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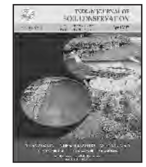

Soil erodibility assessment under various conservation measures at Babina watershed in Bundelkhand region

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ABSTRACT

The study was conducted in Operational Research Project, Babina watershed Jhansi district of Bundelkhand region for resource conservation on sustained yield basis. Soils of the watershed consists of black and red soils; former represents Bedaura (Mar) and Chamraua (Kabar) soil series which were richer in water stable aggregate and less erodible as compared to red soil represents Imilia (Parwa) and Amarpur (Rakar) soil series and followed the erodibility order as: Bedaura < Chamraua < Imilia < Amarpur. The results showed that erodibility in project area varies according to soil conservation measures adopted. Ravines lands with conventional up and down cultivated soils are more erodible in comparison to land treated by various soil conservation practices. On the basis of erosion ratio, erosion index and water stable aggregate as principle indices of erodibility, soil under various soil conservation practices may be arranged in the order of: conventional method > sowing across the slope > sunken structure > submerged bund with vegetation > check dam > contour bunding > land levelling and field bunding > vegetative barriers. Significant positive correlation has been observed between erosion ratio with suspension percentage, clay ratio, dispersion ratio and erosion index while significant negative correlations have been observed between erosion ratio and WHC, ME, WSA (>0.25 mm), clay/ME ratio, OC, exchangeable Ca^{++} and Mg^{++}. Among established eight soil conservation practices, soil erodibility decreased with increasing clay content. In view of above facts, soils of Babina watershed were found erosive in nature and require immediate attention for implementing appropriate soil and water conservation measures in the watershed area to reduce soil erosion and sustained crop productivity. We found that socio-economic conditions have also been uplifted considerably due to diversified agriculture and judicious use of natural resources in the watershed area.

1. INTRODUCTION

Soil and water are the most valuable endowment of nature for growth and sustenance of life and their conservation as well as judicious use is the need of the hour. According to a recent estimate of ICAR, more than 120 m ha of land area is under various forms of land degradation in India, out of which 74 m ha is affected by water erosion. It has been estimated that water erosion alone contributes to 5334 Mt of soil loss every year, at a rate of 16.4 t ha^{-1} of which 29% is lost permanently into the sea, 10% gets deposited in the reservoirs reducing their capacity by 1-2% every year and the remaining 6% gets displaced from one place to another (Maji *et al.*, 2010). About 50% area of the country needs soil and water conservation measures in one or the other ways.

Soil erosion is the function of erosivity of rainfall and erodibility of the soil. Erosivity is an uncontrollable factor which has been worked out for the whole country with the help of rainfall data (Ram Babu *et al.*, 2004). The study of erodibility is an important in the sense that, it is most important parameter in Universal Soil Loss Equation (USLE) suggested by Wishmeier and Smith (1965). Thus, there is a need of detailed information on soil erodibility of various categories of soil to be measured by simple and rapid laboratory techniques. The erodibility map prepared from this information would be helpful for effective soil and water conservation planning and sustained production of selected watershed. Erosiveness of the soil can be evaluated by the measurement of the soil loss through runoff plots. It is superior to other empirical methods, but rather than time consuming and expensive, therefore, can't be adopted for large scale investigation. Though, soil erosion is the function of erosivity of rainfall, the complex inter-relationship of the physical and chemical properties of soil that influence soil erodibility. Soil itself being an important factor in influencing soil erosion. It is matter of particular interest in obtaining various indices of erodibility by measuring some soil properties for conservation measures adopted along with socio-economic impact of watershed development programme.

