forest belts (Figure 3). The organization of cropland is based on a contour-reclamation approach with a distinction between the types of crop rotation depending on the relief, an increase in the share of legumes and perennial grasses in the composition of crops.

Figure 3. Cropland development proposals from the river-basin nature management project: the existing land use (**left**) and ALAS projects (**right**). 1—field crop rotation, 2—fodder/forage crop rotation, 3—soil-protection crop rotation, 4—cropland conservation, 5—grassing of hollows, and 6—contour forest belts.

A comparison of the erosion-control efficiency of the transformation of the cropland structure was carried out within 217 basins of small rivers, starting from the 4th order (according to the Strahler–Filosofov classification) (see Appendix A, Figure A1). Such a division of the territory is the most suitable for assessing the (geo)ecological and resource state of catchments and allows integrating agroecological and hydrological monitoring systems [16]. The efficiency of cropland transformation is expressed in terms of average annual soil losses caused by water erosion within catchments.

2.2. Methodology for Calculating Potential Soil Erosion

The total erosion-induced soil losses are the sum of losses from rainfall erosion and erosion during the spring snowmelt period. Trends in climate change in the forest-steppe zone of the East European Plain in recent decades give an idea of the change in the ratio of melt and storm-induced erosion in favor of the latter. An analysis of the precipitation of the warm period of the year using a network of meteorological stations in the agricultural zone of European Russia [17], 2018) showed a steady increase in the frequency and intensity of erosion showers with a precipitation depth of more than 10 mm over the past 30 years relative to the middle of the 20th century. Related to climate change over the past 30 years, there has been a reduction in the share of snowmelt runoff in erosion; and for the forest-steppe zone, rainstorm soil loss has exceeded snowmelt erosion by 12.6 times [18]. The decrease in the role of erosion during the spring snowmelt period is also confirmed by observations of river runoff. For the forest and forest-steppe zone of the East European Plain [19–21], stable trends have been established to reduce the maximum annual water discharge during the spring snowmelt. Over the past 70 years, it has decreased by 2.5–4 times. Thus, in terms of average annual erosion rates in the forest-steppe zone, storm-induced runoff dominates, and the depth of melt runoff is so small that it does not lead to significant erosion losses during the spring snowmelt period. Therefore, in this paper, we consider only storm-induced erosion.

The annual storm-induced soil erosion rates were calculated for cropland with an empirical model that used a modified version of the USLE-based approach [22] adapted for European Russia's environmental conditions [23,24]:

$$A = R \times K \times LS \times C \times P \quad (1)$$

where A is the average annual storm-induced soil loss (t/ha per year); R is the rainfall erosivity factor (t mm)/(ha min) per year; K is the soil erodibility factor (t ha min/((t × m) ha mm); LS is the slope length-gradient factor (dimensionless); C is the crop/vegetation and management factor (dimensionless); P is the support practice factor (from 0 to 1; dimensionless).

The rainfall erosivity factor R is the multiplication of the kinetic energy of raindrops (falling during the rain on an area of one hectare) by the 30-min maximum intensity of this rain. These data were first generalized for the territory of Russia by the mid-1980s, a corresponding cartogram of the erosion potential of precipitation was constructed, and zoning was carried out [23,25]. Later, the precipitation erosion potential cartogram was updated up to 2015 [26], taking into account the latest changes in the average long-term daily precipitation depth of more than 10 mm in the warm season [27]. This cartogram was interpolated to the study area in a raster format and used in the modeling.

The soil erodibility factor K depends on soil texture and structure, humus content, water permeability, and soil stoniness. The K-factor was calculated using empirical formula (2), which was adapted for European Russia's environmental conditions:

$$K = \{16.67 \times 10^{-6} \times [m_s \times (100 - m_c)]^{1.14} \times (12 - a) + 0.25(b - 2) + 0.193(4 - c)\} \times z \quad (2)$$

where m_s is sand/silt fraction content 0.1–0.001 mm, %; m_c is clay fraction content < 0.001 mm, %; a is the organic matter, %; b is the classes for soil structure (b = 1 when the content of water-resistant soil aggregates with a size of 0.25–1.0 mm is > 55%; b = 2 (55–40%); b = 3 (40–20%); b = 4 (<20%)); c is the classes for soil permeability (c = 1 when permeability rate is <30 mm/h, c = 2 (30–70 mm/h), c = 3 (70–100 mm/h), c = 4 (100–500 mm/h), c = 5 (500–1000 mm/h), and c = 6 (>1000 mm/h)); and z is soil stoniness (rubble) coefficient (z = 1.0 when covered with stones <5%, z = 0.87 (5–10%), z = 0.74 (10–20%), z = 0.52 (20–40%), z = 0.28 (>40%)).

The source of data on the soil cover was the vector soil map of Belgorod Oblast (1:200,000), compiled based on soil surveys in 1965–1980. The map includes 28 soil combinations in 3786 contours; for each, the K-factor was calculated based on the description of the properties of soil types in Belgorod Oblast [28]. For calculations, the cartogram was converted to a raster format.

The relief factor *LS* was calculated using empirical formula (3) [29], which takes into account not only the length and slope, but also the shape of the slope, as well as a correction for soil erosion:

$$LS = 22.1^{-p} \times L^{p} \frac{18.62 \times \sin\left(\arctan\left(S \times 10^{-2}\right)\right)}{1 + 10^{0.53 - 0.015 \times L \times S \times 10^{-2}}} \times T^{p} + 0.065 \quad (3)$$

where L is the slope length, m; S is the slope, %; T is the coefficient of the transverse profile of the slope (dimensionless; the slope is straight at $T = 1$, the slope disperses runoff at $T < 1$, the slope collects runoff at $T > 1$; in Belgorod Oblast, T varies from 0.5 to 1.5); p is calculated by empirical formula (4) as follows:

$$p = 0.2 + 2.067 \times (p_0 - 0.2) \times L^{-0.15} \times K^{-0.45} \quad (4)$$

where p_0 is the exponent equal to 0.2, 0.3, 0.4, and 0.5 for slopes <1, 1–3, 3–5, and >5%, respectively; K is the soil erodibility factor determined by formula (2).

As a general rule, it is the format of the input data referring to the relief that determines the spatial resolution of the future erosion loss model. In this study, vector topographic maps with a relief cross section of 5 m served as initial data on the relief. To construct a DEM, we used the method of interpolating the values of elevations and relief contours using the special algorithm TopotoRaster [30]. This method makes it possible to obtain a more accurate relief model, since it considers the spatial position of isolines and elevations, the location of watercourses, closed reservoirs, and local depressions. As a result, a hydrologically correct DEM was obtained for the entire study area. It was previously revealed [31] that for regional geomorphic conditions, the cell size that provides the highest accuracy with input data at a scale of 1:25,000 is 30 × 30 m. To obtain raster models of relief parameters for calculation based on formula (3), we used the Spatial Analyst and Hydrology toolsets in ArcGIS 10.5, specifically the geoprocessing tools Slope, Curvature, and Flow Length. The remaining rasters of the parameters of the erosion model (1) were spatially compared and reduced to a DEM resolution of 30 × 30 m, which made it possible to obtain a regional soil washout rate model with a sufficiently high level of detail.

2.3. Methodology for Calculating the C-Factor for Different Land-Use Scenarios

The *C*-factor includes the interrelated effects of land cover, crop rotation sequence, productivity levels, length of growing season, farming practices, methods of removal or use of crop residues, and rainfall distribution. Of all the drivers of storm-induced erosion, vegetation is the most easily modified. The regulation of the composition of crops is a powerful and effective tool for controlling erosion, even in the most unfavorable soil–climatic and geomorphic conditions.

In small-scale soil washout assessments, the erosion-control role of the agricultural background is assessed using various types of land cover obtained from public databases (CORINE Land Cover for the European Union [32], TerraNorte RLC for the Russian Federation [33], etc.). In such calculations for cropland, the averaged *C*-factor is used based on statistics for the main cultivated crops. A more differentiated approach to *C*-factor calculation takes into account tillage practices, plant residues, and cover crops, and these data can change *C*-factor values by up to 30% [34].

