Study on Mechanism of Sediment Reduction and Peak Flood Mitigation of "Changzhi Project" in the Hill of Sichuan Basin

Lei Xiaozhang[1] **,** ***Dai Hualong***[1] **,** ***Cao Shuyou***[1] **,** ***Liu Xinnian***[1] and ***Dai Yongbo***[2]

[1]State key lab. of high speeds flow, Sichuan university, and 610065
[2]The developing and planning committee of Sichuan province, 610016

Abstract: This paper used the "Changzhi Project" as object, and analyzed the function of sediment reduction and peak flood mitigation for various water and soil conservation methods on the slope, then using the result and hydrological model to study the benefits for water and soil conservation methods in a watershed under different scales. The result showed that the "Changzhi Project" has obvious effect on sediment reduction and control flood on the slope or in a watershed.

The abbreviation for "Water and Soil Major Protection Project in the Upper Reaches of Yangtze River" is "Changzhi project" in China. This project has been starting in 1989, and has been implemented in the integrative control engineering from the first to the fifth period, and has been completed 700 watersheds, and the total controlled area was 150,000 km^2. For ten years of soil loss control, the "Changzhi Project" has played greatly important role on eco-environmental construction and economic development of in the Yangtze River basin. Meanwhile, in order to improve the integrative effect and study its influence on the sediment transport and peak flood mitigation in river, we implemented the benefits study on sediment reduction and peak flood mitigation of "Changzhi Project".

1 Basic conditions of the region

The studied region locates in the hill of Sichuan basin. The main topography is hilly of shallow to medium with height above 300—700 meters. The earth layers are composed of purple sand-rock and mud-rock, covered by purple soil.

The climate belongs to sub-tropical seasonal dump with characteristics of warmer in winter, earlier in spring, hotter in summer and less sun shining. The precipitation in this area per year is 1,000mm or so and concentrates mainly in May to September. The frost-free day is 280—330d and the average temperature is 17℃.

With large densely population of over 600 persons per square kilometer, the land has higher cultivation ratio and plant crops including rice, corn, wheat, cotton and others to support people. The forestland is less, which covered by artificial young forest, such as cypress, alder and pine. Therefore it is the typical agriculture region in the upper of Yangtze River.

In Sichuan hilly area, the anti-erosion capacity of soil is weak, and rain is concentrative and heavy, meanwhile the slope land was seriously cultivated, all of these results in serious soil and water loss and has prevented the development of industry and agriculture. Hence this region has been regarded as major area of soil and water conservation since 1989. At present, the total controlled area covers 15 thousand km^2.

2 Methods

According to the geological feature and social and economical condition, and connected the located monitoring data and the sub-fixed information and the hydrological model, the methods to study the sediment reduction and peak flood mitigation for "Changzhi Project" were divided two aspects, one is single control method, the other is integrative control way. The single control method finds the reduce rule of each single control way and supply analyzing basis for integrative prediction. The integrative control way analyzes the comprehensive effects of above ways implemented in a watershed and finds out the rule for sediment and water transportation in a watershed or under different scale valley.

3 Benefit analyzing

3.1 Sediment Reduction and control peak flood mitigation functions for single control methods

3.1.1 Slope cultivated land turn into terrace (SCLTT)

Slope cultivated land is the main resource for soil loss in Sichuan basin. Table 1 presents some monitoring data. From this table, we can see that soil loss was largely decreased and more surface run-off changed into soil flow and groundwater when slope cultivated land turned into terrace. The more tilt is the SCLTT, the more surface run-off turned. For example, the amount of soil loss was reduced 94.9% after slope cultivated land turn into level terrace in Suining downtown, meanwhile the amount of soil loss was reduced 86%%—90.2%% after slope cultivated land turn into terrace.

