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PREDICTION OF SEDIMENT REDUCING BENEFIT UNDER DIFFERENT RAINFALL CONDITIONS AND CONTROL DEGREES ON THE LOESS PLATEAU

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ABSTRACT: Based on the distribution of hydrological stations and zoning of types of soil erosion, the Loess Plateau ($310 \times 10^3 km^2$) is divided into 292 erosion units. And taking the erosion modulus > $5000t/km^2$ as a criterion, the emphasis control area ($149 \times 10^3 km^2$) of the Loess Plateau is demarked, and is divided into 10 control regions. The controllable area and the location of control measures are conformed. Level terraces are mainly collocated on the $3° - 15°$ slopes, woodland and grassland are collocated on the > 15° slopes, and the proportion of woodland to grassland is 8∶2 in the forest belt, 5∶5 in the forest steppe belt, and 2∶8 in the steppe belt. The 9000 combinations of soil-water conservation measures in different rainfall conditions are obtained by the permutation and combination method, according to the 9 rainfall frequencies and the controllable areas of level terrace, woodland and grassland at 10% of control progress rate. The quality standards of level terrace, woodland and grassland are ascertained. The evaluation indexes of soil-water conservation benefits of level terrace, woodland and grassland are established respectively in the condition that rainfall index is higher than that of erosive index of sloping field. Based on the results above, the sediment reducing benefit and soil erosion modulus in the different rainfall conditions and control degrees are analyzed, which could provide a decision-making basis for soil-water loss control on the Loess Plateau.

KEY WORDS: Loess Plateau; rainfall; soil and water conservation; sediment reducing benefit

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Soil erosion is one of the most serious environmental problems in the present world. It not only restricts the production of agriculture badly, but also threatens the natural environment on which human being live. And this make the mankind confronted with tremendous challenge. On the Loess Plateau, soil and water loss is terrible, environment is weak, and its high sand yield makes the riverway in the lower reaches of the Huanghe (Yellow) River filled up, riverbed driven up, flood threat pricked up, and results in great hidden troubles to the controlling of flood and the running of irrigation works of the Huanghe River. The sand pouring into the Huanghe River has been decreased evidently, and environment has been renewed and rebuilt through the control for decades. However, as a whole, the situation of environment deterioration and poverty has not been changed at all, the threat of drought and flood also exists. Therefore, how to strengthen the control of soil-water loss and improve the environment on the Loess Plateau, is a very important problem for the researchers of soil-water conservation.

Since the 1970s, the soil loss amount on the Loess Plateau has varied with rainfall conditions, the effects of irrigation works and soil-water conservation measures. Therefore the rainfall conditions, soil-water conservation degrees, and the amount, quality and distribution of soil-water conservation measures are the basis of prediction of sediment reducing benefit. And the study on prediction of sediment reducing benefit under different rainfalls and control degrees will have instructional sig-

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nificance to the programming and designing of soil-water conservation, soil-water loss controlling and ecological environment renewing.

1 REGIONALIZATION OF EMPHASIS CONTROL AREA

Based on the distribution of the hydrological stations and its observation series of sediment information on the Loess Plateau, the study area was divided into 120 hydrological control areas firstly, then according to the map of soil erosion type (CAI, 1989), and taking the borderline of the soil erosion type area as guideline, the soil erosion units were plotted, which were the unabridged areas with the same soil erosion type in a hydrological control area. The areas which were in the same soil erosion type area but incontinuous in a hydrological control area were taken as different units. Above all, the study area was divided into 292 soil erosion units.

Then, according to the sediment intensities of 292 erosion units over the interval of 1955 – 1969, the regions with sediment intensity ≥5000t/(km^2 · a) were regarded as emphasis control area. In order to keep the emphasis control area continuing, some nearby units with sediment intensity < 5000t/(km^2 · a) were merged into the emphasis control area, and some units with sediment intensity ≥5000t/(km^2 · a) at the upper reaches of the Weihe River, north foothill of the Qinling Mountains and the middle and upper reaches of the Fenhe River were not included into the emphasis control area, because of far distance from the emphasis control area and scattered distribution. And the area of the emphasis control area marked off was 149 × 10^{3}km^2.

