RESEARCH ACHIEVEMENTS

2

P-1: WATER EROSION APPRAISAL IN DIFFERENT AGRO-ECOLOGICAL REGIONS

1.1 Inventory and data base of erosion status using modern tools and procedures

Impacts of landuse changes on surface hydrology in Doon Valley through remote sensing and GIS approach (C. Jana, D. Mandal, S.S. Shrimali, Raj Kumar) - Dehradun

The project was started in the year 2011 with the aim to examine the spatio-temporal variability of land use changes and its effects on surface hydrology. The study focuses on identification and quantification and evaluating the impacts of land use changes on surface hydrology of Doon valley for different time periods with the help of RS and GIS. Freely available geocoded high resolution images were used for delineation of study area. Total study area was divided into two main watersheds (outlet Paonta sahib dam and Haridwar) using ArcView software. Generation of spatial information layers, *viz*; land use/land cover, soil layer, rainfall layer etc. for different time periods are in progress.

Effect of slope and land uses on soil carbon stock and soil quality in the Nilgiris (K. Rajan, O.P.S. Khola and R. Ragupathy) - Udhagamandalam

The study was initiated during 2011 in the Nilgiris district with objectives (i) to estimate the soil organic carbon stock, physical, chemical and biological indicator in different land uses under different slope, (ii) formulate soil quality index (SQI) and relative soil quality Index (RSQI), and (iii) identify the land uses with high and low organic carbon stock and soil qualities and suggest measures for the improvement.

The Nilgiris district has rich soil and water resources and total area is 2,54,485 ha out of which the net cultivable area is only 76,172. The remaining areas under forest, waste land, fallow and non-agriculture uses. The degree of soil disturbance is varying according to the land uses and slopes.

There are 63,034 ha of land under plantation crops in the district. Major land under plantation crops is occupied by tea (84%) and coffee (12%). Coco and vanilla are under very meager areas (< 1 %). Tea and coffee are grown in all the 'taluks (Ooty, Coonor, Kotagiri, Kundha, Gudalur and Pandalur) and slopes. Largest area under plantation crops are found in Gudalur (22%) followed by Kotagiri (20%), Coonor (19%) and Pandalur (15%). Lowest areas are in Ooty and Kundha (11% each).

Delineation and characterization of Mahi ravines using remote sensing and GIS in terms of resource potential planning (Gopal Kumar, R.S. Kurothe, V.C. Pande and A.K. Vishwakarma) - Vasad

This study was aimed to delineate and characterize Mahi ravines and to develop methodology to map potential ravine area in the country. Visual boundary delineation of ravine using high resolution satellite imageries applying simple decision rules was completed. Total rugged land (gullied) associated to Mahi ravine in Gujarat is 20,256 ha slightly less than river bed area (24,409 ha) of Mahi ravine. Soils of active sites are poorly developed, very weekly structured, high in bulk density, saturated conductivity and low in water stable aggregates (Table 1). Soil pH and EC were found normal range. Eroding materials flowing out as suspended materials from stable sites are enriched in silt and clay. Land features associated to active sites are broad in range and difficult to segregate as unique factor associated. Slope of table land adjacent to active gully ranges between 1 to 3%. Vertical angle at moving head are >78° (Table 2). Though due to extensive spread, ravine seems to be present around all type of curvature but still a synoptic view using high resolution imageries suggest association with concave curvature of Mahi river. Sparse vegetation, poor soil development, falling of material during dry period, was observed at active sites (Photo 6).

Table 1 : *Soil parameters associated to active and stable sites of Mahi ravine in Gujarat*
तालिका 1 : गुजरात में माही बीहड़ के सक्रिय एवं स्थिर स्थलों से जुडे मृदा परामितियां

Surface soil parameter	Active site			Stable site		
	Top	Slope	bottom	Top	slope	bottom
Sand	78 - 82	80-83	84-88	69-75	70-75	72-76
Silt	8 - 11	10-14	10-13	10-14	8-12	12-14
Clay	7 - 10	9 -13	2 - 6	13 - 21	12-20	8 - 23
Organic matter (%)	0.12 -0.24	0.16-0.20	0.05-0.12	0.16-0.37	0.18-0.32	0.12 -0.27
Bulk density (g cm^{-3})	1.54- 1.67	1.48-1.61	1.59-1.62	1.39-1.56	1.42-1.57	1.46 -1.59
Sat. Hyd conductivity (cm hr^{-1})	2.1 - 4.2	2.2 - 4.0	5.1-8.9	1.5-2.3	1.2-2.1	1.8 - 2.5
Infiltration (cm hr^{-1})	2.84	-	7.81	1.89	-	3.22
Water holding capacity (%)	50-53.1	-	44.5-45.3	52.2-55.4	-	49.5- 51.2
WSA % >0.25 mm)	18.5-24.3	18.5-26.1	26.4-32.1	22.1-27.9	-	23.1 -26.4
WSA (sand correction)	12.1-12.9	11.2-14.5	9-10.2	15.2-18.7	-	13.1- 14.7
WSA (slacking)	17.6-24.6	-	25.2-33.1	18.7-19.3	-	19.5 -21.3
WSA (slacking) Sand correction	11.2-13.1	-	8.4-9.5	14.3-14.8	-	13.5 -15.1
pH	6.91-7.13	7.52-7.8	7.6-7.89	6.83-7.9	7.2-7.95	7.82 -8.1
EC (dS m^{-1})	0.11-0.145	0.14-0.18	0.14-0.18	0.21-0.36	0.14-0.29	0.17- 0.33
$CaCO_3$ (%)	2.4-5.6	3.2-8.4	3.1-3.6	1.8-3.2	-	2.5 - 4.1

Table 2 : *Land parameters associated to active sites of Mahi ravine*
तालिका 2 : माही बीहड़ के सक्रिय स्थलों से जुड़ी भूमि परामितियां