Bundelkhand region comprises seven districts of Uttar Pradesh and six districts in Madhya Pradesh. This region has to support a huge human (9.94 million) and animal population (8.9 million) on merely 2.2% land area of the country (Nitant and Tiwari, 1990). According to conservative estimates by Nitant (1989) about 5.02 m ha (70%) of total geographical (7.0 m ha) area of the Bundelkhand is suffering from varying degrees of land degradation and erosion hazards. Further, about 80% population of the region is still live in rural areas and mainly dependent upon small land holdings and adjoining degraded/wastelands (community land) for their livelihood and basic needs of food, fuel, fodder, fruit and timber. Various technologies related to soil and water conservation particularly, moisture conservation, rainfed crop production and erosion control including watershed management have been developed for the Bundelkhand soils. The impact of soil and water conservation measures on erosion control, nutrient loss in runoff and productivity of crops were also evaluated (Her *et al.*, 2016). In view of poor edaphic properties including low WHC of red soils, it is essential to adopt suitable soil and water conservation practices for maximize infiltration and rainwater conservation in soil profile.

2. MATERIALS AND METHODS

The projected area of Babina hillock watershed is situated about 258 metre above mean sea level and lies on 24°11'-26°27'N latitude and 78°17'-81°34'E longitude. It is located about 15 km away from ICAR-Central Agro-forestry Research Institute. The elevation difference between highest and lowest point is about 30 m. The lowest point of the watershed is very close to the main drainage way crossing the metal road from Jhansi by-pass road situated under Babina block of Jhansi district in Bundelkhand region of Uttar Pradesh. The study area covers about 2217 ha area around the villages of Bethura, Amarpur, Imalia, Chamraua and Kilchavara within catchment of river Pahuj and their tributary. The area is beset with the problem of severe soil erosion and in an acute moisture scarcity owing to as many nalas dissecting the area and collectively draining nearly with terminal drainage to river Pahuj.

Ninety six soil samples have been collected in disturbed and undisturbed state upto 30 cm (three samples from each conservation activities established in all four series of the watershed) and these were analyzed as per standard procedure after that calculation of all important erosion indices have been carried out to correlate them with different physico-chemical properties of soils. Undisturbed soil sample also collected to analysis the water stable aggregates (>0.25 mm) and easily dispersible silt + clay. Particle size distribution, Bulk Density (BD), Moisture Equivalent (ME) and aggregate analysis have been done by adopting standard methods. Soil pH, EC, Exch. Ca^{++} and Mg^{++}, Organic Carbon (OC) were determined as per Piper (1950). Suspension percentage and dispersion, Erosion Ratio (ER) and colloidal/moisture equivalent ratio were computed as per suggested by Middleton (1930). Erosion index was calculated by dividing the dispersion ratio by clay/Water Holding Capacity (WHC). The base line data were collected through bench mark survey from selected farmers at village level to understand and documentation of the present resources and socio-economic status. The pre and post survey data was taken from the starting point of overall development and research activities.

3. RESULTS AND DISCUSSION

Physico-Chemical Properties

Results indicated that Bethura and Chamraua series (Black soils) and Imalia and Amarpur (Red soils) showed wide variation in particle size distribution and other physical properties (Table 1). Red soils, in general, are lighter in texture and have lower value of moisture retention capacity, ME and WSA (>0.25 mm) in comparison to black soils. These values are greater in nearly level (< 2% slope) and slightly eroded soil series and decrease with increase slope and degree of erosion. Higher value of moisture retention and water stable aggregates in nearly level and slightly eroded soils of black soils of Bethura and Chamraua series may be attributed to greater amount of clay content, finer fraction and OC content. The black soils have lower pH, EC, Exch. Ca^{++} and Exch. Mg^{++} than their red counterpart *viz;* Imalia and Amarpur series (Table 2). Conversely, the black soils recorded higher values of OC in comparison to red soils represented by Imalia and Amarpur series (Grewal, 2014).