Table 1 The reducing effect of slope cultivated land turn into terrace

Site	Area (hm^2)	Period of monitor	Control method	Slope (℃)	Precipitation (mm)	Run-off (mm)	Soil intensive erosion (t/(km^2 • a))
1	0.05	1982	The slope cultivated land turn into level terrace	15	1,064.7	260	11,440
	0.05	1984		0	904.5	22	520
	0.05	1989		0	962.1	21	520
2	0.06	1991		15	957.2	260	11,483
	0.06	1992		0	963.6	21	650
3	0.23	1982	Slope land cultivated into terrace	16	1,064.7	255	16,033
	0.23	1984		2	904.5	44	156.0
	0.23	1985		2	946.7	42	1,170
4	0.06	1988		24.5	951.8	308	16,033
	0.06	1989		4	962.1	89	1,733
	0.06	1990		4	979.8	90	1,516

3.1.2 Function of forestation and grass methods

The soil conservation function of forest and grassland depends on the structure and their coverage rate. The soil conservation effect of forest is bigger than grassland; meanwhile, the adult and suitable coverage forest is superior to young trees, of course the young forest has more benefit than grass. The forest has obvious function for sediment reduction and control peak flood mitigation from the monitor data, especially formed forest community.

Table 2 The amount of soil loss on different land in Jianyang County

Form \ Site	No.1 mixed forest	No.2 mixed forest of Cypress	Young forest	Agriculture land
Form of species	4cypressand4oak	10	10	Corn and sweet potato
Age (y)	17	17	2	
Coverage (%)	90	60	10	
Date of monitoring	1990.7.17	1990.7.17	1990.7.17	1990.7.17
Precipitation (mm)	114.9	114.9	156.0	115.6
The amounts of runoff (m^3)	0.873	0.916	2.25	0.68

Continued

Form \ Site	No.1 mixed forest	No.2 mixed forest of Cypress	Young forest	Agriculture land
Runoff (mm)	8.73	9.16	22.50	42.6
Ratio of runoff	0.076	0.080	0.144	0.369
Sediment concentration (kg/m^3)	1.13	1.27	1.84	10.63
Soil erosion (t/km^2)	10	12	41	452
slope(°)	40	35	25	25

3.1.3 Function of preservative cultivation

Compared with the traditional down-slope cultivation, the amount of soil loss in the contour cultivation is obviously reduced, but the runoff is barely changed. The amounts of soil loss reduction in contour cultivation was 28.3%—27.6%, and the runoff was only 4.7%—6.14% according to the monitor data from Suining Water and Soil Conservation Monitor Station (Table 3).

Table 3 The monitoring result of preservative cultivation for control soil loss

Site	Cultivation ways	Areas (hm^2)	slope	Precipitation (mm)	Run-off (m^3)	Sediment (m^3)
1	Down-slope cultivation	0.01	15°	1045.4	173.5	2.97
	Contour cultivation	0.01	15°	1045.4	124.8	2.13
2	Down-slope cultivation	0.14	15°	951.8	173.6	5.8
	Contour cultivation	0.14	15°	962.1	124.8	4.2

3.1.4 Function of small hydraulic engineer

Small hydraulic engineer, such as puddle, pond and pool, can prevent sediment transport into river effectively. According to the investigation in Anyue County and Luozi County, the ratio of settlement sediment in puddles and ditches was 8,892t/(km^2 • a) and 8,346t/(km^2 • a), and the total settlement sediment was 5,750,000t and 4,290,000t. More over, the ratio of settlement sediment in puddles and ditches is related to the slope cultivation land, the more of slope cultivation land was, the higher ratio of settlement sediment in the puddle, pond and pool. By analyzing the statistic data from the settlement sediment in the small hydraulic equipment, the average settlement sediment in ponds was 2.56%, and 0.48%—1.50% in pool.

3.2 Reduction effect of integrative control way

The sediment reduction effect of single control methods can't explain the influence of run-off and sediment in a small watershed under integrative control ways, let alone the moving tendency of sediment and water under different scale. So using the effects of single control methods, the land utility and the industry chain in the urban, the effect of integrative control ways were rewarded by hydrological facts of Panlong River and Mongxi River.

3.2.1 Introduction of panlong watershed

The Panlong watershed, locating in the south west of Suining city, is the first branch of Qiongjiang river on the left bank of Fu river which has the gathering areas 135km^2 with 4.35m^3/s of average flow and 0.7% slope. The form of the topography is plain, shallow and medium hill, so it belongs to the typical agriculture region with large population density of 619/km^2, and less ratio of forest coverage, therefore the loss area was 93.72 km^2, and the amount of soil loss was 78 million tons each year.

① the integrative control in the watershed

The integrative control and it's control area in the watershed was listed in Table 4 since

1989—1991.

