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Scientific Contribution
No.: INCOH/SAR-5/95

RESEARCH IN SOIL AND WATER CONSERVATION IN INDIA WITH SPECIAL EMPHASIS ON WATERSHED MANAGEMENT

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INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
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INDIAN NATIONAL COMMITTEE ON HYDROLOGY
(Committee Constituted by Minsitrry of Water Resources, Govt. of India)

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by the Panel are worth mentioning. The report has been compiled and finalised by Dr. K.K.S. Bhatia, Member Secretary of the Indian National Committee on Hydrology.

It is hoped that this state-of-art report would serve as a useful reference material to practicing engineers, researchers, field engineers, planners and implementation authorities, who are involved in correct estimation and optimal utilization of the water resources of the country.

(S.M. Seth)
Executive Member, INCOH
& Director, NIH

Roorkee

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INTRODUCTION

Soil erosion may be defined as the detachment and transportation of the soil. When natural vegetation and trees are cleared for agricultural purposes, the natural protection for the soil is disturbed and the soil detachment and movement occur at great speeds. In a recent analysis of annual soil erosion rates in India (Narayana and Ram Babu, 1983), it was estimated that about 5333 million tonnes (16.35 t/ha) of soil is detached annually due to agriculture and associated activities alone and of this, about 29 percent is carried away by the rivers into the sea. Nearly 10 percent of it, is being deposited in our surface reservoirs resulting in the loss of 1 to 2 percent of the storage capacity (Table 1).

Table 1. Annual soil loss estimates in different regions of India (Narayana et al. 1983).

Land resource region	Area in thousands of sq. km.	Soil loss (t/sq km)	Major land use
North Himalayan forest region	131.70	287	Forest
Punjab-Haryana alluvial plains	101.25	330	Agriculture
Upper Gangetic alluvial plains including ravines	200.00	1410-3320	Agriculture or wasteland
Lower Gangetic alluvial plains	145.50	287- 940	Agriculture
North-eastern forest region	161.00	2780-4095	Agri., shifting cultivation
Gujarat alluvial plain region (including ravines)	62.75	240-3320	Agriculture
Red soil region	68.80	240- 360	Agriculture
Black soil region	67.34	2370-11250	Agriculture
Lateritic soils	61.00	3930	Agriculture

The soils are impoverished in this manner, dislocated from one place to the other, leading to the deposition of the soil on lands in lower regions, in reservoirs, in waterways and harbours. We hear of and see disastrous floods all over the country so often due to this vicious process.

Research in Soil and Water Conservation in India with Special Emphasis on Watershed Management

In our country, where droughts and floods cause chronic disasters, soil and water conservation measures can, not only increase crop yields, but also prevent further deterioration of land. Large-scale soil and water conservation activity began in India as early as 1951. Till the end of 1983-84, Rs.8616 million have been spent on improvement of about 25.8 million hectare of land through various soil and water conservation measures (Anonymous, 1984). In the early phases, the programmes were mainly confined to the improvement of agricultural lands, contour bunding being the principal activity.

In the last two decades, however, the concept of integrated land use planning on watershed basis was introduced. This was mainly due to the establishment of a chain of Soil Conservation Research Demonstration and Training Centres in the different regions of the country during the First and Second Five Year Plans. In the last three decades, these Centres have identified the Soil and Water Conservation problems of the country and produced some practical technologies for field application.

The various Soil and Water Conservation Centres of the country were brought under the jurisdiction of Indian Council of Agricultural Research in 1967, which, in turn, established the Central Soil & Water Conservation Research and Training Institute, with the headquarters at Dehradun and the other Centres as its Regional Stations.

The Institute and its six Regional Stations are located, broadly, in three different regions. These are :

a) Hill region - in which the main Institute at Dehradun and its regional Stations at Chandigarh and Ootacamund are located.

b) Ravine region - in which the regional Stations at Agra, Kota and Vasad are included to cover the problems of ravines along Yamuna, Chambal and Mahi rivers respectively.

c) Black soil region-of the peninsular India in which Bellary is located.

In this report, some of the results achieved by these Centres are presented in following sections.

EXPERIMENTAL RESULST FROM HILL REGIONS

The climate, soil , runoff and soil loss values in the regions of Dehradun, Chandigarh and Ootacamund Centres are presented in Table-2.

On the basis of various research studies conducted at these Centres, the following soil and water conservation measures are recommended for the region.