Erodibility Characteristics

The higher values of dispersion and erosion ratios in Imalia and Amarpur series suggest that red soil are more easily erodible as compared to black soils *i.e.* Bedaura and Chamraua (Table 3 and Table 4). The higher values of

Table: 1
Physical properties of soil (Mean of four series)

Treatments	Series	Sand (%)	Silt (%)	Clay (%)	Texture	BD ($Mg\ m^{-3}$)	PD ($Mg\ m^{-3}$)	HC ($cm\ sec^{-1}$)	WHC (%)	ME (%)	WSA (%)	Suspension (%)
Conventional	Apr	82.83	10.50	6.67	ls	1.53	2.83	2.83	12.38	6.25	11.20	13.64
	Iml	54.13	31.18	14.69	sl	1.48	2.82	2.29	20.85	10.69	14.36	37.99
	Cru	35.13	36.47	28.40	ls	1.40	2.69	1.57	33.27	16.69	24.12	30.26
	Bdr	34.83	34.67	30.50	cl	1.35	2.68	1.53	34.24	17.59	26.79	29.56
Mean		51.73	28.21	20.07		1.44	2.76	2.06	25.19	12.81	19.12	27.86
Contour bunding	Apr	81.13	9.97	9.20	ls	1.50	2.74	2.70	17.06	8.89	14.37	13.05
	Iml	51.33	29.67	19.00	sl	1.42	2.73	2.17	26.10	13.56	17.93	31.77
	Cru	27.37	38.33	34.30	cl	1.27	2.53	1.47	40.92	21.02	31.89	22.46
	Bdr	27.13	35.74	37.13	cl	1.24	2.46	1.45	43.40	22.05	33.72	20.90
Mean		46.74	28.43	24.91		1.36	2.62	1.95	31.87	16.38	24.47	22.05
Land levelling and field bunding	Apr	78.80	11.23	9.97	ls	1.48	2.63	2.67	18.10	9.33	15.09	13.79
	Iml	45.24	35.63	19.13	sl	1.41	2.62	2.16	27.32	14.02	18.86	31.20
	Cru	22.83	40.63	36.54	cl	1.25	2.52	1.45	42.46	21.84	33.12	20.63
	Bdr	24.73	34.47	37.80	cl	1.23	2.36	1.42	44.90	23.26	34.97	19.60
Mean		42.90	30.49	25.86		1.34	2.53	1.93	33.20	17.11	25.51	21.31
Sowing (across the slope)	Apr	78.17	13.23	8.60	ls	1.52	2.80	2.79	13.94	7.15	12.67	16.97
	Iml	52.35	30.95	16.70	sl	1.47	2.80	2.26	22.18	11.45	15.10	35.71
	Cru	33.97	35.97	30.06	ls	1.37	2.68	1.54	34.09	17.45	25.95	28.56
	Bdr	31.27	36.37	32.36	cl	1.31	2.65	1.51	35.52	18.23	27.76	27.60
Mean		48.94	29.13	21.93		1.42	2.73	2.03	26.43	13.57	20.37	27.21
Check dam	Apr	81.06	9.94	9.00	ls	1.49	2.75	2.72	16.92	8.76	14.12	13.28
	Iml	52.53	30.40	17.07	sl	1.43	2.75	2.19	24.56	12.95	16.82	32.18
	Cru	28.07	39.37	32.56	cl	1.28	2.60	1.48	38.10	19.35	29.15	23.99
	Bdr	24.87	4.20	34.93	cl	1.27	2.50	1.43	42.15	21.50	31.88	22.02
Mean		46.63	20.98	23.39		1.37	2.65	1.96	30.43	15.64	22.99	22.87
Sunken structure	Apr	79.40	11.97	8.63	ls	1.51	2.78	2.78	15.76	7.93	13.01	15.26
	Iml	51.00	32.17	16.87	sl	1.45	2.78	2.23	23.26	11.98	15.64	34.86
	Cru	29.33	39.23	30.97	cl	1.35	2.65	1.52	35.12	17.87	26.34	26.95
	Bdr	29.33	38.07	32.60	cl	1.30	2.62	1.48	38.36	19.36	27.97	25.31
Mean		47.27	30.36	22.27		1.40	2.71	2.00	28.13	14.29	20.74	25.60
Submerged bunding with vegetation	Apr	80.53	10.50	8.90	ls	1.51	2.77	2.75	16.50	8.25	13.75	14.10
	Iml	53.42	29.52	17.00	sl	1.43	2.76	2.20	23.84	12.06	16.00	34.00
	Cru	31.13	37.00	31.87	cl	1.32	2.63	1.49	36.76	18.93	27.06	25.75
	Bdr	25.20	4.63	34.17	cl	1.28	2.58	1.46	39.56	20.18	30.05	23.60
Mean		47.57	20.41	22.99		1.39	2.69	1.98	29.17	14.86	21.72	24.37
Vegetative barriers	Apr	79.67	8.33	11.00	ls	1.46	2.61	2.63	20.20	10.42	15.72	12.75
	Iml	35.13	36.47	28.40	ls	1.40	2.69	1.57	33.27	16.69	24.12	30.26
	Cru	23.49	38.71	37.80	cl	1.23	2.48	1.43	43.30	22.03	34.67	19.33
	Bdr	24.32	37.38	38.30	cl	1.21	2'32	1.41	47.12	24.58	35.52	18.10
Mean	-	40.65	30.22	28.88		1.33	2.53	1.76	35.97	18.43	27.51	20.11
Range	-	22.83-82.83	4.20-40.63	6.67-38.30	-	1.2-1.53	2.3-2.83	1.41-2.83	12.38-47.12	6.25-4.58	11.20-35.52	12.75-37.99
Series Mean	-	46.21	27.28	23.79	-	1.38	2.65	1.96	30.05	15.38	22.80	23.92

