Numerical Analysis of Crop Cover Effect on the Soil Eroaion by Rainfall

Masazumi OGURA*, Nobuhiro MINAMI*and Akio IMAO**

* *Laboratory of Land Conservation, Faculty of Agriculture ;*

** *Laboratory of Land Reclamation, Faculty of Agriculture, Shimane University*

Abstract : The soil erosion by rainfall in sloped farmland is controlled by covered crops on the surface of soil. This paper reports to experimental equation of soil loss from sloped farmland plots cultivating crops, is the corn, soybean and weeping-lovegrass. We obtained following equation from the measurement of rainfall strength, soil loss and cover ratio by crops.

$$W=W_b/(1+C_k x^{d_k})$$

where

W : soil loss from the plot with crop

W_b : soil loss from the bare plot

x : cover ratio of crop

C_k, d_k : crop constants

"Simplex Method" for the computor was used to determinate above two constans of C_k and d_k.

Introduction

We had already obtained following equation of soil loss from bare slope plots by a rainfall[1].

$$W_b=K(s/s_0)^a(l/lo)^b(r/r_0)^c \quad (1)$$

where

K : soil factor.

s, s_0 : slope steepness, unit steepness.

l, l_0 : slope length, unit length.

r, r_0 : rainfall factor, unit factor.

a, b, c : constants.

As the next step, we considred to estimate the erosion loss from the croped plots having each cover ratio of crops depending each crop-stage, and to be expressed in following equation.

$$W=W_bC \quad (2)$$

where

W : soil loss from sloped plots covering crop

C : crop factor

Smith and Wischmeier[2] had described on crop cover and management "each crop row devided into five crop stages, defined relative uniformity of cover and residue effect as follows ;

(1) rough fallow—turnplowing to seedbed preparation

(2) seedbed—first month after crop seeding

(3) establishment—second month after crop seeding

(4) growing cover—from 2 months after seeding uitil harvest

(5) stubble or residue—harvest to plowing or new seedbed"

and they conputed for each crop-stage period for each of 100 combinations of cover, crop sequence, productivity level and residue management those ratio fo soil loss from crop to corresponding loss from continuous fallow.

We considered to compare those results of several crops with the results in Japan. Then we attempted to express the effect of cover ratio of crop for soil erosion analytically.

Apparatus and Measurement

A sloped farmland plot is made from iron box, 1.0 m wide, 5.0 m length and 0.6 m depth, and iron box is packed by weathering granite soil called "MASA". The plot line up in four columns setting slop steepness of 8 degree. Three plots are planted the kind of three crops each, and one plot do not planted crop (bare plot). The crops were sowed the seed at July 5, 1980. These apparatuses are built at Shimane University.

The soil loss is a weight of soil running out from iron box by natural rainfall. The cover ratio of crop on the surface of farmland plots are decided the weight of the picture cutting off the parts of leaves and stalks in the limited area. These pictures are taken a photograph of plot from right above.

The obtained results using this method are show in Table 1.

Table 1 *Observation data in* 1980

No.	date and rainfall time from—to	rain. amount (mm)	max. rain. int. (mm/h)			erosion loss ($g/5m^2$)				cover ratio (%)		
			I_{10}	I_{30}	I_{60}	W_1	W_2	W_3	W_4	x_1	x_2	x_3
1	07010400—07011810	63.0	27	17	9.0	385.0	156.1	95.6	133.7	4.0	5.7	22.5
2	07051220—07071800	70.0	36	27	18.5	639.0	268.6	130.8	276.8	8.8	22.9	42.8
3	07090115—07091300	48.5	27	18	11.5	151.8	92.5	27.9	106.8	15.5	31.1	60.0
4	07110530—07111900	92.0	33	21	20.0	613.8	282.0	50.9	305.2	16.5	34.3	65.7
5	07180420—07181600	16.0	30	17	10.0	133.7	84.3	6.3	151.5	39.0	40.5	81.3
6	07222220—07240240	15.5	36	17	8.5	18.9	33.3	7.8	166.0	50.8	42.2	89.0
7	07260415—07261445	25.5	30	16	10.5	53.9	40.1	4.2	262.5	55.9	42.9	92.4
8	07300010—07301250	54.5	30	20	15.0	207.2	243.3	37.6	528.1	61.0	43.7	96.5
9	08081600—08091050	9.0	6	5	5.0	0.0	13.8	2.1	27.2	67.9	45.0	99.3
10	08161040—08190805	12.5	6	6	5.5	4.1	5.9	6.2	13.6	70.1	46.8	100.0
11	08220955—08230500	28.5	24	16	10.0	1.8	20.8	3.5	114.4	71.0	47.2	100.0
12	08251500—08261530	44.0	30	13	8.5	52.0	549.4	48.0	1868.7	71.0	47.5	100.0
13	08281455—08290640	112.0	36	30	25.5	158.2	588.9	70.6	497.6	71.1	48.0	100.0
14	08291620—08310940	115.0	33	23	16.0	192.7	355.9	41.4	522.5	71.3	48.0	100.0
15	09100530—09101340	18.5	9	6	4.5	9.4	13.1	10.4	15.6	72.0	48.4	100.0
16	10120240—10141445	158.0	36	25	19.5	342.3	289.5	327.3	422.5	5.0	7.7	20.0

