Study on the Reducing Sediment Effect of "Changzhi Project" in the Hill of Sichuan Basin

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Abstract: This paper used the "Changzhi Project" data, and analyzed the reducing sediment effect of various water and soil conservation methods on the slope or in a watershed, then using the result to study the reducing effect for water and soil conservation methods under different scales. The result showed that the "Changzhi Project" has obvious effect on reducing sediment on the slope or in a watershed, but the moving mechanic under different scales need further study.

"Changzhi Project" (short for "water and soil major protection project in the upper of Yangtze River"), starting in 1989, and has been carried out in the integrative control engineering from the first to the fifth phased. Over 700 watersheds, and 150,000 km^2 total was controlled. For ten years of soil loss control, "Changzhi Project" has remarkably effect on eco-environmental construction and economic development for Yangtze River. This paper is a contribution to understand the sediment reduction effect of "Changzhi Project".

1 Introduction

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

The climate belongs to sub-tropical seasonal dump which has the features, such as warmer in winter, earlier in spring, hotter in summer and less sun-shining. The precipitation amount in this area is 1,000mm or so and mainly gathering in May to Sep. 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 more 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.

The serious soil and water loss in Sichuan hilly area are caused by concentration and heavy rain, the soil's weaker prevent erosion capacity, and seriously cultivated slope land, which have prevented the development of industry and agriculture, so this region has been regarded as major preserve and control area since 1989. At present, the total controlled area was 15 thousand km^2.

2 Methods for data collection

Based on the located monitoring data and the sub-fixed information and the hydrological model, the methods for data collection were divided as two aspects which are single control method and 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 functioning rule for sediment and water transportation in a watershed and under different scales.

3 Benefit evaluation

3.1 Benefit of sediment reduction of single control methods

3.1.1 slope cultivated land turn into terrace (SCLTT)

Slope cultivated land is the main resource for river sediment in Sichuan basin, the monitoring data explain (Table 1) that soil loss can be largely decreased and more surface run-off can change into soil flow and groundwater when slope cultivated land turn into terrace. 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 ($t/(km^2 \cdot a)$)
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	0.24	1982	Slope land cultivated into terrace	16	1,064.7	255	16,033
	0.24	1984		2	904.5	44	156.0
	0.24	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 Effect of forestation and grass methods

The soil conservation effect of forest and grass is depended on the structure and their coverage rate. The soil conservation benefit of forest is bigger than grass-land; Meanwhile, the adult and suitable coverage forest is superior to young trees, of course the young forest has more benefits than grass. The forest has obvious effect for reducing sediment and control erosion from the monitor data for consecutive 6 years monitor, especially formed forest community.

Table 2 The sediment statistical form under different forest styles from May to September ($t/(km^2 \cdot a)$)

	Grass-land	The young mingled of Cypress and alder	The young forest of Mexico Cypress	The adult mingled of Cypress and oak	The forest of Cypress
Precipitation (mm)	635.4	635.4	635.4	635.4	635.4
Age (y)		5	5	17	17
Slope (°)	25	28	28	35	34
The amounts of soil loss	61.6	21.8	33.1	29.2	17.8

3.1.3 Effect of preservative cultivation

Compared with the traditional down-slope cultivation, the amount of soil loss in the contour cultivation is obviously reduced, but the run-off is not changed. The reducing amounts of soil loss in

contour cultivation was 28.3%—27.6%, and the runoff was only 4.7%—6.14% according to the monitor data from Suining (Table 3) water and soil conservation monitor.

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	1,045.4	173.5	2.97
	Contour cultivation	0.01	15	1,045.4	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 Effect of small hydraulic engineer

Small hydraulic engineer, such as puddle, pond and pools, can reduce sediment into stream effectively. According to the investigation in Anyue and Luozi counties, 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 0.57 million tons and 0.43 million tons. More over, the ratio of settlement sediment in puddles and ditches is related with slope cultivation land, the bigger of slope cultivation land was, the higher ratio of settlement sediment in the puddle, pond and pools. By analyzing the statistic information of the settlement sediment in the small hydraulic equipment, the average settlement sediment in ponds was 2.56%, and 0.48%—1.50% in pools.

3.2 The cut down effect of integrative control ways in small watershed

The reducing sediment 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 and linked the land utility and the industry chain in the urban, the effect of integrative control ways were rewarded by hydrological facts of Panlong and Mongxi River.

3.2.1 The effect of integrative control ways in panlong watershed

The watershed of Panlong watershed, located in the south west of Suining city and originated in Luozi county, 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, and less ratio of forest coverage, therefore the loss area was 93.72 km^2, and the amount of soil loss was 78,405,000 t each year.

After implemented the integrative control for 5 years (Table 4), the ratio of forest was increased from 7.31% to 22.61%, and the amount of soil loss was decreased from 78,450,000t to 14,230,000t meanwhile the run-off was cut down from 262.0,9 million m^3 to 62.68 million m^3 each year. The biggest reducing sediment 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.