Land characteristics	Parameters
Slope (Head)	78° to > 90°
Elevation diff between gully head and immediate bed	1-5 m
Distance from main river bed	Up to 3.3 km (along drainage line)
Elevation difference from main river bank	7- 40 m
Catchment area associated to active individual gully head	40 - 450 sq m
Dominant associative curvature of main river (Mahi) with ravine	Concave
Slope of adjacent table land near active site	1-3%

Photo 6: a) Active sites despite of very small catchment and no backflow, b) Falling of materials during dry season due moisture loss and reduction in cohesive force
फोटो 6:(अ) एक बहुत छोटे जलग्रहण और बिना प्रतिवाह के बावजूद सक्रिय स्थल (ब) शुष्क मौसम के दौरान मलवा गिरने से नमी ह्रास और एकजुट बल में कमी

Prevailing climate in Mahi ravines in Gujarat is semi-arid with annual average rainfall of about 850 mm. There is large deficit of moisture due to high evaporation rates (Fig.1a). Highest maximum temperature is recorded in May and lowest minimum temperature during January.

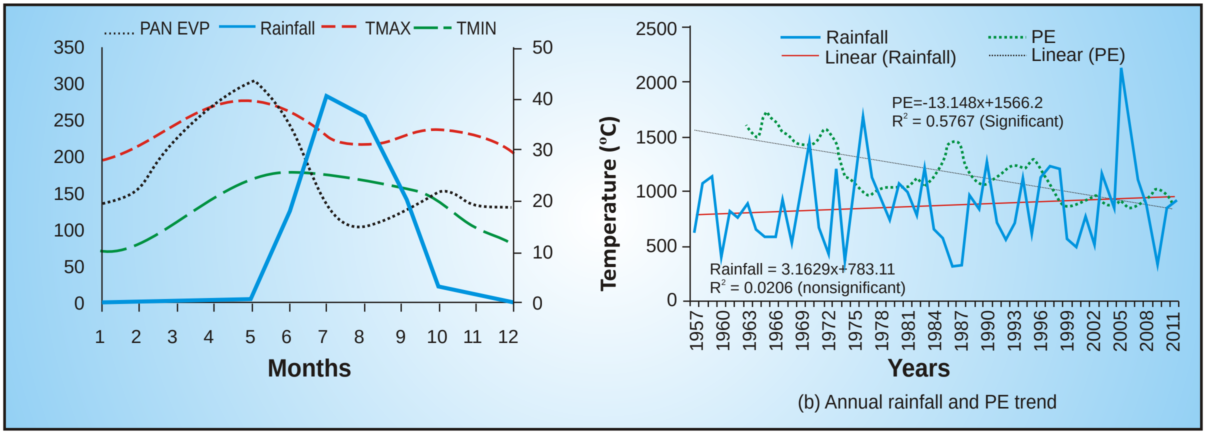

Fig. 1 : a) Fifty year average of meteorological parameters, and b) Trend of annual rainfall and potential evaporation

चित्र 1 : (अ) मौसम संबंधी परामितियों के पचास वर्षों का औसत (ब) वार्षिक वर्षा और संभावित वाष्पीकरण का रूझान

Weather data of last 50 years of RC, Vasad, a representative of Mahi ravines shows reducing trend of potential evaporation which was found highly significant where as increasing trend noticed for rainfall was non-significant (Fig. 1b). Increasing number of water harvesting measures, storage structures, irrigated area and open sewage area may be responsible for reducing atmospheric demand as relative humidity was found increasing significantly for the same period. Reduced potential evaporation may have implication on water requirement and budgeting. No trend in annual maximum temperature could be observed except for July and August where increasing trend between 1957 and 2011 was found significant.

1.2 On-Site and Off-Site Effects of Erosion

Effectiveness of vegetative filter strips in preventing soil and nutrient losses (B. Krishna Rao, A.K. Viswakarma and V.C. Pande) - Vasad

The study was initiated in the year 2010-11. Vegetative filter strips (VFS) is placed at downstream border area of the crop fields (Photo 7). The treatments; T_1: VFS (1 m width *Eulaliopsis binata* + 1 m width *Dichanthium annulatum*), T_2: VFS (1 m width *E. binata* + 2 m width *D. annulatum*), T_3: VFS (1 m width *E. binata* + 3 m width *D. annulatum*), T_4: VFS (1 m width *E. binata* + 4 m width *D. annulatum*), T_5: VFS (1 m width *E. binata*), T_6: VFS (1 m width *D. annulatum*), T_7: Peripheral bund, T_8: Control (VFS) were laid with cotton as the test crop. For all treatments cotton crop was grown uniformly with standard package and practices. In each plot, runoff was recorded by H flume and runoff samples were collected by Coshocton wheel sampler.

Lowest runoff was recorded in treatment T_7 followed by T_4 and lowest soil loss in treatment T_4. The filter strips was able to reduce the sediment concentration in runoff water upto 56% (from 2.76 to 1.2 g litre^{-1}).

Number of harvests for *Eulaliopsis binata* and *Dichanthium annulatum* were 2 and 3, respectively. Vegetative filter strips increased the cotton yield up to 19% as compared to control, but the yield among the filter treatments was not significant. The highest grass yield was recorded in 1 m width treatments, viz; T_5 and T_6 (Table 3).

