Inquiry for a Calculated Method of Soil Loss Amount from Irrigular Slopes

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Abstract: With regards to calculation of soil erosion amount in irrigular slopes, a method to calculate topographical factor LS value put forward by foster and weichmeier was applied. The method was not used well in practice due to without considering change of the irrigular slope curvature and rough slope grading. In fact, however, the natural slope shapes are very complex. Using generalised slope shapes was bound to lead to loss of some imformation. Thinking to solve the problem is to use crossline Between the irrigular slope and its direction of waterflow slope shape lines to present irrigular slope. The irrigular slope is replaced by even slope under the same conditions (to pography, soil ect) except for different slope gradients. Because soil erosion amount between both is equal, and erosive energy is also same. Based on the theory, a method to look for enquivalent even slope under the model of over infiltration runoff was found. The mothed is very simple, without generalised error and confirmed in the field experiment.

1 Question

Environmental problems were paid close attention to the whole mankind at present. The loss of soil and water is one of environmental problems. On the basis of research to soil and water loss about 100 years, a series of prediction and forecast models about soil and water loss had been established. Geomorphology agents were nearly included in all models. The effect on slope shape was followed with interest gradually except slope degree and slope length to all geomorphology agents. Earth’s surface is convex and concave because natural surface is often irregular. Researchs indicated that soil erosion of convex slope and even slope was generally the most intensive at the bottom of the slope, while the phenomenon was adverse to concave slope. Erosion was most intensive in the middle of the slope. Erosion Not only was decreased but also was a phenomenon of heaps surpassed erosion because slope degree became small at the bottom of the slope(John P.Wilson,1986; Zhu X.M.,1981). The phenomena were caused because of difference of erosive energy to different slope position and controlling runoff rate and velocity(Shoichi Tokudome,1982; Guo Y.W,1996). Slope surface was divided into even slope, concave slop, convex slope and composite slope(Foster, meyer,1982; Wan T.C.,1996). The method should be reasonable. The effect on composite slope was obscure if the erosion of irregular slope was calculated by even slope, at the same time, the estimation of erosion to concave slope was high and that of convex slope was low.

Erosion of irregular slope was calculated through the method that the value of *LS* was posed by Foster and Weichmeier(1974), that was $LS=\sum_{i=1}^{n}\left(S_i\lambda_i^{1+m}-S_i\lambda_{i-1}^{1+m} \right)/\left(\lambda t+22.1m\right)$. The ratio of *LS* between irregular slope and even slope was obtained by C. D. Castro and T. M. Zobeck in the certain condition (1986). Thus, there were some methods to calculate ersion of irregular slope.

The former had a problem of neglecting the variance of curvature to irregular slopes while they were thought of as the same. The other problem was that it was too fewer and rougher to division of slope grade. In the latter the first problem was as same as the former. Shapes of Composite slope was only single and ranges of these methods were narrow. It was only suitable to small range slope length through several conditions of determining really. At the same time, it’s hard to know it could be suit able to other the research area. So, it could be seen that the calculation of soil loss to irregular slope hadn’t been really solved.

2 New method to calculate erosion of irregular slope

2.1 Expression of irregular slope

It’s difficult to obtain the calculating equations of irregular slope accurately if the curvature was thought of as an index and the grade of slope degree and slope length was divided further due to the complex and variation of nature slope and difference of absolute erosion. One of thoughts to solve the problem expreses the slope by shape line of real slope in irregular slope(Fig.1). Thus the slope not only included information of geomorphic pattern but also avoided expressing complex of several index. The Methods were that a vertical section was done along direction of water flow in slope. Shape line of slope was the intersect between section and slope. The second thought was that erosion of all kinds of irregular slope was expressed by that of even slope with a kind of topography and same soil in a given area, that it was replaced with corresponding even slope.

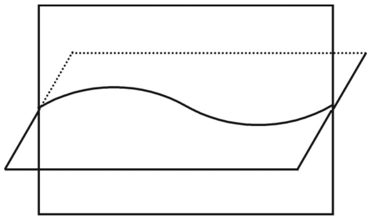

Fig.1 Shape line of slope

2.2 Replacement of irregular slope

The relation of concave slope, convex slope and straight Line slope need to be researched because all kinds of irregular slopes might be expressed by even slope, concave slope and convex slope or combination among them(Fig.2). Due to a large number of erosion took place in the super-infiltration runoff area or season, the slope surface was thought of as the object of research. Three slope shapes with the same starting point and terminal point supposed that they accept to same rainfall intensity and infiltration intensity. To the concave, for an example, vertical section was put on the perpendicular coordinate system with horizon axil x and vertical axil y and the vertical line of their top points was the same to the axil y (Fig.3). The curve of vertical section to concave slope might be expressed as equation: $y=f(x)$. Runoff depth of intensity (I_i) and infiltrating rafe (f_i) expressed as $I_i=f_i$ to any points of curve line of its per width.