3.2.2 Effect of mongxi watershed

Mongxi watershed, located 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 24.95 million tons each year.

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 (10^4m^3)	Taking percent of the total annual reducing water (%)	Per unit of cut down water each year (m^3/hm^2)	Reducing sediment each year (10^4t)	Taking percentage of the total annual reducing sediment (%)	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	

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 0.56 million 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 reducing sediment 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 reducing sediment 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	3058.5	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	1,991.3	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 Effect of “changzi project” for water and soil conservation under different watershed scales

According to analyzing the water and soil conservation benefits of single and integrative harness ways, this paper used the examples of the lower and middle of Jialin River and Jinsha River to explain the effect of “changzi project” for water and soil conservation under different watershed scales.

3.3.1 The effect of "Changzi Project" for water and soil conservation in the lower and middle reaches of Jialing River

The benefits of "changzi project" for water and soil conservation in the lower and middle of Jialin River were estimated by the soil conservation method and the analyzing of water and soil conservation benefits for single and integrative harness ways, and the acceptance test conditions of the first and second phase of the "changzi project", the data which evaluated the benefits of soil conservation under different harness ways vary, terrace was 61.5t/hm^2, economic plants and fruit trees was 51 t/hm^2, Closing of forest area was 12 t/hm^2, soil conservation cultivation was 25.5 t/hm^2, Small hydraulic and soil conservation engineers was 4.65 t/hm^2; meanwhile connected the process and the actual preserve ratio which implemented in the first year was 100%,before the first year was 95%, before the 2nd—3rd was 90%, in proper order, the 4th—5th was 90%, the 6th—7th was 85%,and 8th was stable. The result was showed in Table 6 and Table 7.

Table 6 The implemented statistic of the "changzi project" in the lower and middle of Jialing River

Year	Harnessed area							Small hydraulic and soil conservation engineer	
	km^2	Terrace	Protect forests	Eco-plants and fruits	Grass	Closing for forest	Soil conservati-on cultivation	Quantity of pond	Quantity of Pools
1989	585.6	8.2	19.36	5.84	0.86	7.17	46.43	990	8,491
1990	944.7	47.69	29.85	10.93	2.91	15.28	71.07	1,333	12,253
1991	939.4	11.12	30.69	10.21	2.01	15.26	71.58	1,117	8,768
1992	909.5	10.23	32.4	7.26	2.37	22.36	61.8	706	6,866
1993	547.4	7.37	17.86	8.01	0	8.31	40.57	415	5,041
1994	750.4	10.28	22.49	13.53	0.45	20.99	44.82	606	8,104
1995	680.2	9.58	19.38	15.95	1.11	19.93	36.08	657	2,891
1996	671.4	8.97	23.48	12.51	0.79	19.63	34.89	685	3,199
Total	6,028.6	113.44	195.51	84.24	10.5	128.93	407.24	6,509	55,613

Table 7 The reduce sediment amounts of various soil conservation methods in the lower and middle of Jialing River

Year	Terrace	Protect forests	Eco-plants and fruits	Grass	Closing for forest	Soil conservation cultivation	Small hydraulic and soil conservation engineer)
1989	26.88	0.00	0.00	0.00	0.00	63.39	208.41
1990	38.35	0.00	0.00	0.00	0.00	96.97	285.38
1991	38.73	0.00	0.00	0.00	0.00	103.92	162.81
1992	35.62	84.007	18.863	2.00	3.27	89.66	191.17
1993	27.19	136.84	37.508	7.00	7.00	62.37	141.51
1994	37.90	140.32	35.216	4.86	7.00	68.88	103.84
1995	37.31	119.95	26.506	6.02	10.41	58.55	131.01
1996	36.74	92.825	30.577	0.00	3.93	59.57	159.17
Total	278.74	573.94	148.67	19.88	31.615	603.31	1,383.3

"Changzi project" is not only control soil erosion on the slope, but also reduce sediment moving into river. The average run-off and sediment was less after 1989 since the project implemented than before 1989 from the monitor information of Baibe hydrological station of the Jialin River and the stem stream hydrological station, such as Xiaohekou, Wusheng and Luoxi. The average run-off and sediment in 1989 to 1996 took percent of 86.59% and 37.93% of the average before1989. The areas of the stem stream is 9,733km^2,the average run-off and sediment in 1989 to 1996 took percent of 46.57% and 13.42% of the average before1989.

The change of sediment in river is related with precipitation, the controlled areas of soil loss, and the arrangement of hydraulic engineer. The main reason of reduce sediment in Jialin River was due to the obviously lower of precipitation since 1989, but the reduce ratio of sediment which was 1.39 times in the stem stream region than the jialin river, was attributed to the "changzi project", because the precipitation was nearly equal. Most of the watershed area of Jialin River in the upper of baibe was a not emphasis control county, but the entire stem stream region was emphasis control counties of the "changzi project". If the effects are same of the un-harness for sediment between the stem stream region and the Jialin river, the reduce sediment amount which would move into river was 0.6 million tons each year, and the module of transportation of silt cut down to 622t/m^2 • a (Table 8).