Amarpur (Apr), Imilia (Iml), Chamraua (Cru), Bedaura (Bdr)

suspension percentage and erosion index in red soils further corroborates with the earlier findings (Kumar *et al.*, 2004). According to the criteria of Middleton (1930), soils having dispersion ratio >15 and erosion ratio >10, respectively are erosive in nature and thus, all the four soil series of the watershed were fall under erosive category. Based on erodibility indices, these series can be ranked as Bedaura< Chamraua<Imilia<Amarpur. Amongst all the eight soil conservation measures adopted in all the soils series namely Amarpur, Imilia, Chamraua and Bedaura, the vegetative barriers of *Saccharum munja* was found the most effective conservation practices followed by land levelling and field bunding and contour bunding. Similarly, sowing across the slope has proved better in reducing the soil erosion than conventional method. It was observed that conventional way of up and down cultivation along with slope was found to be most detrimental system for the soil and other natural resources (Chandra and Bhan, 2000; Kumar *et al.*, 2005).

Correlation Studies

The erosion ratio was significantly and negative correlated with clay (r = -0.99**), silt (r = -0.63**), moisture equivalent (r = - 0.98**), water holding capacity (r = -0.98**), water stable aggregate (r =-0.96**), organic carbon (r = -0.97**), total-N (r = -0.96**), available P_2O_5 (r = -0.94**),

Table: 2
Physico-chemical properties of soil (Mean of four series)