DEHRADUN

Mechanical measures : The following mechanical measures were recommended by Tejwani et al. (1975) for the Doon Valley region :

- For 2 to 6 percent sloping land-graded bunding with a channel slope varying form 0.4 to 0.6 percent for disposal of water.
- Narrow based bunds (45 cm wide at top, 55 cm high and have a side slope of 1.5:1) may be adopted where tractor farming is not used.
- Broad based bunds (parabolic in shape with 4 m base width and 27.5 m height) can be adopted with advantage where tractor farming is done.
- Panicum maximum is recommended in grassed waterways.

In addition to the above measures, Sastry et al. (1981) recommended the storage of excess runoff in farm ponds located at suitable places and runoff recycling.

Table 2. Soil, climate, runoff and parameters of USLE in the hill regions (Dehradun, Chandigarh and Ootacamund).

Description	Dehradun	Chandigarh	Ootacamund
		Soils and Climate	
Soil	Deep alluvial medium texture	Sandy loam	Deep lateritic (low pH :4.6.-6.1)
General slope	2-10 percent in the valley	1-3 percent (in good arable land) 10-15 percent (in hills)	16-33 percent
Climate	Temperature sub-humid	Sub-humid tropical	Warm, temperature to sub-tropical

Annual rainfall	1705 mm (80 percent in June -September)	1150 mm (82 percent in June-September)	1310 mm (43 percent in June-August and 31 percent in Sept.-November)
Evaporation (annual)	1093 mm	2300 mm	1210 mm
Computed ET (annual)	1153 mm	—	—
Sunshine (hours)	8-9 (Oct.-March) 6 (July to September)	7-9 (Oct.-March) 7 (July-September)	5-8 (Nov.-April) 2-4 (July-October)
Frost	Severe in winter	Occasional in winter	Heavy ground frost (November-January)

Runoff

Annual runoff as % of rainfall	40-50 percent (Crop :maize, up and down, slope 4 percent) 30-45 percent (Crop :maize, on contour, slope 4 percent)	50 percent in untreated Shiwalik hills	4 percent (Crop : Potato up and down slope 25 percent)

Parameters of USLE

Rainfall factor, R	1066	569	540
Soil erodability factor, K	0.15	Being worked out	0.04
Topographic factor, LS	0.65 (on 4 percent slope)	Being worked out	Being worked out
Crop management factor, C	1.00 (bare fallow)	Being worked out	0.82 (Potato-potato on contour)
Conservation practice factor,P	1.00 (bare fallow)	0.22 (for bunding)	0.05 (for bench terracing)
Computed soil loss (t/ha/yr)	104 (measured value on 8 percent slope 156 t/ha/yr)	80 (measured value)	39 (measured value)
Computed soil loss with agronomic measures (t/ha/yr)	5.2 (CP factor=0.05 for application of 4 t/ha of mulch)		

Agronomical Measures

- Contour cultivation in maize reduces runoff and soil loses from 42 percent (up and down) to 31 percent and 21 t/ha/yr (up and down) to 15 t/ha/yr and the yields are maintained at 1.7 to 1.8 t/ha.

- Maize crop can be grown with a spacing of 90 cm x 20 cm and intercropping may be taken (2 rows of maize + 8 rows of soyabean) (Bonde and Mohan, 1983).

- Mulching @ 2 t/ha/yr reduces runoff and soil loss (runoff - 18 percent of rainfall and soil loss 7 t/ha) and the yield of maize is not affected (Khybri, 1983).

- Cropping mixture (wheat 9 rows + raya 1 row) (net return of Rs.2,738/ ha obtained) (Mohan and Singh, 1983).

- Under rainfed conditions, the crop sequences, maize-wheat, maize-gram, paddy-wheat and paddy-gram, may be taken (Singh and Mohan, 1983).

- 82 to 89 percent increased yield of wheat could be obtained by applying one irrigation (5 cm) either at pre-sowing or at crown root initiation (CRI) stage and 128 percent increase in yield could be obtained by giving two irrigations, one at pre-swoing irrigation (5 cm) and another at CRI stage as compared to control (Singh et al. 1981).

- Under supplementary irrigated conditions, three crops (maize-potato-wheat) or maize-potato with net income of Rs.4,980/ha and Rs.3,680/ha respectively can be taken in a year (Bonde and Singh, 1982).

- Improved high yielding varieties recommended (Singh et al. 1981) are: maize - Ganga-2; Paddy-DR-92, CR-142-3-2; Wheat-HD-2021, HD-2009; and Gram-C-235.

- In areas where top soil is lost due to erosion, the soil fertility can be built up by adding adequate FYM and chemical fertilizers.

Utilization of Degraded Lands

Fuel-fodder/fibre plantations can be successfully raised in the old terraces of the torrents of the region which are boundary in nature.

