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Effectiveness of check dams in sediment control; a survey in kotok watershed in Khuzestan Province, Iran

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Key words: watershed, check dam, soil erosion, sediment.

Abstract

sediment transport are processes that cause annual losses of millions of tons of soil from the natural and agricultural areas in Iran. These processes result in the loss of soil nutrients, as well as filling of reservoirs and deposition of canals, *etc*. Watershed projects are mainly prepared and executed aiming at controlling soil erosion, flood control, and decreasing their destructive consequences. Evaluation of watershed projects plays a vital role in solving technical issues and investment in this type of projects In this research, we studied the Kotok watershed located in Andika County, Khuzestan Province, Iran. The runoff flowed in this sub-basin pours into the Karun River and then enters into the reservoir of Shahid Abbaspour dam. During the rainfall seasons, the watershed flood causes erosion of the regional lands and delivery of abundant sediment to the reservoir of this dam. Accordingly, corrective structures were built to control the sedimentation, such as dry stone and gabion check dams. Kotok Watershed is divided into 12 working units (parcels); in this study, certain parameters were examined for each parcel including hydrologic group and soil erodibility, parcel areas, the annual amount of sediment, the number and size of the built structures, and the volume of trapped sediment. According to the survey, construction of check dams had significantly controlled the transport of sediment as much as 30% to 80% of annual sediment in those parcels where construction of the structure was possible.

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Introduction

Decrease in soil erosion and runoff, retaining soil moisture, and sediment control are considered as the main objectives of watershed management projects. Proper implementation of watershed management plans has significant positive economic and social effects on watershed residents. Substantial sums are spending every year for the implementation of these projects in the country. Various operations are implemented in watershed programs and activities, such as construction of check dams or delay dams. The most important impacts of these structures are stabilization of waterway steep, increased time of concentration, reduced flood, and sediment control. Knowledge of the effectiveness of the implementation of any project including the watershed operation is of the utmost importance for executers; because awareness of the effectiveness of each project not only clarifies the achievement levels of initial objectives, but also identifies the relevant disadvantages and benefits, according to which necessary decisions can be made to correct the defects or revise the execution method or even the type of operations (Masjedi and Tajari, 2007). In this regard, this question arises in the mind that by development of watershed management plans, how much of a project's objectives (erosion and sediment control and containment of surface runoff) are really met.

Pawar P. B. (1998) studied the situation of breakwaters and the performance of watersheds management in mountain and submontane of Maharashtra region in India and concluded that combined biological and mechanical operations in the dams' catchments may result in the best performance in stabilization of sediment and coping with erosion and flood.

ASCE Steering Committee (1998) conducted a comprehensive study on slope control structures. In this research, design, implementation and maintenance principles of various slope control structures such as check dams were studied from the perspective of existing resources in different countries.

Rey F. (2004) investigated the role of watershed management in decrement of erosion and sedimentation in the dams' watersheds in France. In this study, he focused on the distance and scale of constructions in coping with floods and control of sediment and provided a general model for structures.

Yoshikawaa *et al.* (2010) assessed Paddy Field Dam project in Kamihayashi District in Japan. In this study, they examined flow volume reduction and flood damage reduction. The results showed that flood control structures decreased the flow rate by 26%, thus confirming the effectiveness of the structure [Yoshikawaa *et al 2010*].

The present study aimed to evaluate the effectiveness of check dams in sediment control in a watershed. Accordingly, the Kotok watershed in which a series of check dams were built by the Department of Natural Resources and Watershed Management of Khuzestan Province were selected, and their effectiveness was evaluated through field studies.

Materials and methods

The Kotok watershed is located in southwestern Iran, Khuzestan Province, Andika County, with geographical coordinates of 35° 90' 00" to 37° 76' 00" east longitude and 35° 86' 00" to 36° 06' 00" north latitude. The studied area was 9094 hectares which was divided into 12 parcels (Fig. 1).

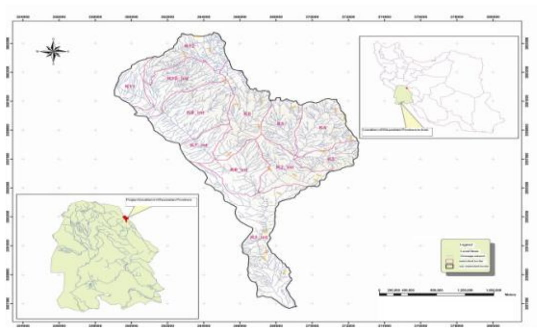

Fig. 1. Parceling and drainage of Kotok watershed.