Treatments	Series	pH	EC ($dS\ m^{-1}$)	Exch. Ca++	Exch. Mg++	OC	Total-N	P_2O_5 ($kg\ ha^{-1}$)	K_2O ($kg\ ha^{-1}$)
Conventional	Apr	8.25	0.62	18.87	2.48	0.16	0.014	21.37	206
	Iml	7.83	0.53	20.16	2.75	0.31	0.028	22.47	242
	Cru	7.73	0.42	20.50	2.94	0.41	0.039	22.85	261
	Bdr	7.81	0.36	19.22	3.08	0.42	0.046	23.12	270
Mean		7.91	0.48	19.69	2.81	0.33	0.030	22.45	245
Contour bunding	Apr	7.97	0.54	19.35	2.60	0.24	0.021	21.75	231
	Iml	7.72	0.47	20.38	2.85	0.37	0.034	22.70	256
	Cru	7.64	0.35	20.65	3.06	0.49	0.047	23.36	272
	Bdr	7.49	0.29	21.30	3.70	0.49	0.058	23.84	279
Mean		7.71	0.41	20.42	3.05	0.40	0.040	22.91	260
Land levelling and field bunding	Apr	7.84	0.52	19.57	2.63	0.26	0.024	21.84	235
	Iml	7.69	0.45	20.41	2.88	0.38	0.035	22.75	257
	Cru	7.65	0.32	20.68	3.10	0.50	0.048	23.45	274
	Bdr	7.45	0.28	22.02	3.75	0.51	0.061	24.00	280
Mean		7.66	0.39	20.67	3.09	0.41	0.040	23.01	262
Sowing (across the slope)	Apr	8.20	0.59	18.96	2.56	0.17	0.015	21.43	211
	Iml	7.80	0.52	20.24	2.78	0.32	0.029	22.53	244
	Cru	7.71	0.40	20.52	2.96	0.44	0.043	22.94	264
	Bdr	7.73	0.35	19.84	3.14	0.43	0.048	23.35	272
Mean		7.86	0.47	19.89	2.86	0.34	0.030	22.56	248
Check dam	Apr	8.00	0.56	19.28	2.67	0.23	0.019	21.70	227
	Iml	7.73	0.49	20.35	2.84	0.35	0.033	22.67	254
	Cru	7.68	0.36	20.61	3.02	0.47	0.045	23.18	270
	Bdr	7.50	0.32	23.36	3.20	0.47	0.055	23.68	278
Mean		7.73	0.43	20.90	2.93	0.38	0.040	22.81	257
Sunken structure	Apr	8.17	0.58	19.05	2.61	0.20	0.017	21.58	219
	Iml	7.78	0.50	20.29	2.81	0.34	0.031	22.58	247
	Cru	7.70	0.39	20.55	2.97	0.46	0.044	22.99	265
	Bdr	7.60	0.34	20.66	3.10	0.45	0.050	23.48	275
Mean		7.81	0.45	20.14	2.87	0.36	0.040	22.66	252
Submerged bunding with vegetation	Apr	8.12	0.53	19.12	2.65	0.22	0.018	21.66	224
	Iml	7.75	0.46	20.32	2.82	0.36	0.032	22.62	251
	Cru	7.63	0.38	20.57	2.99	0.51	0.046	23.09	268
	Bdr	7.48	0.30	20.88	3.16	0.51	0.052	23.55	277
Mean		7.75	0.42	20.22	2.91	0.40	0.040	22.73	255
Vegetative barriers	Apr	7.88	0.51	19.72	2.66	0.29	0.028	21.97	237
	Iml	7.73	0.42	20.50	2.94	0.41	0.039	22.85	261
	Cru	7.62	0.30	20.76	3.12	0.52	0.054	23.52	276
	Bdr	7.31	0.23	22.12	3.80	0.54	0.062	24.15	282
Mean		7.64	0.37	20.78	3.13	0.44	0.050	23.12	264
Range		7.31-8.25	0.23-0.62	18.87-23.36	2.48-3.80	0.16-0.54	0.014-0.062	21.60-24.15	206-282
Series Mean		7.76	0.43	20.34	2.96	0.38	0.040	22.78	255

Amarpur (Apr), Imilia (Iml), Chamraua (Cru), Bedaura (Bdr)

available K_20 (r = - 0.96**), Exch. Ca^{++} (r = -0.74**), Exch. Mg^{++} (r = -0.82**) and clay/moisture equivalent (r = -0.92**) while positively correlated with suspension percentage (r = 0. 32), bulk density (r =0.95**), particle density (r = 0.77**), hydraulic conductivity (r = 0.98**), pH (r = 0.86**), EC (r = 0.96**), dispersion ratio (r = 0.95**), erosion index (r = 0.99**), clay ratio (r = 0.36*) and silt/clay ratio (r = 0.36*). Correlation (Table 5) substantiating the earlier findings. (Dabral *et al.,* 2001; Joshi *et al.,* 2004; Lal *et al.,* 2006; Agnihotri *et al.,* 2007; Das *et al.,* 2007; Singh and Khera, 2009; Gupta *et al.,* 2010; Pal *et al.*, 2014).

