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# Estimation of Erosion Danger Lands of the Reclamation Fund in Georgia

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**Abstract**
Erosion danger of lands of the reclamation fund in Georgia was studied by means of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), which was modified in the Problem Lab of Soil Erosion and River Bed Processes of Moscow State University (Anonymous, 1982). By the investigation was established that average annual potential soil loss, which was counted by means of USLE, is 10,5 % less than real loss of soil. If for the calculation of the potential soil loss we use only rains which provoke soil erosion, the difference between real and counted soil losses is only 1.77 % i.e. exactness of soil erosion forecast increases 5-6 times.

**Keywords:** Georgia, erosion danger, lands of Georgia, erosion forecast, USLE

## 1 Introduction

The climate of of Western Georgia is humid subtropical and that of Eastern Georgia arid subtropical. In the hilly regions of Western Georgia only 0,3-1,5 % of the territory are occupied by arable lands and eroded area is decreased to 30-60 %. Lands of reclamation fund of Georgia include most part of the arable lands.

Georgia is a mountainous country, 70 % of its territory is occupied by mountains. Western and Eastern Georgia is divided by the Ajara-Imereti (Likhi) range which is also watershed of the Black and Caspian Sea basin. There is an elevation of southern Georgia. Eastern Georgia includes volcanic upland (volcanic plateau, with neighboring volcanic ranges) and the hollow of Akhaltsikhi.
As the country is mountainous, it's climate, soils and vegetation changes by the vertical zonality.
By the hydrological investigation it was identified that in Georgia average soil loss is 15-20 tons per hectare. Out of 25 % of total area of the river basin soil losses exceeded 30 t/ha per year (Table 1).

The amount of soil losses from the river basins objectively does not reflect heavy erosion danger on the territory of Georgia. Here, water (rain) erosion and irrigation of erosion on the agricultural lands can be observed, because only 15-20 % of washed out soils are

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**Table 1:** Annual soil loss by the erosion in the river basins of Georgia

| *Soil loss (t/ha)* | *Area of the river basins* ($km^2$) | |
|---|---|---|
| | *Western Georgia* | *Eastern Georgia* |
| $< 5$ | – | 4,217 |
| 5 - 10 | 5,118 | 10,803 |
| 10 - 15 | – | – |
| 15 - 20 | 5,900 | 4,980 |
| 20 - 30 | 17,060 | 4,351 |
| $> 30$ | 6,484 | 10,987 |

going into a river (Brown, 1984; Kokoreva, 1985). In mountainous regions of the Western Georgia, arable lands occupy only 0,3-1,5 % of the total area. Among them, 80 - 90 % are eroded. In Eastern Georgia area of arable lands increases up to 5-15 % and area of eroded soils decreases from 30 to 60 %.

Considering the above represented facts, it is clear, that studying soil erosion processes and its cartography is inevitable for Georgia. Research and cartography of study results in this field have not yet been conducted in Georgia.

## 2 Objectives and Methods

Erosion danger of lands was studied by means of the Universal soil Loss Equation (USLE) (Wischmeier and Smith, 1978):

$$A = R * K * S * L * C * P \tag{1}$$

where:
$A$ is the soil loss in t/ha;
$R$ is the rainfall erosivity index (MJ*mm/ha*min*year);
$K$ is the soil erodibility factor (t*ha*min/ha*MJ*mm);
$S$ and $L$ are the dimensionless topographical slope and length factors;
$C$ - the dimensionless cover of soil surface and management factor;
$P$ - the dimensionless specific erosion control practices factor.

The rainfall factor was calculated by the equation of Zaslavski *et al.* (1981):

$$R_{30} = 0,25841 * H * I_{30} - 0.14921 \tag{2}$$

where:
$R_{30}$ is the rainfall factor (MJ mm/ha min year);
$H$ is the amount of rain (mm);
$I_{30}$ is the 30min maximum intensity of rain (mm/min)

By definition, the $K$ factor is the average amount of soil eroded annually from a standard fallow plot (which is of 22.1 m (72.6 f) length on a uniform slope of 9 %, in continuous fallow and tilled up and down the slope) per unit of erosion index ($R$). This factor was determined using the nomogram and formula of Wischmeier and Smith (1978); Wischmeier *et al.* (1971):

$$K = \sum A/R \tag{3}$$

The $K$ or soil erodibility factor is based on six factors: % clay, % silt plus very fine sand, % organic matter, coarse fragment content, permeability and structure (Wischmeier and Smith, 1978).