The species are : Dalbergia sissoo (fuel), Chrysopogon fulvus (fodder), Acacia catechu (fuel) + Eulaliopsis binate (fibre) (Mohan et al., 1979).

In the old riverbeds, sweet oranges (Malta blood red and Mosambi) can be grown successfully (net return about Rs.5,000/ha) (Arora and Saraswat, 1983).

CHANDIGARH

Mechanical Measure

For undulating region, minor land levelling, alongwith good cultural practices like improved seeds, fertilizers, weed control etc. are found to increase crop yields by two to three times.

In addition to these, the following measures are also recommended, especially for the denuded Shiwalik hill region (Anonymous, 1983).

- Digging of staggered contour trenches at about 200 nos/ha (trench size 2.5 m x 0.45 m x 0.45 m; spacing 2m apart both in the same line and from row to row). In heavily eroded areas, the cross-section has to be increased to 0.6 m x 0.6 m.
- Digging of pits at 300 nos/ha (pit size - 0.45 mx 0.45 m).
- Construction of check dams (20 nos on an average/ha), its size depending upon the situation. Where stones are not available, earthen and vegetative check dams can be constructed.
- Construction of stone stabilizers at 1 to 1.5 m V.I.
- Construction of spurs to prevent side cutting and caving.
- Construction of debris basins at suitable places in main channel (one debris basin for a watershed of 30 to 40 ha with storage capacity of 1.2 to 1.5 ha.m). In areas having drainage density of more than 6.5 km/sq m of catchment, the storage capacity of deribs basin should be 1 1/2 times that of the above.

Agronomical Measures

- Maize followed by wheat, taramira and gram are promising crop sequence for the region.
- Maize in combination with groundnut gives the highest net return of Rs.4,456/ ha followed by maize and urd (Rs.3,915/ha) (Mittal et al. 1983).

Forestry Measures

- Acacia catechu (Khair) is recommended for planting on sloppy areas while Dalbergia sissoo along the cho beds and lower reaches.
- On 4 percent sloping land by Tie ridge technique, 179 t/ha of dry biomass of Eucalyptus + 45 t/ha of bhabar grass could be obtained within a period of 8 years and 3 months (Misra and Sud, 1983).

OOTACAMUND

The following soil and water conservation measures are recommended for the region :

Mechanical Measures

- 10 to 15 percent sloping land-construction of graded trenches.
- 16 to 35 percent sloping land-construction of bench terraces of 100 m long and with an inward gradient of 2.5 percent and longitudinal gradient of 1 percent with vertical drains and drop pits. Risers of benches to be planted with grasses (Tejwani et al. 1975).

Agronomical Measures

- Contour cultivation.
- Improved high yielding potato varieties like Kufri jyothi, SLB-292 and Kufrimuthu are recommended for crop production on the bench terraces.
- The following three crops can be taken in an year, if supplementary irrigation is available (Pooranchandran et al. 1982).

I crop - Potato (var. Kufri jyothi grown from the 2nd fortnight of February to 1st fortnight of June).
II crop - Potato (var. Kufri jyothi grown from the 1st fortnight of July to 1st fortnight of November).
III crop - Radish (var. Nilgiri red grown from the 1st fortnight of November to 1st fortnight of February).

Utilisation of Steep Slopes (Greater than 33 percent)

- Staggered contour trenches and planting of Eucalyptus globules+Acacia mearnsii (Tejwani et al. 1975).
- Trenching and mulching in case of freshly raised tea plantations.
- Eroded lands can be planted up with the grass species, Eragrostis curvula for stabilization (Chinnamani et al . 1983).

In runoff plot studies on 25 per cent slopes, up and down cultivation of potato gave a runoff of 4.0 per cent rainfall and 39 t/ha/yr soil loss. These values were reduced when simple contour cultivation was practiced (runoff 2.3 percents of rainfall and soil loss 15 t/ha) (Tejwani et al. 1975). The losses got further reduced when bench terracing was adopted (runoff 1.1 percent of rainfall and soil loss 1 t/ha) (Das et al. 1967).

On large watersheds, ranging in area from 7.5 to 335 km^2 the annual runoff varies from 14.0 to 68 percent of the corresponding rainfall and the maximum peak discharge varies from 33 to 342 m^3/sec (peak per unit area varied from 0.57 to 7.68 $m^3/sec/km^2$). In natural grassland watersheds, there was no sediment loss (Raghunath et al. 1969).

