Evaluation of specifications for graded bunds and suitable intra-terrace measures in the deep black soils of semi-arid region of South India

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Abstract

Soil loss from Vertisols of semi-arid region of India ranges from 12 to 65 t/ha. To prevent soil erosion, drainage type of terraces (graded bunds) having 0.8 sq. m. cross section connected to waterways are presently recommended at 1.0 m vertical interval. In order to make conservation programme cost effective, a study was initiated to determine optimum cross section (0.4, 0.6 and 0.8 sq.m.) and spacing (0.50, 0.75 and 1.25 m) of graded bunds and their impact on runoff, soil loss and grain yield of sorghum. The impact of intra-terrace land management practices such as border strips, vertical mulch were also evaluated for resource conservation and land productivity. Across 3 years (1993-94 to 1995-96), graded bund at 0.75 m vertical interval with 0.6 sq. m. cross section recorded highest grain and straw yield of sorghum (1271 and 2021 kg/ha, respectively), followed by the treatment consisting of 0.75 m vertical interval with 0.8 sq.m. cross section (1256 and 1953 kg/ha, respectively) as against control yield of 879 and 1485 kg/ha. Among intra-terrace treatments, border strips and vertical mulch recorded 884 and 856 kg/ha of grain yield respectively, which was 46 and 42 per cent higher than control. Agro-horti treatment recorded 5 per cent increase in sorghum yield in addition to fruit yield of 73, 6, 7 and 34 kg/plant of ber, drumstick, sapota and pomogranate, respectively. Lowest runoff (17 mm) and soil loss (0.57 t/ha/year) were recorded from bunds with 0.6 sq.m. cross section spaced at 0.75 m vertical interval, as against 66 mm runoff and 3.81 t/ha/year soil loss observed under control. Considering the cost and maintenance of bunds 0.6 sq.m. cross section is ideally suited for these black soils. Among the intra-terrace treatments border strip recorded lowest runoff and soil loss and control recorded highest runoff and soil loss.

Additional keywords: Vertisols, runoff, soil loss, soil productivity, sorghum yield.

Introduction

Vertisols and associated soils occupy about 73 m ha and are mostly confined to the semi-arid areas of the central plateau of India (Murthy 1988). Due to poor physical conditions these soils are problematic and can be cultivated only within a narrow range of soil moisture content. Medium and deep black soils are, therefore, usually kept fallow during *kharif* and cropped only in post-rainy season. In these black soils, dryland/rainfed agriculture is the major land use and as such they remain devoid of vegetative cover during most part of the year. These soils have a rolling topography with mild slopes (<6 per cent) extending over long lengths. Low infiltration rate (0.5 to 5 mm/hr), poor structure due to low organic matter and the presence of high exchangeable sodium, renders them highly erodible with *k* (erodibility factor) values ranging from 0.3 to 0.6 (Rama Mohan Rao and Seshachalam 1976). The soil losses to the extent of 12 to 65 tons/ha are reported from these soils which reduces the soil fertility, finally affecting the productivity of land (Kanitkar *et al* 1960; Dhruvanarayana and Rambabu 1983). Reduction in soil depth due to erosion has caused the irretrievable loss of agricultural land and its productivity (Tejwani 1980; Rama Mohan Rao 1996).

Based on the earlier studies on the performance of different mechanical measures, drainage type of terraces (graded bunds) having 0.8 sq.m. cross section connected to waterways are recommended at 1 m vertical interval for erosion control in the deep black soils

(Chittaranjan *et al.* 1980). Land management practices influence *in situ* conservation of rain water and ultimately crop productivity. Different practices such as vertical mulching (V.M.), graded border strips (B.S.) etc., earlier identified were found to have positive influence on moisture conservation at field/plot level (Rama Mohan Rao *et al.* 1978). Therefore a study was initiated in deep black soils at Central State Farm, Jawalgera, Raichur district, Karnataka State during 1992 and continued till 1995, to know the optimum cross section (C.S) and spacing for graded bund and *in situ* land management practices B.S., V.M. and others on runoff, soil loss and sorghum grain yield, as this information is vital to make the conservation programme cost effective for watershed development.

Materials and methods

Experimental site is located at Central State Farm, Jawalagera, Sindhanur district (Karnataka, India) which is situated at 360 m above MSL in semi-arid agroecological zone. The physico-chemical characteristics of soil is presented in Table 1, and the morphological description of soil profile in Table 2.

