MODEL STUDY OF BASIN SOIL LOSS (BSL) OF LOESS PLATEAU IN CHINA

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ABSTRACT

Based on remote sensing interpretation, site verification and analysis of 30 year's hydrometeorological data, the mechanism of basin soil loss (BSL) in Gu Shan Chuan River Basin of Loess Plateau have been found out and two main factors caused BSL are determined. They are dynamic force factor (rain) and underlayer factor (topography and landuse) and involve 13 elements obtained respectively from meteorological observation and remote sensing interpretation.

Take every square kilometer as a unit, the interpretated data of underlayer factor of Gu Shan Chuan Basin were processed and then, DEM and landuse data bases were established. By classification analysis of ISOMIX, the underlayer are divided into four regions with defferent erosion intensity.

After getting the rain species of P_m, I_a and I_m, the soil loss model are established with analysis of multivariate and weighted revising:

$$S_{mi} = K_i C^{-2.0162} \cdot P_m^{0.9878} \cdot I_a^{0.2662} \cdot I_m^{0.3726}$$

By using the model, the soil loss quantity of whole basin or each region with different erosion intensity can be estimated after every rain.

Key Words: Basin Soil Loss(BSL), Dynamic Force Factor, Underlayer Factor, Classification, Data Base, DEM, Remote Sensing

PREFACE

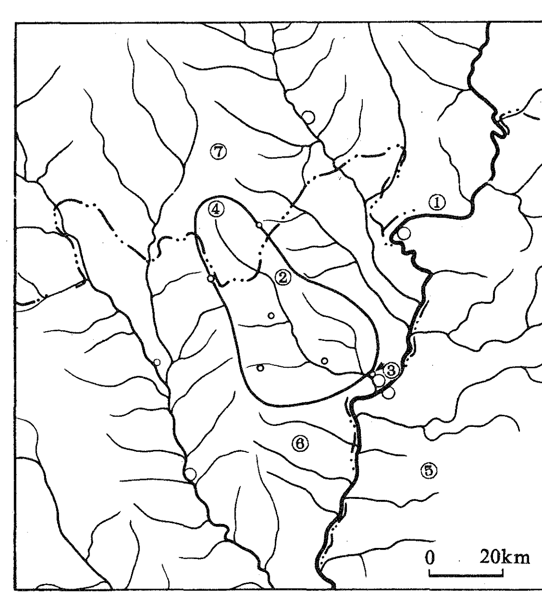
The erosion in the Loess Plateau of China has been attracting worldwide attention. The classification of erosion intensity and the estimation of soil loss quantity are so important for erosion control and economic construction that it makes people to study for a long time without satisfied results. Now, with the technology of remote sensing and GIS, the research on the subjects gain a strong support and reaches a new level.

1. Brief introduction to Gu Shan Chuan basin and the basin soil loss (BSL)

1.1 Brief Introduction

As fig.1, Gu Shan Chuan river, which is in the intensive erosion area of Loess Plateau in China, is a branch of the middle reach of the Yellow River. It is 79 Kilometers long and the river basin covers an area of 1265.7 Km^2.

Most of the basin is composed of loess ravines. The elevation of the basin is in the range of 740m–1394m above sea level. The 10–50m thick loess covers the basin with sand, clay, shale and coal layers underlying.



o meteorological stations ► hydrometric station
① The Yellow River
② Gu Shan Chuan River
③ FuGo Country
④ The boundary of Gu Shan Chuan Basin
⑤ Shan Si Province
⑥ Shǎn Si Province
⑦ Nei Mong

Fig 1. Gu Shan Chuan Basin

There are 6 meteorological stations distributed in the basin and a hydrometric station near the river mouth.

1.2 BSL

BSL means the quantity of soil loss measured near the river mouth. It is the result of processes of rain→erosion→soil transportation in the basin area.

Owing to that the transmission ratio of the suspended soil in loess plateau is about 1, the quantity of the transmission soil measured near the mouth is approaching to that of the soil erosion of the whole basin.

BSL in Gu Shan Chuan possesses the typical properties of the Loess Plateau as follows:

① rain and its run off is the main dynamic force of BSL. So absolute majority BSL occurs in the rain season.

② The quantity of BSL is very unstable and far more changeable than rain.

2. The Environment Factors Affecting BSL

The environment factors affecting BSL at Gu Shan Chuan can be summarized into two types: rain–dynamic force factor and topography, landuse–underlayer factor.

2.1 Rain–dynamic force factor

As mentioned above rain is the main dynamic force for BSL. By analysing the 30 year's data of rain–hydrometric records and multivariate statistics the specific elements of rain affecting BSL are determined as shown in following:

Pm—the precipitation until the rain intensity is less than 4mm / h.
Ia—the average intensity of rain
Im—the maximum intensity of rain

The analysis indicates that when $Pm < 10mm$, $Ia < 1.2mm / h$ and $Im < 4mm / h$, the rain, called non–BSL rain, causes no obvious BSL. Otherwise, it is called BSL rain. Only BSL rain, is discussed in this paper.