In a study on hydrological behaviour of two natural grassland watersheds (comprising grassland, sholas and swamps) under natural conditions, average runoff of 30 percent of rainfall was obtained. There was no soil loss. One of the watersheds was treated by planting Eucalyptus in grassland and the other watershed was untreated. The results at the end of 10 years rotation indicated a reduction of 87 mm/year in water yield due to Eucalyptus plantation (16 percent lesser than untreated watershed) (Samraj and Tiwari, 1983). However, a net income of Rs.3,280/ha/yr was obtained from the harvest of Eucalyptus tree at the end of 10 years of plantation (Samraj et al. 1983).

EXPERIMENTAL RESULTS OF RAVINE REGION

Out of 3.67 million ha of ravine load in India, nearly 0.39 ha is affected along the river Yamuna in UP; about 0.45 million ha along the river Chambal and its tributaries in Rajasthan and 0.4 million ha in Gujarat along the river Mahi, Sabarmati and Watrak.

The climate, soil, runoff and various parameters of Universal Soil Loss Equation (USLE) for the Regional Stations located in ravine regions are given in Table-3.

On the basis of research studies conducted at regional stations Agra, Kota and Vasad, the following soil and water conservation measures are recommended for the various regions :

AGRA

Mechanical Measures

Very small (depth 1 m), small (depth 1-3m), medium (depth 3-9 m, with bed width of 18 m) and deep gullies (depth 9 m and large bed widths) can be reclaimed into level bench terraces by cutting the soil from humps and the side slopes and filling the soil into adjacent gullies and depressions. The cost will naturally depend upon the quantity of earth work involved in this reclamation practice. A continuous bund along the periphery of the terrace with an outlet is to be constructed (Tejwani et al. 1975).

Agronomic Measures

- Under rainfed conditions, crops like bajra, guar, cowpea, moong and urd can be grown in the reclaimed ravine areas during the kharif. Mustard, taramira, linseed, barley and gram are the suitable crops for rabi season.
- Moong (var. PS-16) followed by mustard (var. Aruna) is relatively the most productive crop rotation for this region. This crop rotation gives a net return of Rs.5,712/ha/yr) (Agnihotri and Bhushan, 1982).
- Green gram followed by safflower (yield 1,258 kg/ha) and green gram followed by taramira (yield 1,028/ha) are also productive.
- Some of the improved high yielding varieties of different crops found suitable for this region are : Bajra - BJ 106, PHB-14; Moong PS-16, ML-3; Guar-B-19-1-55, Durgapur safed; Arhar-T-2, Hyd-2; Soyabean-PK-71-21, Soya-2; Groundnut-AK-12-24; Cowpea-CC 170, C-152; Mustard-Aruna, Pusa Kalyani and Gram-Local.

Table 3. Soil, climate, runoff and parameters of USLE in ravines (Agra, Kota and Vasad)

Description	Agra	Kota	Vasad
		Soils and Climate	
Soil	Deep alluvial light texture	Clay loam to clay (pH; 7.8-8.5)	Sandy loam and loamy sand
Climate	Semi-arid	Dry sub-humid and microthermal	Semi-arid
Annual rainfall	756 mm (97 percent July-September)	787 mm (88 percent July-September)	850 mm (96 % received from S-W monsoon)
General	-High intensity storms in July and August causing heavy erosion. -Wind velocity and temperature are high and hence ET is high.	-30 min. rainfall intesity at 50 percent chance is 6.9 cm/hr Area is subject to occasional frost	-July rains cuases 30 percent of total erosion. -Fertility status of soil is very poor except for potash.
		Runoff	
Annual runoff as % of rainfall	20 percent (under cultivated fallow on 2 percent slope)	15-20 percent	41 to 52 percent (2 to 9 percent slope under cultivated fallow).
		Gully erosion	
Extension of gullies	2500 sq m/yr/ha of gullied catchment	1000 sq m/yr/ha	1670 sq m/yr/ha
		Parameters of USLE	
Rainfall factor, R	495	354	519
Soil erodibility factor, K	0.20	0.11	0.11
Topographic factor LS	Being worked out	Being worked out	Being worked out
Crop management factor, C	0.61 for bajra 0.42 for guar	Kharif cereals 0.50 to 0.62 Kharif pulses 0.39 to 0.43 Grasses : 0.1-0.22	0.35 for moong, 0.33 for groundnut, 0.27 for cowpea, 0.26 for bajra + cowpea.
Conservation practice factor, P	Being worked out	0.75 (Sorghum on contour) 0.63 (Sorghum + pigeonpea on contour)	Being worked out
Soil loss (t/ha/yr)	15.7	4 to 9	36 to 107 (on 2 to 9 percent slope)
Soil loss with agronomic measures (t/ha/yr)	4 (Moong or cowpea as intercrop in bajra)	2.1 to 3.5 (pulses) 1.9 to 4.5 (oilseed crops)	---------

Wheat (var. RR-21) can be grown in the rabi season, only if supplementary irrigation can be given.

