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Qualitative Performance of Different Soil and Water Conservation Structures in Raholi Watershed[1]

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Abstract

Introduction: With the limited scope of development of irrigation potential, rain water management plays an important role to supplement the surface water for domestic, irrigation and industrial uses. Therefore, efficient conservation and scientific management of harvested water is crucial for optimum utilization for crop production. Soil and water conservation structures create temporary storage of water and help in groundwater recharge.

Materials and Methods: Watershed is geographical area that drains to a common point, which makes it an attractive unit for technical effort to conserve soil and maximize the utilization of surface and subsurface water for crop production. The research was carried out during 2015-16 at Raholi watershed (602 ha) of Maharashtra state of India. The Raholi watershed is situated in Hingoli district of Marathwada region, which is 9 Km away from Hingoli city. It is located at 19º70’ N latitude and 77º07’ E longitude. The watershed has

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been developed by Department of Agriculture, Government of Maharashtra in the year 2010-11. Different soil and water conservation structures namely graded bunds, earthen nala bund, cement nala bunds and continuous contour trenches were undertaken in the watershed. Representative soil and water conservation structures were selected to study their effect on reducing soil erosion and soil loss in the area. On an average reduction in cross sectional area of graded bund was found to be 29.46 per cent (23.81 to 35.71 per cent) over a period of four years after their construction.

Results: On an average reduction in cross sectional area of Continuous Contour Trenches (CCT) was found to be 39.61 per cent (33.33 to 64.71%) over a period of four years after its excavation. Reduction in cross sectional area of earthen nala bunds was found 19.14 per cent over a period of four years after their construction where as its storage capacity reduced by 3.91 per cent for the same period. No change in the dimension of three cement nala bunds was found at the post development stage of the watershed. Reduction in the storage capacity of the cement nala bunds was found in range to be 2.43 to 4.50 per cent over a period of four years after their construction.

Conclusions: It can be concluded that average depth and area of silt deposited at different Cement nala bunds (CNB) including CNB 1, CNB 2, CNB 3 were 0.13, 0.16 and 0.15 m and 1073.25, 746.32, 510.00 m^2 respectively. The weight of silt deposited at CNB 1, CNB 2 and CNB 3 were found to be 184.16, 157.62 and 100.98 tonnes respectively. The total silt deposited in all cement nala bunds was found to be 442.76 tonnes during the period of four years after their construction. The per cent reduction in storage capacity of CNB 1, CNB 2 and CNB 3 was found to be 2.43, 2.79 and 4.5 per cent respectively over the period of four years from their construction. The reduction of storage capacity was due to deposition of silt in the nala on the upstream side of these cement nala bunds.

Keywords: Watershed, Bunds, Trenches, Soil Erosion, Storage Capacity, Water Conservation.

1. Introduction

Soil and water are the basic resources essential for survival of human kind. Every kind of farm activity is connected with land and prosperity of nation depends on the quality of its land resources. One of the principal reasons for low productivity is agriculture is the progressive deterioration of soil due to erosion. Water is most essential input to agricultural production. With the limited scope of development of irrigation potential, rain water management plays an important role to supplement the surface water for domestic, irrigation and industrial uses. Therefore, efficient conservation and scientific management of harvested water is crucial for optimum utilization for crop production. Soil and water conservation structures create temporary storage of water and help in ground water recharge.

Watershed is geographical area that drains to a common point, which makes it an attractive unit for technical effort to conserve soil and maximize the utilization of surface and subsurface water for crop production. Watershed development project are designed to harmonize the use of water, soil and pasture resources in a way that conserves these resources while raising agricultural productivity, both through *insitu* moisture conservation and increased irrigation through water harvesting.

In planning of watershed development programme various type of soil and water conservation works such as bunding, terracing, nalabunding, underground dam, diversion ditches, vegetative waterways are taken up according to the availability of site, location and land capability classification. The conservation structures are integral part of soil and water conservation programs and are important component of the Watershed Development and Management programme. Conservation structures not only control the erosion and conserve the water but also help in meeting the socio-economical demands in various ways.

The study aims to study the effect of water conservation structures like graded bunds, earthen nala bund, cement nala bunds and continuous contour trenches on soil erosion and soil loss in the Raholi watershed.

