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Evaluation of Contour Vegetative Barriers as Soil and Water Conservation Measures in Arid Lands

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Abstract: Contour vegetative barriers (CVB) of locally adapted, drought resistant plant species were evaluated for their effectiveness in reducing runoff and soil loss in the farmers' fields. Perennial grasses of desert tract performed the best and formed effective barriers against soil erosion from second year onwards. The runoff was reduced by 28 to 97% with negligible soil loss. The resultant overall 2.5 times increase in soil moisture storage increased yield of clusterbean crop by 37 to 51%. These barriers are inexpensive and acceptable to the farmers in the Indian arid zone.

Key words: Vegetative barriers, vertical interval, runoff, soil loss, soil moisture, yield.

In arid regions the desertification is often connected with extensive soil erosion since these regions have a potential for generation and transportation of large quantities of sediment due to torrential rainfall, erodible soils and human interference with biosphere (Sharma *et al.*, 1993). The engineered soil and water conservation measures such as bunding, furrowing, terracing, etc., are too expensive and are difficult to maintain over a long period (Wilborts, 1995).

The farmers do not feel themselves involved with such techniques and these are essentially the government sponsored programmes (Graaff, 1993). Today the focus of soil and water conservation programmes is, how the farmers can manage their lands and maintain or restore the productivity of their soils. For this they need cheap and easily implementable practices (Dano and Siapno, 1992). With a growing interest in the protection of environment, there is a revival in the use of vegetation for soil and water conservation in the developing countries.

The World Bank (1990) makes grandiose claims for the capability of *Vetiveria zizanioides* grass in controlling the soil erosion. However, due to adverse climatic and edaphic factors this grass does not grow effectively in the Indian arid zone. Therefore, there is a need to evaluate suitable plant species from the indigenous drought resistant floral elements to form the effective contour vegetative barriers (CVB) against soil erosion in the arid lands. These barriers could be planted with or without support of the earthen embankments.

Materials and Methods

Study on the performance of CVB as soil and water conservation measures was conducted from 1992 to 1994 in nineteen farmers' fields in area ranging from 0.8 to 3.8 ha at village Bhujawar near Jodhpur (26.5°N, 73.1°E), India. The area receives

an average rainfall of 360 mm per annum in 17 rainy days; 90% of which occurs during the monsoon period from June to September. The rainfall variability from year to year is high with a standard deviation of 123 mm and coefficient of variation of 49%. The soils are sandy loam to loamy sand and are deep to very deep. The region is subjected to severe sheet and rill erosion.

Rooted slips of 8 species of perennial grasses, and seedlings of 6 species of shrubs (Table 1) were transplanted during 1992 on contours at 1 m vertical interval and clusterbean (*Cyamopsis tetragonoloba*) was grown in between the rows of CVB. The average width of each CVB was 1 m. The fields were bounded by earthen banks. Data on rainfall, runoff, soil loss, soil moisture storage, growth and performance of barriers, and crop production were recorded.

Results and Discussion

Runoff, soil loss and soil moisture storage

The area received 387, 280 and 544 mm rainfall during the growing season in 1992, 1993 and 1994, respectively. Fourteen rainfall events generated runoff in a period of three years. The rainfall events varied from 8 to 94 mm with duration ranging from 20 minutes to about 11 h. The rainfall intensity for a five minute duration ranged between 3 and 150 mm h^{-1}

Reduction in runoff volume and peak flow was recorded in the CVB fields over control. The runoff volume was reduced by 28 to 97% and the specific peak discharge was reduced by 22 to 96% (Table 2). The *Vetiver* CVB reduced runoff volume by 30 to 47% (World Bank, 1990). Also the CVB fields stored 10.6 to 24.6 cm m^{-1} soil moisture compared to 4.3 to 9.9 cm m^{-1} in the control fields (Table 2). Figure 1 depicts an observed sample runoff hydrograph. The CVB do not channelise runoff, as do engineered measures, but allow surface runoff to slowly flow through the hedge resulting in greater opportunity time for rainwater infiltration. Infiltration reduces the volume of potentially erosive surface flow. The flow retarding effect of CVB may provide additional control on the velocity of flow. Dalton *et al.* (1996) named the CVB as 'flow-through' system in contrast to the conventional diversion system used in contour bunds.