Given the abundance of stony aggregates, the check dams built in this area are of dry stone and gabion types; analysis of the drainage map revealed that the grade 1 canals have dry stone dams while the dams in grade 2, 3, 4, and 5 canals are gabion in different types. The survey showed that all designed structures have been implemented in the study phase. Table 1 represents the number of the implemented check dams in each parcel.

Table 1. The implemented check dams in Kotok watershed.

Sub-basin name	Number of gabion dams	Number of dry stone dams
K1-int	11	565
K2-int	-	8
K6-int	-	133
K7-int	2	146
K8	-	21
K9-int	21	153
K10-int	14	75
K11	7	184
K12	8	4

Fig. 2. Structures built in Kotok watershed.

Sedimentation and sediment yield in this area are usually associated with phenomena such as fall, landslide, collapse, and mass flows. The annual sediment in the project area has been calculated by the PSIAC method which is one of the best empirical methods to estimate sediment and erosion in basins lacking data and hydrometric and sediment gauging stations. In this method, the impacts of 9 factors on soil erosion are evaluated and each factor attains a score.

Results

Table 2 depicts the effect of nine factors on erosion and sediment yield; the rate of erosion in the basin is shown in Table 3.

Table 2. The effect of nine factors on erosion and sediment yield in Kotok watershed.

Row	Factor	Land	Soil		Weather		Flows		Topo-graphy		Vegetation		Land use		Surface erosion		River erosion		Total
	Parcel name	y1=x1	y2=16.67x2		y3=0.2x3		y4=0.2x4		y5=0.33x5		y6=0.2x6		y7=20-		y8=0.25x8		y9=1.67x9		
			x2	y2	x3	y3	x4	y4	x5	y5	x6	y6	x7	y7	x8	y8	x9	y9	
1	K1-int	6.50	0.49	8.09	5.81	1.16	73.88	14.78	55.03	18.16	43.75	8.75	56.25	8.75	27.04	6.76	3.91	6.52	79.47
2	K2-int	4.00	0.53	8.88	5.97	1.19	93.58	18.72	118.7	39.17	47.15	9.43	52.38	9.43	27.44	6.86	3.98	6.65	104.33
3	K3	3.5	0.51	8.46	5.98	1.2	79.38	15.88	145.79	48.11	51.25	10.25	48.75	10.25	27.97	6.99	4.00	6.68	111.31
4	K4	3.50	0.48	7.97	5.84	1.17	57.00	11.40	118.03	38.95	56.00	11.20	44.00	11.20	26.51	6.63	3.86	6.44	98.46
5	K5	3.50	0.49	8.13	5.77	1.15	68.29	13.66	120.23	36.68	40.00	8.00	60.00	8.00	26.36	6.59	3.75	6.26	94.98
6	K6-int	4.00	0.48	7.96	5.87	1.17	120.83	24.17	71.26	23.52	41.25	8.25	58.75	8.25	26.76	6.69	3.82	6.37	90.38
7	K7-int	3.50	0.48	8.05	5.91	1.18	47.88	9.58	45.85	15.13	38.00	7.60	62.00	7.60	27.41	6.85	3.91	6.53	66.02
8	K8	4.00	0.48	8.05	5.51	1.10	121.46	24.29	111.59	36.82	49.50	9.90	50.50	9.90	27.99	7.00	4.00	6.68	107.75
9	K9-int	3.00	0.47	7.86	5.46	1.09	56.00	11.20	69.82	23.04	40.50	8.10	59.50	8.10	27.99	7.00	4.00	6.68	76.07
10	K10-int	5.50	0.47	7.90	5.57	1.11	60.50	12.10	85.49	28.21	48.50	9.70	51.50	9.70	27.78	6.94	3.97	6.63	87.80
11	K11	6.50	0.47	7.91	5.52	1.10	62.80	12.56	79.22	6.34	48.50	9.70	51.50	9.70	27.99	7.00	4.00	6.68	67.49
12	K12	3.00	0.50	8.27	5.63	1.13	63.50	12.70	76.69	25.31	59.00	11.80	41.00	11.80	27.98	7.00	4.01	6.70	87.70
Total watershed		4.35	0.49	8.12	5.79	1.16	76.89	15.38	85.07	28.07	46.80	9.36	53.20	9.36	27.16	6.79	3.90	6.51	89.10

Table 3. Data of sediment yield and erosion in Kotok watershed through PSIAC method.