2. Materials and Methods

Project implementing agency (PIA): The Raholi watershed development programme has been implemented by Department of Agriculture Government of Maharastra of Hingoli tehsil, dist. Hingoli under integrated watershed management programme.

General feature of Raholi watershed: Raholi watershed is part of Purna sub-basin, which drains in Godavari River. The micro watershed PPG-7/3/5 was implemented during the year 2010-11 in Raholi village, Hingoiltahasil of Hingoli district.

Location: The Raholi watershed is situated in Hingoli district of Marathwada region, which is 9 Km away from Hingoli city. It is located at 19º70’ Nlatitude and 77º07’ Elongitude.

Soil and topography: The total geographical area of Raholi watershed is 602 ha out of that 509.66 ha area is under cultivation. The topography of watershed is flat to undulating. The watershed comes under semi-arid area. The general slope of cultivable land ranges from 1 to 4 per cent while slope of non-cultivable area ranges from 3 to 15 per cent. The Raholi watershed area consists of two types of soils which are medium to deep black and lateritic soil. The population of Raholi village is 883, out of which 453 are males and 430 are females. The land capability classification and soil characteristics of Raholi watershed are given in following table.

Table 1: Land capability classification of Raholi watershed

Sr. No.	Land capability class	Area (ha)
1	Class –II	185.42
2	Class –III	306.00
3	Class –IV	50.25
4	Class –V	37.71
5	Class –VI	22.62
	Total	602.00

Climate: The watershed area falls within the tropical semi-arid zone of central Maharastra. The average annual rainfall ranges from 750-800 mm, which is uneven, erratic and varies from year to year. South-West monsoon is the major source of rainfall and about 90 per cent rainfall receives during monsoon season i.e from the month of June to October. The average maximum temperature of 44.40^{o}C is normally recorded during the month of April to May, while the lowest temperature is 15.60^{o}C recorded during December to January. The average temperature during rainy season varies from 30 to 37^{o}C. The average annual rainfall recorded at Raholi during monsoon 2015 was 452mm.

Soil and Water Conservation Treatment Details: The various soil and water conservation structures adopted at Raholi watershed are listed in following Tabl (2).

Table 2: Soil and water conservation structures in Raholi watershed

Sr. No.	Soil and water conservation structure	No. of structures constructed in watershed area	No. of structures under study
1	Graded Bunds	427.00	50 ha
2	Continuous Contour Trenches	60.33	8 ha
3	Earthen Nala Bund	1 No.	1 No.
4	Cement Nala bund	3 No.	3 No.

Graded bunds: Graded bunds are used for conservation of moisture and safe disposal of excess runoff in high rainfall areas with heavy soil. In Raholi watershed graded bunding were constructed in 427.00 ha area having the slope of 0-4%. Grade bunding involves the construction of earthen bund having section near about 2.20×0.50×0.80 m^2 along the longitudinal slope. In Raholi watershed from 427.00 ha area was under graded bunding out of which 50 ha area was selected for the study.

Continuous contour trenches: In Raholi watershed continuous contour trenching work was undertaken in 60.33 ha area at upper ridge of catchment area having sope ranges 4-12% to control runoff and soil erosion. Continuous contour trenching involves construction of small trench with section near about 0.6×0.3 m^2 along the contour line on non-cultivable land. The horizontal interval of trenches was in the ranges of 8 to 10 m. From the 60.33 ha area under trenching, an area of 8 ha was selected for the study.

Earthen Nala Bund: In Raholi watershed earthen nala bunds were constructed to harvest runoff and control soil erosion at specific side. Earthen nala bunds involve construction of the bund of suitable size across the nala or gully for interception of the runoff coming from catchment area and to create temporary water storage for few days or weeks. Earthen nala bund reduce the soil erosion and provide a mean of ground water recharge. One earthen nala bund was constructed along the gully which was selected for the study.

Cement Nala Bund: The cement nala bund is a permanent masonry structure which is constructed along a nala at suitable site for graded stabilization, improving water table and control erosion. In Raholi watershed development programme three cement nala bunds have been constructed to control the flow through nalas and impounding the water on its upstream side, which can used for domestic purpose or irrigation purpose. These three cement nala bunds were selected for the study.