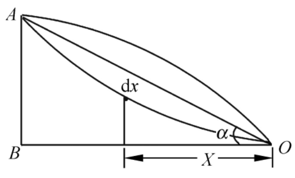

Fig. 2 Expression of even slope, concave slope and convex slope

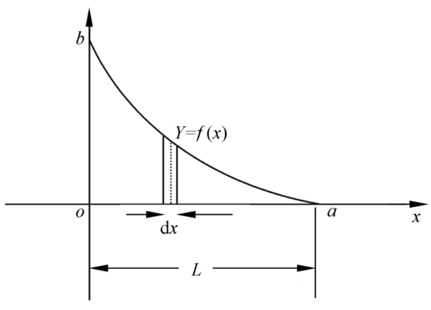

Fig. 3 Calculating chart of runoff energy to concave slope

Micro length is choosed dx, and its runoff is expressed as: $(I_i - f_i) \cdot L\mathrm{d}x$. It has potential power of $\rho(I_i - f_i)\mathrm{d}x \cdot g \cdot f(x)$ apposite to axil x. Whole runoff potential power of all concave slopes to the same time was expressed as:

$$\int_0^L \rho\left(I_i - f_i\right)\,\mathrm{d}x \;\cdot\; g \;\cdot\; f\left(x\right) = \rho g\left(I_i - f_i\right)\int_0^L f\left(x\right)\,\mathrm{d}x$$

where $\int_0^L f\left(x\right)\mathrm{d}x$ is the area of Δoab. The whole potential power might be expressed as $\rho g = (I_i – f_i) A$ if the area of Δoab was expressed as A.

The whole runoff potential power of per width concave slope was expressed as $\int_0^L \rho g\left(I_i - f_i\right) \cdot A \cdot \mathrm{d}t$ during some rainfall due to they varied with time.(rainfall intensify I_i and soil infiltration rate f_i). A straight line was drawed perpendicular y axil from the beginning of point a there is a intersect point c. Thus Δoac and Δoab have the same area between them, axil x and axil y. The runoff potential power is also $\int_0^L \rho g(I_i - f_i)A \cdot \mathrm{d}t$ during time rainfall on the straight slope of ac. Erosion decide on runoff if the difference of raindrop impact and soil particle steadiness was neglected. Thus erosion and moving of concave slope ab might be replaced with that of straightline slope ac. The contrast relation among erosion dilivery was reflected through that of runoff energy to different slope shape due to erosion dilivery was caused by runoff scouring,that is:

$$\frac{\text{Mcancave}}{\text{Mstraight}} = \frac{\text{Econcave}}{\text{Estraight}} = \frac{\left(I - f\right)\rho g \cdot \text{Aconcave}}{\left(I - f\right)\rho g \cdot \text{Astraight}} = \frac{\text{Aconcowe}}{\text{Astraight}} \text{ and}$$

$$\frac{\text{Mconvex}}{\text{Mstraight}} = \frac{\text{Econvex}}{\text{Estraight}} = \frac{\left(I - f\right)\rho g \cdot \text{Aconvex}}{\left(I - f\right)\rho g \cdot \text{Astraight}} = \frac{\text{Aconvex}}{\text{Astraight}}$$

Equivalent straight line slope of concave slope was obtained by the method. Equivalent straight line slope of convex slope was also be obtained by the same way (Fig.4).

During the condition of equivalent gradient ration, erosive energy of convex slope surpassed that of straight line slope and erosive energy of concave slope lowed to that of straight line slope. To composite slope, it was complex. It depends on situation and degree of composition. Erosive energy of composite slope might low, surpass or equal to that of straight line slope. On the effect of erosive energy, the sequence of soil erosion from high to low was convex slope, straight line slope, concave slope to all slope shapes. Composite slope may overpass, equal or low to straight line slope.

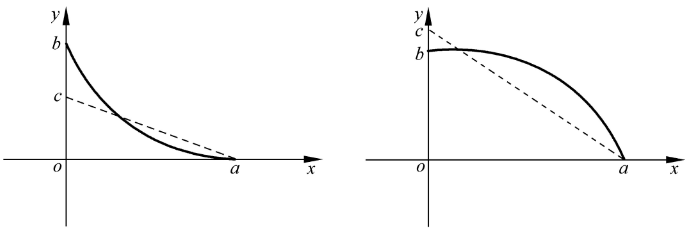

Fig. 4(a) Method of replacing straight line slope

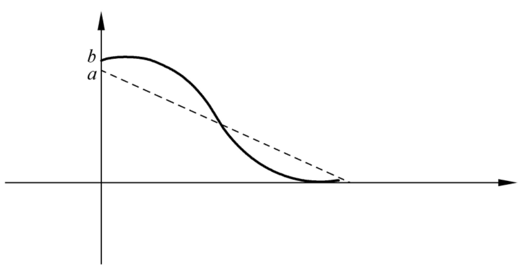

Fig. 4(b) Straight lime slope of composite slope replacement

2.3 Calculation of erosion to irregular slope

From the above analysis, the results showed that soil erosion of irregular slope might be calculated by the method of equivalent straight line slope. The gradient ration of equivalent straight line slope lowed to original gradient ration of concave slope. Thus phenomenon of soil loss in slope on convex>straight> concave was clarified in theory.

