Mapping of the Soil Erosion Using the Digital Relief Model

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Abstract: The erosion of tillage soil depends on relief locality. The relief is a very important factor for soil-formation. It influences the soil genesis, structure of soil cover, contrast characteristics and spatial heterogeneity of soil. It is suggested to use the digital model of relief for mapping the soil erosion. The results of the using of the mathematical equation for processing of matrix are shown on example of the Fergana valley.

Keywords: soil, erosion, digital relief model, mapping

1   Introduction in methodology

One of the main parameters of the erosion of tillage soil is the relief locality. The relief a very important factor for soil-formation. It influence the genesis, structure, contrast characteristics and spatial heterogeneity of soil.

With due regard of the influence of all the factors of soil-formation, within the range of the concrete locality lands and physic and geographic conditions, it is possible to estimate the role of the relief in soil-formation. At the same time the relief to a considerable extent influences the erosion processes.

One of the indices of the soil erosion it is the factor of the washing away of solid particles from river basins territories and flow of alluvia in the outlet of the river basin. O.Shcheglova (1984) suggested to use the investigations of solid flow as the index of total level of erosion. The exposure of high regularity of change of washing away and its response preceded by determination of the genetic component of alluvial flow and composition of balance of the tiny-soil bearing out.

For example, for estimation of rain washing away from slopes the equation is used :

$$M_i = 10\, R\, H_i \tag{1}$$

where M_i: zonal washing away with rain in i: elevation - zone, $t \cdot km^{-1}$

R: fictitious turbidity, $kg \cdot m^{-3}$

H: zone rate of liquid precipitations in this zone, mm

With due regard of the wash away for snow and ice components, the maps of zone wash away for high lands of Central Asia were constructed. However, for using this method necessary the dense network system of hydrological observations is needed.

Makkaveev N.I. (1979) showed that every investigator makes his own classification of soil for soil erosion categories. However, it was revealed of that the slope influence on soil erosion, especially on tillage lands.

For tillage land the maximum slope steepness is about 3°—5°. On over load pastures it is 15°—20°. On slopes 25°—35° the erosion is combined with gravitation sliding subsoil and observed deepening of the erosion process.

The tracks of wash away on the tillage foothills have been noticed, when slope steepness was 1°, if 3°—5° more (south slope), then in 50% cases, the moderate and strong wash away of soil was registered.

The influence of length of slope on the erosion is defined by the occurrence of temporary water courses, which transport a particles, depending on the intensity of rain up to accumulation zone. The exposition of slope is a very important component in erosion processes.

Basing on competent investigations it is suggested to use digital model of relief and mathematical methods for processing of number matrix in the mapping of lands by the degree of erosion danger of tillage lands.

The base of digital model of relief is formed by the set of attached coordinates. For construction of model the method with due regard of the digitizing by horizontals was used. It is problem, which requires the considerable labor consuming character.

On topographic map took the character points of relief - talwegs, watersheds and intermediate points, drawing of which give the geographic recognition of relief. The object of investigation - foothills zone of the Fergana valley was considered (Fig.1). For digitizing of relief the map with scale 1:100 000 was used.
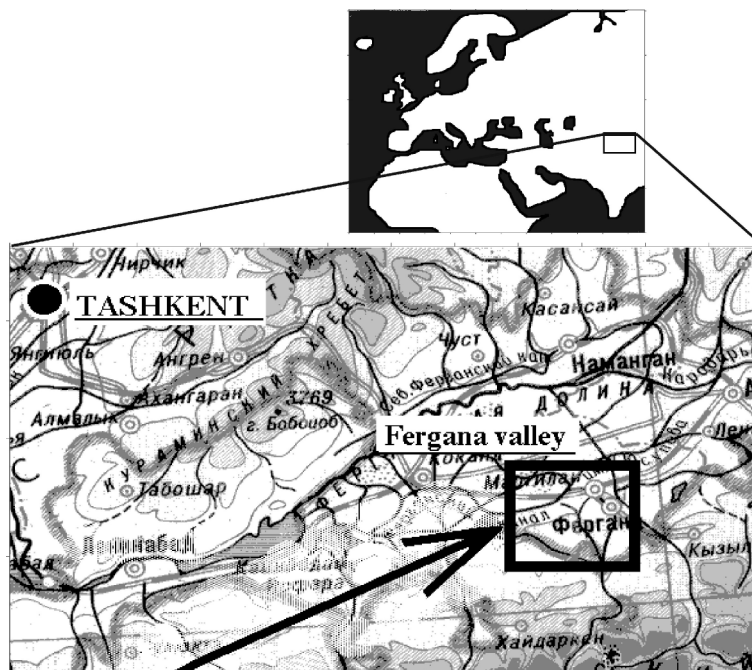