2.2 Topography, landuse–underlayer factor

The underlayer factor affecting BSL mainly includes 4 types of subfactors which consist dozens of elements. The 4 subfactors are the anti–erosion property of the surface material, the topography, the land cover and the recent tectonic motion. If all subfactors were in the BSL model, that would be very complex. The factors must be simplified. By site investigation and analysis of a great number of data, two main underlayer subfactors— topography and landuse, are generized from above mentioned 4 subfactors. Since the other two factors, tectonic and anti–erosion property, are closely related with topograph, they can be replaced by it.

2.2.1 Topography

The topographic factor affecting BSL can be devided into 4 elements: slope (SL), shady slope ratio (Sh), gully density (Gde) and gully depth (Gd). The study indicate that BSL will strengthen with the increase of SL ($0° \sim 28°$), Sh, Gde and Gd in the BSL process.

2.2.2 Landuse.

The landuse factor is devided into 6 elements, expressed as A, B, C, D, E and F.

A—over 30% land covered with arbor or bush
B—constructive basic farm land
C—natural or artificial grass land
D—steep slope plough land
E—bare loess land
F—water body, river, lake, reservior ···.
In fact, both topography and landuse factors have already reflected the influence of nature and human activity on Loess erosion.

3. Analysis of the process of soil loss

3.1 There is only a general activity pattern or tendency of BSL

The process of BSL consists of soil erosion occurrence, soil transportation and measurement of soil loss in the river mouth. Lots of factors (mentioned above), as well as some random factors such as landslide, mudflow eruptting, vegetation destruction or reforest, rush or silt of the river ···, take part in the BSL process. Therefore, it is a very complex and variable course.

Thus, it is very difficult to establish a model to reflect the process involving so many factors, but in general, the BSL can be considered as a process that rain–the dynamic force acts upon the underlayer and causes soil loss. Simply to say, this is the process of input–output. Basin is a natural system which accepts rain, forms run off, occurs erosion and transports soil. In the scope of basin, the activities of rain, run off, erossion and soil tranportaion possess some patterns and certain trail. Therefore, the basic relation among them is something certain too. And it is possible to propose a basic BSL structure which is based on the general relationship and activity patterns. The model can be determined by statistical analysis.

3.2 Rain and underlayer factor have different characteristics in the BSL process respectively.

Underlayer factor is a relative stable (no changes with time) and passive (soil loss triggering off only by rain) factor, and it determines the erosion intensity in different place for the same rain.

But, rain is an active factor. The occurance and variance of BSL are mainly caused by rain.

Therefore, the formula that takes the rain factor as an independent variable and underlayer factor as a constant can match every property. We consider

$$S = C \cdot R \qquad (1)$$

as the basic structure of BSL.

3.3 The relationship of each rain element (P_m, I_a, I_m) in the process of BSL

Rain causes BSL which enlarges the variance of rain, as a result, e.g. more concentrated and with a larger quantity change. Therefore, it is infered that each rain element should be multiplicated in the BSL process i.e. $R \sim P_m \cdot I_a \cdot I_m$.

4. Establishment of BSL Model

4.1 Data collecting and preprocessing

For convenience, Gu Shan Chuan basin is devided into a net of 1km × 1km unit. All underlayer factors are digitized by the unit.
Before BSL modeling LP(Loess Plateau)GIS included DEM and landuse data base are established.

4.1.1 Topogrophy factor

DEM (digit elevation model) of Gu Shan Chuan is collected from DEM data base of LPGIS and then processed. The data of SL / km^2, Sh / km^2, Gde / km^2 and Gd / km^2 are obtained.

4.1.2 Landuse factor

Landuse data is collected from landuse data base of LPGIS and the occupied squares of A, B, C, D, E and F in every km^2 are obtained by calculation.

4.1.3 Rain factor

From 54 rain records during 1977–1983, the P_m, I_a, I_m of every rain are acquired. By means of interpolation of second degree curved surface, the P_m / km^2, I_a / km^2, I_m / km^2 and the rain covered area (S_R) are obtained.

4.2 The model of grading basin erosion intensity

With mothed of ISOMIX combined with real conditions, all the underlayer factors of Gu Shan Chuan basin which have been preprocessed are devided into 4 grades of erosion intensity: most intense (266.0 km^2), intense (564.3 km^2), middle (429.5km^2) and weak (6.0km^2). This is a relative grading model.

4.3 The model establishment of BSL

4.3.1 The average erosion modulus of BSL—S_m

According to 3.2, 3.3 we have:

$$S_m = C_0 P_m^{C_1} \cdot I_n^{C_2} \cdot I_m^{C_3} = \frac{S}{S_R} \qquad (2)$$

S_m: average erosion modulus
C_0, C_1, C_2, C_3: undetermined coefficient
For 54 rain, we have 54 formulas of (2).