For estimation of LS-length and steepness factor, on the lands of reclamation fund of Georgia, which contains the most part of arable lands, division into districts was carried out on the map of 1 : 500 000 scale (Litvin and Mirgorodskaia, 1976), the reason of geomorphologic division is separation resembling type of relief. Non-erosion danger area – lowland bog soil area, wide plains soline soils and solonchaks and also sands were seperated onthe map. On the cartographic net for each geomorphological district, the topographical maps were selected 1 : 25 000 scale.

Quantity of maps depends on the area of region dismember of relief. In general, it is desirable for plane regions to take not less than 10 sheets of topographical maps, but foothills, uplands and mountainous region not less than 20 sheets. On the selected sheets of topographical maps, length and inclination of slopes are measured by the point-statistical method (Anonymous, 1982; Litvin and Mirgorodskaia, 1976; Litvin, 1976). By the above mentioned method of separated points, a big amount of measuring on the map gives an objective characteristic of its average meaning. On each kind of arable land of the geomorphologic district compartment of measurements for various arable lands will be different. If arable land is surplus (70-80 %), then it is quite enough to measure at the knot of the coordinate net. On hay mowing and pasture lands, length and inclination must be measured separately from each other by 1, 1.5, 2 and i.e. cm., points to collect quite enough amount of measurements. In local agricultural regions conversely, it is inevitable to condense the measured net on the arable land.

In the chosen points for measurements, there must be drawn line till watershed beyond the men-made border – such as line of protective afforestation, profile of roads or border of arable land (field, pasture) and down, also till the arable lands or above mentioned man-made border, ravine thalweg. Below, in case of sharply straighten, line of flow is finishing at the section of slope sag (straighten) (Anonymous, 1982).

Therefore, in the arable land already we have length (m) and inclination (%) by geomorhologic region. Next stage is calculation of erosion index of relief by the following equation according to Wischmeier and Smith (1978)

$$LS = \left(\frac{X}{22.13}\right)^m (0.065 + 0.45S + 0.0065S^2) \tag{4}$$

where:
$LS$ is the dimensionless factor of the relief
$S$ - inclination of the slope (in %);

$X$ - length of the slope (in m);
$m$ - index of degree.

WISCHMEIER and SMITH (1978) gave the following m-index of degrees:
$m = 0.5$ - if inclination of slope is $> 5$ %;
$m =$ 0,4 - if inclination is $\leq$ 5 and $>$ 3 %;
$m =$ 0.3 - if inclination is $\leq$ 3 and $\geq$ 1 %;
$m =$ 0.2 - if inclination is $<$ 1 %.

After finishing of the morphological works, for each region will be drown up diagram of erosion index of relies, with fixed interval, which for arable land is 0.25 and pasture - 1.0. Because, on the last classes fit small amount of measured parameter, therefore, we are correcting the left side of the diagram.

To compare the neighbor regions to each other, to determine true difference according the distribution of erosion potential of relief, criterion of Kolmogorov has been used (ANONYMOUS, 1982)

$$\lambda = \left( \frac{\sum n_1}{N_1} - \frac{\sum n_2}{N_2} \right) \sqrt{\frac{N_1 * N_2}{N_1 + N2}} \tag{5}$$

where:
$\sum n_1 / N_1$ and $\sum n_2 / N_2$ are accumulated frequencies (measurement) sum for each class, divided by the total amount of data of the first and second distribution (for the comparable regions).
If $\lambda \geq$1.36, difference among the regions is true.

Then the area of arable land and pasture will be calculated, in % by classes the erosion index relief. Area of $P$ class lands is $S_p$, and calculated by the following equation,

$$S_p = \frac{n_p}{N} * 100\% \tag{6}$$

where:
$n_p$ is the number of measurements by $P$ class of the relief erosion index;
$N$ is the total amount of measurements in geomorphological region on the arable lands and pasture.

Results are written in the table of the land distribution by geomorphological region.
Fort the calculation plant cover and management factor it is possible use method of USLE (WISCHMEIER and SMITH, 1978), but for large and small scale investigation it was calculated by the equivalent soil protection plant group.

All plants were divided the following groups:
1) Winter crop(wheat, barley, oats and etc.);
2) Spring crop, with height stalk hoe (maize, sunflower);
3) Low stalk hoe (sugar beet, folder root crops, melons, potato, tobacco);
4) Perennial grasses.