Photo 7: Vegetative filter strips with crop

फोटो 7 : फसल के साथ वनस्पतीय छनन पट्टियाँ

Table 3 : *Cotton and grass yield of various treatments*

तालिका 3 : विभिन्न उपचारों के अन्तर्गत कपास और घास की उपज

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Cotton yield (q ha^{-1})	18.97	20.73	20.94	21.25	18.43	18.05	20.86	17.87
E. binata yield (kg m^{-2})	1.86	1.77	1.54	1.65	2.72	-	-	-
D. annulatum yield (kg m^{-2})	5.94	5.08	4.85	4.43	-	6.2	-	-

1.3 Soil Erosion Processes and Models

Erosion productivity relationships for evaluating vulnerability and resiliency of soils under different agro-climatic regions of India

A. Dehradun (D. Mandal, S. Patra, N.K. Sharma and P. Dogra)

The core project was started during 2008 with the objective to quantifying impact of erosion on productivity of soils. Eight runoff plots (7.0 m wide by 50 m long) with slopes ranging from 0.5% to 9.5% were cultivated manually and planted with maize (*Zea mays*) at a spacing of 0.6x0.3 m, using two treatments during *kharif* 2011. Fertilizer was applied as one of the treatment at 100 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} and was incorporated into the soil. Each plot had an endplate and runoff collector that routed water into a runoff tank.

Analysis of data generated through comparative plot study revealed that soil loss varied from 6.0 to 43.9 t ha^{-1} depending on slope and fertilizer application. With respect to slightly eroded soil, soil loss increased by as much as 7.3 times, and runoff by 110% in severely eroded plots. In general, runoff and soil losses were higher in unfertilized plots than fertilized plots (Fig. 2). Higher runoff and soil loss in unfertilized plots as compared to fertilized plots may be attributed to the poor canopy cover of maize in unfertilized condition. Concentration of clay and organic carbon (OC) was found 1.14 to 1.86 and 1.45 to 2.65 times higher, respectively than original soil (Table 4). Clay and OC enrichment of sediments were

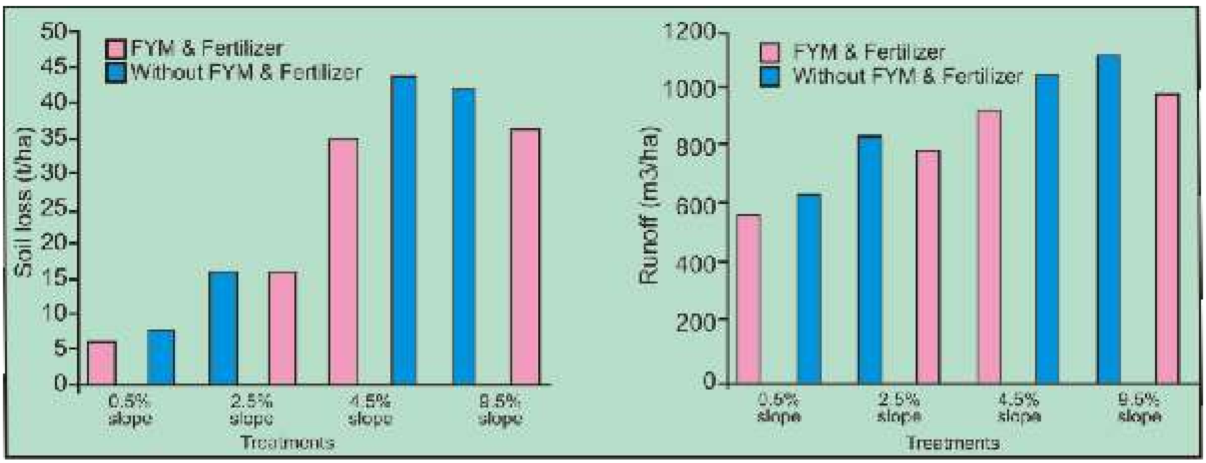

Fig. 2 : Soil loss and runoff on different land slopes

चित्र 2 : विभिन्न भूमि ढलानों पर अपवाह एवं मृदा ह्रास

Table 4 : *Concentration of Clay and OC in sedimentation at different land slopes*

तालिका 4 : विभिन्न भूमि ढलानों में अवसादन क्ले एवं जैविक कार्बन की सांद्रता

Soil attribute	0.5%	4.5%	9.5%
OC (%)$_{soil}$	0.8	0.56	0.38
OC (%)$_{sediment}$	2.12 (2.65)	1.02 (1.82)	0.55 (1.45)
Clay (%)$_{soil}$	20.8	16.6	13.6
Clay (%)$_{sediment}$	38.7 (1.86)	24.4 (1.47)	15.8 (1.14)
Aggregate (>1 mm) (%)	19.3-22.6 (20.4)	14.4-17.6 (15.8)	10.6-14.2 (12.4)

Sediments at 2.5% slopes were not analyzed for enrichment ratio.

higher in case of lower slopes. However, net loss of clay and OC increased with the increase of slopes and soil loss.

B. Chandigarh (R.P. Yadav, Pratap Singh and A.K. Tiwari)

Losses of organic carbon and clay content due to erosion have been identified as key factors influencing productivity; magnitude of which will vary with soil type, climatic conditions and crops grown. First step towards determining such effects is to determine variation in losses of organic carbon and clay contents under different intensities of soil erosion by water.

Eight runoff plots of standard size (22.13x1.83 m) were constructed with four slopes of 0.5, 1.0, 2.0 and 4.0% in two replications. In one set of four slopes, maize (var. MRM 3845) crop was sown with farmers practice and under second one with improved package of practices. Maize was sown on contour across slope and with fertilizer doses of 100:40:20:: N: P_2O_5: K_2O. Half of nitrogen, full P and K was applied before sowing and 50% N was applied 21 days after sowing.

Organic carbon content in the sediment ranged between 0.83 and 1.71% which is much higher than the original soil (0.50%). Similarly, clay content sediment was 38% compared to 20% and silt content was higher by 12% in sediment over original soil. The study revealed that runoff preferentially removed OC and clay content. It increased with per cent slope indicating higher removal of finer fraction of soil with more intensity of runoff.

Maize grain and straw yield ranged from 24.00 to 40.78 and 42.94 to 97.03 q ha^{-1}, respectively. Grain yield decreased with increase in slope but yields were higher with improve management practices than farmer's practice at all the slopes. Improved management practice of contour sowing with recommended doses of fertilizers caused increase in grain yield. The impact of management practice was more noticeable at lower slopes.