Impact on Socio-Economic Status

The degraded cultivated and barren land was remained constant while literacy rate was improved by 3% (Table 6). The initial productivity (8.46 $q\ ha^{-1}$) was increased up to 35.21 $q\ ha^{-1}$ recorded after termination of project and almost sustained due to potential increase in conservation irrigation. The improved farm implements *viz.,* tractor, cultivator, ferti-seedrill, pump-sets, thresher, etc. along with some other useful implements are frequently used by the farmers community in project areas at mass scale. The milch cattle like buffalo and cow were also increase after

Table: 3
Erodibility indices of soil (Mean of four series)

Treatments	Series	Total silt +clay	DR	EI	ER	CR	Si : Cl	Clay : ME	Clay:1/2WHC
Conventional	Apr	17.17	78.48	72.75	73.18	2.62	1.57	1.07	1.08
	Iml	45.87	82.97	59.23	61.03	2.95	2.13	1.37	1.41
	Cru	64.87	46.52	27.28	27.30	2.31	1.30	1.70	1.71
	Bdr	65.17	46.36	26.30	26.30	2.16	1.16	1.73	1.78
Mean		48.27	63.58	46.39	46.95	2.51	1.54	1.47	1.50
Contour bunding	Apr	19.17	68.78	62.30	66.47	2.06	1.05	1.03	1.08
	Iml	48.67	64.95	44.92	46.63	2.58	1.58	1.40	1.46
	Cru	72.63	30.88	18.45	18.91	2.12	1.12	1.63	1.68
	Bdr	72.87	29.21	17.33	16.87	2.01	1.01	1.68	1.71
Mean		53.34	48.46	35.75	37.22	2.19	1.19	1.44	1.48
Land levelling and field bunding	Apr	21.20	65.93	60.08	61.78	2.16	1.16	1.07	1.10
	Iml	54.76	56.75	40.55	41.54	2.86	1.86	1.36	1.40
	Cru	77.17	26.73	15.80	16.26	2.12	1.12	1.67	1.72
	Bdr	75.27	26.58	16.15	16.15	2.03	1.03	1.63	1.68
Mean		57.10	44.0	33.15	33.93	2.29	1.29	1.43	1.48
Sowing (across the slope)	Apr	21.83	77.94	61.76	63.75	2.32	1.32	1.20	1.23
	Iml	47.65	74.78	49.92	51.60	2.87	1.87	1.56	1.51
	Cru	66.03	43.67	26.17	26.17	2.11	1.22	1.72	1.76
	Bdr	68.73	43.00	23.72	26.34	2.35	1.35	1.78	1.82
Mean		51.06	59.85	40.39	41.97	2.41	1.44	1.57	1.58
Check dam	Apr	18.94	68.43	64.04	66.34	2.09	1.09	1.03	1.06
	Iml	47.47	67.62	48.80	52.11	2.78	1.79	1.32	1.39
	Cru	71.93	33.34	19.54	19.90	2.21	1.22	1.68	1.71
	Bdr	75.13	29.75	18.37	18.67	2.16	1.16	1.62	1.66
Mean		53.37	49.79	37.69	39.26	2.31	1.32	1.41	1.46
Sunken structure	Apr	20.60	73.78	67.74	68.10	2.39	1.39	1.09	1.10
	Iml	49.07	71.33	48.45	50.10	2.94	1.94	1.41	1.45
	Cru	70.20	37.89	21.86	22.22	2.38	1.40	1.73	1.76
	Bdr	70.76	37.21	22.06	20.06	2.19	1.18	1.68	1.70
Mean		52.66	55.05	40.03	40.12	2.48	1.48	1.48	1.50
Submerged bunding with vegetation	Apr	19.47	71.76	66.00	66.42	2.17	1.17	1.08	1.09
	Iml	46.52	68.12	44.56	44.93	2.81	1.81	1.41	1.43
	Cru	68.87	37.33	21.91	22.63	2.20	1.18	1.68	1.73
	Bdr	74.80	31.85	18.49	19.00	2.21	1.11	1.69	1.68
Mean		52.42	52.27	37.74	38.25	2.35	1.32	1.46	1.48
Vegetative barriers	Apr	20.33	63.72	54.36	55.61	1.70	0.70	1.06	1.19
	Iml	64.87	46.52	27.28	27.30	2.31	1.30	1.70	1.39
	Cru	76.51	25.23	14.46	14.76	2.03	1.02	1.71	1.75
	Bdr	75.68	24.32	15.14	15.79	1.99	0.99	1.56	1.63
Mean		59.35	39.95	27.81	28.37	2.01	1.0	1.51	1.49
Range		17.17-77.17	24.32-82.97	14.46-72.75	14.76-73.18	1.70-2.95	0.70-2.13	1.03-1.78	1.06-1.82
Series Mean		53.44	51.62	37.37	38.26	2.32	1.32	1.47	1.50