Besides, the separate area of the fallow is taken into account. These groups are devided by methods of soil till and agrotechnics:

a) Turn over a clod (traditional agrotechnique);
b) Cultivation with subsurface cultivator;
c) Industrial technology.

Total soils protection coefficient by agricultural plant group were calculated from the equation:

$$C = (C_1R_1 + C_2R_2 + ... + C_nR_n) * 100 \quad (7)$$

where:
$C$ is the soil protection coefficient of the agricultural plants group;
$C_1, C_2, ..., C_n$ is the soil protection coefficient of the agricultural plants group in different periods, when soil protection of the plants didn't change;
$R_1, R_2, ..., R_n$ - is amount of erosion index of rain in % per relevant period. Finally, soil protection cartogram composed for investigation region or country.

It's advisable to separate regions from each other with 0.05 stages. Dimensionless erosion control factor ($P$) wasn't used.

Qualitative deflation and irrigation erosion danger of the reclamation fund lands of Georgia studied by the method of Moscow State University Problem Lab of Soil Erosion and Riverbed Processes (ANONYMOUS, 1982).

## 3 Results and Analysis

For assessment of danger and cartography of lands of reclamation fund of Georgia, the Universal Soil Loss Equation (USLE) (WISCHMEIER and SMITH, 1978) and the Hydromechanical Model of Soil Erosion (MIRTSKHOULAVA, 1978) were chosen. The Hydromechanical model of water erosion prognosis and USLE from the physical point of view are different from each other.

The model of Ts. Mirtskhoulava (MIRTSKHOULAVA, 1978) is physically well grounded, but the map-making of territory by the USLE (WISCHMEIER and SMITH, 1978) is relatively easy. The USLE is based on the experimental results of the soil erosion plots data. It's provided with corresponding coefficient of plants and agricultural management. By that USLE stands out from the other methods, because its practical use is easier.

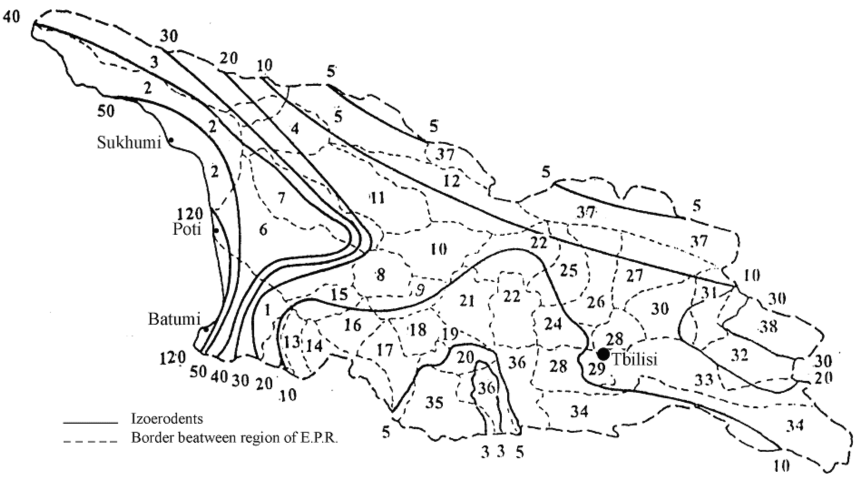
By investigations it was identified that erosion index of the rain ($R_{30}$) is directly proportional to soil loss (WISCHMEIER and SMITH, 1978). Soil losses were calculated by the MIRTSKHOULAVA (1978) model for each rain and erosion index of rain by the USLE. For investigation was taken environs of Akhaltsikhe, in southern Georgia. Length of slope was 150 m, inclination - 11 %. 21 years data of rainfall was used. Correlation coefficient between erosion index of rain and soil loss is 0.959; coefficient of determination is 0.920.

Carrying out tests (9 years) within the mountainous Adjara area, provide that annual potential soil loss calculated by the USLE is 10.5 % less than factual soil loss, relatively. But if soil loss is calculated only by foreseen of rains, which had washed out the soils. Difference between factual and calculated amount of soil losses is 1.77 %, because of the exactness of prognoses (forecast) increases 5-6 times (GOGICHAISHVILI *et al.*, 2003).