C. Udhagamandalam (D.V. Singh, V. Selvi and K. Kannan)

A field experiment has been laid out under rainfed condition to assess the impact of erosion on crop productivity for principal crops (potato-cabbage) in the Nilgiris. Runoff plots (18 m length and 2.5 m width) have been constructed at the Research Farm with six different slopes (5, 9, 14, 20, 24 and 28%) and three replications in order to induce various levels of erosion in the study. Data on plant growth, crop yield, soil moisture, runoff and soil loss are recorded from each plot.

Runoff varied from 75.1 mm (5.6% of rainfall) in 5% slope to 99.6 mm (7.5% of rainfall) in 20% slope while soil loss varied from 4.43 t ha^{-1} under 5% slope to 41.79 t ha^{-1} under 28% slope categories (Table 5). Loss of clay through runoff

Table 5: ***Runoff, loss of soil, clay, OC, canopy and crop yield under different slope with soil fertility status on completion of first crop rotation***

तालिका 5: प्रथम फसल चक्र के उपरान्त विभिन्न ढलानों के अन्तर्गत अपवाह, मृदा ह्रास, मिट्टी, जैविक कार्बन, आच्छादन एवं मृदा उर्वरता के साथ फसल उपज

Slope (%)	Runoff		Soil loss (t/ha)	Loss of Clay (t/ha)	Loss of OC (kg/ha)	Potato		Cabbage		pH	EC (dSm^{-1})	OC (%)	Nutrients ($Kg Ha^{-1}$)	
	mm	%				Canopy (%) 90 DAP	Yield ($t ha^{-1}$)	Canopy (%) 100 DAP	Yield ($t ha^{-1}$)				N	K
5	75.1	5.6	4.43	1.11	24.15	50.2	18.0	38.7	16.5	4.04	0.11	0.99	424.7	304.9
9	97.9	7.3	22.62	6.56	185.51	51.1	19.6	38.6	6.3	4.02	0.07	1.12	331.3	300.1
14	83.0	6.2	38.20	14.14	624.65	55.8	20.8	35.8	8.9	4.05	0.09	1.55	351.8	322.0
20	99.6	7.5	39.36	15.35	419.19	66.1	22.7	42.3	11.0	3.98	0.10	1.48	359.3	317.2
24	79.7	6.0	35.31	15.18	515.46	67.2	26.8	44.2	24.7	4.11	0.08	1.59	401.3	232.2
28	96.4	7.2	41.79	16.30	330.11	77.0	27.0	45.6	16.1	4.06	0.08	1.56	354.7	254.9
Rainfall =1333.3 mm														

water was found to increase with increase in land slope while no trend was observed in case of loss of OC through runoff water with land slope.

Potato was cultivated in the experiment during the period from April to August, 2011. Variation in canopy coverage at 90 days after planting (DAP) and yield under different levels of soil erosion was found to be significant. Higher canopy and yield were recorded for potato crop under higher slope as compared to lower slope categories (Table 5). This could be attributed to the low intensity rainfall received during the crop period with no major runoff event occurring. The better drainage facilitated in the higher slope ranges had led to higher crop growth and yield of potato, a crop sensitive to water logging (Photo 8).

Second crop of cabbage was cultivated during the period from September to December, 2011. For this, canopy did not differ significantly among the different slope groups while yield varied significantly among the treatments. However, the effect of erosion could not be clearly discerned in both these parameters (Table 5). On completion of first crop rotation, soil fertility parameters did not vary significantly except OC which was significantly lower under 5 and 9% slopes.

Soil moisture data was recorded on monthly basis from three soil depths (Fig. 3). Higher soil moisture values were observed under the plots of 14 and 20% slope categories in all three depths (0-15, 15-30 and 30-45 cm). However, during the driest spell in 2011, higher moisture was observed under the plots of 5% slope in upper layer of 0-15 cm while in rest of the period, soil moisture level was found to be lower under the plots of 5 and 28% slopes in all three layers.

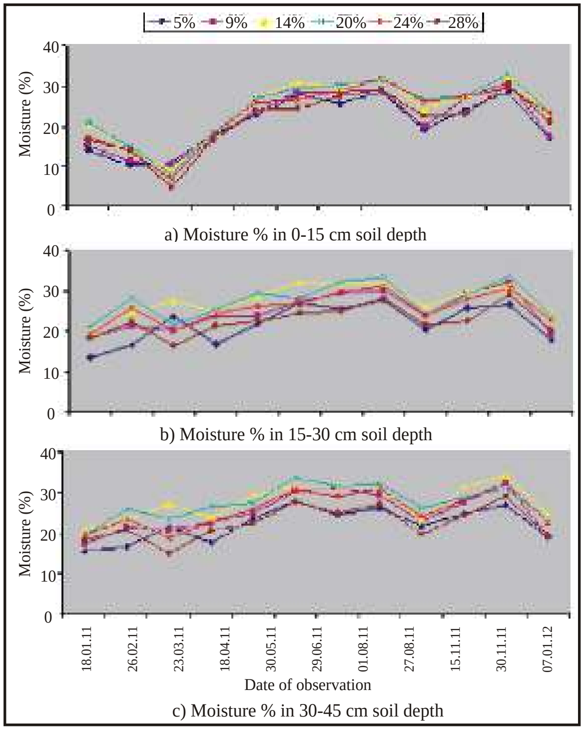

Fig. 3: Soil moisture recorded under different slope categories during 2011

चित्र 3: विभिन्न ढलान श्रेणियों पर अभिलेखित मृदा आर्द्रता, 2011

D. Agra (S.K. Dubey, A.K. Singh and R.K. Dubey)

Rainfall, runoff and soil loss data were collected during monsoon season 2011 from standard runoff plots of 0.5, 1.0, 2 and 3% slopes. Total rainfall received during the monsoon was 352.5 mm (July - 120.3 mm, Aug. - 156.2 mm and Sept. - 76.0 mm) in 23 rainy days (July - 9, Aug. - 8 and Sept. 6 days). It was observed that as slope increases from 0.5% to 3%, runoff also increased by 262.3% and soil loss by 321% (Table 6). Yield from standard runoff plots having slopes 0.5 to 3% slopes was recorded (Table 7).