Amarpur (Apr), Imilia (Iml), Chamraua (Cru), Bedaura (Bdr)

the termination of the project. The initial milk productivity was 1.50 litre day^{-1} animal^{-1} that increased up to 6.90 litre day^{-1} animal^{-1} due to more availability of palatable fodder. The resource and facilities like roads, schooling, banking, marketing and extension networks also enhanced remarkably over the base year. It is also worthwhile to mention here that the base years benefit: cost ratio was 0.95 which improved to the tune of 2.10.

4. CONCLUSIONS

The Bedaura (Mar) and Chamraua (Kabar) soil series of Babina watershed representing typical black soils were richer in water stable aggregate and less erodible as compared to Imilia (Parwa) and Amarpur (Rakar) series (red soil) and followed the erodibility order as: Bedaura < Chamraua < Imilia < Amarpur. On the basis of erosion ratio, erosion index and water stable aggregate as principle indices of erodibility, the efficacy of various soil conservation practices were in the order of : conventional method > sowing across the slope > sunken structure > submerged bund with vegetation > check dam > contour bunding > land levelling and field bunding > vegetative barriers. It is also obvious from the data of resource survey that there are remarkable change in average productivity of cereals, pluses, oilseeds and other useful crops. Simultaneously, socio-economic condition of rural people have also uplifted considerably due to diversification of agriculture and

Table: 4
Erodibility indices and related properties

Particulars	Black soil		Red soil	
	Bedaura series	Chamarua series	Imilia series	Amarpur series
Erodibility indices				
Dispersion ratio	33.53	35.2	68.30	71.12
Erosion index	19.70	20.68	47.43	63.63
Erosion ratio	20.03	21.02	49.28	65.21
Clay ratio	2.14	2.19	2.80	2.19
Silt/clay ratio	1.12	1.20	1.82	1.18
Clay/ME ratio	1.67	1.69	1.38	1.09
Clay/½ WHC ratio	20.33	19.00	12.27	8.18
Physical properties				
Sand (%)	27.71	28.92	51.21	80.2
Silt (%)	37.57	38.21	31.28	10.71
Clay (%)	35.72	32.81	16.51	9.13
Suspension (%)	23.34	24.74	33.54	14.11
Bulk density (Mg m^{-3})	1.27	1.31	1.44	1.50
Particle density (Mg m^{-3})	2.52	2.60	2.73	2.74
ME (%)	20.84	19.40	12.73	8.37
Hydraulic conductivity (cm hr^{-1})	1.46	1.49	2.21	2.73
WHC (%)	40.66	38.00	24.53	16.36
WSA (>0.25mm) %	31.08	29.05	16.73	13.74
Physico-chemico properties				
pH	7.55	7.67	7.75	8.05
EC (dS m^{-1})	0.31	0.37	0.48	0.56
Exch. Ca^{++} (c mol(p^+)kg^{-1})	20.78	20.61	20.32	19.24
Exch. Mg^{++} (c mol(p^+)kg^{-1})	3.37	3.02	2.83	2.61
Chemical properties				
OC (%)	0.48	0.48	0.35	0.22
Total-N (%)	0.054	0.046	0.032	0.02
Available P_2O_5 (kg ha^{-1})	23.65	23.17	22.64	21.66
Available K_2O (kg ha^{-1})	277	269	251	224