2-1. Observations recorded

Measurement of dimensions of structures: In present study, different soil and water conservation structures like graded bund, continuous contour trenches, earthen nala bund and cement nala bunds were evaluated. The existing dimension of the structure i.e top width, bottom width and height were measured with the help of measuring tape and compared with the designed dimensions for determing the per cent change in dimension of different structures. Data of designed dimensions of each structure was collected from Office of Taluk Agriculture Office, Department of Agriculture, Hingoli (DistHingoli).

Measurement of silt deposition: The observation on silt deposition behind different structure i.e depth of silt deposited; area of silt deposited were recorded. For this, small pits were excavated in impounding area of the structure upto a depth of original ground surface at different location and average depth of silt deposited was determined. The area of silt deposited was measured. Volume of silt deposited at each structure was determined by multiplying the silt deposited area and depth of silt deposited. Weight of silt deposited was calculated by multiplying the volume of deposited silt to the bulk density of silt. The bulk density of silt was considered for calculation purpose was 1.32 gm/cc.

3. Results

Eight graded bunds, continuous contour trenches on 8 ha area, one earthen nala bund and three cement nala bunds were selected for their qualitative performance. The qualitative performance of selected structures has been evaluated on the basis per cent reduction in their cross-sectional area as well as silt deposition on upstream side of these structures.

3-1. Graded bunds (GB)

Table 1.1: The design and present dimensions of graded bunds

GB Line No.	Design dimensions				Present dimensions				Per cent reduction in C/S area (m^2)
	TW(m)	BW(m)	Ht(m)	C/S area (m^2)	TW(m)	BW(m)	Ht(m)	C/S area (m^2)	
1	0.50	2.50	0.80	1.20	0.65	2.50	0.55	0.87	27.50
2	0.50	2.50	0.75	1.13	0.70	2.50	0.46	0.73	35.40
3	0.50	2.30	0.90	1.26	0.55	2.30	0.63	0.90	28.57
4	0.50	2.50	0.85	1.26	0.72	2.50	0.57	0.92	26.98

GB Line No.	Design dimensions				Present dimensions			C/S area (m^2)	Per cent reduction in C/S area (m^2)
	TW(m)	BW(m)	Ht(m)	C/S area (m^2)	TW(m)	BW(m)	Ht(m)		
5	0.50	2.50	0.80	1.20	0.78	2.50	0.49	0.80	33.33
6	0.50	2.30	0.85	1.19	0.69	2.30	0.60	0.90	24.37
7	0.50	2.30	0.75	1.05	0.80	2.30	0.52	0.80	23.81
8	0.50	2.30	0.80	1.12	0.59	2.30	0.50	0.72	35.71
				Average					29.46

The results presented in table 1.1 indicates that for all selected graded bunds lines top width (TW) increased while the height (Ht)reduced with respect to design dimensions, also it was observed that there was no change in design and present bottom width (BW) of all graded bunds. Increase in top width and reduction in height might be due to compaction of bunds. It was clear from table 1.1 that per cent reduction in cross sectional area of graded bund ranges between 23.81 to 35.71 per cent with an average reduction in cross sectional area of 29.46 per cent as compared to design cross sectional area of graded bunds. Similar results were found by Patil & Bangal (1987).

3-2. Silt deposition at graded bunds

Table 1.2: Silt deposition at graded bunds

GB Line No.	Average depth of silt deposited (m)	Length of G.B (m)	Area of silt deposited (m^2)	Volume of silt deposited (m^3)	Weight of silt deposited (tonnes)
1	0.22	108.50	271.25	59.67	78.76
2	0.16	95.50	238.75	38.20	50.42
3	0.18	98.20	225.86	40.65	53.66
4	0.20	80.40	201.00	40.20	53.06
5	0.15	110.20	275.50	41.33	54.56
6	0.19	88.60	203.78	38.72	51.11
7	0.15	101.30	232.99	34.95	46.13
8	0.16	93.00	213.90	34.22	45.17
		Total silt deposition at graded bunds			432.87

From Table 1.2, it can be observed that average depth and area of silt deposited at selected graded bunds ranges between 0.15 to 0.22 m and 201.00 to 271.25 m^2 respectively while weight of silt deposited at different graded bunds ranges from 45.17 to 78.76 tonnes. About 432.87 tonnes silt has been deposited at all eight graded bunds over the period of four year after their construction. From the results obtained, it was found that graded bunds have helped in arresting the silt on their upstream side and thereby helped in reducing the soil loss.