Photo 8 : Potato crop in the experiment

फोटो 8 : प्रयोग क्षेत्र पर आलू की खेती

Table 6 : ***Runoff and soil loss from standard runoff plots of different slopes***
तालिका 6: विभिन्न ढलानों के मानक अपवाह भूखंडों से अपवाह एवं मृदा ह्रास

Month	0.5% slope			1.0% slope			2% slope			3% slope		
	Runoff (mm)	% runoff	Soil loss (kg ha^{-1})	Runoff (mm)	% runoff	Soil loss (kg ha^{-1})	Runoff (mm)	% runoff	Soil loss (kg ha^{-1})	Runoff (mm)	% runoff	Soil loss (kg ha^{-1})
July	6.2	5.2	124.0	13.1	10.9	312.0	17.2	14.3	443.0	24.8	20.6	511.0
Aug.	11.2	7.2	268.0	18.4	11.8	578.0	26.0	16.6	785.0	36.9	23.6	1318.0
Sept.	1.6	2.1	73.0	3.9	5.1	113.0	6.7	8.9	217.0	7.6	10.0	127.5
Total	19.1	5.4	465.0	35.4	10.0	1003.0	49.9	14.2	1445.0	69.2	19.6	1956.5

Table 7: ***Bajra grain and stover yield at standard runoff plots of different slopes***
तालिका 7: विभिन्न ढलानों के मानक अपवाह भूखंडों से बाजरा अनाज एवं पशुचारा उपज

Slopes (%)	Yield (kg ha^{-1})	
	Bajra grain	Stover
0.5	2484	7426
1.0	2136	5551
2.0	1962	5352
3.0	1552	5129

E. Kota (R.K. Singh and B.K. Sethy)

For developing erosion-productivity relationships for medium - deep black soils of south-eastern Rajasthan, erosion status and crop productivity levels are being monitored on 12 standard size runoff plots having 0.5, 1.0, 2.0, and 4.0% slopes. These plots were cultivated for rainfed soybean with 0, 100% and 150% recommended doses of fertilizers. During the year 2011 *kharif* season runoff increased by 30, 59 and 83% as the land slope increased from 0.5% to 1, 2 and 4%. Corresponding increase in soil loss were 52, 89 and 99%. OC, clay content and available nutrients in surface soil progressively declined with increasing slope. Contrary to the previous year, soybean yields increased with increasing slope which are expected due to better drainage conditions (Table 8). Yield reduction in plots having slopes less than 2% was due to prolonged excessive wetness as 2011 was a high rainfall year. Fertilizer levels had a marginal effect which indicated that moisture stress due to either excess or its deficiency is a primary factor influencing crop yields.

Table 8 : ***Erosion, fertility status and soybean yield on different slopes during kharif 2011***
तालिका 8 : खरीफ, 2011 में विभिन्न ढलानों पर कटाव, उर्वरता स्थिति एवं सोयाबीन उपज

Land slope (%)	Fertilizer Appli-cation	Runoff (% rainfall)	Runoff (mm)	Soil loss (t ha^{-1})	Clay (%)	OC (%)	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})	Soybean grain yield (q ha^{-1})
0.5	F_0	12.60	129.73	7.60	34.2	0.49	338	12.90	10.20	17.63
	F_1	15.50	159.59	9.80	35.8	0.52	338	12.00	10.40	20.86
	F_2	16.10	165.77	8.20	33.8	0.51	301	13.50	10.80	22.72
	Average	14.73	151.69	8.53	34.60	0.51	325.67	12.80	10.47	20.40
1.0	F_0	21.20	218.28	14.40	34.2	0.44	326	12.40	9.60	22.4
	F_1	19.40	199.74	10.80	33.1	0.48	275	13.10	10.20	22.55
	F_2	17.20	177.09	13.64	32.6	0.46	313	13.60	10.60	23.84
	Average	19.27	198.37	12.95	33.30	0.46	304.67	13.03	10.13	22.93
2.0	F_0	25.20	259.46	17.30	30.8	0.38	313	11.60	9.20	26.82
	F_1	23.10	237.84	16.20	32.6	0.44	225	11.80	9.20	26.45
	F_2	21.80	224.45	14.80	28.9	0.37	225	12.40	9.60	29.8
	Average	23.37	240.58	16.10	30.77	0.40	254.33	11.93	9.33	27.69
4.0	F_0	24.57	252.97	20.60	29.8	0.36	250	11.50	8.90	28.32
	F_1	27.20	280.05	22.30	30.4	0.40	201	12.40	9.10	29.8
	F_2	29.10	299.61	23.80	31.2	0.38	263	12.90	9.70	34.8
	Average	26.96	277.55	22.23	30.47	0.38	238.00	12.27	9.23	30.97

F. Vasad (Gopal Kumar, R.S. Kurothe and A.K. Vishwakarma)

Kharif rainfed pearl millet was grown on runoff plots of different degree of slope and slope lengths with N: P: K @ 100: 50: 25 with 25 kg ha^{-1} of zinc sulphate (Photo 9). Runoff and soil loss was measured by means of tanks and multi-slot divisor. Under natural condition it is difficult to segregate the effect of erosion on crop yield due to concurrent changes in soil management, soil moisture regime, natural recovery mechanism of soil, etc. which act differently at different slope and slope length.