In our study, the calculation of potential soil washout was carried out for three cropland models: (1) soil washout from bare (clean) fallow areas; (2) soil washout considering the actual structure of sown areas; and (3) soil washout with the proposed erosion-control organization of cropland. These modeled erosion-induced soil washouts were assessed only within cropland area. The contours of cropland are vector layers obtained by deciphering high-resolution satellite images and correspond to a scale of 1:10,000.

Model 1. For the bare (clean) fallow soil washout model, all cells of cropland were assigned the maximum value of "1". This model assumes the complete absence of agricultural background conditions that restrain erosion. The washout values according to this scenario characterize the maximum erosion potential of the territory under the current soil, topographic, and climatic conditions.

Model 2. The actual structure of sown areas is calculated using the average annual values of the vegetation index NDVI. The initial data were MODIS average spatial resolution images and derived composite images MOD13Q1 (Vegetation Indices), showing the values of the normalized NDVI for 16 days [35]. The time series of MOD13Q1 products currently includes continuous data since 2000, which allows both seasonal and long-term analysis of the dynamics of the vegetation index. The use of this type of information products has shown significant opportunities in the analysis of seasonal changes in vegetation, the identification of plowed fields, and the assessment of the projective cover of vegetation [36]. We selected images for the period from 2012 to 2021 for the months in which there was no stable snow cover (April to October). The images were reprojected from sinusoidal projection to WGS-84 UTM 37-N. For each month, mosaics of annual averages were calculated. The following formula was used to generate the *C*-factor from NDVI values [37,38]:

$$C = exp^{-\alpha \cdot \frac{\mathrm{NDVI}}{\beta - \mathrm{NDVI}}} \tag{5}$$

where α and β are dimensionless parameters that are determined by the shape of the curve related to NDVI and the *C*-factor; they have values of 2 and 1, respectively. For images for each month, the vegetation factor on cropland was calculated using formula (5) for a month. The *C* values for each year are averaged over them, and then the average for 5 years is calculated.

The use of NDVI shows quite acceptable results in comparison with the *C* values for various land-cover classes in the CORINE land cover database (cropland, meadows, vineyards, and forests). It is widely used to estimate runoff at the scale of large objects–regions, countries, geographical areas, and river basins [39–44]. However, it is noted [45–47] that the use of spectral indices to estimate the *C*-factor requires that this parameter be adjusted taking into account regional climatic conditions and crop composition.

To calibrate the *C*-factor for regional environmental conditions, the structure of sown areas in Belgorod Oblast for the same period was analyzed [48]. Based on the total ratio of crops, a weighted average *C* of 0.342 was calculated. At the same time, the average annual *C*-factor in Belgorod Oblast, calculated by formula (5), shows an underestimated value of 0.158. To adjust the agricultural background factor from MODIS according to the average regional value, a multiplier of 2.16 was added to the *C*-factor.

Model 3. The calculation of the *C*-factor was carried out for the scenario of the erosion-control organization of sown areas according to the current regional programs for the greening of agriculture. Based on the results of work on the river-basin nature management in Belgorod Oblast [49,50], a geodatabase of contours of crop rotation fields was formed depending on the relief. The estimated areas of recommended crop rotations and the proportion of perennial grasses in their composition are presented in Table 1.

Row crops and bare fallows should be placed only in a field crop rotation with a steepness of up to 3°: Grain-grass-rowed, grain-fallow-rowed, and grain-rowed crop rotations can be organized there. Forage crops are placed on slopes of 3–5° as part of grain–grass crop rotations. The soil-protection crop rotation consists mainly of perennial grasses; the inclusion of densely covered (thick cover) grain crops is allowed. Moreover, within cropland area, it is planned to grass hollows and gullies, conservation of degraded cropland, and carry out forest reclamation activities.

Table 1. Modeled structure of cropland in Belgorod Oblast, according to the project of river-basin nature management.

Land-Use Category	Slope (Degrees)	Cropland Area		Perennial Grasses	
		$\times 10^3$ ha	%	$\times 10^3$ ha	%
Crop rotations:					
Field	0–3	1047.1	68.6	209.4	20
Forage	3–5	336.1	22.0	168.1	50
Soil-protection	>5	129.1	8.5	129.1	100
Conservation		8.7	0.6		
Grassing of hollows		4.0	0.3		
Forest belts		2.3	0.2		
In total		1527.3	100.0	506.6	33

For each type of crop rotation, according to the adopted technology of crop rotation in Belgorod Oblast [51], the average *C*-factor was determined. Calculations were carried out for each main crop, considering rotation periods and storm-induced erosion indices for regional environmental conditions [23]. The calculated values of the *C*-factor were assigned to each contour of cropland and converted into a raster format with a resolution of 30 m.

3. Results

The outcome of this study is a quantitative assessment of potential soil losses caused by storm-induced erosion on cropland in Belgorod Oblast for three land-use models (Figure 4). The value of potential erosion on cropland varies widely and varies unevenly across the territory. The distribution of soil losses by area of the study territory and the average value for each scenario are given in Tables 2 and 3.

Table 2. Eroded soils areas in Belgorod Oblast, according to different land-use models.

Soil Losses, t/ha per year	Bare Fallow		Actual Crop Composition		ALAS Projects	
	km^2	%	km^2	%	km^2	%
0–1	3378.5	22.1	7030.1	46.0	8362.2	54.7
1–3	3732.9	24.4	4608.8	30.2	4631.7	30.3
3–5	2228.7	14.6	1460.5	9.6	1171.2	7.7
5–10	2518.3	16.5	1273.0	8.3	769.2	5.0
10–15	1112.9	7.3	427.5	2.8	189.7	1.2
>15	2314.1	15.1	485.6	3.2	161.4	1.1

Table 3. Average annual erosion-induced soil losses (t/ha per year) in Belgorod Oblast, according to different land-use models (between the models 1 and 2, and the models 2 and 3, statistically significant differences are with a probability of over 99.999%, according to *t*-test).

Bare Fallow (Model 1)	Actual Crop Composition (Model 2)	ALAS Projects (Model 3)
11.3 ± 0.8	3.5 ± 0.3	2.2 ± 0.1