3-3. Continuous contour trenches (CCT)

Table 2.1: The design and present dimension of continuous contour trenches

CCT Line No.	Design dimension				Present dimension				Per cent reduction in C/S area (m^2)
	TW (m)	BW (m)	H (m)	C/S area (m^2)	TW (m)	BW (m)	H (m)	C/S area (m^2)	
1	0.60	0.55	0.30	0.17	0.64	0.55	0.10	0.06	64.71
2	0.60	0.55	0.30	0.17	0.62	0.55	0.18	0.11	35.29
3	0.65	0.60	0.35	0.22	0.68	0.60	0.21	0.13	40.91
4	0.65	0.55	0.35	0.21	0.66	0.55	0.22	0.13	38.10
5	0.60	0.60	0.30	0.18	0.62	0.60	0.20	0.12	33.33
6	0.60	0.55	0.30	0.17	0.63	0.55	0.19	0.11	35.29
7	0.60	0.60	0.30	0.18	0.63	0.60	0.18	0.11	38.89
8	0.65	0.60	0.35	0.22	0.67	0.60	0.20	0.13	40.91
9	0.60	0.55	0.30	0.17	0.62	0.55	0.19	0.11	35.29
10	0.60	0.60	0.30	0.18	0.63	0.60	0.20	0.12	33.33
				Average					39.61

The data presented in table 2.1 indicates that for all selected CCTs top width has been increased, while height has been reduced during the period four years after their excavation. Increase in top width of CCTs might be due to inflow of water from upstream side while reduction in height might be due to deposition of silt. Reduction in cross sectional area of CCT was found in range between 33.33 to 64.71 per cent. On an average reduction in cross sectional area was found to be 39.61 per cent over a period of four years after its excavation. Storage capacity of CCTs has been reduced by 39.61 per cent due to deposition of silt. The results were in accordance with the results of Rajmane (2004), Deshmukh (2009) and Patil & Patil (2007)

Table 2.2: Silt deposited at different continuous contour trenches

CCT Line No.	Length (m)	Average depth of silt deposited (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Weight of silt deposition (tonnes)
1	456.00	0.20	250.80	50.16	66.21
2	496.00	0.18	272.80	49.10	64.81
3	358.00	0.21	214.80	45.10	59.53

CCT Line No.	Length (m)	Average depth of silt deposited (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Weight of silt deposition (tonnes)
4	432.00	0.22	237.60	52.27	68.99
5	410.00	0.20	246.00	49.20	64.94
6	466.00	0.19	256.30	48.69	64.27
7	380.00	0.18	228.00	41.04	54.17
8	420.00	0.20	252.00	50.40	66.52
9	480.00	0.19	264.00	50.16	66.21
10	400.00	0.20	240.00	48.00	63.36
		Total silt deposited at CCTs			639.01

From Table 2.2, it can be revealed that average depth and area of silt deposition at selected continuous contour trenches ranges between 0.18 to 0.22 m and 214.80 to 272.80 m^2 respectively while weight of silt deposited at different continuous contour trenches ranges from 54.17 to 68.99 tones. About 639.01 tones silt has been deposited at all ten continuous contour trenches over the period of four year after their excavation. From the results obtained, it was found that earthen embankment has helped in arresting the silt on their upstream side and thereby helped in reducing the soil loss. The deposition of silt and conservation of the moisture in CCTs created a favorable condition to stand good grass as well as vegetative cover on the bunds formed on downstream side of CCTs.

3-4. Earthen nala bunds (ENB)

Table 3.1: Design and present dimension of earthen nala bund

ENB No.	Design dimensions				Present dimensions				Per sent reduction in C/S area (m^2)
	TW(m)	BW(m)	H(m)	C/S area (m^2)	TW(m)	BW(m)	H(m)	C/S area (m^2)	
1	1.50	9.90	4.50	25.62	2.30	9.90	3.40	20.74	19.14

The data on change in dimension of earthen nala bund are presented in Table 3.1. From the comparison of designed and present dimension, it was observed that top width increased and height was decreased. It is observed that there is no change in bottom width of earthen nala bunds. From table 4.5 it is clear that that per cent reduction in cross sectional area of earthen nala bund is 19.14 per cent. These findings are similar to the findings of Pendke (2009). Reduction in cross sectional area of earthen nala bunds was due to the compaction and consolidation of bunds.