Taking the soil erosion type as the main factor, and also taking the vegetation-climate belt and integrality of region into account, the emphasis control area was divided into 10 control regions. They were 1) wind-sand steppe region in the upper reaches of the Kuye River and the Huangpuchuan River; 2) loess flat hillock hilly and gully region between Hequ and Toudaoguai; 3) loess "*Mao*" hilly and gully region between Hequ and Wubu; 4) loess "*Mao*" hilly and gully region in the lower reaches of the Qingjian River, the Wuding River and the Sanchuan River; 5) loess "*Liang*" hilly and gully region in the Yanhe River valley, the Xinshui River and the Fenchuan River; 6) wind-sand loess hilly and gully region in the northwestern part of the emphasis control area; 7) arid loess hilly and gully region in the upper reaches of the Jinghe River and the Bailuo River; 8) loess tableland and gully region in the middle and lower reaches of the Jinghe River; 9) arid loess hilly and gully region in the upper reaches of the Zuli River and the Qingshui River; and 10) arid loess hilly and gully region in the upper reaches of the Weihe River (Fig. 1) The characteristics of soil loss in the 10 control regions are shown in Table 1.

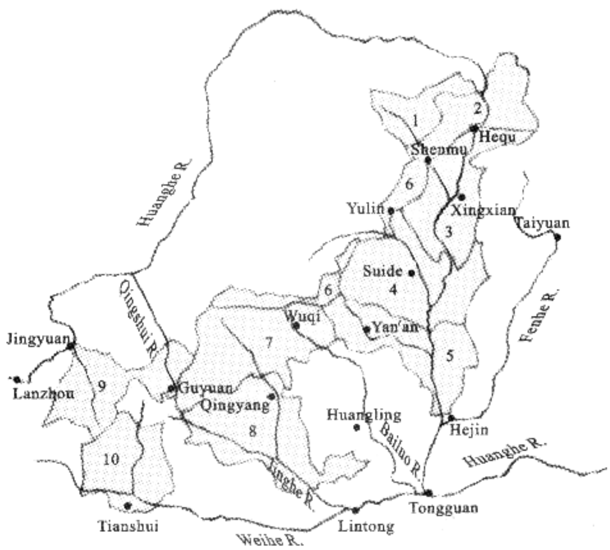

Fig. 1 The regionalization of the emphasis control region

2 COLLOCATIONS OF CONTROL MEASURES

The amount, quality and distribution of control measures are the basis of the calculation of soil-water conservation benefits and the prediction of soil loss, and also confine the precision and veracity of the results. Because of the effects of statistic methods, socio-economic and other man-made factors, the information of soil-water conservation measures in large-scale areas have discrepancy with actual conditions, and it is very difficult to estimate the sediment reducing benefits and predict the trend of soil loss accurately. Therefore, the estimation of effect of regional soil-water loss control on Loess Plateau to the sediment of the Huanghe River in the future should be based on the scientific collocation of soil-water conservation measures in the 10 control regions.

2. 1 Principles of Collocation

2. 1. 1 Taking soil erosion reducing as the main goal

The main effect of the soil-water conservation measures is to reduce or avoid soil-water loss, and to decrease the sediment in the Huanghe River. The effect of slope measures is mainly to reduce sand, and the effect of gully measures is mainly to block sand. Thus, in order to reduce sediment, the slope measures including

Table 1 Soil loss in the 10 control regions

Control region	Area (km^2)	Sediment intensity ($t/km^2 \cdot a$)		The ratio of sediment intensity of control regions in that of the whole study area* (%)		Sediment yield ($\times 10^6 t$)		The proportion of the sediment yield of control regions in that of the whole study area* (%)	
		1955 – 1969	1970 – 1989	1955 – 1969	1970 – 1989	1955 – 1969	1970 – 1989	1955 – 1969	1970 – 1989
1	6574.2	9493.7	9146.7	1.51	2.33	62.414	60.132	3.2	4.9
2	13091.9	12170.7	9551.7	1.93	2.43	159.338	125.042	8.2	10.3
3	16073.5	18468.5	11178.8	2.93	2.85	296.853	179.682	15.2	14.8
4	20125.3	15337.0	7251.3	2.43	1.85	308.662	145.935	15.8	12.0
5	15636.7	12103.1	6857.8	1.92	1.75	189.253	107.233	9.7	8.8
6	7809.1	7562.5	3744.8	1.20	0.95	59.056	29.244	3.0	2.4
7	17835.8	11895.5	8313.9	1.89	2.12	212.166	48.285	10.9	12.2
8	23742.2	8300.5	5851.5	1.32	1.49	197.071	138.926	10.1	11.4
9	13641.1	6314.1	3599.3	1.00	0.92	86.131	49.098	4.4	4.0
10	14472.6	9626.6	6011.3	1.53	1.53	139.321	87.000	7.1	7.1