Crop yield for *kharif* 2011 ranged from 9.5 to 14.1 q ha^{-1} and harvest index between 0.12 and 0.17. Lower yield was recorded at 6% and 9% slopes but data generated were insufficient to segregate the cause and effect. Soil loss ranges from 1.61 to 7.17 t ha^{-1} with highest on 9% slope. Soil loss was higher at higher degree of slope and slope length (Fig. 4). Lowest total runoff (90.4 mm) was recorded on lowest slope and slope length (slope length-11 m at 2% slope) and highest runoff (209.2 mm) on 9% slope. Runoff and soil loss increased with slope length (up to 66 m) and degree of slope (Fig. 4).

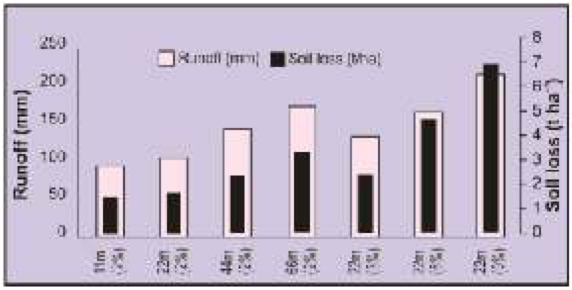

Fig. 4: Runoff and soil loss on different degree of slope and slope length under pearl millet crop

चित्र 4: बाजरे की फसल के अन्तर्गत विभिन्न ढलान एवं ढलान लम्बाई पर अपवाह एवं मृदा ह्रास

Photo 9 : Pearl millet grown on standard runoff plots during kharif 2011

फोटो 9 : खरीफ, 2011 के दौरान मानक अपवाह भूखंडों पर बाजरे की खेती

Silt, clay and OC in sediment were higher by 2-3 times, 1.5 times and 2.4-3.2 times, respectively as compared to native soil (Table 9). OC enrichment of sediment was lower at higher slope, which may be due to relatively lower concentration of suspended materials coming out at higher slope.

Depth wise moisture was monitored at 10-12 days intervals to segregate the effect of soil moisture regime on different slope and slope length. Slightly lower profile

Table 9 : *Silt, clay and organic matter in sediment and surface soils, crop yield and harvest Index of pearl millet grown on different slope and slope length*

तालिका 9 : विभिन्न ढलान एवं ढलान लम्बाई पर तलछट एवं सतही मिट्टी में गाद, मिट्टी और जैविक पदार्थ, बाजरे की फसल पैदावार एवं फसल सूचकांक

Plots	Silt (Soil) 0-2 cm	Silt (Sed)	Clay (Soil) 0-2 cm	Clay (Sed)	OC (Soil) 0-15 cm	OC (Sed)	Yield (q ha^{-1})	Harvest index
11m (2%)	10.6	22.7	17.2	26.7	0.26	0.86	11.3	0.16
22m (2%)	12.3	22.3	17.7	23.0	0.30	0.88	14.1	0.15
44m (2%)	13.1	28.8	18.1	19.4	0.27	0.84	11.6	0.15
66m (2%)	12.8	31.6	18.3	18.4	0.25	0.88	12.3	0.15
22m (3%)	11.6	32.8	17.3	16.9	0.30	0.86	10.0	0.17
22m (6%)	10.8	30.5	17.6	18.1	0.31	0.79	9.5	0.16
22m (9%)	12.7	25.4	17.9	24.3	0.30	0.71	9.5	0.12

moisture in top 90 cm profile was observed on slope of 9% for a short period during July as compared to 2% slope. No appreciable difference in top 30 cm soil profile moisture was observed at different slope. Analyzing two year of data, no effect of slope on soil moisture could be established.

G. Datia (H. Biswas, Dev Narayan and D.G. Durbude)

Impact of erosion on crop productivity, and soil (particularly clay) and nutrient (particularly organic matter) losses on red soils of Bundelkhand region is being studied with the experimental set up consisting of four runoff plots (each measuring 20 m x 10 m) with 0.5, 1.5, 2.5 and 3.5% slopes.

During the current year sorghum was sown during the first week of July, 2011 using standard package of practices and recommended doses of fertilizers (NPK @ 80:60:40 kg ha^{-1}), respectively. The rainfall received during the year was 828.4 mm, of which 512.4 mm with four runoff-producing storms occurred during the cropping period. The runoff as a percentage of rainfall ranged from 42 to 66% across the four treatments. Data on crop yield, runoff, soil loss, and loss of organic carbon and clay is shown in Table 10. While the soil organic carbon contents of the initial plots ranged from 0.2-0.3%, those in the sediments ranged from 0.3 to 0.5%, which indicates an enrichment of organic carbon in the sediments. Similarly, the clay content of initial soils ranged from 7.5 to 9.2%, whereas those of the sediments ranged from 12.4 (under 0.5% slope) to 24.1% (under 3.5% slope).

Sorghum yield ranged from 7.3 to 10.6 q ha^{-1} with the recommended package of practices, the yield varied from 3.5 to 6 q ha^{-1} on farmers' fields in the nearby villages, with slopes varying between 0.5 and 2%.

H. Bellary (M. Prabhavathi, S.L. Patil and R.N. Adhikari)

A field study was conducted on deep black soils having 0.5, 1.0 and 2.0% slopes in the existing standard runoff plots (22.2×1.80 m) equipped with multi-slot devices at research farm. The treatments consisted of crops cultivated with fertilizer (T_1) and without fertilizer (T_2) (Control). The major cultivated crops during the post rainy (*rabi*) season of this region (sorghum and chickpea) were cultivated with application of recommended rate of fertilizers (RRF) with farmyard manure and without fertilizer application in 0.5%, 1.0% and 2.0% slopes runoff plots.

The total annual rainfall received in 2011 was 325 mm and was lower by 35% than the normal rainfall (501.7 mm). Higher rainfall received during June (107.6 mm) resulted in wetting of soil profile completely. No rainfall was received during critical crop growth stages. This resulted poor vegetative growth of sorghum as compared to chickpea. The yield of both crops were low and was attributed to scarcity of rainfall.