I_{10} : 6 times max. rainfall amount in 10 minute.
I_{30} : 2 times max. rainfall amount in 30 minute.
sufix : 1-corn, 2-soybean, 3-weeping lovegrass, 4-bare state

Equation of crop factor

The ratio of soil loss from crop to corresponding loss from bare plot W/W_b is defined as crop factor C which is expressed in the function of cover ratio x as following eq.(3).

$$C=W/W_b=f(x) \tag{3}$$

It is said that growth of crops are usually according to the mathematical growth curve as eq. (4).

$$y=G/(1+A/expBt) \tag{4}$$

where

y : relative growth amount

t : time A,B,G : constants

Considering in bare plot ($x=0$) $W=W_b$, in completly covered plot ($x=1$)some soil loss exists and W decrease with x. Now if t is defined $ln\ x$ to be sutisfied with the condition $W=W_b$ at $x=0$ and $G=1$, we obtaine eq. (5) based on eq. (4).

$$C=W/W_b=1/(1+C_k x^{dk}) \tag{5}$$

where

C_k : crop coefficient

d_k : crop index

Calculation of C_k and d_k

Because of non linearity of eq. (5), usual least square method do not used to determine these two constants.

Then try and error method so called "simplex method[3]" approaching to fixed values step by step may be allowed to obtain above two constants.

This method is including following contents : drowing several contours of sum of square residues (Sm) calculated from eq. (6) on the plane with C_k and d_k axials, the minimum value point will show the most adequate combination of C_k and d_k.

$$Sm=\sum(W-W_b/(1+C_k x^{dk}))^2 \tag{6}$$

Obtained values and curves are shown in Fig. 1.

Results and conclusion

When the estimated values from eq. (5) are compared with observation values, we consider to be fairly good agreement on both crop constant values in Fig. 2.

In this paper a few samples were worked out and only showed analytical method. Further investigation will be developed to approve two constants by data of various many experimental studies.

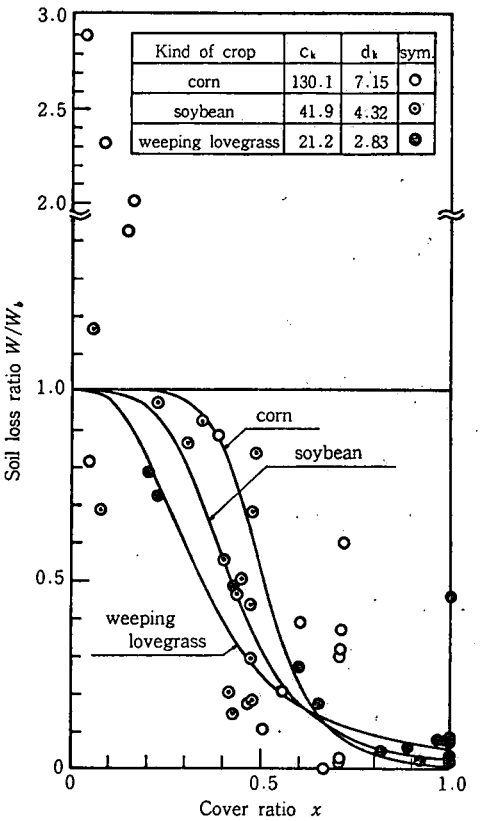

Fig. 1. Relationship between soil loss ratio (W/W_b) and cover ratio (x).

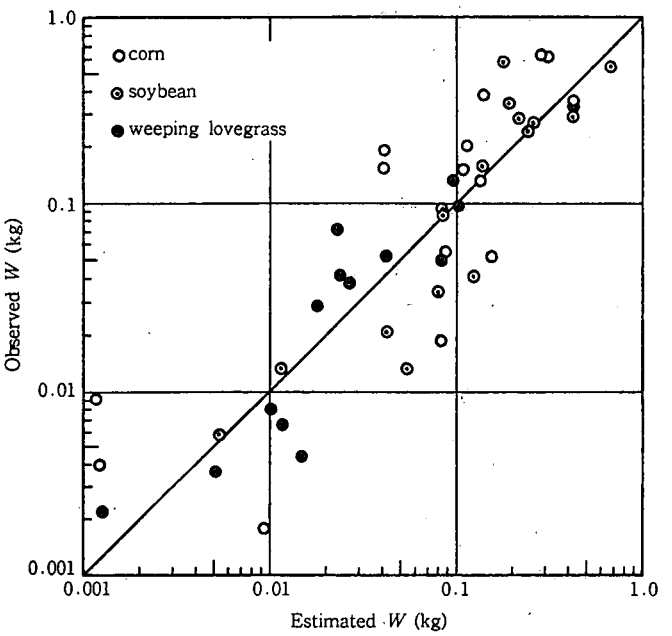

Fig. 2. Comparison between the estimated and the observed soil loss (W).

References

1) Minami, N and M. Ogura ; Stratificated multiple regression analysis of soil erosion loss at bare sloping field. Trans. of Japan Soc. Irr. Drai. and Recl. Eng. (under cotribution)
2) Smith, D. D and W. H. Wischmeier, Rainfall erosion. *Advance in Agronomy*, **14**, 109-148(1962).
3) Nelder, J. A. and R. Mead, A simplex method for function minimization. *The Computer J.*, **7**, 308-313(1965).

(Manuscript received September 26.1981)
(Published : February 20, 1982)