* The average sediment intensity of the whole study area was 6302.1 $t/(km^2 \cdot a)$ over the interval 1955 – 1969, 3928.4 $t/(km^2 \cdot a)$ over the interval 1970 – 1989; and the average sediment yield was $1.95 \times 10^9 t$ over the interval 1955 – 1969, $1.22 \times 10^9 t$ over the interval 1970 – 1989.

terrace, woods and grass were considered in the paper.

2.1.2 Collocation of terrace according to the gradient of arable land

According to the features of soil erosion taking place in the field with different gradients (CHENG and FAN, 2000; TANG *et al.*, 1990; TANG *et al.*, 1998; ZHU, 1990), terraces were collocated on the sloping field with gradient 3° – 15°.

2.1.3 Collocation of woods and grass following the rule of vegetation zone distribution

Geographical distribution of vegetation are restricted by the factors such as climate, landform, and soil, especially the conditions of water and heat. The different combinations of water and heat result in the disciplinary subrogation of climate, vegetation and soil in geographical distribution. From southeast to northwest, there are 4 vegetation belts on the Loess Plateau, i.e. forest, forest steppe, typical steppe and desert steppe. Therefore, the proportion of woods and grass should be chosen according to the vegetation zones.

2.2 Results of Collocation

2.2.1 Total controllable area

In a region, serious soil-water loss does not exist in all of the region, such as the flat land, water area, residential area, industrial estate, mining area, bare rock and gravel area, etc. Thereby, it should ascertain the controllable area of the 10 control regions firstly, and then collocate the different combination of terrace, woods and grass within the controllable area. Therefore, the controllable area of the control regions is the total land area minus residential area, industrial estate, mining area, transportation area, water area, bare rock and gravel area and < 3° arable land area.

2.2.2 Controllable area of terrace

Based on the gradient grade information of counties on the Loess Plateau and the area proportion of counties in the 10 control regions respectively, the gradient grade data of the 10 control regions are obtained. In one control region, the area of 3° – 15° arable land is the controllable area of terrace.

2.2.3 Controllable area of woods and grass

The controllable area of woods and grass is the total controllable area minus controllable area of terrace in one control region. Based on the regional distribution of the 10 control regions, region 1, 2, 3, 6 and 9 are in the steppe belt; region 4, northwest from Yan'an of region 5, region 7, northwest from Xifeng of region 8 and region 10 are in the forest steppe belt; southeast from Yan'an of region 5 and southeast from Xifeng of region 8 are in forest belt. And the collocation proportion of woods and grass is 8∶2 in forest belt, 5∶5 in forest steppe belt, and 2∶8 in the steppe belt. The data in Table 2 are total controllable area, controllable area of terrace, woods and grass of the 10 control regions.

2.2.4 Area collocation of control measures in different rainfall conditions

In order to analyze the sediment reducing benefit under different rainfall and control conditions, it needs to collocate the combination of the rainfall index under different rainfall conditions and the area of terrace, woodland and grassland under different control degrees stochastically. And 9000 combinations of soil-water conservation measures in different rainfall conditions are obtained by the permutation and combination method, according to the 9 rainfall frequencies (10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90%) and

Table 2 The controllable area of 10 control regions(km^2)

Control region	Total area	Controllable area			
		Terrace	Woods	Grass	Subtotal
1	6574.4	473.4	1100.4	4401.4	5975.2
2	13092.5	2186.7	4530.2	4925.9	11642.7
3	16074.4	2705.0	5751.7	5751.7	14208.4
4	20126.5	3678.5	7246.1	7246.1	18170.6
5	14693.2	2083.2	7969.9	3338.9	13392.0
6	7810.3	805.5	1238.8	4955.1	6999.4
7	18152.3	2010.6	6109.9	8583.7	16704.2
8	23743.8	4490.8	10433.6	4420.0	19344.3
9	13641.9	2757.9	1820.6	7283.1	11861.8
10	14473.1	4025.4	4130.9	4130.9	12287.2

the controllable areas of level terrace, woodland and grassland at 10% of control progress rate.