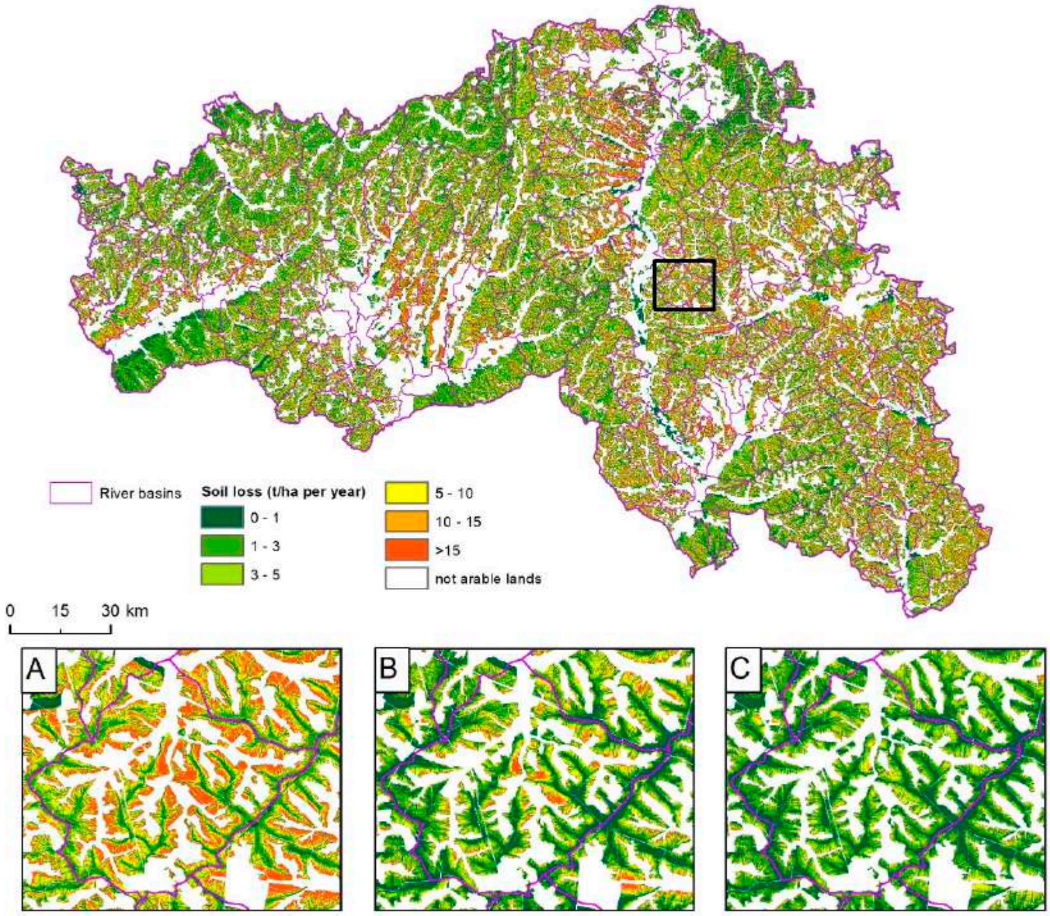

Figure 4. Potential erosion-induced soil losses on cropland in Belgorod Oblast: (**A**)—for bare (clean) fallow conditions, (**B**)—for actual crop composition, (**C**)—for ALAS projects. NB: The map of the upper panel characterizes the erosion-induced soil losses for bare fallow conditions.

For the bare (clean) fallow model, the average soil loss is 11.3 t/ha per year. In the absence of the protective factor of vegetation, the share of soils with an annual erosion rate of up to 1 t/ha is only 22%. More than half of the soils of cropland are located in conditions under which soil erosion exceeds 3 t/ha per year. The share of soils with erosion of more than 10 t/ha per year is also 22%; and for 15%, the erosion rates are catastrophic and exceed 15 t/ha per year. It can be concluded that Belgorod Oblast has an extremely high water-erosion potential of agricultural lands, which is primarily determined by the features of its topography.

The soil erosion model with the actual agricultural background factor reflects soil losses with the crop composition adopted over the past 10 years. The average value of soil losses is 3.5 t/ha per year. For the environmental conditions of Belgorod Oblast, the agricultural background factor reduces the average annual soil washout from cropland by more than three times. As compared to bare-fallow areas, the proportion of soils with water-erosion rates less than 3 t/ha per year increased by 1.6 times; soil losses over 10 t/ha per year decreased by 3.8 times (Figure 5A). However, the problem of erosion-induced soil losses has not lost its relevance: on steep slopes of >5°, the erosion hazard remains high. The average soil loss in such areas is 13 t/ha per year (Figure 5B). This is primarily owing to the cultivation of row crops in erosion-prone areas.

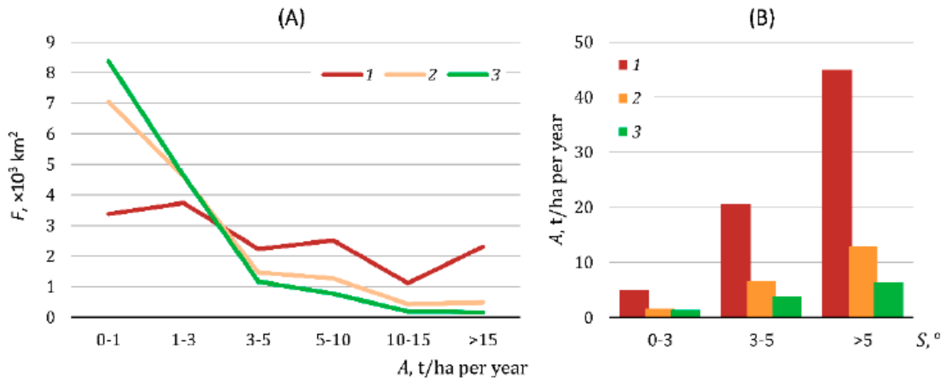

Figure 5. Changes in modeled average annual soil losses (*A*) due to storm-induced erosion in Belgorod Oblast, according to different land-use models: (**A**) soil losses versus area (*F*); (**B**) average annual soil losses versus slope (*S*). *1*—for bare (clean) fallow conditions, *2*—for actual crop composition, *3*—for ALAS projects.

The model for the implementation of ALAS projects is similar in terms of the shape of the soil loss distribution curve to the actual model (Figure 5A) but shows greater efficiency: The average value of soil losses is 2.2 t/ha per year, and their distribution is more balanced. Due to the "transfer" of row crops only to slopes of 0–3°, the share of soil losses up to 1 t/ha per year increased by 9% as compared to the actual model. However, due to this, more favorable erosion conditions were formed on steep slopes. Thus, the territories with soil losses over 5 t/ha per year decreased by 2 times. The average value of soil losses on the slopes of cropland above 5° decreased to 6.4 t/ha per year. With the implementation of project solutions, cropland with a soil washout rate of >15 t/ha per year will amount to 1%. These are predominantly plowed dark gray and gray forest-steppe soils, which have a high *K*-factor (≈3). For such territories, it is necessary to plan a separate complex of soil protection measures.

The spatial distribution of soil losses was analyzed within the studied river basins of the study region (Figure 6). More detailed calculations of the factors of average annual soil losses according to formula (1) in the river basins for each model are given in Appendix A (Figure A1, Table A1). These data can be further used as a basis for subsequent assessments of the consequences of soil erosion and the introduction of agricultural practices. The maximum erosion potential (excluding the agricultural background) is typical for the eastern part of the region, as well as the Seversky Donets River basin in its western part (Figure 6A). Soil losses under actual land-use conditions (Figure 6B) are distributed across the area in a similar way. The soil-protection capacity of agrocenoses, according to the crop rotation system adopted over the past 10 years, has the greatest effect in the west of the study region, where, on average, soil losses do not exceed 3 t/ha per year. However, the erosion potential of cropland is still high, especially in the eastern part of the region with more unfavorable topography.

With the successful implementation of regional programs for soil protection and the implementation of ALAS projects, the overall effect of the absolute majority of the region's river basins is expected (Figure 6C). River basins with an average soil washout value of more than 3 t/ha per year are confined to areas of soils with high erodibility.

The higher the erosion potential of the territory, the greater the effect of the implementation of the ALAS program will be visible. For river basins with more complex topography, a higher percentage of reduction in soil losses is observed (Figure 7). In the western part of the study region showing a flatter relief, the soil washout will decrease by 25% on average, and by 40% in the more dissected eastern part.

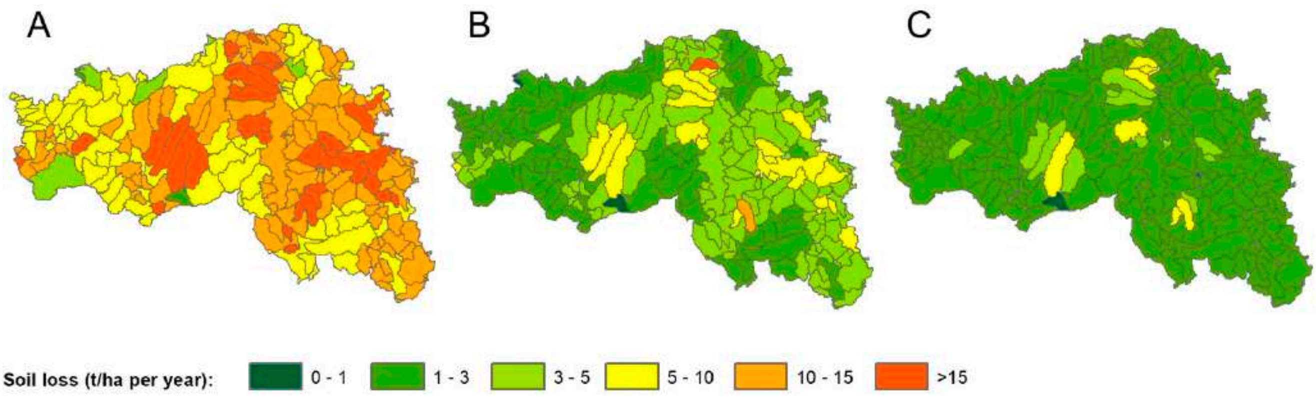

Figure 6. Modeled erosion-induced soil losses in the studied river basins of Belgorod Oblast: (**A**)—for bare (clean) fallow conditions; (**B**)—for the actual composition of crops; (**C**)—for ALAS projects.