Fig. 1   The area of investigations is shown by arrow and outline

The process of constructing of digital relief model books as follows. The topographic map was scanned. With using special computer program SURFER, the digitizing of relief is made, for which the relative coordinates on plane are automatically written into data file. To the plane coordinates of point was be additive high point of earth surface by hand. The data file which content digital model in view of the non-regular three-dimensional coordinates are created.

Then using interpolation method the regular grid of the altitude is constructed. On screen of computer either the map of territory is constructed as horizontals or three-dimension projection and visually its correspondence to topographic base is defined. This stage is necessary to find mistakes, which appear during digitizing. The visual control of the relief model and topographic map correspondence decrease the number digitizing of errors. Thus we obtain relief model as digital matrix of altitude marks which can be processed with the mathematical methods to define the character of relief parameters.

As it is generally known, the slope steepness define a potential possibility of slope erosion for other equal conditions.

For estimating of the slope steepness the gradient equation was used:

$$\mathrm{grad}Z = \frac{\partial Z}{\partial x}i + \frac{\partial Z}{\partial y}j \qquad (2)$$

where Z：altitude mark of territory,

   x, y：direction by coordinate axes.

On Fig.2 the results of calculations for digital model of relief as the direction of movement of the surface flow on slopes are show.
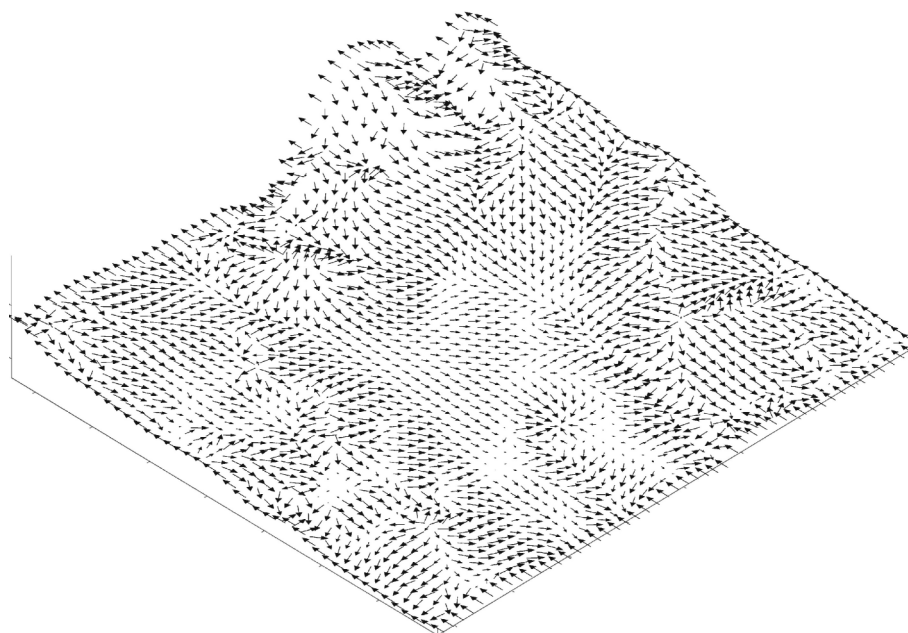

Fig. 2 The presentation of slope flow calculated by the parameters of digital relief model. The arrows show the direction of surface flows, size of the arrows show the calculated speed of water flow.

The dependence of the slope washing away on the extent of the vegetation cover is known. For Central Asia there is the direct relation between orientation of slope, soil cover, character and thickness of vegetation on it.

The slope of the sun exposition have more thinly vegetation covered. The vegetation cover is more thick on slopes of the north exposition. The stability of the south exposition slopes is lower then the north exposition slopes and average turbidity of the slope flow is 204 kg · m^{-3}, with maximum 565 kg · m^{-3}.