3 PREDICTION METHOD OF SEDIMENT REDUCING BENEFIT

3.1 Conformation of Rainfall Frequency

Rainfall is the force of soil erosion. So the prediction of soil loss should be connected with rainfall factor. The relationships between soil loss amount and annual maximum 1-hour rainfall, annual maximum 24-hour rainfall, annual maximum 30-day rainfall, flood season (from May to Sept.) rainfall were analyzed respectively, and the results showed that the relationship between soil loss amount and annual maximum 30-day rainfall was closest, and the next was the relationship between soil loss amount and flood season rainfall. According to the availability of rainfall data, flood season rainfall was chosen for rainfall index to predict soil loss in this paper. The observed rainfall data of 3 – 5 hydrological stations in a control region with 35 years time series (1955 – 1989) were selected to analyze the frequency of flood season rainfall, and the flood rainfall in different frequencies of the 10 control regions were shown in Table 3.

3.2 Conformation of Control Degree

Usually, the control degree is expressed as the ratio of controlled area to controllable area. It is difficult to build the relationship between sediment reducing benefit and control degree as a result of the difference in sediment reducing amount per acreage of control measures. For example, the benefit of sediment reducing benefit of 1ha of terrace and 1ha of woodland is different, and also the sediment reducing benefit of woodland and grassland is affected by coverage. Accordingly, taking terrace area as criterion area, and the sediment reducing benefit of woodland and grassland with various coverage under different rainfall conditions were standardized as the coefficient for converting the area of woodland and grassland to criterion area. The formula for calculating control degree is as follows:

$$C = (T + F \times \xi_1 + G + \xi_2) / A \times 100\% \qquad (1)$$

In the formula above, C is the control degree (%); T is the area of terrace; F is the area of woodland; G is the area of grassland; A is the controllable area; ξ_1 is the coefficient for converting the area of woodland to criterion area, which is the ratio of the sediment reducing benefit of woodland to that of terrace in the same rainfall conditions; ξ_2 is the coefficient for converting the area of grassland to criterion area, which is the ratio of the sediment reducing benefit of grassland to that of terrace in the same rainfall conditions.

The quality of the soil-water conservation measures affects the sediment reducing benefit very greatly, so in this study, the quality of the control measures were supposed that the bank of level terrace was in good condition, the field of level terrace was flat or anti-sloping and fertile, there was no soil-water loss under 5% frequency rainfall condition in the terrace fields, and the coverage of woodland was 70%, the coverage of grassland was 80%.

3.3 Calculation of Soil Loss Amount in Uncontrolled Condition

Soil loss amount in uncontrolled condition of a control region should be enumerated firstly to calculate the soil-water conservation benefits and predict the trend of soil loss, especially the soil loss amount in uncontrolled condition under different rainfalls. The year 1970 was the time division between un-control and control, so the data adopted to calculate soil loss amount in uncontrolled condition of the 10 control regions were the rainfall and sediment information of hydrological stations before 1970(1955 – 1969). Firstly, to calculate the local rainfall of the 10 control regions by choosing more than 3 representative hydrological stations in a control region; and then to build the relationships between soil loss amount and local rainfall. Considering 15 years series was short to reflect soil loss under various rainfall conditions, the frequencies of flood season rainfall over the interval 1955 – 1989 were analyzed, with the established relationships, the soil loss amount in uncontrolled condition under different rainfall frequencies of the 10 control regions were obtained (Table 4).