The pH of soil varied from 8.26 - 8.65 and EC from 0.16 - 0.30 dS m^{-1}. OC content of soil was low and varied from 0.24 to 0.42%. The available N and P status of the soil was low to medium which was 251 to 414 kg ha^{-1} and 19.0 to 38.6 kg ha^{-1}, respectively. High available K content (484 to 624 kg ha^{-1}) was recorded in all plots.

The runoff and soil loss increased with increase in slope from 0.5% to 2.0% slope, in the

Table 10: ***Crop yield, runoff, soil and nutrient loss as influenced by land slope***

तालिका 10: भूमि ढलान के कारण प्रभावित फसल उपज, अपवाह, मृदा एवं पोषक तत्व ह्रास

Slope (%)	Runoff		Soil loss (kg ha^{-1})	Loss of soil OC (kg ha^{-1})	Loss of clay content (kg ha^{-1})	Sorghum grain yield (q ha^{-1})
	(mm)	(%)				
0.5	58.4	42.0	610	2	75.6	10.6
1.5	61.5	44.2	1136	5	192.0	10.0
2.5	72.6	52.2	2024	10	429.2	8.6
3.5	91.6	65.9	3113	16	750.3	7.3

treatments with application of recommended rate of fertilizer along with farmyard manure and without application of RRF (Table 11). Lower runoff and soil loss in chickpea was observed compared to sorghum and was attributed to better canopy development of chickpea compared to sorghum with higher organic carbon and infiltration rate with higher soil water content in the profile.

The nutrient losses i.e. N, P and K increased with increase in slope from 0.5% to 2.0% in both sorghum and chickpea cultivated plots with and without application of RRF along with FYM (Table 12). The NPK losses were higher in control plots compared to application of RRF in both sorghum and chickpea at 0.5, 1 and 1.5% slope.

Due to drought and scarcity of rainfall, yields of sorghum and chickpea were low. The grain and straw yields of both sorghum and chickpea decreased with the increase in land slope from 0.5% to 2%. Higher grain and straw yields of sorghum and chickpea were recorded in the 0.5% slope as compared to 1.0% and 2.0% slopes and it was mainly attributed to higher soil water in profile and lesser soil erosion at 0.5% slope over 1.0% and 2.0% slopes (Table 13 and Fig.5). Higher chickpea grain yield of 392.7 kg ha^{-1} was observed with recommended rate of fertilizer application along with farmyard manure at 0.5% slope and decreased up to 109.9 kg ha^{-1} without fertilizer application at 2.0% slope. The straw yield decreased by 30% and 27% with and without recommended rate of fertilizer application at 2% slope.

Table 11 : ***Runoff and soil loss under different crops on varying slopes (2011-12)***

तालिका 11 : विभिन्न फसलों के अन्तर्गत ढलानों पर अपवाह एवं मृदा ह्रास (2011-12)

Treatments	Runoff (mm)						Soil loss (t ha^{-1})					
	Sorghum			Chickpea			Sorghum			Chickpea		
	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
T_1: With fertilizer	52.30	66.78	94.80	48.71	64.45	84.56	2.45	4.04	5.67	2.01	2.72	4.79
T_2: Without fertilizer	63.16	66.85	101.79	49.06	65.64	92.99	2.72	4.79	6.08	2.19	3.31	5.35

Runoff causing rainfall: 96.65 mm; Total annual rainfall: 325 mm

Table 12 : ***Nutrient losses under different slopes in sorghum and chickpea (2011-12)***

तालिका 12 : विभिन्न ढलानों पर बाजरा एवं चना में पोषक तत्वों का ह्रास (2011-12)

Treatments \ Slope	Nutrient loss (kg ha^{-1})								
	0.5%			1.0%			2.0%		
	N	P	K	N	P	K	N	P	K
Sorghum									
T_1: Recommended rate of fertilizer	1.85	0.74	1.88	2.15	0.83	1.94	3.05	0.83	2.04
T_2: Without fertilizer (Control)	2.25	0.85	2.03	2.47	0.92	2.13	3.19	0.95	2.18
Chickpea									
T_1: Recommended rate of fertilizer	1.67	0.42	1.26	2.08	0.68	1.71	2.08	0.79	2.03
T_2: Without fertilizer (control)	1.86	0.53	1.93	2.31	0.91	1.93	2.31	0.81	2.15

Table 13 : ***Grain and straw yield of sorghum and chickpea under different slopes (2011-12)***

तालिका 13 : विभिन्न ढलानों पर बाजरा एवं चना के अनाज और पुआल की उपज (2011-12)

Treatments	Yield (kg ha^{-1})											
	Sorghum grain			Straw			Chickpea grain			Straw		
	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
T_1: With fertilizer	75	49	7.1	804.6	571	540.4	392.7	325.1	115.2	427.2	366.2	299.6
T_2 : Without fertilizer	57	22.3	7.0	674.8	568	498.3	340.2	124.0	109.9	391.5	351.4	285.3