② Benefit Analyze

After implemented the integrative control, the ratio of forest was increased from 7.31% to 22.61%, and the amount of soil loss was decreased from 78 million tons to 14.23 million tons meanwhile the runoff was cut down from 0.26 billion m^3 to 0.626 billion m^3 each year. The biggest sediment reduction benefit in the integrative control way reflected on the small hydraulic engineer and soil conservation engineer (44.7%), next was conservation cultivation, protect forest and terrace, however the highest cut down sediment intensity of per area was terrace with 0.27t/ hm^2. Table 4 shows the reducing effect of various soil conservation ways in Panlong River.

Table 4 The reducing water and soil effect for various soil conservation ways in Panlong River

Control methods	Harness areas (hm^2)	Reducing run-off each year ($10^4 m^3$)	Taking percentage of the total annual reducing water (%)	Per unit of cut down water each year (m^3/hm^2)	Sediment reduction each year (10^4t)	Taking percentage of the total annual sediment reduction (%)	Per unit of cut down sediment each year (T/ hm^2)
Slop land turned into terrace	873.33	262.00	13.14	3,000	5.37	8.36	60.75
Protect forest	1,120	302.4	15.17	2,700	6.89	10.73	60.75
Eco-fruit trees	966.67	290.00	14.54	3,000	4.93	7.86	51.75
Closing of forest area	513.33	92.40	4.63	1,800	0.62	0.97	11.93
Conservation cultivation	5,900	885.00	44.38	1,500	17.70	27.56	29.25
Small hydraulic and soil conservation engineers	72,600	162.29	8.14	22.5	28.71	44.70	4.05
Total		1,994.09	100		64.22	100	

3.2.2 Function of mongxi watershed

Mongxi watershed, locates in Guang'an prefecture, belongs to the first branch of Qu River with the gathering areas of 51.12 km^2, and flow from Wangcong village to Xiexing village, and then joins the Qu River in Dalong village. The earth layer is composed of purple mud-rock, covered by purple soil. The main topography is hilly of shallow to medium heights, so it belongs to the typical agriculture region with high population density of 696, and lower ratio (3.95%) of forest coverage, therefore the loss area was 34.25 km^2, and the amount of soil loss was 2.49 billion tons each year.

① the integrative control methods in the watershed

The integrative control methods and it's control area in the watershed was listed in Table 5 since 1989—1991.

② Benefits

After implemented the integrative control ways for 5 years, the ratio of forest was increased from 3.95% to 19.59%, and the amount of soil loss was decreased from 2.49 billion tons to 0.56 billion tons. The highest cut down sediment and water intensity of per area was terrace in the whole ways, and took percent of 41.5%and 41.2% of the total controlled. The next was small hydraulic and soil conservation engineer which reducing surface runoff, it took percent of 23%, but sediment reduction was soil conservation cultivation with 27.9%. The effect of per unit was biggest for water and soil conservation among the whole harness ways was slope land turn into terrace.

Table 5 The statistic table of various soil and water conservation engineer for sediment reduction in Mongxi River

Harness ways	Harness areas (hm^2)	Run-off reducing per year (10^4t)	Taking percent f the total run-off reducing (%)	Per unit run-off reducing each year (m^3/hm^2)	Sediment reducing (10^4t/a)	Taking percent f the total sediment reducing (%)	Per unit run-off reducing each year (t/ hm^2)
Terrace	326.67	100.10	41.5	3,058.5	7.96	41.2	243.15
Protect forest	427.33	50.40	20.9	456	3.99	20.6	36.15
Economic fruit trees	319.33						
Closing of forest area	359.33						
Soil conservation cultivation	1991.3	35.20	14.6	178.5	5.3877	27.9	27
Small hydraulic and soil conservation engineers	146.9	55.5	23.0	5.7	1.99	10.3	0.21
Total		241.20	100		19.3277	100	

3.3 The mechanism of sediment reduction and control peak flood mitigation for the "Changzi Project"

Based on the monitoring data from Suining water and soil conservation observation station on 13th august, 1989 and using the distribution function of P-Ⅲ, the mechanism for sediment reduction and control peak flood mitigation was explored (Table 6).