Table 8 The water and silt change state between the stem stream region and the Jialing River round about the "changzi project"

Region	Period	Precipitation (mm)	Run-off (10^8m^3)	Transportation of silt (10^4t)
Stem stream region	1954—1988	1,055.9	67.0	24.7
	1989—1996	1,001.2	31.2	3.1
Jailing River	1954—1988	1,165.2	697.4	145.0
	1989—1996	1,180.0	603.9	55.0

3.3.2 The effect of "changzi project" for water and soil conservation in the lower reaches of Jinsha River

The benefits of "changzi project" for water and soil conservation in the lower reach of Jinsha River were estimated by the same way of the Jialin River. The total reduce sediment was 245.55 million tons by the end of 1996 which was listed in Table 9 and Table 10.

Table 9 The implemented statistic of the "changzi project" in the lower reach of Jinsha River in Sichuan (10^4t)

Year	Comple-ted areas (10^3hm^2)	Terrace (10^3hm^2)	Protect forest (10^3hm^2)	Economic plants and fruit trees (10^3hm^2)	Grass (10^3hm^2)	Soil conserva-tion cultivation (10^3hm^2)	Closing for forest (10^3hm^2)	Hydraulic and soil conservation engineer					
								Quantity of Ponds	Quantity of Debris dam	Quantity of Pools	Quantity of Drainage channel (km)	Quantity of Drainage ditch (km)	Quantity of Settling tanks
1989	28.81	2.2	6.87	1.84	1.74	4.89	11.57	19	102	10,423	287.5	42.8	
1990	45.23	3.93	12.88	3.44	2.94	10.24	11.82	82	387	17,803	247.8	161.2	
1991	47.3	3.98	13.02	3.37	2.96	12.06	11.92	40	355	16,362	513.1	169.4	
1992	43.97	3.34	9.9	2.20	1.98	18.90	7.68	88	240	12,300	482.3	131.8	
1993	28.2	2.54	5.04	2.72	1.78	3.17	12.96	55	303	8,878	304.8	106.6	1.81
1994	46.19	3.85	14.14	5.76	4.31	5.66	12.48	31	417	6,937	401.0	272.7	1.39
1995	50.48	4.33	13.91	5.50	6.19	6.67	13.9	117	1,332	6,077	833.0	197.08	2.01
1996	51	4.36	15.02	5.61	5.58	6.73	13.71	117	1,412	6,177	847.7	202.6	2.01

Total	341.2	28.5	90.48	30.42	27.47	68.31	96.03	549	4,465	84,957	3,917.2	1,284.2	21.23

Table 10 The implemented statistic of the "changzi project" in the lower reach of Jinsha River

Year	Completed areas (10^3hm^2)	Terrace (10^3hm^2)	Protect forest (10^3hm^2)	Economic plants and fruit trees (10^3hm^2)	Grass (10^3hm^2)	Soil conserva-tion cultivation (10^3hm^2)	Hydraulic and soil conservation engineer			
							Quantity of Ponds	Quantity of Debris dam	Quantity of Pools	Quantity of Settling tanks
1989	5.64		3.78		5.87		0.05	0.14	1.98	4.26
1990	15.73	11.38	10.81	3.39	12.29	7.3	0.28	0.66	5.36	10.25
1991	25.94	33.64	17.73	9.1	14.48	14.74	0.39	1.14	8.47	15.35
1992	34.51	56.14	22.24	14.86	22.68	22.24	0.63	1.46	10.87	19.96
1993	41.02	73.24	27.82	18.71	3.8	27.08	0.78	1.87	12.50	22.54
1994	76.32	81.96	39.64	22.16	6.8	35.25	0.87	2.44	13.81	24.52
1995	62	106.38	50.92	30.53	8.01	43.11	1.19	4.23	14.97	27.39
1996	73.17	130.41	62.43	42.56	8.07	51.84	1.51	6.14	16.14	30.25
Total	308.85	493.11	235.35	141.3	81.97	201.55	5.70	18.09	84.04	154.53

The increased storage water was 4 billion cubic meter and the reducing sediment was 300 ten thousand cubic meter by preliminary estimates of the "changzi" project using above methods. If thinking of the extend control soil loss, the increased storage water was 5 billion cubic meter and the reducing sediment was 400 ten thousand cubic meter, in other words, there was 5 billion cubic meter precipitation was intercepted in the soil, ponds and pools, and matched 50 pools with the volume of 0.1 billion cubic meters; and reducing sediment 400 ten thousand cubic meter equivalent to 10.57% of the average of transport of silt of the Yichang station.

4 Conclusions

One, 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.

Two, the integrative control for soil loss in watershed operated well. Using the effect of Panlong 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 0.56 million 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 reducing sediment 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.

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