Control of Gully Erosion

The treatment consists of providing small earthen check dams of 1.5 m x 2 m V.I. Suitable water disposal structures are to be provided. Tree species like Bamboo, Agave, Arundo donax, Acacia spp., Prosopis sp. and Dalbergia sissoo can be planted to provide the more permanent biological control, besides making these lands productive in terms of fuel and fodder.

Farm Forestry

Gullie lands of this region can support the combination of perennial trees and grasses like Acacia nilotica and Cenchrus ciliaris or Dichanthium annulatum, which can also provide for the fuel and fodder requirements.

Horticulture

In degraded and denuded ravines, ber (Zizyphus sp.) orchards (var. Banarasi, Ponda Safeda, Ponda) can also be raised. They start giving profitable income after 3 years. With a proper management and supply of nutrients, the returns could be as high as Rs.10,000/ha/yr. Papaya and guava are the other fruit trees which hold promise in this region. Adequate watering atleast in the early years of establishment and soil and water conservation measures are necessary for this land use (Bhushan et al. 1981).

An untreated ravine watershed of 8.4 ha in an area under natural conditions gave an annual runoff of 8.7 percent of annual rainfall and soil loss of 4.5 t/ha/yr. In comparison, when the same was treated with check dams and grassed waterways were provided at appropriate places, the corresponding runoff was only 10 percent of the rainfall and the soil loss was 0.4 t/ha (Tiwari and Bhushan, 1983). An agricultural watershed, having an area of 22.3 ha under traditional system of cultivation (no soil conservation measure) produced an annual runoff 15 percent of the rainfall and a soil loss of 3.7 t/ha/yr. When the watershed was provided with field bunds subsequently the corresponding runoff value was 0.3 percent of rainfall and the soil loss was 0.13 t/ha (Sharda et al. 1981).

KOTA

Mechanical Measures

Very shallow (< 1.5 m depth), shallow (1.5-3.0 m depth) and medium (5.0-6.0 m depth) gullies can be reclaimed for raising agricultural crops.

- A diversion bund has to be provided at a distance from the gully rim equal to twice the depth of the gully at the gully head. The recommended cross-section of the bund is 2.7 sq m.
- Runoff, so diverted by the peripheral bund is to be safely disposed off into the ravines by providing spillways at appropriate points. These can be made of coarse rubble masonary with lime mortar. Considering the easiness of design and construction, each spillway can be designed to take care of a catchment area of 4 m.
- On sloping cultivated lands (slopes upto 4 percent), graded bunds on $1m^2$ cross-section can be provided at 0.5 to 1.0 m V.I. On flat lands, provision of drainage channel is essential for growing kharif crops in soils characterised by poor drainage and permeability. Such soil are also common in this region (Tejwani et al. 1975).

Agronomic Measures

Rainfed Conditions

- Mixed cropping of sorghum (CSI-1) and pigeonpea (local variety) grown in alternate lines of 30 cm apart is found to be economical for this region. Application of 25 kg/ha to sorghum is found desirable (Pratap Narain et al. 1980).
- When normal kharif crops fail due to failure of rains or due to heavy rains during mid July, Castor (var. Aruna) can be sown during the mid season upto mid August. Yields of 1.5-2.0 t/ha were obtained from such mid season corrective crop of castor.
- Rabi crops are normally taken in this region if some supplementary irrigation is available after short duration of kharif crops like green gram, black gram. Optimum sowing dates for rabi crops are : Gram upto end of October, Wheat upto first week of October and Safflower upto first week of October.
- Dust mulching is found to be helpful for rabi crops.
- Optimum fertilizer dose for the rabi crops are : Gram - 25 kg N + 50 kg P_2O_5/ ha; and wheat - 80 kg N + 40 kg P_2O_5/ha.
- The improved high yielding crop varieties found suitable for Kota region are : Sorghum - Ashpuri, 604 and CSH-5; Maize-Ganga-2; Black gram T-9, Khargone No. 43, 55; Cowpea-FS-68; Pigeonpea-Local, GWA-3; Soyabean-T-1; Sesamum-Pratap; Castor-Aruna; Wheat-Kalyansona, Malvi, A-K-30-1; Barley-RS-6; Gram-RS-10; Rape-Durgamani; Taramira-Local; Safflower-No.10; and Linseed-57-1-62.