Table 1. Physico-chemical characteristics of soil

Depth (cm)	Sand (2-0.05 mm) %	Silt (0.05-0.002 mm) %	Clay (<0.002 mm) %	Moisture (%) 33 kPa	Moisture (%) 1500 kPa	Moisture (%) Available	$CaCO_3$ (%)	pH (1:2.5 H_2O)	EC dS m^{-1}	OC (%)	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
0-15	19.5	18.7	47.9	44.6	28.6	16.0	13.4	9.0	0.54	0.65	12.4	520
15-30	15.3	18.4	48.2	48.0	29.0	19.0	11.1	9.0	0.68	0.60	11.2	520
30-60	24.8	17.0	51.6	49.6	30.4	19.2	12.5	8.7	1.62	0.59	8.4	552
60-90	25.8	17.2	51.8	52.1	31.1	21.0	12.9	8.3	2.81	0.52	3.7	520
90-120	26.2	15.6	52.1	52.4	31.2	21.2	13.8	8.4	2.60	0.39	2.5	553

Table 2. Description of soil profile

Horizon	Depth (cm)	Description
Ap	0-15	Very dark grey (10YR 3/1 M) clay; gradual boundary; moderate medium subangular blocky structure, hard, firm, sticky and plastic, many thin roots, cracks more than 20 mm wide, few fine lime nodules, violent effervescence, pH 9.0.
A	15-30	Very dark grey (10 YR 3/1M) clay, gradual boundary, moderate medium subangular blocky structure, hard, firm, sticky and plastic, common fine roots, few quartz fragments, slightly effervescent, pH 9.0.
Bss1	30-60	Very dark grey (10 YR 3/1M) clay, gradual boundary, strong medium to coarse angular blocky peds, very firm, very sticky and very plastic, many thin roots, fine lime concretions, violent effervescence, pH 8.7.
Bss2	60-90	Very dark grey (10YR 3/1M) clay, gradual boundary, slickensides, strong medium coarse angular blocky peds, very firm, very sticky and very plastic, few fine roots, few irregular nodules and quartz fragments, violent effervescence, pH 8.3.
Bck	90-120	Very dark grey (10YR 3/1M) clay, with coarse lime concretions, strong coarse angular blocky peds, very firm consistency, few very fine roots, violent effervescence, pH 8.4.

Graded bunds having different specifications viz., cross sections (C.S) of 0.4, 0.6 and 0.8 sq.m. with three vertical intervals (V.I) of 0.75, 1.00 and 1.25 m, were formed with each treatment having 0.75 ha catchment area and were time replicated. Each plot was fitted with a V-notch and stage level recorder for measuring runoff. Soil loss was computed by collecting part of the runoff with time, by determining the sediment load. The dimensions of graded bunds are given in Table 3. In order to study the impact of intra-terrace measures on runoff, soil loss and productivity, in a separate experiment four plots of 100 x 100 m were established and intra-terrace area was superimposed with (i) B.S. of 10 m width on contour with no cross slope; (ii) V.M. at 8 m apart on contour, using sorghum stubbles of 15 cm wide and 30 cm long placed in trenches protruding 10 cm above the ground level to act as vertical drains and (iii) agro-horti system with paired rows of horticultural plants spaced at 3 m x 6 m with staggard planting separated by 12-15 m in blocks of 0.5 ha each for drumstick, pomogranate, ber and sapota. These plots were fitted with Ramser samplers for collecting 1/100th portion of runoff and sediment samples to estimate runoff and soil loss along with control. Sorghum (SPV-86) was sown with rains during September-October and was harvested during February-March for yield estimations after following the recommended package of practices. Total annual rainfall received during 1993, 1994 and 1995 are given in Table 4.

Table 3. Dimensions of graded bunds

Cross section of graded bunds (m^2)	Measurements of bund (m)			
	Top width	Bottom width	Depth	Side slope
0.40	0.40	1.60	0.40	1.5:1
0.60	0.45	1.95	0.50	1.5:1
0.80	0.45	2.25	0.60	1.5:1

Table 4. Rainfall data at Central State Farm, Jawalagera

Month	Rainfall (mm)		
	1993	1994	1995
January	0.0	0.0	8.2
February	0.0	0.0	0.0
March	0.0	0.0	6.0
April	0.0	0.0	1.0
May	2.4	8.8	49.8
June	2.0	12.6	140.2
July	141.5	71.7	122.5
August	113.4	49.4	69.4
September	154.0	0.0	114.3
October	206.0	293.4	202.1
November	0.0	14.8	0.0
December	60.5	0.0	0.0
Total	680.7	450.7	713.5

