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Effect of landform and soil depth on productivity of soybean-based cropping systems and erosion losses in Vertic Inceptisols

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ABSTRACT : A field study was conducted at the ICRISAT, Patancheru, Hyderabad, India, to evaluate the effect of landform and soil depth on water, soil and nitrate-nitrogen loss through runoff and performance of soybean - based cropping systems. Total system's productivity (seed yield) of soybean + chickpea was significantly higher than soybean/pigeonpea intercropping system. Soybean followed by chickpea grown on broad bed furrow (BBF) landform on medium-deep soil produced maximum yield in 1997 (2410 kg ha^{-1}) and in 1998 (3000 kg ha^{-1}) compared to flat land form on medium-deep soils. The seasonal runoff (287 mm, 33% of seasonal rainfall), NO_3-N loss (13 kg N ha^{-1}) and soil loss (5.35 t ha^{-1}) from the flat landform was observed to be maximum when compared to BBF landform. These results indicated that BBF landform on Vertic Inceptisols reduced runoff, NO_3-N loss and soil loss considerably and marginally increased the yield of soybean, pigeonpea and chickpea.

Key words: Cropping system; Erosion losses; Land configuration; Vertic Inceptisols; Watershed

Vertic Inceptisols, which occur in association with Vertisols on a toposequence occupy about 60 M ha out of 72 M ha Vertisols and associated soils in India (Sehgal and Lal 1988). These soils have similar physical and chemical properties as the Vertisols except that these are shallow to medium deep (25-60 cm) and somewhat lighter in texture. The productivity of different cropping systems in these soils is threatened because of low water holding capacity, low organic matter status, poor biological nitrogen fixation (BNF), and loss of nutrients and beneficial organisms resulting in degradation of soil. In order to sustain the productivity of these soils, there is an urgent need to identify suitable cropping systems and land management practices.

Improved landform systems are reported to increase crop yield and decrease runoff and soil erosion in few field studies. There is need to manage the natural resources for Vertic Inceptisols in the region, particularly rainfall, to control soil erosion and to improve rainfall use efficiency for crop production. This paper deals with the study on the effects of different landform treatments and soil profile depths on the performance of the soybean / pigeonpea and soybean + chickpea cropping systems on water, soil and NO_3-N loss through runoff in Vertic Inceptisols.

MATERIALS AND METHODS

The study was conducted during 1997-98 and 1998-99 at ICRISAT, Patancheru (17^0 32' N latitude, 78^0 16'E longitude and 540 m above mean sea level) Andhra Pradesh, India. Total rainfall received during 1997 and 1998 at ICRISAT centre was about 523 mm and 862 mm, respectively. On the basis of a topographical survey, a small watershed of 4.7 ha was designed and developed. The general slope of the land was less than 2%. The soil was a Vertic Inceptisol, which is classified as the member of the fine, montmorillonitic and isohyperthermic family of paralithic Vertic Ustropepts. The pH, E.C (mmhos cm^{-1}), organic carbon (%) and mineral N (kgha^{-1}) of soil before sowing ranged from 8.02 to 8.85, 0.15 to 0.25, 0.23 to 0.94 and 5.66 to 7.02, respectively. The soil profile in the watershed varied in depth from 30 to 90 cm underlain by a relatively coarse weathered material locally known as "*murrum*".

The whole watershed thus consisted of four hydrological units arising from the factorial combination of two soil depths and two landforms, as flat shallow (<45 cm), BBF shallow, flat medium-deep (45-90 cm) and BBF medium-deep. Tropicultor mounted implements were used for making BBF and flat landforms. Installing the neutron moisture probe in each sub-plot monitored the soil moisture dynamics. The total water retained in the shallow soil was 410 mm, while the medium-deep soil profile retained 540 mm in the flat and 600 mm in the BBF treatment (Singh *et al.* 1999).

Sole soybean crop (Cv. PK 472) was sown with 0.3 m row spacing and in case of soybean / pigeonpea (Cv. ICPL 87119) inter crop at 4:1 ratio of respective crop rows (additive series) in both the land forms in rainy season followed by chickpea (Cv. ICCC 37) in winter season. Detailed observations on various aspects of crop growth and resource use were recorded from the sub-plots of each hydrological unit (Singh et al. 1999). The crops were harvested at maturity. Run-off

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from each hydrological unit was measured by installing 1.51 H-flumes with mechanical stage level recorders. Runoff water samples were collected and analyzed in the laboratory for NO_3 - N.

RESULTS AND DISCUSSION

Dry matter and yield of crops

Total dry matter yield of soybean was significantly influenced by landforms in 1997. The highest total dry matter (2340 kg ha^{-1}) and seed yield (820 kg ha^{-1}) were observed when the crop was grown on the BBF landform compared to flat landform. Similar results were also observed at different locations by Ingle *et al.* (1999), and Klaij *et al.* (1996). However, during 1998 rainy season the seed and dry matter yields of soybean were not significantly affected by the landform treatments. Under well distributed rainfall conditions, landform treatments may not affect the yield in Vertic Inceptisol (Alagarswamy *et al.* 1996). Soil profile depth also did not significantly affect the total dry matter and seed yield of soybean in both the years of investigation. However, the medium - deep soil recorded marginally higher yield (dry matter and seed) when compared to the shallow soil (Table 1).