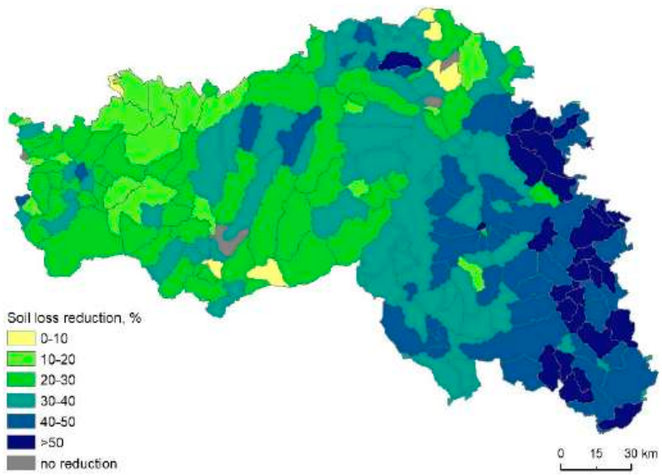

Figure 7. Reduction of modeled erosion-induced soil losses in the studied river basins of Belgorod Oblast after the implementation of ALAS projects.

It can be pointed out that the complex topography of river basins can be considered simultaneously from both negative and positive sides. On the one hand, the dissected relief determines the high potential for erosion processes and limits agriculture and the cultivation of certain crops. On the other hand, erosion-prone areas of cropland are a potential ecological "buffer" with a competent approach to the organization of agricultural landscapes. A rational soil protection organization of cropland can give a positive economic and environmental effect due to:

- Reducing the total anthropogenic load in agricultural landscapes;
- Reducing the rate of water erosion owing to the soil-protection role of agrocenoses;
- Reproduction of organic matter and nitrogen by increasing the share of perennial grasses and legumes in crop rotations.

4. Discussion

For the first time, the effects of regional programs for the greening of agriculture from the standpoint of erosion-control efficiency were evaluated for the study region. It is rather difficult to compare the calculated rates of water erosion based on the results of the presented work with the exiting data of previous studies. Other studies are rare, exiting calculations were based on different methods, and maybe other types of land were covered. According to the generalized estimates of published sources, the average rate of cropland soil erosion in Belgorod Oblast is 5–6 t/ha per year [52].

The results of a recent study of potential soil losses on cropland for European Russia according to the adapted RUSLE model [26] turned out to be methodically closest to our work. However, its results give noticeably overestimated values: soil losses from fallow areas were 25 t/ha per year, and considering agrocenoses, 11 t/ha per year (as compared to 11.3 and 3.5 t/ha per year obtained by us, respectively; see Table 3). This discrepancy, when using a similar calculation methodology, is due to different scales of estimates (global versus regional) and, consequently, different data sources and ways of obtaining and processing them. Thus, in [26], a lower DEM resolution was used, the calculation of the *C*-factor was carried out according to the statistical data general for the region without spatial reference, and a less detailed soil map was used.

As shown by the results of modeling of actual erosion-induced soil losses, Belgorod Oblast, according to this criterion, fits well into the pan-European picture (Figure 8). According to Eurostat data [53], for 38% of the regions of the European Union (according to the NUTS 2 classification: basic regions for the application of regional policies), the average annual soil loss from cropland exceeds 3 t/ha per year.

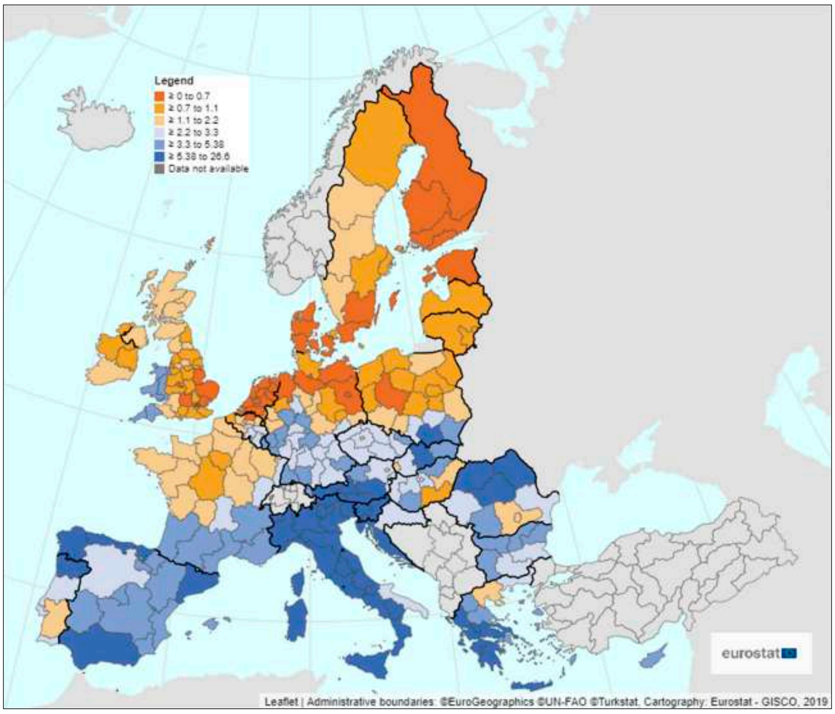

Figure 8. Estimated rates of runoff-induced soil losses (t/ha per year) within agricultural areas at the European Union by the NUTS 2 regions (as of 2016) [53].

Soil erosion by water is one of the agri-environmental indicators for monitoring the integration of environmental concerns into the Common Agricultural Policy at the European Union [54]. Therefore, the experience of Belgorod Oblast in regulating the rates of water erosion through a centralized system for rearranging cropland may be in demand. The key task in this case is the transformation of heavily eroded and disturbed soils into areas for the reproduction of soil fertility without removing them from agricultural use.

However, it should be noted that no changes will occur without proper control over the implementation of the proposed measures before the stage of their actual implementation. This problem especially concerns the conditions of private land use, where there is a steady trend towards a decrease in soil fertility [55].

Land users are obliged to carry out measures for the protection and reproduction of soil fertility according to the requirements in greening programs. For example, it is mandatory to have any ALAS project, which, considering soil and climatic conditions, developed a specific plan for the introduction of a set of biologization techniques as part of the development of the recommended farming system [56]. They include subsystems of agrotechnical, hydrotechnical, meadow reclamation, forest reclamation, and organizational and economic activities (Figures 9 and 10). At the moment, ALAS projects have been implemented on 1.3 million hectares (85% of the total area of cropland in Belgorod Oblast) [56]. This is a unique result for the Central Chernozem region of European Russia, of which Belgorod Oblast is a part.

Figure 9. An example of the contour-reclamation organization of cropland in Belgorod Oblast: erosion-control forest belts (Krasnogvardeisky district).

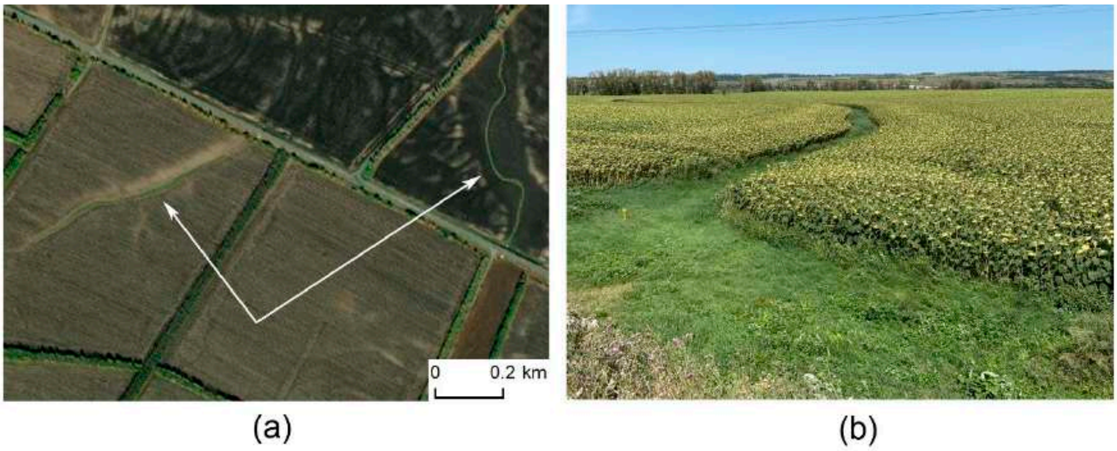

Figure 10. An example of erosion-control grassing of hollow bottoms within cropland area in Belgorod Oblast (Alekseyevsky district; 50.6466 N, 38.5421 E): (**a**)—view on a satellite image, (**b**)—view on the ground.