Results and discussion

Terrace level measures

(a) Runoff and soil loss: The catchment characteristics of the experimental plots under study are given in Table 5. There were ten, seven and one runoff causing events with 403, 210 and 58 mm during 1993, 1994 and 1995, respectively. For comparison of the graded bund treatments, runoff and soil loss from all the runoff producing storms (only storms of rainfall more than 25 mm) occurring in a particular year are summed up to give a cumulative runoff and soil loss in t/ha/year (Table 6). During all the three years 1993, 1994 and 1995, the highest runoff (143.0, 33.9 and 21.3 mm) and soil loss (7.59, 1.83 and 2.02 t/ha/year) was recorded in control respectively, whereas the lowest runoff (35.2, 1.2 and 14.3 mm) was recorded in the treatment having bunds of 0.6 sq.m. C.S. at 0.75 m V.I. Only during 1993 lowest soil loss (0.94 t/ha/year) was observed in the treatment having bunds of 0.8 sq.m. C.S. at 0.75 m V.I. followed by the treatment having bunds of 0.6 sq.m. C.S. and 0.75 m V.I. (1.09 t/ha/year). During both the years 1994 and 1995, the lowest soil loss (0.06 and 0.56 t/ha/year) was recorded in the treatment having bunds of 0.6 sq.m. C.S. at 0.75 m V.I. The bunds of 0.4 sq.m. C.S. at all V.I.s were found to be vulnerable to damages and breaches due to swelling and shrinkage characteristics of soils. The results are in confirmity with the findings of Katti (1981). Hence 0.4 sq.m. C.S. may not be useful in black soils. Observations carried out on rill formation revealed that least number of rills with 0.6 sq.m C.S. at 0.75 m V.I. followed by 0.8 sq.m. C S. at 0.75 m V.I. when compared to 0.4 sq.m C.S. at 0.75 m V.I. and control.

Table 5. Catchment characteristics

Sl. No.	Description of parameter	Control plot	0.5m VI Graded bund			0.75 m VI Graded bund			1.25 m VI Graded bund		
			0.40 sq.m C.S	0.60 sq.m C.S	0.80 sq.m C.S	0.40 sq.m C.S	0.60 sq.m C.S	0.80 sq.m C.S	0.40 sq.m C.S	0.60 sq.m C.S	0.80 sq.m C.S
1.	Area in ha (A)	1.50	0.27	0.23	0.29	0.37	0.46	0.47	0.67	0.65	0.60
2.	Difference in elevation between remote and outlet points (m)	2.70	0.78	0.68	0.63	0.49	0.69	1.09	1.05	1.15	0.98
3.	Length of water stream (L) in m	380	84	77	83	101	96	113	126	154	138
4.	Farm factor (W/L)	0.10	0.38	0.39	0.42	0.36	0.50	0.37	0.42	0.28	0.32
5.	Perimeter (m) P	851	222	226	238	248	290	302	362	356	351
6.	Compactness coefficient[a]	1.95	1.20	1.32	1.23	1.14	1.20	1.23	1.24	1.23	1.26
7.	Slope percentage (H/L) x 100 (S)	0.71	0.92	0.88	0.76	0.49	0.72	0.96	0.84	0.75	0.71
8.	Average width (m)[b]	39	3	30	35	37	48	42	53	42	44
9.	Time of concentration (minutes) (Tc)[c]	13	4	3	4	5	4	4	5	6	6

VI - Vertical Interval C.S - Cross Section.

a) $\dfrac{0.28\ P}{\sqrt{A \times 10000}}$ b) $\dfrac{A\ (m^2)}{L\ (m)} = (W)$ c) $Tc = 0.01948 \times \dfrac{L^{0.77}}{S^{0.38}}$

Table 6. Influence of size (C.S.) and spacing (V.I.) of bund on runoff (mm) and soil loss (t/ha/year)

Year	Rainfall (mm)	0.6 sq.m cross section graded bund						0.8 sq. m cross section graded bund							
		0.5 m VI		0.75 m VI		1.25 m VI		0.5 m VI		0.75 m VI		1.25 m VI		Control	
		RO	SL	RO	SL	RO	SL	RO	SL	RO	SL	RO	SL	RO	SL
1993	197	110.9	3.65	35.2	1.09	58.1	2.22	116.8	4.58	76.1	0.94	93.7	2.09	143.0	7.59
1994	65	29.2	2.34	1.2	0.06	13.0	1.30	13.9	0.61	7.0	0.47	12.4	0.88	33.9	1.83
1995	58	31.3	1.16	14.3	0.56	15.9	0.86	31.8	1.19	24.2	0.91	18.7	0.82	21.3	2.02
Av.	106.7	57.1	2.38	16.9	0.57	29.0	1.46	54.2	2.13	35.8	0.77	41.6	1.26	66.1	3.81

VI - Vertical Interval RO - Runoff (mm) SL - Soil loss (t/ha)

(b) Crop performance: Across three years, bunds of 0.6 sq.m. C.S. at 0.75m V.I. recorded highest grain (1271 kg/ha) and straw (2021 kg/ha) yield which were 45 per cent and 36 per cent more than that recorded under control (Table 7) (Anonymous 1981). The positive influence of mechanical measures in controlling runoff and increasing yields was reported earlier by Dixit (1981) and Ramaiah (1981).