The result showed that the smaller is curvature of irrgular slope, the nearer is the distance between irregular slope and equivalent straight line slope through the above. Thus it was accurate to replace the upslope surface is steep and downslope surface is gentle gradually on increasing of curvature to irregular slope. So the phenomenon of depositing is more obvious due to scour action of increasing runoff energy the upper and decreasing runoff energy on the latter. Erosion was decreasing gradually due to the upper slope degree become gentle and erosion was ceasing due to the latter runoff energy increased.

3 Test and verify of experiments

The experiment was done in order to test and verify the reliability of replacing and explore the major factors of replacing accurate degree on the Chunhua county the super-infiltration runoff area. Chunhua County (Longitude is 108º81'—108º50', latitude is 34º43'—35º03'. The average rainfall for many years is 600.6mm. and concentrate in July. August and September) lie on the south part of Loess Plateau. The natural and typic convex slope, concave slope and composite slope deal with bare field entirely. Plots of width 2m segregated arccording experimental design and the same specification plot of equivalent straight line slope was established at the same plot. Soil loss was collected on the condition of natural rainfall. Calculated values were obtainted by the method of replacing observation on the condition of the same soil(Huang shan)rainfall and handle and runoff of observation the average rainfull rate is 583.7mm(1997—1999)and runoff plot data (straight line slope). The results were following (Table 1).

Table 1 Soil loss contrast between irregular slope and equivalent slope(bare, loess soil)

Number	Slope shape	Slope degree	Slope length(m)	Curvature	Erosive modulus (t/(km^2 •a))	Equivalent slope	Erosive modulus of equivalent slope M' (t/(km^2 • a))	Error $\frac{M-M'}{M}\times 100\%$
1	Convex	4º15'	20	$\frac{0.6}{20}$	234.90	5º47'	712.25	+3.2
2	Convex	4º58'	40	$\frac{0.8}{40}$	520.31	6º08'	508.21	+2.4
3	Convex	5º21'	60	$\frac{1.0}{60}$	546.03	6º23'	536.85	+1.7
4	Convex	2º52'	20	$\frac{0.2}{20}$	251.11	3º11'	250.34	+0.3
5	Convex	7º14'	20	$\frac{1.5}{20}$	1,694.79	11º34'	1,643.11	+3.9
6	Convex	8º43'	20	$\frac{1.2}{20}$	2,311.18	14º52'	2,216.10	+4.3
7	Convex	18º26'	20	$\frac{1.6}{20}$	3,674.98	21º22'	3,428.0	+7.2
8	Concave	8º52'	20	$\frac{0.8}{20}$	767.85	6º22'	782.90	+3.2
9	Concave	7º57'	40	$\frac{1.1}{40}$	808.09	6º37'	837.40	–3.5
10	Concave	6º50'	60	$\frac{1.3}{60}$	709.92	5º52'	724.60	–2.3
11	Concave	3º28'	20	$\frac{0.2}{20}$	305.96	2º53'	308.46	–0.8

Coninued

Number	Slope shape	Slope degree	Slope length(m)	Curvature	Erosive modulus (t/(km^2 •a))	Equivalent slope	Erosive modulus of equivalent slope M' (t/(km^2 • a))	Error $\frac{M-M'}{M}\times 100\%$
12	Concave	16º31'	20	$\frac{1.3}{20}$	1,778.35	12º47'	1,854.37	–4.1
13	Concave	18º12'	20	$\frac{1.5}{20}$	2,201.16	15º21'	2,307.30	–4.6
14	Concave	23º59'	20	$\frac{1.7}{20}$	3,095.67	19º49'	3,224.67	–5.4
15	composite	6º03'	40	$\frac{0.3}{40}$	554.65	6º21'	554.26	0.7
16	composite	5º49'	60	$\frac{0.4}{60}$	591.21	6º09'	597.09	0.1

Note: ① Curvature was expressed as $\frac{h}{L}$,where h is the perpendicular distance between the most concave (convex)point and straight line slope of same slope degree. L is length of slope.
② Erosive modulus were expressed by the average of 3 years.
③ repeated number is 1.

4 Conclusion and analysis

(1) The difference of irregular slope erosion was reflected by runoff energy, thus is the whole slope and different position of slope.

(2) A straight line slope was done. The area of triangle composed by axil x, axls y for right angle coordinate system and the straight line slope equal that of triagule composed by axil x, slope was treated as the equivalent slope of irregular slope.

(3) Erosion of irregular slope might be replaced by that of equivalent slraight slope and their value is same.

(4) The smaller is curvature of irregular slope, the better is replacing effect with equivalent slope, that is, error of calculating erosion is smaller, on the contrary, the error increased. The error surpassed 5% when curvature $\left(\frac{h}{L}\right)$ exceeded 0.08.

(5) The error was caused to replacement because of difference of raindrop impact erosion to different topography and transient velocity of runoff, the effect of wind and difference of infiltration rate different position.

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