The experience of implementing the solutions presented in this study on the spatial organization of cropland shows positive changes in the state of soils. A significant increase in soil fertility and productivity is noted [56]. This is due both to an increase in the application of organic fertilizers and to changes in the structure of sown areas and the composition of crops. The share of legumes in the structure of sown areas reached 26.4%, and the accumulation of symbiotically bound nitrogen increased to an average of 23.7 kg/ha. As by 1 January 2020, in the arable soils of the study region, the maximum weighted average content of organic matter was noted in the entire history of observations—5.89%, mobile forms of phosphorus and potassium—144 and 171 mg/kg, respectively. Naturally, the productivity of the main agricultural crops has increased significantly; as a result, the average productivity of agrocenoses reached its maximum value—4.94 thousand fodder units per 1 ha of sown area. In some farms of the region, the implemented contour-reclamation organization of crop rotations showed high energy efficiency [57]: the ratio of the amount of energy received with the harvest is 3–5 times higher than the amount of anthropogenic energy expended. Thus, we can conclude that regional programs for the protection of arable soils combine environmental efficiency and economic benefits for land users in Belgorod Oblast.

5. Conclusions

For the first time for Belgorod Oblast, an assessment of potential soil losses from cropland due to storm-induced erosion in the context of regulating the agricultural policy of the study region was made. Soil erosion rates were calculated for three land-use scenarios: for soil erosion from bare-fallow areas; for soil erosion considering the actual structure of crop areas; and for soil erosion, taking into account the proposed program of erosion-control management of cropland and soil protection. It is assumed that the current programs for the biologization of agriculture and the contour-reclamation organization of cropland will have a noticeable environmental and economic effect. The implementation of ALAS projects will help to reduce average annual erosion losses by an average of 1.6 times as compared to the current situation. It should be noted that a greater environmental and economic effect is achieved for areas with an increased erosion potential of the relief: on steep plowed slopes of >5°, soil losses will reduce by 2 times with the introduction of soil-protective crop rotations.

The results of this research confirm that the strategy for the transformation of cropland in Belgorod Oblast is an example of an effective tool for the spatial organization of agricultural landscapes with a focus on the dominant process of soil degradation in the study region—runoff-induced erosion. The implementation of ALAS projects will ensure non-conflict soil-rehabilitation land use in conditions of increased erosion risk.

The proposed approach can be replicated in countries with similar water-erosion risk conditions and mechanisms of state regulation of agriculture. Its use will help reducing the rate of soil losses caused by water erosion and restoring the fertility of degraded soils.

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Appendix A

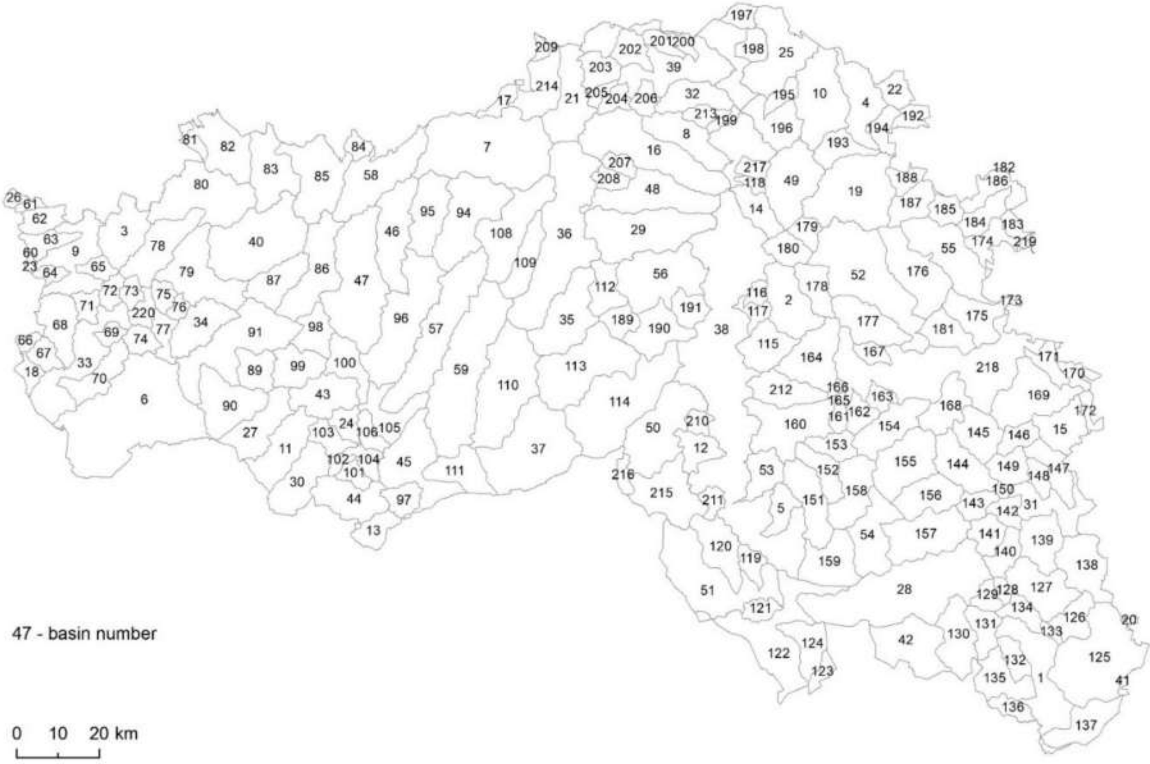

Figure A1. Location of the studied river basins in Belgorod Oblast (see Table A1).

Table A1. Parameters for calculating the average annual soil loss in the studied river basins of Belgorod Oblast (see Figure A1). M1—for bare (clean) fallow conditions; M2—for the actual structure of sown areas; M3—for ALAS projects.

Basin Number	Basin Area, $\times 10^3$ ha	Cropland Area, %	*R*-Factor	*K*-Factor	*LS*-Factor	*C*-Factor			Soil Losses, t/ha per year		
						M1	M2	M3	M1	M2	M3
1	216.3	57.0	8.71	0.87	1.11	1.00	0.41	0.25	7.90	2.96	1.60
2	160.4	63.5	9.69	1.16	2.01	1.00	0.33	0.25	13.86	4.30	2.57
3	141.3	67.6	10.30	1.08	1.14	1.00	0.30	0.27	7.30	2.00	1.51
4	151.8	61.7	9.78	1.04	1.58	1.00	0.35	0.27	10.96	3.39	2.29
5	62.4	46.4	9.52	1.89	2.06	1.00	0.30	0.23	27.51	8.37	5.10
6	626.4	59.5	9.21	1.11	0.77	1.00	0.35	0.30	4.47	1.41	1.06
7	477.1	70.2	10.23	1.11	0.68	1.00	0.36	0.28	5.47	1.84	1.33
8	140.3	57.3	9.91	1.97	2.33	1.00	0.31	0.23	33.57	9.26	6.04
9	173.4	62.1	10.21	1.10	1.12	1.00	0.30	0.27	7.31	2.07	1.57
10	223.9	54.2	9.79	1.56	0.71	1.00	0.34	0.28	7.72	2.25	1.92
11	152.9	62.3	8.93	1.04	1.12	1.00	0.37	0.27	7.45	2.60	1.65
12	72.6	49.0	9.62	1.06	2.37	1.00	0.29	0.24	13.48	3.56	2.15
13	62.1	74.1	8.58	1.11	1.35	1.00	0.33	0.25	9.41	2.98	1.85
14	79.1	73.6	9.79	1.41	1.05	1.00	0.36	0.29	9.17	3.03	2.17
15	108.6	59.8	8.96	1.12	1.81	1.00	0.36	0.24	13.64	4.65	2.39
16	313.2	52.8	9.96	1.69	1.86	1.00	0.30	0.27	19.07	5.18	4.10
17	34.3	79.2	10.30	1.18	0.57	1.00	0.38	0.29	5.78	2.07	1.51
18	33.7	59.6	9.66	1.64	2.03	1.00	0.30	0.24	18.00	5.04	3.24
19	302.2	74.9	9.71	1.12	1.31	1.00	0.38	0.27	10.34	3.70	2.18
20	6.3	77.8	8.52	1.30	1.62	1.00	0.32	0.25	12.80	3.84	2.31
21	170.4	81.0	10.14	1.23	0.66	1.00	0.36	0.24	7.17	2.35	1.62