Table 3.2: Silt deposition at earthen nala bunds.

ENB No.	Catch-ment area (ha)	Designed storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Weight of silt deposition (tonnes)	Present storage capacity (m^3)	Per cent reduction in storage capacity (%)
1	80	19699.20	0.48	1604.55	770.18	1016.64	18929.02	3.91
	Total silt deposition at earthen nala bunds					1016.64		

From Table 3.2, it was observed that depth of silt deposited at earthen nala bund was 0.48 m and area of silt deposition was 1604.55 m^2, Weight of silt deposition was found to be 1016.64 tonne during the period of four years after its construction. The per cent reduction in storage capacity of earthen nala bund was 3.91 per cent. It was clear that the storage capacity of earthen nala bund has been reduced due to deposition of the silt.

3-5. Cement nala bunds (CNB)

Table 4.1: Design and present dimension of cement nala

CNB No.	Design dimensions				Present dimensions				Per sent reduction in C/S area (m^2)
	TW (m)	BW(m)	H(m)	C/S area (m^2)	TW (m)	BW (m)	H (m)	C/S area (m^2)	
1	1.20	1.80	2.50	3.75	1.20	1.80	2.50	3.75	NIL
2	0.80	1.40	2.30	2.53	0.80	1.40	2.30	2.53	NIL
3	0.60	1.20	2.00	1.80	0.60	1.20	2.00	1.80	NIL

The Table 4.1represented that the design dimension of three cement nala bunds which were selected in Raholi watershed for study were not changed. This might be due to the construction of structures with permanent material like cement, sand and stone etc. No change was observed in the cross-sectional area of selected cement nala bunds over the period of four years after their construction

Table 4.2: Silt deposition at cement nala bunds

CNB No.	Catch-ment area (ha)	Designed storage capacity (m^3)	Average depth of silt deposition (m)	Area of silt deposition (m^2)	Volume of silt deposition (m^3)	Weight of silt deposition (tonnes)	Present storage capacity (m^3)	Per cent reduction in storage capacity (%)
1	150	5737.50	0.13	1073.25	139.52	184.16	5597.98	2.43
2	208	4278.00	0.16	746.32	119.412	157.62	4158.58	2.79
3	110	1700.00	0.15	510.00	76.50	100.98	1623.50	4.5
	Total silt deposition at cement nala bunds					442.76		

From table 4.2, it can be concluded that average depth and area of silt deposited at CNB 1, CNB 2, CNB 3 were 0.13, 0.16 and 0.15 m and 1073.25, 746.32, 510.00 m^2 respectively. The weight of silt deposited at CNB 1, CNB 2 and CNB 3 were found to be 184.16, 157.62 and 100.98 tonnes respectively. The total silt deposited in all cement nala bunds was found to be 442.76 tonnes during the period of four years after their construction. The per cent reduction in storage capacity of CNB 1, CNB 2 and CNB 3 was found to be 2.43, 2.79 and 4.5 per cent respectively over the period of four years from their construction. The reduction of storage capacity was due to deposition of silt in the nala on the upstream side of these cement nala bunds.

4. Conclusion

Based on the results obtained following conclusions are drawn;

1. Reduction in cross sectional area of graded bund was found in the range between 23.81 to 35.71 per cent. On an average reduction in cross sectional area is found to be 29.46 per cent over a period of four years after their construction.

2. Reduction in cross sectional area of CCT was found in range between 33.33 to 64.71 per cent. On an average reduction in cross sectional area was found to be 39.61 per cent over a period of four years after its excavation. The reduction in storage capacity of CCTs was due to deposition of silt.

3. Reduction in cross sectional area of earthen nala bunds was found 19.14 per cent over a period of four years after their construction. Reduction in storage capacity of earthen nala bund was found 3.91 per cent over the period of four years after its construction.

4. No change in the dimension of three cement nala bunds was found at the post development stage of the watershed. Reduction in the storage capacity of the cement nala bunds was found in range to be 2.43 to 4.50 per cent over a period of four years after their construction.

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