Even under rainfed conditions, with normal rainfall, it is possible to have 200 per cent cropping intensity in this region with such crops like green gram/ black gram (Kharif) followed by taramira/safflower (rabi). Such rotations give annual yields of 1.5 to 2.5 t/ha from the two crop sequences (Verma et al. 1978).

When irrigation water is available for the crop of gram, better water use efficiencies can be obtained by adopting skip furrow irrigation by skipping one or even two furrows.

Forestry Measures

The best land use for deep and narrow gullies is permanent vegetation.

- Gully beds are to be protected with live check dams.
- Prosopis juliflora (on humps and side slopes), Acacia nilotica (on side slopes), Dendrocalamus strictus (in gully beds) and grass species like Dichanthium annulatum and Cenchrus ciliaris are recommended (Tejwani et al. 1975).

VASAD

The following soil and water conservation measures are recommended for the region.

Mechanical Measures

- Small gullies (less than 3m deep) can be reclaimed by clearing, minor levelling and construction of a series of contour bunds at V.I. of about 0.9 m. Pipe outlets or grassed rims are to be provided for draining the excess runoff water, if any, from the treated area. At the end of a small gully system, a composite check dam is provided as a protective measure against any loss of soil. The expenditure incurred on these measures is expected to be recovered in five years.
- A medium gully, 3-9 m deep, can also be reclaimed by clearing, levelling the gully and constructing a series of composite earthen and brick masonary check dams at a V.I. of about 1.2 m with an outward slope of 0.75 percent between two structures, and bench terracing the side slopes (8-15 percent). The expenditure is recoverable in 7-8 years (Dhruva Narayana et al. 1962, Tejwani and Dhruva Naryana, 1961).

Agronomic Measures

- Ridge planting is recommended for cotton.
- Two year rotation of bajra-bidi tobacco, bajra-moong (in strips)-green manuring tobacco was found promising under rainfed condition on table lands (Sharma et al. 1981).
- Intercropping of cowpea (var. Pusa phaguni) with widely spaced long-duration crops like rainfed redgram and castor is recommended.
- Irrigation water is available in Vasad region. In such cases, cotton intercropped with cowpea, bajra followed by safflower or mustard are recommended (Sharma et al. 1981).

Forestry Measures

Deep gullies are reclaimed by appropriate afforestation techniques with suitable tree species like Porospis juliflora (pump and side slopes), Acacia nilotica (side slopes) and Dendrocalamus strictus (gully beds) and constructing gully plugs in the bed of the main and branch gullies. Gully beds and sides are stabilized by planting grass species like Dichanthium annulatum. Gully plugging is done with small earthen check dams and live hedges. Fruit orchards of lemon, papaya and banana can be successfully raised in this region especially in gully beds and terraces because irrigation water is available (Sharma et al. 1981).

From runoff plot studies, it was observed that under cultivated fallow on 2,3,6 and 9 percent slopping lands, annual runoff of 41 to 52 percent of rainfall and a soil loss of 46 to 142 t/ha respectively were obtained. The runoff and soil loss values increased with increase in the steepness of the slope (Subhash Chandra and Rao, 1983). Studies on gully extension indicated that gullies increase at the rate of 1870 sq m/yr/ha.

EXPERIMENTAL RESULTS OF BLACK SOIL REGION

BELLARY

The area falls under a rain shadow belt with an average annual rainfall of 508 mm in 35 rainy days. An assured rainfall of 20 mm and above may be expected between 17th September to 4th November, which is considered to be the safe period for cropping in the tract. Moisture is the major constraint for crop production in this region.

Soils are vertisols and fall under the sub order Usterts and palleusterts with the soil depth ranging from 45 to over 90 cm. Soils are highly clayey with poor structure, poor infiltration (0.8 mm/hr) and high erodibility. They are deficient in nitrogen and phosporus and alkaline in reaction (pH 8.5 to 9.2). Soils heavily creck during the summer.

Mean annual erosion index (EI_{30}) is 293. The annual average runoff and soil loss from small agricultural catchments treated with soil conservation measures worked out to 20 percent of rainfall and 2.3 t/ha, respectively. Under fallow runoff plots, the soil loss on 1 percent and 2 percent slopes was 4 and 7.5 t/ha, respectively. Computation of the various parameters of the USLE are being worked out.