Table 7. Grain and straw yield (kg/ha) as influenced by different specifications of bunds

Cross section (m^2)	Grain						Straw					
	Vertical interval (m)						Vertical interval (m)					
	Control	0.50	0.75	1.25	Mean	Increase (%)	Control	0.50	0.75	1.25	Mean	Increase (%)
Control	879	—	—	—	879	—	1485	—	—	—	1485	—
0.40	—	930	1140	1011	1024	17	—	1922	1909	1532	1788	20
0.60	—	1039	1271	1140	1117	27	—	1945	2021	1911	1959	32
0.80	—	1017	1256	960	1017	16	—	1642	1953	1529	1708	15
Av.	879	995	1222	1037	—	—	1485	1803	1961	1657	—	—
Increase over control(%)		13	39	18	—	—	—	21	32	12	—	—

Across V.I. 0.6 sq.m. C.S. recorded 27 and 32 per cent more grain and straw yield over control. Across the three C.S.'s , 0.75 m V.I. recorded 39 per cent more yield compared to control. Yield increases were similar in case of straw also.

The results prove that, in medium to deep black soils the size of the graded bund could be safely reduced to 0.6 sq.m. C.S. as against presently recommended 0.8 sq.m. C.S. for reducing runoff and soil loss which would save considerable money in terms of reduced earth work.

Intra-terrace treatment

(a) Runoff and soil loss: For comparison of the intra-terrace treatments, runoff and soil loss from all the runoff producing storms (only storms of rainfall more than 25 mm) occurring in a particular year are summed up to give a cumulative runoff and soil loss in t/ha/year (Table 8). Among the intra-terrace treatments, during both the years 1994 and 1995, formation of border strips produced least runoff (10.6 and 7.4 mm) and soil loss (0.62 and 0.05 t/ha/year) respectively followed by agro-horti and vertical mulch. Similar results were reported by Itnal (1996) and Gupta *et al.* (1994) in black soils of Bijapur and Indore, respectively.

(b) Crop performance: The highest grain yield was recorded in B.S. (884 kg/ha), followed by V.M. (856 kg/ha) and lowest was in control (605 kg/ha), whereas V.M. recorded 1767 kg/ha of straw, followed by BS (1729 kg/ha) and the lowest was in control (1156 kg/ha) (Table 9). Agro-horti system recorded 638 and 1353 kg/ha grain and straw yield respectively. In addition horticultural plants started yielding fruits from 1994 onwards. Across two years (1994 to 1995) the fruit yields of pomogranate, sapota, drumstick and ber were 34, 6.5, 6.3 and 73 kg/plant, respectively. Converting the economic yields under different treatments into sorghum grain equivalent the treatment with B.S. recorded a maximum of 1044 kg/ha followed by V.M. (1924) kg/ha and lowest (731) kg/ha from control (Table 10). However, the alternate land use of agro-horti system would be superior to the rest when fruit trees start yielding at their potential due to high value of the fruits apart from its efficiency in resource conservation.

Table 8. Runoff, soil loss and rainfall relationship as influenced by different intra-terrace management techniques

Year	Runoff causing rainfall (mm)	Control			Border strip			Vertical mulch			Agro-horti system		
		RO	% RO	SL	RO	% RO	SL	RO	% RO	SL	RO	% RO	SL
1994	154	24.8	16.1	1.79	10.6	6.9	0.62	16.9	11.0	0.68	15.2	9.9	1.01
1995	58	11.8	20.3	0.13	7.4	12.8	0.05	8.5	14.7	0.07	10.4	17.9	0.11
Average	106	18.3		0.96	9.0		0.34	12.7		0.38	12.8		0.56

RO - Runoff (mm); % RO - % of runoff to runoff causing rainfall; and SL - soil loss (t/ha/year)

Table 9. Effect of intra-terrace management techniques on grain and straw yield (kg/ha) of *rabi* sorghum

Treatments	1993-94		1994-95		1995-96		Average of 3 Years		Per cent increase	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Control	1101	1533	386	933	327	1001	685	1156	--	—
Border strip	1154	1733	557	1333	540	2120	884	1729	46	50
Vertical mulching	1627	2000	514	1200	427	2100	856	1767	42	53
Agro-horti system	1121	1600	431	1000	361	1460	638	1353	6	17

Table 10. Effect of intra-terrace management techniques on the sorghum grain equivalent

Treatments	1993-94	1994-95	1995-96	Average
Control	1268	488	436	731
Border strip	1743	618	771	1044
Vertical mulch	1845	570	656	1024
Agro-horti system	1296	602	821	906

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