The above mentioned research was carried out for estimation erosion danger lands of reclamation fund of Georgia by the USLE (WISCHMEIER and SMITH, 1978).

On the basis of the data of all meteorological stations of Georgia, from 1936 to 1990 average annual erosion index of rain was calculated and the map of Georgia was composed (Fig. 1) (Gogichaish vili and Gorjomeladze, 1998).

**Figure 1:** Average annual erosion index of rain of Georgia.




On the second stage, on the basis of geomorphological division into districts (Gogichaish vili and Gorjomeladze, 1998) in the separate geomorphological region on the arable lands, perennial plantation, haymaking and pasture length and inclination of slope were measured according to the point-statistical method (Litvin and Mirgorodskaia, 1976; Litvin, 1976). After that, for different area the erosion index of relief (LS) was counted (Wischmeier and Smith, 1978).
Geomorphological regions were divided by Kolmogorov criterion (Anonymous, 1982). As for high erosion danger of the lands of the reclamation fund of Georgia indicated that from the separated 20 regions and subregions, in 13, 20-55 % of arable lands were arranged on the slopes with erosion index of relief (LS) which ranges from 5 to 10 unit.

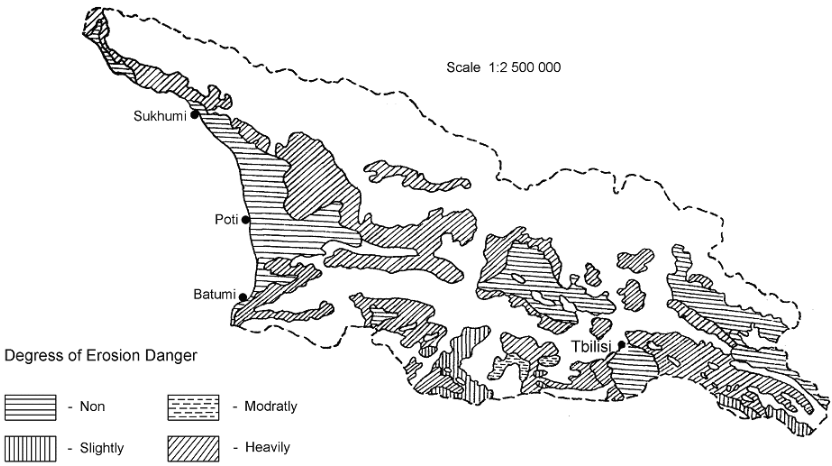
On the third stage, according to the private and fund materials erodibility of top layer soils of Georgia (K-factor) was determined which range from 0.8 to 3.8 t/ha (Gogichaishvili and Urushadze, 2000).

In the next stage for 69 regions of Georgia their plant and agricultural management factor (C - factor) was calculated for winter and spring crop, maize, sunflower, potato, sugar beet, tobacco and perennial plantation. It was identified by investigations that in the most part of Georgia factor C varies from 0.419 to 0.661 (Gogichaish vili and Gorjomeladze, 1998). Based on above mentioned data and the USLE (Wischmeier and Smith, 1978) for the lands of reclamation fund of Georgia annual soil loss was calculated.

Lands and territories where combination of natural conditions is producing possibility of prompt erosion in condition of economic use without methods of erosion control use (Zaslavski, 1979). Soil tolerance was acceptance 2.5 t/ha per year and such territories are considered as non erosion danger lands or weak erosion danger, where potential soil loss is from 2.5 to 5.0 t/ha/year. Lands are of medium erosion danger when potential loss from this land is 5.0-10 t/ha/year and lands are heavy erosion danger where potential soil loss is more than 10 t/ha/year.

Potential soil loss for lands of reclamation fund of Georgia was calculated and composed a map in 1:500,000 scale (Fig.2).

**Figure 2:** Potential soil loss for lands of reclamation fund of Georgia.




Investigations ascertained that out of 103 thousand ha of Autonomous Republic of Abkhazia, 10 thousand ha (10 %) is of weak erosion danger (Table 2). Out of 50 thousand ha of the reclamation fund of A.R. of Adjara 41 thousands ha (82 %) are in condition of erosion danger. Among them 5 thousand ha (13 %) are weak erosion danger, 10 thousand ha medium and 26 thousand ha (63 %) heavy erosion danger. In South Osetia Autonomous District, out of the 64 thousand ha lands of the reclamation fund, 40 thousand ha (62.5 %) is in erosion danger condition. Among them 13 thousand ha (32 %) is weak erosion danger, 8 thousand ha (20 %) - medium and 19 thousand ha (48 %) - heavy erosion danger.