Table: 5
Simple correlation of erosion ratio with soil properties and erosion indices

Correlation between		Correlation	Regression equation Coefficient (r)
X Soil properties	Y Erosion ratio (ER)		
Physical properties			
Sand (%)	ER	0.97**	Ye=-3.103+0.888X
Silt (%)	ER	-0.63**	Ye=65.731-1.007X
Clay (%)	ER	-0.99**	Ye=80.931-1.794X
Suspension %	ER	0. 32	Ye=-52.953+0.614X
Bulk density (Mg m^{-3})	ER	0.95**	Ye=-221.969+188.612X
Particle density (Mg m^{-3})	ER	0.77**	Ye=-278.001+119.329X
Hydraulic conductivity (cm hr^{-1})	ER	0.98**	Ye=-33.021+36.448X
WHC (%)	ER	-0.98**	Ye=94.316-1.866X
ME (%)	ER	-0.98**	Ye=94.041-3.626X
WSA (>0.25 mm) (%)	ER	-0.96**	Ye=93.052-2.403X
Physico-chemical properties			
pH	ER	0.86**	Ye=-576.877+79.311X
EC (dSm^{-1})	ER	0.96**	Ye=-40.522+184.277X
Exch. Ca^{++} (C mol (p^+) kg^{-1})	ER	-0.74**	Ye=351.890-15.421X
Exch. Mg^{++} © mol (p^+) kg^{-1})	ER	-0.82**	Ye=189.099-51.014X
Chemical properties			
Organic carbon (%)	ER	-0.97**	Ye=104.337-172.898X
Total N (%)	ER	-0.96**	Ye=90.548-1377.221X
Available P_20_5 (kg ha^{-1})	ER	-0.94**	Ye=590.766-24.253X
Available K_20 (kg ha^{-1})	ER	-0.96**	Ye=264.734-0.888X
Erosion indices			
Dispersion ratio	ER	0.95**	Ye=-13.249+0.998X
Clay ratio	ER	0.36*	Ye=-15.485+23.180X
Silt/clay ratio	ER	0.36*	Ye=8.685+22.371X
Clay/ME ratio	ER	-0.92**	Ye=142.643-70.996X
Clay/½WHC ratio	ER	-0.98**	Ye=94.245-3.732X
Erosion index	ER	0.99**	Ye=-0.289+1.032X

* Significant at $p < 0.05$ probability level; ** Significant at $p < 0.01$

Table: 6
Impact of watershed development activities on socio-economic conditions

Particulars	Before start of Watershed project (1998)	After completion of Watershed project (2003)
Social status		
Population	14551	18365
Literacy (%)	73.0	76.0
Cultivated area	2197.6	2197.6
Barren land	19.20	19.20
Economic status		
Productivity (q ha^{-1})	8.46	35.21
Improved farm implements		
1) Tractor	17	103
2) Tractor cultivator	17	101
3) Thresher	03	32
4) Seed drill	05	33
5) Diesel operated pump	11	709
Irrigated area (ha)	719.6	2197.6
Milch cattle	4315	9707
Browses	1848	3567
Milk productivity (lit. Day^{-1})	1.50	6.90
Recreation source (TV, Radio *etc.*)	29	103
B:C ratio	1 : 0.95	1 : 2.10

allied agri-enterprises, judicious use of natural resources, adoption of low cost soil and water conservation measures, drought tolerant varieties, timely sowing with optimum seed rates, integrated use of manures and fertilizers with life saving irrigation at critical stages of crop growth in the Babina hillocks watershed.

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