Table A1. *Cont.*

Basin Number	Basin Area, $\times 10^3$ ha	Cropland Area, %	*R*-Factor	*K*-Factor	*LS*-Factor	*C*-Factor			Soil Losses, t/ha per Year		
						M1	M2	M3	M1	M2	M3
22	52.1	59.2	9.78	1.06	1.48	1.00	0.31	0.26	11.62	3.15	2.41
23	5.0	33.8	10.20	1.20	1.51	1.00	0.24	0.28	7.18	1.48	1.81
24	45.9	42.8	9.20	1.06	1.79	1.00	0.31	0.24	11.68	3.51	2.21
25	210.7	36.2	9.82	1.45	0.72	1.00	0.28	0.25	8.96	2.45	1.82
26	16.7	45.0	10.50	1.00	1.91	1.00	0.25	0.25	9.84	2.37	1.80
27	140.1	77.8	9.09	1.00	0.84	1.00	0.36	0.28	5.74	1.88	1.36
28	517.3	61.9	9.19	0.97	1.33	1.00	0.37	0.26	7.35	2.47	1.45
29	287.2	58.4	9.89	1.26	1.81	1.00	0.35	0.25	14.58	4.47	2.75
30	144.6	69.9	8.72	1.11	1.35	1.00	0.33	0.26	9.21	2.86	2.04
31	126.8	56.6	8.90	0.91	1.29	1.00	0.36	0.23	9.53	3.40	1.72
32	104.3	28.2	9.91	1.78	2.29	1.00	0.45	0.22	40.82	32.64	6.26
33	218.5	58.5	9.65	1.43	0.98	1.00	0.34	0.28	10.81	3.26	2.56
34	129.1	42.5	9.77	1.76	1.57	1.00	0.28	0.26	15.62	4.12	3.33
35	198.8	67.7	9.81	1.05	1.35	1.00	0.36	0.29	7.28	2.40	1.73
36	465.9	57.4	9.95	1.24	1.45	1.00	0.33	0.26	10.84	3.14	2.22
37	347.9	55.7	9.42	1.13	1.18	1.00	0.32	0.28	8.84	2.56	1.81
38	1448.8	40.8	9.72	1.26	1.68	1.00	0.31	0.26	13.63	3.99	2.69
39	194.7	23.9	9.95	1.14	1.07	1.00	0.40	0.26	10.36	3.71	2.25
40	328.2	64.6	10.17	1.14	1.22	1.00	0.33	0.29	6.58	1.90	1.64
41	8.2	60.3	8.45	1.40	2.34	1.00	0.38	0.26	13.13	4.27	2.83
42	185.3	68.8	9.10	0.97	1.32	1.00	0.39	0.26	7.82	2.79	1.45
43	132.2	18.6	9.35	1.02	1.86	1.00	0.28	0.25	10.84	2.77	2.06
44	140.2	68.3	8.70	1.09	1.42	1.00	0.31	0.27	8.52	2.49	1.94
45	217.8	36.0	9.09	1.39	1.26	1.00	0.31	0.27	11.36	3.17	2.42
46	188.9	52.3	10.11	1.19	1.83	1.00	0.33	0.25	12.90	4.08	2.49
47	359.7	48.3	9.93	1.17	1.83	1.00	0.32	0.26	11.51	3.25	2.23
48	208.1	60.0	9.91	1.75	2.09	1.00	0.31	0.25	24.17	7.09	4.59
49	195.0	81.0	9.77	1.21	0.69	1.00	0.40	0.29	6.52	2.44	1.74
50	251.3	75.1	9.64	1.19	1.02	1.00	0.36	0.28	8.73	2.92	1.90
51	307.4	56.7	9.42	1.14	1.68	1.00	0.31	0.23	13.38	3.98	2.35
52	385.9	50.3	9.60	1.20	1.89	1.00	0.33	0.25	13.38	4.11	2.56
53	83.0	62.0	9.57	1.12	1.82	1.00	0.35	0.24	11.92	4.03	2.28
54	158.5	51.1	9.35	1.38	1.69	1.00	0.35	0.26	9.02	2.73	1.84
55	211.3	41.9	9.51	1.43	2.25	1.00	0.33	0.22	17.34	5.23	2.29
56	246.6	51.1	9.83	1.85	2.41	1.00	0.32	0.25	27.37	8.04	5.25
57	315.1	54.5	9.73	1.86	1.43	1.00	0.35	0.27	19.44	6.30	4.16
58	221.9	70.5	10.32	1.06	0.77	1.00	0.37	0.30	4.95	1.69	1.36
59	432.5	36.5	9.59	2.28	1.85	1.00	0.28	0.26	31.66	8.52	6.09
60	5.0	52.0	10.24	1.03	0.96	1.00	0.28	0.29	4.87	1.27	1.28
61	15.7	70.2	10.46	1.00	1.18	1.00	0.25	0.27	6.44	1.50	1.34
62	58.7	62.8	10.40	0.99	1.38	1.00	0.28	0.26	8.69	2.30	1.60
63	55.4	61.3	10.30	0.92	1.04	1.00	0.28	0.26	6.60	1.79	1.35
64	25.7	50.3	10.16	1.11	1.50	1.00	0.24	0.26	7.86	1.77	1.55
65	35.9	35.1	10.15	1.09	1.64	1.00	0.25	0.26	8.48	1.97	1.60
66	19.2	68.7	9.84	1.21	1.46	1.00	0.33	0.24	11.52	3.84	2.22
67	45.1	52.1	9.74	1.58	1.71	1.00	0.27	0.26	12.56	3.05	2.55
68	118.8	54.0	9.90	1.17	1.49	1.00	0.27	0.25	9.84	2.56	1.93
69	27.9	53.8	9.79	1.00	1.23	1.00	0.37	0.27	7.77	2.61	1.74
70	102.5	69.0	9.55	1.51	1.01	1.00	0.36	0.27	11.10	3.99	2.48
71	40.0	57.5	9.97	1.17	1.54	1.00	0.26	0.24	10.85	2.75	2.00
72	37.4	50.1	10.02	1.09	1.70	1.00	0.27	0.24	10.79	2.73	1.81
73	33.3	60.9	10.01	1.09	1.04	1.00	0.37	0.25	7.61	2.60	1.50
74	47.1	38.0	9.73	1.39	1.91	1.00	0.27	0.23	14.70	3.77	2.66
75	36.5	44.7	9.97	1.16	1.43	1.00	0.28	0.25	9.73	2.52	1.84
76	22.6	34.2	9.89	1.12	1.47	1.00	0.27	0.26	9.68	2.51	1.98
77	49.1	59.7	9.74	1.23	1.08	1.00	0.33	0.28	10.51	3.29	2.38