On the north slope the turbidity is about 2 kg · m^{-3}. The wash away on slope of the north exposition in average is 0.11% in comparison with the slope of the south orientation.

For calculation of the volume of the slope wash away depending on orientation following equation is used :

$$V = 0.5\,[\,V_{max}\,(1 - \cos\alpha) + V_{min}\,(\,1 + \cos\alpha)] \qquad (3)$$

where V：volume of the washing away,
V_{max}：maximum volume of the washing away on the northern exposition slope for concrete geographic area,
V_{min}：minimum volume of the washing away on the southern exposition slope
α：azimuth of slope, counted from the northern direction moving clock-wise.

All investigators noted, that difference between wash away from north exposition and south exposition was not more than 0.11% (territory of Central Asia). For mountain and foothills regions of Central Asia the washing away from the slope of southern exposition, for one rain is within 0.076 kg · m^{-2} – 0.141 kg · m^{-2}.

With taking it into account then write:

$$V = V_{max}\,(1 - \cos\alpha)\,/\,2 \qquad (4)$$

If assume a proportionality of dependence of erosion on the orientation of slope and its steepness as in equation (2) and (4), and normalize it relatively to unit, then equation for some statistic function can be used :

$$E = a * V + b * \text{grad}Z \tag{5}$$

where a,b： some coefficients of proportionality, depending on physical and geographical area,
        E： dimensionless index of slope erosion.

2   Results

The results of using equation (4) is shown on Fig.3. The parts most subjected to the erosion are shown as more dark parts. The extent of subjection to slope erosion is normalized and is within   0 — 1. The parts mostly subjected erosion correspond to 1 and are shown by dark tone, less subjected by light.

On the grounds of the long-term investigations in Central Asia it was succeeded to generalize the method to preliminary mapping of degree of subjection to water erosion of the slopes.

In results of using this method for modeling of surface, with use topographic base the method of mapping with using mathematical functions for processing of the matrix was suggested.

This method can serve to prepare the   base attached to next map of soil erosion with use of the characteristics of vegetation cover and economic use of lands.
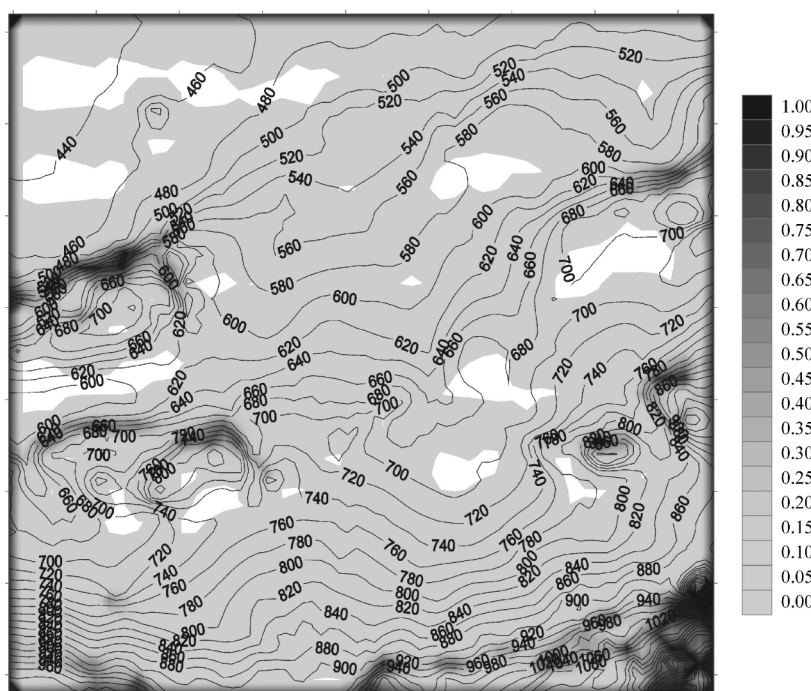

Fig. 3   The results of calculation of degree of slope stability to erosion for choose part of the Fergana valley. The most subjected to erosion is shown as dark tone and corresponds 1, the least - 0. Isolines corresponds to altitude marks   of territory, in meters.

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