Row	Sub-basin name	Area (Km²)	Parcel final score	Parcel specific sediment (m³/yr/km²)	Parcel total sediment (m³/yr)	Specific erosion (m³/yr/km²)	Parcel total erosion (m³/yr)
1	K1-int	17.05	79.47	640.86	10924.13	1780.18	30344.82
2	K2-int	7.41	104.33	1541.71	11431.13	4057.14	30081.92
3	K3	4.67	111.13	1972.46	9217.85	5330.99	24913.12
4	K4	8.89	98.46	1252.92	11143.95	3212.62	28574.24
5	K5	5.97	94.98	1108.00	6619.40	2841.01	16972.82
6	K6-int	7.61	90.38	942.02	7164.48	2415.42	18370.47
7	K7-int	3.97	66.02	398.68	1584.05	1022.25	4061.68
8	K8	10.39	107.75	1739.18	18065.68	4459.43	46322.26
9	K9-int	12.83	76.07	568.46	7291.16	1457.60	18695.27
10	K10-int	8.50	87.80	895.98	7307.62	2205.07	18737.48
11	K11	4.32	67.49	419.97	1814.68	1076.85	4653.02
12	K12	7.43	67.70	856.89	6364.05	2197.16	16318.07
Total watershed		99.04	89.10	900.44	89180.01	2308.83	228666.70

To evaluate the performance of check dams in controlling sedimentation, it was necessary to calculate the volume of sediment trapped in the reservoir of these structures. To this end, an extensive field visit was conducted and the necessary information was collected. It is noteworthy that the volume of sediment trapped behind the structures corresponded to a 4-year period from 2010 when the check dams were constructed to 2014 when the sediment volume was measured and calculated. The volume of sediment accumulated due to construction of dams in Kotok watershed is represented in Table 4.

Table 4. Sediment accumulated behind the check dams in Kotok watershed.

Row	Sub-basin name	Dry stone sediment volume (m³)	Gabion sediment volume (m³)	Sum (m³)
1	K1-int	18080	815.9	18895.9
2	K2-int	124	-	124
3	K6-int	2394	-	2394
4	K7-int	2482	186.5	2668.5
5	K8	273	-	273
6	K9-int	2754	6584.6	9338.6
7	K10	1425	12105.6	13530.6
8	K11	3496	2447.5	5943.5
9	K12	48	132.6	180.6
	Total	31076	22272.7	53348.7

Table 5 shows the performance of sediment control in the check dams.

Table 5. The performance of corrective structures in sediment control.

Working unit (Parcel)	Area (m³)	Gabion dam number	Dry stone dam number	Sediment yield (m³/yr)	Controlled Sediment volume (m³/yr)	Sediment control efficiency (%)
K1	17.05	11	565	10924.13	4723.9	43.24
K2	7.41	-	8	11431.13	31	0.27
K6	7.61	-	133	7164.48	598.5	8.35
K7	3.97	2	146	1584.05	667	42.11
K8	10.39	-	21	18065.68	68.3	0.38
K9	12.83	21	153	7291.16	2334.7	32.02
K10	8.5	14	75	7307.62	3382.7	42.29
K11	4.32	7	184	1814.68	1485.87	81.88
K12	7.43	8	4	6364.05	45	0.71
Whole watershed	99.04	63	1289	89180.11	13327.2	14.94

Discussion and conclusions

The results of the comparison of the sediment deposition rate controlled during a 4-year period showed that the check dams in parcels K11, K1, K10, and K9 had a significant performance in sediment control and their efficiencies were 81.88, 43.24, 42.29, and 32.02%, respectively.

The efficiency of sediment control in parcels K6, K12, K8, and K2 was low, being 8.35%, 0.71%, 0.38%, and 0.27%, respectively. This indicates a mismatch between the number of structures constructed with sediment yield and erosion rate in each of these parcels; this

mismatch may be related to the lack of road access to this parcel and steepness of the canals. In general, the sediment control efficiency was 14.94% in the whole watershed.

Suggestions

1. It is necessary to measure the amount and the efficiency of sediment control when designing corrective structures in any watershed in order to identify the performance of the project and carry out the implementation phase if economically justifiable. This leads to not spending money for the projects lacking an acceptable efficiency.

2. In addition to the mechanical activities, biomechanical activities such as terracing, flaky holes, plowing perpendicular to the slope, banquette, *etc.* have a significant impact on the control of soil erosion and sediment yield.

3. Biological operations along with mechanical activities and vegetation are of important factors in preventing the flow of runoff. Biological operations and promotion of vegetation have a significant impact on raising soil permeability and preventing soil erosion, especially in those parcels where the steepness lowers the possibility of building check dams.

4. Brush dams can be used for grade 1 canals in the region. Given their low costs of implementation and effectiveness in controlling erosion and reducing sediment transport distances, they are technically and economically justifiable and will have acceptable performance. This type of structure was not implemented in the studied area so far.

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