Table A1. *Cont.*

Basin Number	Basin Area, $\times 10^3$ ha	Cropland Area, %	*R*-Factor	*K*-Factor	*LS*-Factor	*C*-Factor			Soil Losses, t/ha per Year		
						M1	M2	M3	M1	M2	M3
78	155.6	57.5	10.21	1.05	1.08	1.00	0.34	0.29	6.73	1.97	1.57
79	213.1	71.6	10.06	1.14	0.92	1.00	0.33	0.29	6.66	2.05	1.61
80	260.9	59.4	10.40	1.09	1.18	1.00	0.33	0.29	8.04	2.24	1.83
81	26.6	56.9	10.66	0.98	0.30	1.00	0.33	0.31	2.35	0.72	0.69
82	156.3	60.3	10.61	1.02	0.84	1.00	0.32	0.30	4.58	1.30	1.16
83	162.0	68.9	10.47	1.17	1.06	1.00	0.33	0.29	7.03	2.14	1.75
84	30.6	60.7	10.47	0.87	1.14	1.00	0.39	0.30	6.69	2.20	1.72
85	214.7	67.8	10.40	1.03	0.98	1.00	0.33	0.30	5.72	1.69	1.41
86	195.7	60.8	10.01	1.12	1.10	1.00	0.34	0.29	6.91	2.21	1.64
87	111.4	60.2	9.98	1.27	1.46	1.00	0.32	0.27	10.45	3.05	2.28
89	80.6	77.9	9.50	1.09	0.96	1.00	0.35	0.27	7.41	2.44	1.68
90	173.2	72.6	9.26	1.07	1.00	1.00	0.37	0.29	6.20	2.13	1.53
91	298.1	50.1	9.64	1.53	1.23	1.00	0.33	0.28	9.99	2.67	2.29
94	245.0	64.8	10.09	1.13	1.38	1.00	0.37	0.28	9.45	3.24	1.96
95	147.6	62.9	10.14	1.09	1.67	1.00	0.35	0.27	10.64	3.55	2.10
96	314.1	38.2	9.77	1.49	1.62	1.00	0.30	0.27	19.02	5.26	3.93
97	56.3	27.3	8.86	1.36	2.22	1.00	0.24	0.20	15.31	3.45	2.26
98	82.7	48.4	9.71	1.02	1.77	1.00	0.29	0.25	10.29	2.62	1.92
99	102.8	48.8	9.52	1.08	1.74	1.00	0.29	0.25	9.67	2.68	1.95
100	91.4	14.6	9.55	1.06	1.24	1.00	0.32	0.29	6.80	2.06	1.76
101	34.9	57.2	8.87	1.11	1.88	1.00	0.28	0.23	11.96	3.14	2.42
102	20.3	49.9	8.92	1.08	1.99	1.00	0.27	0.21	12.44	3.04	2.21
103	55.0	42.2	9.08	1.03	1.97	1.00	0.29	0.22	12.03	3.35	2.19
104	43.1	55.9	8.99	1.04	1.73	1.00	0.29	0.29	7.99	2.06	2.05
105	106.8	30.5	9.33	1.37	1.24	1.00	0.30	0.30	8.81	2.31	2.48
106	42.1	34.8	9.17	0.94	1.58	1.00	0.29	0.23	12.21	3.36	2.20
108	216.3	64.8	10.02	1.20	1.32	1.00	0.36	0.27	10.81	3.61	2.14
109	100.9	62.7	9.94	1.20	1.29	1.00	0.33	0.27	10.20	3.10	2.13
110	319.8	47.0	9.59	1.68	1.49	1.00	0.33	0.27	16.00	4.32	3.06
111	111.8	34.8	9.17	1.19	0.66	1.00	0.37	0.31	2.94	0.93	0.85
112	83.1	61.2	9.85	1.21	1.68	1.00	0.34	0.27	10.40	3.33	2.11
113	280.7	67.1	9.71	1.09	1.49	1.00	0.33	0.28	9.55	2.90	1.99
114	370.1	71.3	9.66	1.00	1.27	1.00	0.34	0.28	7.11	2.19	1.65
115	112.0	60.9	9.68	1.25	2.07	1.00	0.32	0.25	14.77	4.56	2.60
116	24.1	44.5	9.73	1.32	2.12	1.00	0.33	0.25	13.94	4.49	2.84
117	36.1	43.4	9.72	1.08	1.50	1.00	0.33	0.27	14.04	4.52	3.08
118	18.6	73.5	9.81	1.62	0.62	1.00	0.34	0.30	8.71	2.85	2.30
119	43.8	59.9	9.46	1.30	1.92	1.00	0.28	0.21	15.97	4.49	2.51
120	127.8	58.2	9.48	1.16	1.91	1.00	0.28	0.21	14.33	4.04	2.43
121	39.1	43.0	9.37	1.20	2.11	1.00	0.28	0.20	16.96	4.82	2.82
122	287.8	52.3	9.31	0.94	0.99	1.00	0.34	0.26	8.25	2.64	1.62
123	29.3	67.6	9.20	0.73	1.08	1.00	0.40	0.28	5.76	1.95	1.34
124	92.4	63.1	9.27	0.88	0.75	1.00	0.38	0.27	5.09	1.89	1.23
125	353.0	67.3	8.57	1.18	1.70	1.00	0.41	0.24	12.61	4.80	2.44
126	75.2	72.4	8.69	1.04	1.57	1.00	0.40	0.24	10.55	3.74	1.97
127	151.5	65.0	8.83	1.03	1.71	1.00	0.39	0.23	12.21	4.39	2.14
128	22.8	71.1	8.94	1.07	1.84	1.00	0.37	0.23	12.17	3.96	2.19
129	36.6	61.6	8.98	1.01	1.78	1.00	0.35	0.25	11.21	3.62	2.20
130	132.0	62.4	9.00	1.05	1.77	1.00	0.39	0.22	11.36	4.01	1.73
131	68.6	64.8	8.94	1.01	1.72	1.00	0.38	0.22	10.92	3.61	1.67
132	50.7	63.5	8.81	1.09	1.79	1.00	0.39	0.23	11.11	3.94	1.84
133	14.5	63.8	8.74	0.80	1.10	1.00	0.40	0.28	9.52	3.37	2.19
134	51.9	61.2	8.86	0.91	1.63	1.00	0.38	0.21	10.12	3.66	1.84
135	108.5	55.1	8.81	0.97	1.53	1.00	0.39	0.22	11.89	4.48	1.93
136	41.9	59.3	8.74	1.02	1.73	1.00	0.37	0.24	11.40	3.98	2.09
137	116.7	62.5	8.51	1.08	1.59	1.00	0.41	0.24	10.67	4.06	2.00