Table 6 The basic condition of the test area

No.	Slope	Control methods	Coverage ratio of plants (%)	98.8.13 flood	
				Run-off (mm)	Module of transportation of silt (t/km^2)
Parent rock slope		Original	38	157.5	1,238.2
No.1 of slope	5°	Contour ridge cultivated, Planted corn, sweet potato	100	19.3	141.1
No.2	10°		100	31.0	224.1
No.3	15°		100	32.6	258.0
No.4	20°		100	54.0	344.1
No.5	25°		100	61.0	514.8
014 - 1	10°		100	46.5	263.5
2	10°		100	47.9	316.3
3	10°		100	50.1	345.5
4	10°		100	49.0	339.5
5	15°		100	56.9	337.5
6	15°		100	57.3	417.8

The areas of parent rock slope and cultivated slope land are 66.07m^2 with the width of 7.5m and length of 8.81m, and the cultivated slope land was finished in1989. The No.014 was cultivated from parent rock slope with 100 m^2.

According to the modeling with the distribution function of P-Ⅲ,The storm rainfall, happened on 13th August,1989, equaling to the 24 hours precipitation per ten years or that of the 10 hours per twenty years, and meeting requirement of water and soil conservation design, so the mechanism for sediment reduction and control peak flood mitigation was analyzed with the rain. The effect obtained by the actual data of precipitation, run-off and sediment, and using the method of storm run-off and listed below.

① The infiltration intensity of slope land was bigger than parent rock slope and gradually reduce as exponential function with the increase of slope. The proportion relation of parent rock slope and slope land was 1∶9—1∶12.6.

② The time of flow together on slope land was longer than parent rock slope under the same slope length and gradually extension as the decrease. The time of flow together increased 14%—82% when slope land cultivated into terrace.

③ The ratio of peak flood mitigation was cut down 15%—26% when parent rock slope turned into slope land, and reduce the run-off for making peak flood mitigation. The more lower was the slope of the land, the more cut down of the making peak flood mitigation flow was.

④ The peak flood mitigation or the model of peak flood mitigation was obviously lower when parent rock slope turned into slope land with 29%—49%, and cut down more when the slope drop.

⑤ The runoff depth of slope land was equal to 13%—39% of the parent rock slope and decreased follow the slope drop.

⑥ The sediment came from slope land was 11%—42% of the parent rock slope and decreased follow the slope drop, meanwhile amounts of sediment has good line relation with the runoff on the slope land.

4 Conclusion

(1) The soil conservation effects of single way were more obviously, such as the terrace was 61.5t/hm^2, economic plants and fruit trees was 51 t/hm^2, closing for forest was 12 t/hm^2, the soil conservation cultivated was 25.5 t/hm^2; the water storage effects were varied with different control way, for example, the slope cultivated land turned into gentle slope terrace, the average run-off took percent of 24.4% of the precipitation, it equaled to the precipitation of 75.6% was turned into groundwater and soil water; when the slope cultivated land turned into contour terrace, the average run-off took percent of 0.23% of the precipitation, it equaled to the precipitation of 99.77% was turned into groundwater and soil water. The conservation level cultivated can reduce bigger run-off than down slope cultivation.

(2) The integrative control for soil loss in watershed operated well. Using the effect of Pan long watershed to show it. After implemented the integrative control ways for 5 years, the ratio of forest was increased from 3.95% to 19.59%, and the amount of soil loss was decreased from 24.95 million tons to 0.56million tons and soil loss was controlled effectively. The highest cut down sediment and water intensity of per area was terrace in the whole ways, and took percent of 41.5%and 41.2% of the total controlled. The next was small hydraulic and soil conservation engineer which reducing surface run-off, it took percent of 23%, but sediment reduction was soil conservation cultivation with 27.9%. The effect of per unit was biggest for water and soil conservation among the whole harness ways was slope land turn into terrace.

(3) The infiltration intensity of slope land was bigger than parent rock slope and gradually reduction as exponential function with the increase of slope. The proportion relation of parent rock slope and slope land was 1∶9—1∶12.6. The ratio of peak flood mitigation was cut down 15%—26% when parent rock slope turned into slope land, and reduce the run-off for making peak flood mitigation. The more lower was the slope of the land, the more cut down of the making peak flood mitigation flow was.

References

[1] Richard lee. Forest hydrologic. Columbia university press 1981.
[2] Haac C t. *et al*. Hydrological modeling of small watershed AnAn Monograph. ASAE, 1982 (5).