Table 3 Flood season rainfall in different frequency of 10 control regions

Control region	Flood season rainfall in different frequency (mm)								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
1	466.1	386.8	340.4	307.5	282.0	261.1	243.5	228.2	214.7
2	527.6	438.4	386.3	349.3	320.6	297.1	277.3	260.1	245.0
3	529.9	448.0	400.1	366.0	339.7	318.1	299.9	284.1	270.2
4	483.8	442.6	404.9	370.4	338.9	310.0	283.6	259.5	237.4
5	572.5	525.9	483.0	443.7	407.5	374.3	343.8	315.8	290.1
6	470.6	423.3	380.7	342.4	308.0	277.0	249.2	224.1	201.6
7	539.4	496.5	456.9	420.5	387.0	356.2	327.8	301.7	277.7
8	549.0	506.8	467.8	431.9	398.7	368.0	339.7	313.6	289.5
9	400.0	364.1	331.4	301.7	274.6	250.0	227.6	207.1	188.6
10	523.6	482.4	444.4	409.4	377.2	347.5	320.1	294.9	271.7
Total	500.8	445.9	403.9	368.4	337.4	309.9	285.1	262.6	242.3

Table 4 Soil loss amount in uncontrolled condition under different rainfall frequency of the 10 control regions

Control region	Soil loss amount in uncontrolled condition under different rainfall frequency ($t/km^2 \cdot a$)								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
1	20323.6	12627.5	9559.1	7845.8	6731.3	5939.3	5342.8	4874.8	4496.1
2	22492.7	13411.4	9910.9	7996.6	6770.4	5909.4	5267.5	4768.0	4367.0
3	15412.3	8974.0	6540.2	5225.3	4390.3	3808.1	3376.6	3042.5	2775.4
4	22497.6	16966.5	13106.3	10349.5	8338.5	6843.0	5711.1	4840.3	4160.5
5	17773.6	14075.5	11360.8	9331.2	7788.1	6596.6	5663.5	4923.2	4328.8
6	11732.8	8503.8	6366.2	4906.8	3882.3	3144.9	2602.1	2194.4	1882.6
7	19725.5	14791.3	11348.6	8892.9	7105.2	5779.3	4778.8	4011.8	3415.1
8	15091.0	11089.2	8344.0	6417.2	5035.9	4026.3	3275.0	2706.5	2269.7
9	7912.8	6289.1	5102.6	4218.4	3547.4	3029.9	2624.7	2303.2	2044.9
10	12656.6	10172.6	8317.9	6910.1	5824.9	4976.6	4304.9	3766.6	3330.5
Total	19547.9	13828.3	10612.3	8488.4	6982.7	5869.0	5020.0	4359.0	3834.0

3.4 Sediment Reducing Index of Soil-water Conservation Measures

3.4.1 Benefit in runoff plot

The sediment reducing benefit of high-quality level terrace can reach 100% under 10% of rainfall frequency. But in actual fact, this index is on the high side because of the effect of rainfall factor and the quality of level terrace such as the flatness of field, the height and fastness of bank. Thus, it is determined that the flood rainfall amount under which the sediment reducing benefit is 100% is 450mm, according to the rainfall erosion data of runoff plots in sloping fields and level terrace on the Loess Plateau. When flood season rainfall is lower than 450mm, the sediment reducing benefit is 100%; and when flood season rainfall is higher than 450mm, the sediment reducing benefit is 95%.

According to the analysis on rainfall erosion information of runoff plots in woodland and grassland, the relationships between sediment reducing benefit of woodland and grassland and rainfall and coverage are as follows:

Woodland: $S(\%) = -0.565 + 1.165\log(v) - 0.309\log(P_{59})\quad n = 57\quad r = 0.722\quad F = 29.37^{**}$ (2)

Grassland: $S(\%) = -0.269 + 1.054\log(v) - 0.342\log(P_{59})\quad n = 40\quad r = 0.737\quad F = 21.95^{**}$ (3)

In the equations above, $S(\%)$ is the sediment reducing benefit of woodland or grassland (%); v is the coverage of woodland or grassland (0 – 100%); P_{59} is the rainfall amount of May to Sept. (100 – 700mm).