Conservation Measures - The following soil and water conservation measures are recommended for the Region :

Mechanical Measures

- Graded bunds/channel terraces are to be provided at a V.I. of 0.6 m. The upstream channels may have a grade upto 0.3 percent. Soil loss from treated agricultural lands can then be brought down to about 1 t/ha/annum (Anonymous, 1980).
- As an alternative to graded bunds, conservation ditching can be tried. The ditch serves not only as a drainage channel but also as a storage reservoir. The water stored in the ditches could be recycled for the crops (Patnaik et al. 1982).
- Conservation bench terracing (Zingg terrace) with 50:50 or 60:40 ratio of the contributing and receiving areas and application of gypsum can also be adopted for getting increased yields of crops (Anonymous, 1980).
- A dug out pond of 30m x 30m having a depth of 5.0 m with 1:1.5 side slope for every 8 to 10 ha watershed is recommended. The water so stored could be utilised for atleast one supplemental irrigation of 5 cm over 80 percent of the catchment area, when the crop experiences mild stress during its growth period (Tejwani et al., 1975).

Agronomic Measures (Rao et al.1980; Rao et al. 1983)

- Contour cultivation alone can increase the sorghum yield by 35 percent in gently sloping (<3 percent) lands.
- Vertical mulching with sorghum stables, packed in trenches of 30 x 15 cm protruding 10 cm above ground level, at 4m intervals across the slope conserves more moisture and give increased yields of crops.
- Surface mulching.
- Inter-culturing is necessary for creating dust mulch.
- Use of improved ferti-seed drill increases crop yields.
- Pressing the seed rows with light press wheels results in increase in germination in jowar, safflower and gram.
- Broad beds on 0.3 percent grade conserve more moisture and give 28 percent increased yields of jowar.
- Balanced use of fertilizer based on soil test results particularly with respect to P and K is a necessity.
- Surface mulching (bajra straw @ 5 t/ha) immediately after sowing conserves more moisture and gives 60 percent increased yield of jowar than control.
- The sowing season spreads from mid September to late October.
- Lima bean and redgram are good for early sowing and bengal gram with late sowing.
- Castor performs well under early sown conditions. Safflower and coriander are found to be suitable for mid and late season sowing.
- Recommended improved varieties of crops are : rabi : sorghum SPV 86, CSH8R, Safflower A-1, S-144; Gram A-1 and N-52; Coriander-533, CO-1, Redgram 290, C-11; Bengal gram BDN-9-3, 862-2; Cluster beans HFG 75, 182 and Field beans MS-9815, C-205.
- Deep ploughing may be done once in 3 years. In general, 2 harrowings prior to seeding and 2 to 3 inter-cultivations with blade harrow to create dust mulching depending upon rainfall is sufficient.
- A population of 1 to 1.3 lakh/ha is optimum for jowar for normal seasonal conditions. For sub-normal conditions, a population of 30 to 50 thousand/ ha is optimum.
- For early stoppage of rains towards the end of season, apply mid season correction by thinning the population-apply supplemental irrigation, interculturing and closure of cracks, row spacing of 60 to 75 cm for jowar and 60 to 90 cm for safflower is recommended. Jowar and cotton in alternate years benefit the crops. Inclusion of gram in the rotation benefits the succeeding crops.
- Maize-gram, maize-safflower followed by bajra-safflower double cropping sequences are promising under dry-cum-wet irrigation.
- If canal water is available upto mid March, 300 percent intensity of cropping could be possible with bajra-cowpea/coriander-jowar under intensive management.

Utilization of Marginal and Degraded Land

- Acacia nilotica and Cenchrus ciliaris have been found to be good fuel-cum-fodder plantation (Anonymous, 1980).
- Tree species like Eucalyptus hybrid, Acacia nilotica, Acacia nubica, Prosopis cineraria, Azadirachta indica are promising (Anonymous, 1980).
- Subabul (0.75m x 0.25m) performance as pure fodder crop yielded a biomass of about 20 t/ha/yr (average of two years).

TRAINING & TECHNOLOGY TRANSFER

Soil Conservation Training

It is generally accepted that in order to deal with soil conservation problems appropriate education of the scientists, field workers and the masses is essential and indispensable. Senior officers sponsored by the State are trained at Dehradun and the Assistants at Kota, Ootacamund and Bellary Centres and also at Hazaribagh (DVC). Upto March, 1986, a total of 1423 senior officers and 4602 Assistants have been trained at the Central Soil & Water Conservation Research and Training Institute, Dehradun and its Centres to man the much needed soil conservation programmes in the respective States. This Institute has also trained the soil conservation officers from neighbouring countries.