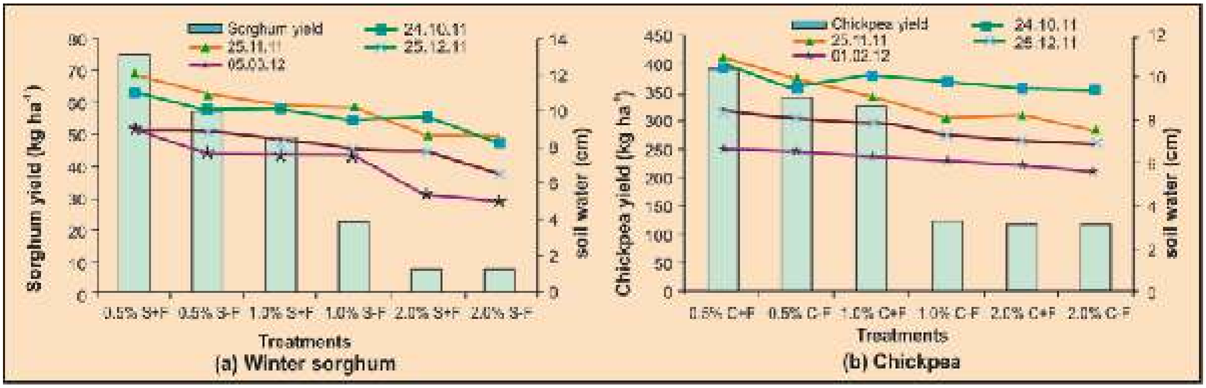

Fig. 5: Grain yield and soil water content

चित्र 5 : अनाज पैदावार एवं मृदा जल तत्त्व

I. Koraput (D. Barman, Praveen Jakhar and B.S. Naik)

The experiment is being conducted for two principal *kharif* crops, *viz*; Ragi and upland paddy at Centre Research Farm. Farmers cultivate these crops in natural slopes varying from 2% to 16% under rainfed condition without taking consideration of soil and water conservation aspects. The result of 2011 showed that with increase in slope from 2 to 10% there was significant increase in the runoff irrespective of the crop. The effect was more pronounced from 2 to 4% than 5 to 10%. On 10% slope maximum soil loss (23.02 t ha^{-1}) was recorded. Highest yield of ragi and paddy was recorded as 15.92 and 17.03 q ha^{-1} on 2% slope (Table 14).

Assessment of soil carbon in transit under erosion process: A source or sink for atmospheric CO_2 (M. Sankar, D.R. Sena and N.M. Alam) - Dehradun

The study was started during 2011-12 to understand the fate of eroded SOC by measuring and monitoring SOC pool in different eroded landscape position as influenced by intensity and frequency of tillage practices. In this attempts, engineering survey have been completed at study site and 48 soil samples were collected from various depths of mini-pits to analyze the bench mark physical and chemical preparation of the study site.

Development of Scalogram model based on soil parameters, land use and topographic characteristics for estimation of sediment yield from small watersheds (Sharmistha Pal, V.K. Bhatt and A.K. Tiwari) - Chandigarh

The study was initiated during the year 2010. Site specific quantitative estimation of sediment yield is necessary for designing and implementing appropriate soil and water conservation measures and also to mitigate the ill effects of sedimentation. Extensive dataset with respect to soil, land use and topographic characteristics were collected for 80 watersheds, covering Shivalik regions, Damodar, Mayurakshi and Chambal basins.

The selected study area of Damodar barakar and Mayurakashi basin is located in Jharkhand

Table 14 : *Runoff, soil loss and yield under ragi and upland paddy cultivation on different slopes*

तालिका 14 : विभिन्न ढलानों पर अपवाह, मृदा ह्रास एवं रागी और उच्चभूमि धान की खेती के अन्तर्गत उपज

Slope (%)	Runoff (%)		Soil loss (t ha^{-1})		Yield (q ha^{-1})	
	Ragi	Upland paddy	Ragi	Upland paddy	Ragi	Upland paddy
2%	12.83	17.13	9.24	6.92	15.92	17.03
4%	17.42	19.02	10.92	9.16	14.25	15.12
5%	20.47	20.64	14.73	14.24	13.82	14.84
10%	22.22	25.75	23.02	17.02	13.16	14.52

and Bihar states of India, with longitude between 84°52' to 86°44' E and latitude 23°33' to 24°57' N. The missing data of land use of many watersheds were generated from digitization of survey of India toposheets. The basic information regarding the watersheds was collected from the Deptt. of Agri. and Cooperation, S&WC Division, New Delhi. Mean annual rainfall for different stations varied from 843 to 1466 mm. The watersheds under Damodar basin were dominated by forest plantation of sal, bamboo, palas, mahua, followed by gullied lands and area under permanent cultivation of agricultural crops. Red loam and lateritic soil was dominantly found in the area. In case of Mayurakshi basin, dominant soil was sandy loam, loam and clay loam, major land use being agriculture and forest. Based on the result of principal component analysis, for Damodar Barakar and Mayurakshi basin, the relative importance of factors to sediment yield (in 0-1 scale) followed the order: catchment area (0.35) > rainfall (0.209) > silt % (0.18) > slope (0.102) > land use factor (0.078) > hydraulic conductivity (0.029) > clay (0.05) > bulk density (0.0012) > sand % (0.0008). Linear regression model could not give satisfactory result. Non-linear regression equations for runoff and sediment yield estimation are as follows:

$$\text{Runoff} = 0.0036 \times A^{1.01} \times P^{0.709} (N = 30, R^2 = 0.80)$$

$$\text{Sediment yield} = 1.395\text{x}10^{-8} \times A^{1.058} \times P^{1.396} (N = 30, R^2 = 0.41)$$

where, A = Catchment area and P = Annual rainfall

Thirty six watersheds of Chambal basin were chosen for the study. The area lies between longitude 74°45' to 75° 50' E and latitude 23° 30' to 25° 10' N and spreads over the states of Madhya Pradesh and Rajasthan. Based on the result of principal component analysis, for Chambal basin the relative importance of factors to sediment yield (in 0-1 scale) followed the order Rainfall (0.40) > catchment area (0.30) > slope (0.12) > silt % (0.11) > land use factor (0.055) > bulk density (0.005) > clay (0.0042) > hydraulic conductivity (0.006) > sand % (0.0097). Non-linear regression equations for runoff and sediment yield estimation are as follows:

$$\text{Runoff} = 0.0045 \times A^{0.905} \times P^{1.121} (N = 30, R^2 = 0.68)$$

$$\text{Sediment yield} = 0.986 \times 10^{-6} \times A^{1.028}\, \text{x}^{0.884} (N = 30, R^2 = 0.55)$$

where, A = Catchment area and P = Annual rainfall

Attempts are being made for incorporation of other parameters in the model subsequently.