3.4.2 Benefit in a region or watershed

In a region or watershed, the sediment reducing benefit of slope control measures includes sand reducing amount in slope, and the sediment reducing amount in gully owing to the runoff reducing amount in slope not pouring into gully. In loess hilly and gully regions, the intergully and gully land was about 50% of the total area, and the erosion of gully and intergully was respectively about 60% and 40%. A half of the gully erosion, at least, was caused by intergully runoff flowing down the gully (JIAO *et al.*, 1992). Therefore, the soil-water conservation measures in slope could reduce 40% sediment in slope and 30% sediment in gully, that is to say, 70% sediment in a watershed. In the gully, there were some terrace, woodland and grassland which were supposed to have 10% sediment reducing benefit. Hence, the maximum sediment reducing benefit of terrace, woodland and grassland could account for 80% sediment of a watershed. And the formula for calculating the sediment reducing benefit of terrace, woodland and grassland is as follows:

$$\triangle S = 0.8 \times S(\%) \quad (4)$$

In the formula above, $\triangle S$ is the sediment reducing amount of slope measures (t); S is the total sediment amount of watershed (t); $S(\%)$ is the sediment reducing index of slope measure (%).

3.5 Calculation of Sediment Reducing Benefit

Sediment reducing amount (ΔS)

$$\triangle S_i = 0.8 A_i \cdot S_u \cdot S_i(\%)$$

$$\triangle S = (\triangle S_T + \triangle S_F + \triangle S_G) \quad (5)$$

Sediment reducing benefit

$$S(\%) = \triangle S / S \times 100\% \quad (6)$$

Soil loss amount

$$M = S - \triangle S \quad (7)$$

Soil erosion modulus

$$E = (S - \triangle S) / A \quad (8)$$

In the formulas above, $\triangle S_i$ is the sediment reducing amount of measure i (terrace, woodland or grassland) (t); A_i is control area of measure i (km^2); S_u is the soil loss in uncontrolled condition of a control region ($t/km^2 \cdot a$); $S_i(\%)$ is the sediment reducing index of measure i (%); $\triangle S_T$ is the sediment reducing amount of terrace (t); $\triangle S_F$ is the sediment reducing amount of woodland (t); $\triangle S_G$ is the sediment reducing amount of grassland (t); $S(\%)$ is the sediment benefit (%); M is soil loss amount of a control region (t); E is the soil erosion modulus of a control region ($t/km^2 \cdot a$); S is the soil loss amount in uncontrolled condition of one control region (t); and A is the total area of a control region (km^2).

4 PREDICTION OF SEDIMENT REDUCING BENEFIT UNDER DIFFERENT RAINFALL AND CONTROL CONDITIONS

4.1 Sediment Reducing Benefit in the Emphasis Control Region

The sediment reducing benefit, sediment reducing amount and soil loss amount in the 10 control regions under 9000 combinations in different rainfall frequencies and control degrees were calculated (Table 5). For example, when the rainfall frequency is 50% and control degree reaches 90%, the sediment reducing benefit of region 1 will be 58.3%, the sediment reducing amount will be 25.818×10^6t, and erosion modulus will be 2804.2t/($km^2 \cdot a$); the sediment reducing benefit of region 2 will be 55.8%, the sediment reducing amount will be 49.455×10^6t, and erosion modulus will be 2992.8 t/($km^2 \cdot a$); the sediment reducing benefit of region 3 will be 54.7%, the sediment reducing amount will be 38.624×10^6t, and erosion modulus will be 1987.4t/($km^2 \cdot a$); the sediment reducing benefit of region 4 will be 56.1%, the sediment reducing amount will be 94.067×10^6t, and erosion modulus will be 3664.4t/($km^2 \cdot a$); the sediment reducing benefit of region 5 will be 54.3%, the sediment reducing amount will be 66.153×10^6t, and erosion modulus will be 3557.5t/($km^2 \cdot a$); the sediment reducing benefit of region 6 will be 57.3%, the sediment reducing amount will be 17.385×10^6t, and erosion modulus will be 1656.0t/($km^2 \cdot a$); the sediment reducing benefit of region 7 will be 56.0%, the sediment reducing amount will be 71.015×10^6t, and erosion modulus will be 3123.6t/($km^2 \cdot a$); the sediment reducing benefit of region 8 will be 49.3%, the sediment reducing amount will be 58.986×10^6t, and erosion modulus will be 2551.5t/($km^2 \cdot a$); the sediment reducing benefit of region 9 will be 56.9%, the sediment reducing amount will be 27.537×10^6t, and erosion modulus will be 1528.7t/($km^2 \cdot a$); the sediment reducing benefit of region 10 will be 53.1%, the sediment reducing amount will be 44.776×10^6t, and erosion modulus will be 2731.1t/($km^2 \cdot a$). The erosion modulus of the 10 control regions will be below 4000t/($km^2 \cdot a$), and there will be 7 regions in which erosion modulus will be below 3000t/($km^2 \cdot a$), 3 regions in which erosion modulus will be below 2000t/($km^2 \cdot a$). And for the whole emphasis control area, the sediment reducing benefit will be 54.8%, the sediment reducing amount will be 570.429×10^6t, and erosion modulus will be 3154.4t/($km^2 \cdot a$).