Table 1. Plant species tried as contour vegetative barriers.

Grass	Shrub
Cenchrus ciliaris, Linn.	*Agave americana*, Linn.
Cenchrus setigerus, Vahl.	*Aloe barbedensis*, Mill.
Cymbopogon jwarancusa, Jones. (Schult)	*Barleria prionitis*, Linn.
Lasiurus sindicus, Henr.	*Euphorbia antisyphylitica*, Zucc.
Panicum turgidum, Forsk.	*Ipomoea carnea*, Cooke
Panicum antidotale, Retz.	*Leptadenia pyrotechnica*, Forsk. (Decne)
Saccharum bengalense, Retz.	
Vetiveria zizanioides, Linn. (Nash)	

Table 2. Summary of mean observed rainfall, runoff, soil loss and soil moisture storage data

Date	Rainfall (mm)	With CVB				Without CVB			
		Runoff (mm)	Specific peak discharge (l/s/ha)	Soil loss (kg/ha)	Soil moisture storage (cm/m)	Runoff (mm)	Specific peak discharge (l/s/ha)	Soil loss (kg/ha)	Soil moisture storage (cm/m)
19 Jul 92	8.0	0.4	1.2	1.59	10.6	2.1	7.5	504.00	4.3
2 Sep 92	11.9	2.7	13.2	8.91	11.4	4.7	27.2	310.20	5.5
3 Sep 92	37.5	5.1	23.1	5.09	13.8	8.0	39.3	528.23	7.3
4 Sep 92	93.5	17.7	32.6	32.75	24.6	24.6	92.6	1169.74	9.9
10 Sep 92	40.5	3.5	15.3	7.68	15.5	7.3	22.2	630.72	7.6
26 Jun 93	71.0	3.8	3.3	6.50	16.2	7.5	11.6	378.75	8.9
12 Jul 93	52.4	2.5	1.8	2.51	14.9	5.3	2.3	457.92	8.7
16 Jul 93	8.7	0.8	1.1	2.12	10.8	4.7	18.6	406.08	5.2
17 Jul 93	83.5	14.2	10.3	14.69	23.1	20.9	18.2	689.70	9.9
18 Jul 93	79.1	14.5	14.2	9.80	17.7	23.1	24.9	473.25	9.5
19 Jul 93	21.2	0.2	0.2	7.25	12.4	1.1	0.4	273.46	6.0
30 Jun 94	13.7	0.1	1.1	3.98	11.2	3.0	31.8	869.55	6.8
1 Jul 94	77.1	1.9	12.4	7.03	16.6	4.9	22.7	193.06	9.2
13 Aug 94	10.0	0.4	6.5	3.0	10.3	8.5	19.9	487.05	4.9

The CVB fields lost an average 8.07 kg ha^{-1} soil compared to 526.84 kg ha^{-1} under control. Thus, there is a negligible soil loss with CVB of native plant species as against 43 to 74% decrease in the soil loss with *Vetiver* CVB (World Bank, 1990). The CVB of native plant species decreased soil loss within tolerance limit of 5-10 kg ha^{-1} (Morgan, 1979). In general, the sheet and rill erosion were checked to a greater extent.

Performance of CVB

A refinement of the selected plant species which can form an effective contour vegetative barrier against soil erosion is essential (Clark and Howell, 1992). This comprises of critical evaluation of the vegetation on site by recording survival rates and the rates and characteristics of growth of plant roots and canopies.

The rooted slips of grasses developed at the farmers' fields and transplanted on contours at 1 m vertical interval had 92% survival rate. These grasses developed into clumps of 10-15 cm diameter in the first year and 25-40 cm diameter in the second year. The grass species such as *Cymbopogon jwarancusa, Cenchrus ciliaris* and *Cenchrus setigerus* performed exceedingly well and formed effective barriers against soil erosion in a span of two years as against 1-4 years for the *Vetiver* grass (World Bank, 1990).