Technology Transfer

Under Lab-to-Land Programme, the Institute and its Centres have successfully adopted about 1000 small and marginal farmers during 1983-84. The Scientists of the Institute and its Centres generally found good response from the farmers in taking up the programme and adopting the improve agricultural practices and other systems of farming for integrated rural development. The farmers seem to have developed a liking for adopting soil and water conservation practices and technology for better production and improved income and for improving their living standards.

In the Lab-to-Land programme conducted by the Institute, crop cutting surveys showed that average yields on demonstration fields showed increase varying from 12 to 40 percent due to adoption of improved technology.

Watershed Approach

ORP watersheds : The deterioration of natural resources in an area can be contained and the total resources properly developed only by adopting the Watershed Approach. The basic unit of development is a watershed, which is a manageable hydrological unit. In this approach, development is not confined just to agricultural lands alone, but covers the area, starting from the highest point of the area (ridge line) to the outlet of the nalah or the natural stream. This will involve implementation of ameliorative measures on barren hill slopes, marginal lands, privately owned agricultural land and badly cut nalahs and river courses.

The Central Soil & Water Conservation Research and Training Institute, Dehradun and its regional Stations have been playing a pioneering role in popularising this watershed approach, through research, demonstration and training over the last 25 years or so. The Institute had undertaken 3 Operational Research Project watersheds at Fakot (Tehri-Garhwal district, UP) (Anonymous, 1978),

Sukhomajri/Nada (Chandigarh) (Mishra et al. 1981) and G.R. Halli (chitradurga district, Karnataka) (Anonymous, 1981). In each case, a complete watershed of 300-400 ha were covered by watershed development. The actual work involved fuel-fodder plantations in the denuded catchments, construction of erosion control structures like check dams, graded bunds, construction of small water storage reservoirs, adoption of appropriate cropping systems, cultural methods and water management practices, etc.

These case studies have shown that the integrated watershed development approach is economically beneficial (overall B:C ratios are greater than 1.8:1), especially in places where dependable water resource is developed in such a programme. Based on the successes, the Institute is now implementing watershed development in 18 locations all over the country.

SOIL CONSERVATION RESEARCH GAPS AND PEOPLE'S PARTICIPATION

The soil conservation research centres have been in existence for the last 30 years in a number of regions of the country and have done tremendous work in providing the technology needed for implementing the soil conservation programmes in the country. However, the following research gaps still exist:

1. The regional Stations cater only a few regions and many areas such as those of red soil regions, regions where shifting cultivation is practices, the eastern ghat high lands, high rainfall areas of western ghats and black soils, coastal region where sea erosion is predominant, middle and greater Himalayan regions, Andaman Islands, etc., Regional Research Stations have yet to be established.
2. The research conducted so far has been of applied nature and there is greater need for precise measurements of cause and effect relationships in general and analysis of benefit-cost ratios of individual treatments and those of combinations.
3. No Science can develop and prosper without basic research and the science of soil conservation is no exception. The modern and precise methods of experimentation and analysis must be adopted both, in the field and in the laboratory.
4. Since soil and water conservation research is inter-disciplinary in nature, there should be greater inflow of knowledge and expertise from the specific disciplines into this subject matter area.

Involvement of people

In planning soil conservation programmes in most instances, community or cooperative action is indispensable. Small farms which are characteristic in our country, do not allow for an individual farmer to have an impact on land improvement. Soil conservation programmes will, therefore, have to be tackled on a watershed basis, as a concerted action where all efforts reinforce and complement each other. Some erosion or flood control measures may be within reach of a group of farmers but for larger undertakings, the support of Government is also called for. It is clearly the Govt.'s role to maintain the country's basic resources of soil and water. Technical assistance programmes often deny priority to soil conservation programmes because of lack of immediate economic returns. Ensuring the continuity of agriculture rather than immediate economic returns should be the deciding factor for investments in soil conservation work. At all times, farmers should be closely involved in the planning and execution of field programmes as in the Sukhomajri model. New management techniques should not become a continuous burden to the farmer; on the contrary, they should be within the capacity of the farmer and he should understand the beneficial effects.

Our experience at Sukhomajri and other Operational Research Projects has shown that the following will have to be considered in order to make the transfer of soil conservation technology a popular programme :

1. Constitution of the village societies so that the people of the area feel that the programme is therein.
2. Each member of the village society has an equal share in the common natural resources developed.
3. Granting the annual grass cutting and tree prunning rights from the Government wastelands and Panchayat common lands to the village societies at reasonable rates to ensure not only the revenue of the Govt. institute but also Panchayat Institutions.
4. Entrusting the job of raising nurseries etc. to the village schools.
5. Development of marketing facilities for the natural resources generated by the village people.

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