In Georgia, of 304 thousand ha (19 %) of the erosion danger lands of the reclamation fund, (19 %) is weak erosion danger, 80 thousand ha (5 %) - medium and 1194 thousand ha (76 %) - heavy erosion danger. Also 12 thousand ha of irrigated lands are erosion danger.

**Table 2:** Potential erosion and deflation danger of the agricultural and reclamation fund lands.

| *Administrative regions* | *Lands of the potential danger of erosion (thousand ha / %)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Agricultural lands* | | | *Lands of reclamation fund* | | | | |
| | *total* | *among them* | | *total* | *among them* | | | *irrigation lands* |
| | | *arable lands* | *mowing and pasture* | | *weak* | *middle* | *heavy* | |
| Eastern Georgia | 1070 | 283 | 787 | 964 | 276 | 42 | 646 | 12 |
| | 100 | 26 | 74 | 100 | 29 | 4 | 67 | – |
| Western Georgia | 500 | 425 | 75 | 430 | – | – | 430 | – |
| | 100 | 85 | 15 | 100 | – | – | 100 | – |
| Regions without autonomous republics | 1570 | 708 | 862 | 1394 | 276 | 42 | 1076 | 12 |
| | 100 | 45 | 55 | 100 | 20 | 3 | 77 | – |
| Abkhazian A.R. | 150 | 130 | 20 | 103 | 10 | 20 | 73 | – |
| | 100 | 87 | 13 | 100 | 10 | 19 | 71 | – |
| Adjaria A.R. | 50 | 45 | 5 | 41 | 5 | 10 | 26 | – |
| | 100 | 90 | 10 | 100 | 13 | 24 | 63 | – |
| South-Osetia A. Region | 64 | 34 | 30 | 4 | 13 | 8 | 19 | – |
| | 100 | 95 | 5 | 100 | 32 | 20 | 48 | – |
| Total of regions of the Eastern Georgia | 1134 | 317 | 817 | 1004 | 289 | 50 | 665 | 12 |
| | 100 | 28 | 72 | 100 | 29 | 5 | 66 | – |
| Total of regions of the Western Georgia | 700 | 600 | 100 | 574 | 15 | 30 | 529 | – |
| | 100 | 86 | 14 | 100 | 3 | 5 | 92 | – |
| Total | 1834 | 917 | 917 | 1578 | 304 | 80 | 1194 | 12 |
| | 100 | 50 | 50 | 100 | 19 | 5 | 76 | – |

| *Administrative regions* | *Potential danger of deflation* | | | | | | | *Potential danger of irrigation* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Agricultural lands* | | | *Lands of reclamation fund* | | | | *Lands of reclamation fund* | | | |
| | *total* | *among them* | | *total* | *among them* | | | *total* | *among them* | | |
| | | *arable lands* | *mowing and pasture* | | *weak* | *middle* | *heavy* | | *weak* | *middle* | *heavy* |
| Eastern Georgia | 585 | 193 | 392 | 505 | 216 | 223 | 66 | 137 | 128 | 9 | – |
| | 100 | 33 | 67 | 100 | 43 | 44 | 13 | 100 | 93 | 7 | – |
| Western Georgia | – | – | – | – | – | – | – | 33 | 26 | 7 | – |
| | – | – | – | – | – | – | – | 100 | 79 | 21 | - |
| Regions without autonomous republics | 585 | 193 | 392 | 505 | 216 | 223 | 66 | 170 | 154 | 16 | – |
| | 100 | 33 | 67 | 100 | 43 | 44 | 13 | 100 | 91 | 9 | – |
| Abkhazian A.R. | 7 | – | 7 | – | – | – | – | 10 | 10 | – | – |
| | 100 | – | 100 | – | – | – | – | 100 | 100 | – | – |
| Adjaria A.R. | 2 | – | 2 | – | – | – | – | 4 | 3 | 1 | – |
| | 100 | – | 100 | – | – | – | – | 100 | 75 | 25 | – |
| South-Osetia A. Region | 15 | 7 | 8 | 5 | 4 | 1 | – | – | – | – | – |
| | 100 | – | – | 100 | 80 | 20 | – | – | – | – | – |
| Total of regions of the Eastern Georgia | 600 | 200 | 400 | 510 | 220 | 224 | 66 | 137 | 128 | 9 | – |
| | 100 | – | – | 100 | 43 | 44 | 13 | 100 | 93 | 7 | – |
| Total of regions of the Western Georgia | 9 | – | 9 | – | – | – | – | 47 | 39 | 8 | – |
| | 100 | – | 100 | – | – | – | – | 100 | 83 | 17 | – |
| Total | 609 | 200 | 409 | 510 | 220 | 224 | 66 | 184 | 167 | 17 | – |
| | 100 | 33 | 67 | 100 | 43 | 44 | 13 | 100 | 91 | 9 | – |