By multivariate regression, S_m can be obtained.

$$S_m = e^{-2.0126} \cdot P_m^{0.9878} \cdot I_a^{0.2662} \cdot I_m^{0.3726} \qquad (3)$$

F test of significance:

$\alpha = 0.01 \quad F_\alpha(4, 54-4-1) \leqq 2.06$
$F_{C0} = 39.7499$, $F_{C1} = 80.0368$,
$F_{C2} = 2.4563$, $F_{c3} = 3.1795$

Thus formula (3) significant.

4.3.2 The erosion modulus of each erosion region— S_{mi} and weighted coefficiat— Ki

As mentioned above, Gu Shan Chuan basin has already devided into 4 grades of erosion regions and the place and involved units of each grade of region are determined. For every rain, the P_m, I_a, I_m and S_R (rain cover area) of each grade of region can also be obtained. With (3) the modulus of each grade of region–S_{mi} can be got and $S_{mi} \cdot S_{Ri} = Si$. Then for 54 rains during 1977–1983, we have got 54 groups of S_i (i: grade number, i = 1, 2, 3, 4) and S' (the real measured quantity BSL), then, making S_i correlated with S', the correlated coefficiat (r_i) is obtained: $r_1 = 0.7961$, $r_2 = 0.7682$, $r_3 = 0.7565$, $r_4 = 0.5612$. With r_i, the weighted coefficiat (K_i): is acquired

$$K_i = \sqrt{\frac{r_i \cdot 4}{\sum_{i=1}^{4} r_i}} \qquad (4)$$

thus, the revisionary model of each erosion grade is as follows:

$$S'_{mi} = K_i e^{-2.0162} \cdot P_m^{0.9878} \cdot I_a^{0.2662} \cdot I_m^{0.3726}$$

4.3.3 The model of BSL

The quantity of BSL is:

$$S = \sum_{i=1}^{4} S'_{mi} \cdot S_{Ri}$$

The results of calculate and real measured BSL of Gu Shan Chuan for 54 rain (1977–1983) shows as table 1.

5. Conclusion

① By collecting DEM and landuse data from the data base of LPGIS and preprocessing the data with ISOMIX, the basin can be devided into different erosion grades.

② By collecting and preprocessing the rain records of the whole basin, with BSL model, the quantity of soil loss of each graded erosion region or the BSL can be estimated.

REFERECE

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table.1

NO. (Rain)	Q_1—Real measured BSL (10^4T)	Q_2—Calculated BSL (10^4T)	Q_1–Q_2 (10^4T)	$\frac{Q_1 - Q_2}{Q_1}$ %
1	324.950	233.806	91.144	−28.0
2	251.424	151.597	99.827	39.7
3	224.621	188.954	35.667	−15.9
4	59.784	43.029	16.183	27.1
5	30.560	63.218	−32.653	106.8
6	203.558	45.029	158.530	77.8
7	13.742	14.160	−0.436	−3.2
8	12.105	30.792	−18.688	−154.4
9	8.441	5.251	3.190	37.8
10	432.000	340.691	91.309	21.1
11	205.632	302.068	−96.436	−46.9
12	81.907	68.458	13.450	16.4
13	63.513	66.625	−3.111	4.9
14	35.856	40.696	−4.840	−13.5
15	37.117	61.930	−24.812	66.9
16	104.653	113.422	−8.769	−8.4
17	12.010	9.843	2.166	18.0
18	326.880	99.531	263.343	72.6
19	199.238	62.978	136.260	68.4
20	130.464	84.960	45.504	34.9
21	177.206	155.870	21.337	12.0
22	48.125	46.832	1.292	2.7
23	23.149	72.844	−49.695	214.7
24	22.982	46.673	−23.691	−103.1
25	7.318	8.962	−1.645	−22.5
26	73.374	59.387	13.983	19.1
27	48.652	61.021	−12.370	−25.4
28	33.782	30.589	3.193	9.5
29	32.054	54.491	−22.437	−70.0
30	26.577	42.072	−15.496	−58.3
31	197.193	241.654	−44.461	−22.6
32	39.398	45.109	−5.711	−14.5
33	35.873	129.292	−93.419	−260.4
34	33.214	44.600	−11.386	−34.3
35	22.205	12.168	10.037	45.2
36	17.764	31.285	−13.521	−76.1
37	36.426	44.117	−7.791	−21.1
38	40.262	53.168	−12.806	−32.1
39	1.403	3.657	−2.254	−160.7
40	312.077	354.362	−42.285	−13.5
41	74.740	68.660	6.08	8.1
42	31.983	61.234	−29.251	−91.4
43	24.581	34.106	−9.525	−38.7
44	26.559	11.543	15.016	−56.5
45	12.269	16.364	−4.095	−33.3
46	214.099	263.895	−49.795	−23.2
47	108.000	66.769	41.231	38.1
48	58.761	27.001	31.760	54.0
49	68.861	75.771	−6.910	−10.0
50	62.294	63.883	−1.589	−2.5
51	34.517	25.444	9.073	26.2
52	32.357	77.446	−45.089	−139.3
53	10.558	6.342	4.216	39.9
54	3.240	5.167	−1.729	−59.4