4.2 Sediment Reducing Benefit in the Huanghe River

According to the results, the contribution of sediment reducing benefit of the emphasis control area to the Huanghe River could be estimated. The average sediment amount of the emphasis control area over the interval 1955 – 1969 was 1.52×10^9t, and the sediment

Table 5 Sediment reducint benefit, sediment reducing amount and soil erosion modulus under different rainfall frequencies and control degrees of the 10 control regions

Control region	Rainfall frequency (%)	Sediment reducing benefit (%)				Sediment reducing amount (10^6t)				Soil erosion modulus (t/km^2 · a)			
		30%	50%	70%	90%	30%	50%	70%	90%	30%	50%	70%	90%
1	10	17.8	29.7	41.6	53.5	23.814	39.689	55.562	71.436	16701.2	14286.5	11872.0	9457.5
	20	18.5	30.8	43.2	55.5	15.363	25.604	35.845	46.085	10290.6	8732.9	7175.2	5617.6
	50	19.4	32.4	45.4	58.3	8.607	14.344	20.081	25.818	5422.1	4549.5	3676.8	2804.2
2	10	17.2	28.7	40.2	51.6	50.677	84.457	118.235	152.014	18621.9	16041.7	13461.5	10881.5
	20	17.8	29.7	41.5	53.4	31.245	52.072	72.899	93.725	11024.8	9434.0	7843.2	6252.4
	50	18.6	31.0	43.4	55.8	16.487	27.477	38.466	49.454	5511.1	4671.6	3832.2	2992.8
3	10	17.1	28.4	39.8	51.2	42.271	70.449	98.626	126.801	12782.4	11029.4	9276.4	7523.5
	20	17.6	29.3	41.0	52.7	25.334	42.222	59.108	75.994	7397.9	6347.3	5296.7	4246.2
	50	18.2	30.4	42.6	54.7	12.876	21.459	30.042	38.624	3589.2	3055.3	2521.3	1987.4
4	10	17.4	29.1	40.7	52.3	78.976	131.620	184.262	236.902	18573.4	15957.6	13341.9	10726.3
	20	18.0	29.9	41.9	53.9	61.353	102.250	143.145	184.038	13917.9	11885.8	9853.8	7821.8
	50	18.7	31.1	43.6	56.1	31.359	52.262	73.165	94.067	6780.3	5741.6	4703.0	3664.4
5	10	16.9	28.1	39.4	50.6	46.881	78.130	109.379	140.627	14775.5	12777.0	10778.6	8780.2
	20	17.4	29.0	40.6	52.2	38.279	63.795	89.310	114.824	11627.5	9995.7	8364.0	6732.3
	50	18.1	30.2	42.3	54.3	22.054	36.754	51.454	66.153	6377.7	5437.6	4497.5	3557.5
6	10	17.4	29.1	40.7	52.3	15.988	26.645	37.302	47.958	9685.5	8320.7	6956.1	5591.5
	20	18.1	30.2	42.3	54.4	12.052	20.086	28.120	36.153	6960.4	5931.6	4902.9	3874.2
	50	19.1	31.9	44.6	57.3	5.796	9.659	13.522	17.385	3140.1	2645.4	2150.7	1656.0
7	10	17.4	28.9	40.5	52.1	61.103	101.834	142.562	183.290	16299.6	14016.0	11732.5	9449.0
	20	17.9	29.9	41.8	53.8	47.280	78.796	110.311	141.825	12140.4	10373.4	8606.5	6839.6
	50	18.7	31.1	43.6	56.0	23.674	39.455	55.235	71.015	5777.9	4893.1	4008.3	3123.6
8	10	15.5	25.8	36.1	46.5	55.512	92.514	129.516	166.517	12752.9	11194.4	9635.9	8077.5
	20	15.9	26.5	37.1	47.7	41.854	69.753	97.651	125.548	9326.4	8251.3	6976.3	5801.3
	50	16.4	27.4	38.4	49.3	19.664	32.772	45.879	58.986	4207.7	3655.6	3103.5	2551.5
9	10	17.7	29.5	41.3	53.1	19.123	31.870	44.617	57.363	6511.0	5576.5	4642.1	3707.7
	20	18.2	30.4	42.6	54.7	15.654	26.088	36.522	46.955	5141.6	4376.7	3611.8	2846.9
	50	19.0	31.6	44.3	56.9	9.180	15.299	21.418	27.537	2874.4	2425.8	1977.3	1528.7
10	10	16.8	28.0	39.2	50.4	30.762	51.266	71.770	92.274	10531.1	9114.3	7697.5	6280.8
	20	17.2	28.6	40.1	51.5	25.294	42.155	59.015	75.874	8424.8	7259.8	6094.9	4929.9
	50	17.7	29.5	41.3	53.1	14.927	24.877	34.826	44.776	4793.5	4106.0	3418.5	2731.1
Total	10	17.0	28.4	39.7	51.1	496.203	826.963	1157.709	1488.446	16217.7	13997.9	11778.2	9558.5
	20	17.6	29.3	41.0	52.7	361.812	602.990	844.157	1085.318	11400.1	9781.5	8162.9	6544.4
	50	18.3	30.5	42.6	54.8	190.164	316.923	443.678	570.429	5706.5	4855.7	4005.0	3154.4