510 thousand ha of the reclamation fund are deflation danger. Among them 220 thousand ha ( 43 %) is concern to weakly deflation danger (Table 2), 224 thousand (44 %) - middle and 66 thousand (13 %) - heavy deflation.

As deflation danger is determined only by the deflation index of the wind, above mentioned estimation is qualitative and approximate (Anonymous, 1982). Estimation of erosion danger of irrigation land is based on the quantitative forecast method.

In western Georgia out of 137 thousand ha lands of reclamation fund, 128 thousand ha (93 %) is weak erosion danger and 8 thousand ha (17 %) - medium erosion danger. Using the of above mentioned method, heavy erosion danger area was not obswerved.

According to the separate regions of Georgia, in case of producing the traditional agricultural crops and having carried out the erosion processes, the use of the USLE gives an opportunity to control ecological condition on the agricultural lands of reclamation fund of Georgia.

## References


Anonymous; Methodical instruction for determination of reclamation fund. Section: Erosion-Deflation Ground. Scheme of development reclamation and winter economy of SU for period to 2000 year; Moscow State University; 1982; Russian.

Brown, L. R.; The global loss of topsoil; *J. Soil and Water Conservation*; 39(3):165–165; 1984.

Gogichaishvili, G. P. and Urushadze, T. T.; Some Data on Georgian Soils Stability Against Erosion; *Bull. Of the Georgian Academy of Sciences*; 161(2):235–237; 2000.

Gogichaishvili, G. P., Urushadze, T. T. and Gordjomeladze, O. L.; Universal soil loss equation for application in Georgia; *J. Pochvovedenie*; 3:240–243; 2003; (Russian).

Kokoreva, M. L.; Erosion processes in the eastern and southeastern localities near Moscow; In coll. Study of natural condition and its applied aspects, Moscow, pp. 62-66; 1985; (Russian).

Litvin, L. F.; Estimation of relief of medium and small scale draw a map of erosion danger of lands; In coll. Regularity exposure erosion and riverbed processes in different natural condition. M., MSU, pp. 64-65; 1976; (Russian).

Litvin, L. F. and Mirgorodskaia, N. N.; Cartografical-statistical method of estimation of slope inclination; In coll. Regularity exposure erosion and riverbed processes in different natural condition. M., MSU, pp. 54-55; 1976; (Russian).

Mirtskhoulava, T. E.; Methodical recommendation for prognosis of the water (rain) erosion of soil; Methodical recommendation worked out by academician of Vaskhnil Ts. E. Mirtskhoulava, Moscow, 60 pp.; 1978; (Russian).

Gogichaish vili, G. P. and Gorjomeladze, O. L.; Estimation of Soils Protection of Agricultural Plants in Georgia; *Bull. Of the Georgian Academy of Sciences*; 158(2):303–305; 1998.

Wischmeier, W. H., Johnson, C. B. and Cross, B. V.; A soil erodibility nomograph for farmland and construction sites; *J. of Soil and Water Conservation*; 26(5):189–193; 1971.

Wischmeier, W. H. and Smith, D. D.; *Predicting rainfall erosion losses, a guide to conservation planning*; no. 537 in Agricultural Handbook; USDA, Washington DC;

1978.

ZASLAVSKI, M. N.; *Soil Erosion*; Publishing House "Misl", Moscow; 1979; (Russian), 243 p.

ZASLAVSKI, M. N., LARIONOV, G. F., DOKUDOVSKAIA, O. G. and TARABRIN, N. P.; A map of erosion index of precipitation in the European territory of the USSR and Caucasus; In Coll. Soil Erosion and River Bed Processes. M., Publ. MSU, 1981, Issue 8, p. 17-29; 1981; (Russian).