Amongst all the fields, the highest seed yield of clusterbean was obtained in the field having CVB of *Cymbopogon jwar-*

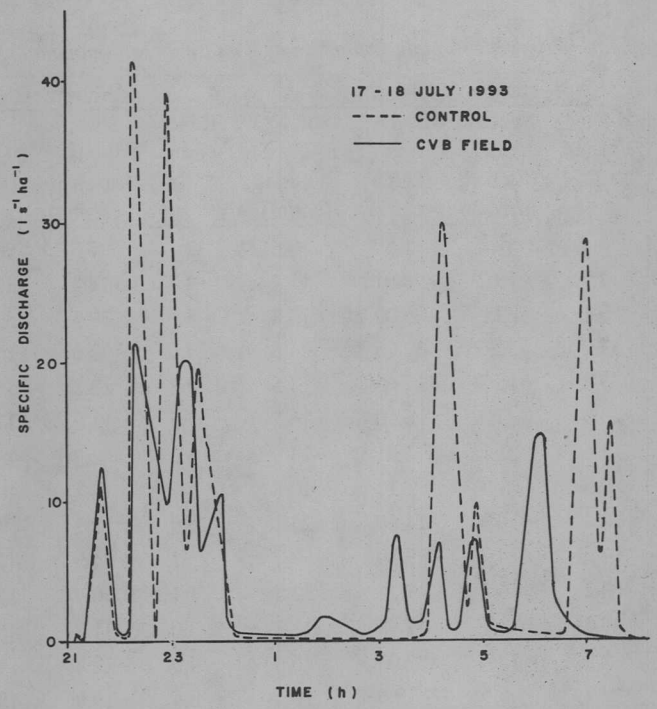

Fig. 1. An example of effect of contour vegetative barriers on runoff hydrograph.

ancusa and *Cenchrus ciliaris* followed by *Barleria prionitis* and *Cymbopogon jwarancusa* (Table 3). The seed yield increased between 37 and 51% over control. These yield averages are significantly higher than only 6 to 26% increase with the *Vetiver* CVB (World Bank, 1990). The clusterbean seed production was the highest during 1994 due to better rainfall regime.

There is an increase in plant density to the tune of 120 and 300% in the annual and perennial grasses, respectively, during third year in the CVB causing reduction in the perennial weeds by 81% and elimination of sedges (Table 4). The better grass density and good growth might be attributed to the improved moisture regime in the CVB.

Table 3. Yield of clusterbean under different contour vegetative barriers

Contour	Seed yield (kg/ha)			
	1992	1993	1994	Mean
Cenchrus	543	390	1283	739
Barleria + *Cymbopogon*	469	333	1459	754
Cenchrus + *Cymbopogon*	1122	375	989	829
Euphorbia	408	626	1252	762
Control	496	378	772	549

Table 4. Plant density (m^{-2}) of ground vegetation in CVB

	Year			Growth over
	1992	1993	1994	1992 (%)
Annual grasses	59.5	151.0	130.0	119.5
Perennial grasses	1.0	10.5	4.0	300.0
Annual weeds	20.0	46.5	24.0	20.0
Perennial weeds	5.5	1.5	1.0	-81.0
Sedges	6.0	0.5	0.0	0.0

Social acceptability

In the study area the CVB of indigenous species of economic importance, were found to be the most acceptable by the farmers. These farmers believe that the CVB are less expensive, easy to raise, less labour intensive and provide nutritive fodder for utilization in the lean periods.

Conclusion

Attempts to introduce universally applicable plant species as CVB against soil erosion have not been as successful as may have been supposed for the arid lands. The indigenous, drought tolerant grasses form the effective barriers in the arid region; their effectiveness increases with time. They are more acceptable to the farmers because they are cheap and provide forage to animals during the dry season.

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