amount in the Huanghe River (the sum of sediment amount of Hejin Station in the Fenhe River, Longmen Station in mainstream of the Huanghe River, Huaxian Station in the Weihe River and Zhuangtou Station in the Bailuo River) was 1.78×10^9t in the same series, the sediment yield of the emphasis control area come up to 85.4% of the sediment yield in the Huanghe River. According to the sediment yield proportion of the emphasis control region to the Huanghe River, the calculated sediment yield in the Huanghe River under different rainfalls and control degrees are as following:

(1) When control degree arrives to 50%, the sediment yield of the Huanghe River will decrease from 1.22×10^9t to 0.85×10^9t in average year ($P = 50\%$), from 0.76×10^9t to 0.52×10^9t in low-flow year ($P = 80\%$), and from 2.41×10^9t to 1.71×10^9t in high-water year ($P = 50\%$). In the average conditions, the sediment yield of the Huanghe River will decreased from 1.78×10^9t to 1.25×10^9t, and the reducing amount will be 0.53×10^9t, when it is calculated as the sediment reducing benefit being 30%.

(2) When control degree arrives to 80%, the sediment yield of the Huanghe River will decrease from 1.22×10^9t to 0.62×10^9t in average year ($P = 50\%$), from 0.76×10^9t to 0.38×10^9t in low-flow year ($P = 80\%$), and from 2.41×10^9t to 1.28×10^9t in high-water year ($P = 50\%$). In the average conditions, the sediment yield of the Huanghe River will decrease

from 1.78×10^9t to 0.93×10^9t, and the reducing amount will be 0.85×10^9t, when it is calculated as the sediment reducing benefit being 48%.

(3) When control degree arrives to 100%, the sediment yield of the Huanghe River will decrease from 1.22×10^9t to 0.48×10^9t in average year ($P=50\%$), from 0.76×10^9t to 0.29×10^9t in low-flow year ($P=80\%$), and from 2.41×10^9t to 1.00×10^9t in high-water year ($P=50\%$). In the average conditions, the sediment yield of the Yellow River will decrease from 1.78×10^9t to 0.71×10^9t, and the reducing amount will be 1.07×10^9t, when it is calculated as the sediment reducing benefit being 60%.

(4) When the whole emphases control region is actualized with soil-water conservation measures, i. e. control degree reaches 100%, the sediment yield of the Huanghe River calculated on the basis of the sediment yield being 1.6×10^9t over the interval 1919 – 1969 will decrease to 0.64×10^9t.

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