Table A1. *Cont.*

Basin Number	Basin Area, $\times 10^3$ ha	Cropland Area, %	*R*-Factor	*K*-Factor	*LS*-Factor	*C*-Factor			Soil Losses, t/ha per Year		
						M1	M2	M3	M1	M2	M3
138	146.0	70.9	8.73	1.14	1.82	1.00	0.40	0.23	13.74	5.12	2.43
139	114.3	70.3	8.89	1.09	1.72	1.00	0.34	0.22	13.34	4.11	2.27
140	63.0	55.0	8.98	1.00	1.83	1.00	0.34	0.24	9.87	3.34	1.67
141	64.9	57.6	9.06	1.03	2.06	1.00	0.36	0.24	12.08	4.05	2.00
142	45.3	61.0	9.03	0.94	1.51	1.00	0.38	0.23	11.10	4.01	2.00
143	50.8	65.5	9.12	0.98	1.71	1.00	0.35	0.23	11.71	4.04	1.78
144	129.3	60.2	9.21	1.14	1.73	1.00	0.34	0.23	14.56	4.57	2.55
145	107.5	62.0	9.19	1.21	1.85	1.00	0.33	0.23	15.85	4.92	2.62
146	51.1	69.9	9.08	1.11	1.60	1.00	0.37	0.24	12.09	4.21	2.05
147	84.1	60.3	8.94	1.01	2.00	1.00	0.36	0.23	13.01	4.52	2.21
148	38.6	63.7	8.97	1.16	2.18	1.00	0.38	0.21	16.68	6.17	2.56
149	68.9	55.7	9.07	1.02	1.99	1.00	0.36	0.21	15.73	5.27	2.37
150	11.3	59.8	9.06	0.74	1.17	1.00	0.45	0.22	13.61	6.34	2.24
151	139.7	28.1	9.49	1.65	2.38	1.00	0.26	0.22	38.84	10.02	6.60
152	78.6	22.2	9.51	1.84	2.53	1.00	0.28	0.24	21.62	4.87	4.10
153	60.0	47.1	9.51	1.43	2.24	1.00	0.33	0.24	15.20	4.45	2.90
154	135.4	56.7	9.42	1.13	1.77	1.00	0.34	0.25	11.24	3.49	2.10
155	180.3	56.7	9.35	1.15	1.93	1.00	0.34	0.24	12.94	3.92	2.27
156	119.7	64.5	9.26	1.02	1.52	1.00	0.33	0.24	9.42	2.78	1.66
157	194.2	68.9	9.23	0.95	1.47	1.00	0.35	0.25	8.93	2.79	1.59
158	134.9	29.2	9.44	1.66	2.27	1.00	0.31	0.22	14.87	4.66	2.66
159	144.7	50.3	9.39	0.99	1.06	1.00	0.40	0.29	7.17	2.52	1.63
160	209.2	69.4	9.59	1.09	1.51	1.00	0.38	0.26	10.42	3.53	2.01
161	26.1	64.9	9.53	1.25	1.88	1.00	0.35	0.24	12.58	3.90	2.30
162	49.9	57.3	9.49	1.19	2.09	1.00	0.33	0.24	12.68	3.86	2.26
163	34.4	66.1	9.47	1.32	1.68	1.00	0.35	0.24	14.81	5.10	2.73
164	165.9	51.6	9.61	1.34	2.17	1.00	0.30	0.24	15.04	3.94	2.54
165	6.7	67.0	9.54	0.55	0.39	1.00	0.34	0.26	3.47	1.29	0.93
166	12.6	45.0	9.56	1.05	2.09	1.00	0.34	0.19	16.26	5.57	2.67
167	34.9	33.4	9.52	1.97	3.01	1.00	0.26	0.21	26.77	6.63	4.07
168	103.8	52.2	9.31	1.24	2.16	1.00	0.35	0.21	19.22	6.51	2.82
169	198.6	59.0	9.10	1.25	1.76	1.00	0.37	0.21	14.99	5.40	2.52
170	39.8	67.7	9.01	1.18	1.65	1.00	0.37	0.24	10.63	3.77	1.87
171	50.3	64.3	9.10	1.19	1.75	1.00	0.36	0.23	13.92	4.73	2.25
172	27.7	60.1	8.91	1.09	1.79	1.00	0.31	0.24	10.88	3.32	1.96
173	8.9	43.1	9.30	0.59	0.30	1.00	0.39	0.21	3.90	1.60	0.85
174	68.6	30.8	9.47	1.84	2.23	1.00	0.33	0.24	13.17	4.06	2.18
175	113.6	61.1	9.36	1.53	1.39	1.00	0.39	0.23	10.42	3.80	1.55
176	192.9	57.1	9.54	1.26	1.99	1.00	0.34	0.23	14.76	4.71	2.34
177	138.1	38.4	9.56	1.81	2.50	1.00	0.31	0.20	20.98	5.88	3.08
178	82.0	66.4	9.67	1.12	1.84	1.00	0.34	0.26	10.60	3.51	2.14
179	41.9	56.3	9.72	1.17	2.04	1.00	0.33	0.26	11.70	3.36	2.34
180	66.0	65.1	9.73	1.18	1.91	1.00	0.33	0.27	10.88	3.33	2.13
181	84.2	62.8	9.39	1.37	1.04	1.00	0.36	0.29	8.08	2.44	1.83
182	2.6	92.3	9.61	1.65	0.54	1.00	0.35	0.29	8.60	2.98	2.61
183	27.0	63.3	9.47	1.22	2.68	1.00	0.33	0.26	13.13	3.91	2.17
184	69.7	46.3	9.54	1.31	2.71	1.00	0.34	0.19	15.34	4.68	1.83
185	49.9	62.1	9.60	1.10	2.25	1.00	0.33	0.21	10.64	3.24	1.55
186	83.0	54.4	9.57	0.92	1.21	1.00	0.34	0.24	7.24	2.47	1.46
187	79.1	55.3	9.65	1.18	2.08	1.00	0.33	0.22	11.92	3.79	1.80
188	40.8	71.7	9.69	1.06	0.86	1.00	0.41	0.26	5.12	1.97	1.17
189	53.1	65.6	9.80	1.13	1.69	1.00	0.32	0.28	8.20	2.33	1.90
190	125.5	59.0	9.77	1.09	1.73	1.00	0.30	0.27	9.94	2.95	2.18
191	60.6	66.1	9.78	1.99	1.86	1.00	0.32	0.28	20.69	6.51	4.87
192	40.4	72.3	9.75	1.03	0.91	1.00	0.39	0.29	7.93	2.73	1.90
193	74.2	82.3	9.76	1.18	0.63	1.00	0.41	0.29	6.30	2.37	1.54

Table A1. *Cont.*

Basin Number	Basin Area, $\times 10^3$ ha	Cropland Area, %	*R*-Factor	*K*-Factor	*LS*-Factor	*C*-Factor			Soil Losses, t/ha per Year		
						M1	M2	M3	M1	M2	M3
194	51.4	60.1	9.75	1.23	1.26	1.00	0.36	0.28	14.77	4.75	3.37
195	36.2	28.0	9.81	1.71	0.54	1.00	0.22	0.29	6.90	1.50	1.89
196	114.3	24.1	9.81	1.74	0.47	1.00	0.32	0.31	4.13	1.31	1.28
197	38.2	52.2	9.85	1.75	0.48	1.00	0.30	0.29	6.87	1.89	1.85
198	47.8	0.7	9.84	1.37	0.57	1.00	0.24	0.28	5.36	1.29	1.27
199	20.3	53.7	9.86	1.96	1.97	1.00	0.32	0.24	26.93	7.34	5.56
200	25.8	72.9	9.94	1.26	1.70	1.00	0.32	0.27	14.86	4.61	3.17
201	34.4	63.3	9.98	1.24	1.94	1.00	0.32	0.25	16.57	4.90	3.19
202	64.3	49.2	10.04	1.11	1.56	1.00	0.36	0.25	13.19	4.29	2.51
203	67.7	52.4	10.11	1.15	1.61	1.00	0.31	0.25	15.04	4.29	2.78
204	37.8	63.2	10.05	1.16	1.41	1.00	0.35	0.26	11.10	3.79	2.30
205	23.2	44.8	10.08	1.26	1.73	1.00	0.33	0.24	15.98	5.07	2.83
206	41.3	56.5	9.99	1.13	1.15	1.00	0.39	0.26	11.70	4.53	2.62
207	33.9	68.5	9.98	1.18	1.91	1.00	0.31	0.26	12.30	3.33	2.42
208	37.5	63.1	9.98	1.33	1.98	1.00	0.32	0.27	15.12	4.14	3.35
209	19.6	47.5	10.28	1.07	0.38	1.00	0.35	0.26	4.09	1.34	1.04
210	30.7	50.1	9.66	1.10	2.94	1.00	0.26	0.23	14.49	3.38	2.30
211	33.6	46.1	9.55	1.11	2.46	1.00	0.31	0.22	11.72	3.54	1.96
212	109.5	63.5	9.63	1.09	1.78	1.00	0.34	0.25	11.91	3.71	2.18
213	37.4	59.1	9.89	2.33	2.53	1.00	0.35	0.23	30.68	9.85	5.24
214	125.3	73.1	10.23	1.24	0.84	1.00	0.32	0.24	8.65	2.38	1.83
215	182.1	74.5	9.54	1.09	1.04	1.00	0.38	0.28	7.04	2.46	1.60
216	26.3	66.1	9.53	0.96	0.88	1.00	0.37	0.28	5.97	2.01	1.35
217	32.4	66.9	9.81	1.61	0.57	1.00	0.25	0.30	7.01	1.71	2.09
218	527.3	41.2	9.36	1.46	1.69	1.00	0.35	0.22	15.28	5.04	2.53
219	7.7	49.2	9.41	1.08	1.66	1.00	0.35	0.23	12.66	4.36	1.73
220	40.6	75.3	9.90	1.07	0.77	1.00	0.38	0.28	6.07	2.19	1.45

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