During 1997 rainy season, landform x soil depth interaction was significant on the drymatter yield, but not on the seed yield of soybean. The BBF landform on the shallow soil recorded the highest mean dry matter (2760 kg ha^{-1}) and seed yield (940 kg ha^{-1}) of soybean, because the BBF landform increases infiltration of water into the soil and water content of the medium-deep soil Bhatawadekar 1985; Anon 1990). In addition, the cropping system treatment had a significant effect on total drymatter and seed yield of soybean during both the years of investigation (Table 1). Higher drymatter and seed yield was observed in case of sole soybean than intercropped soybean. It might be due to the low light intensity because of shading by pigeonpea, reduced the yield of intercropped soybean (Selvaraju 1994). Landform x soil depth x cropping system interaction significantly changed the dry matter and seed yield of soybean. During 1997, maximum drymatter and seed yield was observed in case of sole soybean grown on BBF landform on shallow soil. However, during 1998, maximum drymatter and seed yield was recorded in case of sole soybean grown on the flat landform on the shallow soil. The yield differences between the two years were mainly due to the varying rainfall during the years of study.

The landform treatment and the interaction of landform x soil depth (during 1997) significantly influenced pigeonpea dry matter yield (Table 2). Higher dry matter yield was recorded in BBF landform (6360 vs 5430 kg ha^{-1}) than flat bed during 1997. Mean seed yield of pigeonpea was marginally higher on BBF landform than the flat landform treatment (1380 kg vs 1220 kg) during 1998 but it was similar from both shallow and medium deep soils. This was due to higher stored moisture in BBF as reported by Singh *et al.* (1999).

Total drymatter and seed yield of chickpea was not significantly influenced by landforms during the years of investigation (Table 2). But higher dry matter and grain yields were observed in medium-deep soil than in the shallow soil as it has the capacity to store more soil water and nutrients. The BBF landform on the medium-deep soil showed the highest drymatter and grain yields of chickpea than flat landform treatment on the shallow vertic soil. Similar results were reported by Abebe *et al.* (1994) who found that higher chickpea seed yield in BBF landform than the flat bed in Vertisols.

Total system productivity of soybean + chickpea (sequential crop) and soybean/ pigeonpea (intercrop)

The total system productivity (seed yield) of soybean + chickpea sequential cropping system was significantly higher (1.6 and 1.2 times) than that of soybean / pigeonpea intercropping system during 1997 (2120 vs 1480 kg ha^{-1}) and in 1998 (2630 vs 2290 kg ha^{-1}), respectively (Table 3). In general during normal and above normal rainfall years sequential systems such as soybean + chickpea produced more than the intercropping systems (Dwivedi *et al.* 1998; Joshi *et al.* 1997; Jadhao *et al.* 1994). However, in the absence of late season rains which affect the winter season crop establishment, intercropping systems produced more than the sequential cropping systems (Singh *et al.* 1999). Bhaskar *et al.* (1992) also reported that the soybean-chickpea sequential cropping system was promising for crop productivity and economics on Vertisols

In the present investigation, maximum system productivity (seed yield) was found in the soybean followed by chickpea grown on BBF on medium-deep soil during 1997 (2410 kg ha^{-1}) and 1998 (3000 kg ha^{-1}). This might be due to the BBF landform increased water infiltration into the soil and increased soil water content of the medium-deep soil (Singh *et al.* 1999).

Runoff, soil and nitrogen losses

In the deficit rainfall year 1997, with 523 mm rainfall recorded during the rainy season, no runoff events were recorded. In 1998 rainy season 862 mm rainfall was characterized

Table 1. *Total drymatter and seed yield (kg ha⁻¹) of sole and intercropped soybean grown on flat and BBF landfoms on shallow and medium-deep Vertic Inceptisols*

	1997							1998						
	Shallow			Medium-deep				Shallow			Medium-deep			
	Sole	Inter crop	Mean	Sole	Inter crop	Mean	Total mean	Sole	Inter crop	Mean	Sole	Inter crop	Mean	Total mean
Total drymatter yield (kg ha⁻¹)														
	Flat	2750	1900	2320	2920	2080	2500	2410	3530	2170	2850	3400	2410	2900
2880														
BBF	3180	2340	2760	2960	2120	2540	2650	3410	2380	2900	3430	2270	2850	2870
	L*	**S***		**LS***	**LC***	**SC***	**LSC***	**L**	**S**	**C**	**LS**	**LC**	**SC**	**LSC**
Mean	2965	2124	2764	2940	2098	2519	2532	3473	2276	2875	3417	2339	2878	2877
CD(0.05)	178.9	NS		259.5	257.5	255.5	318.9	NS	NS		NS	256.1	256.1	
Seed yield (kg ha⁻¹)														
Flat	1020	700	860	900	700	800	830	1690	980	1340	1630	1080	1350	1350
BBF	1060	820	940	1010	720	870	910	1570	990	1280	1630	1040	1330	1310
Mean	1040	760	900	960	710	840	870	1630	990	1310	1630	1060	1340	1330
CD(0.05)	NS	NS	114.0	NS	156.7	155.6	212.6	NS	NS	129.4	NS	172.7	169.0	230.2

* L = Landform system; S = Soil depth; C = Cropping system; LS = Landform x Soil depth; LC = Landform x Cropping system; SC = Soil depth x Cropping system; LSC = Landform x Soil depth x Cropping system
NS = Not significant

Table 2. *Total drymatter and seed yield(kg ha⁻¹) of chickpea and pigeonpea grown on flat and BBF landforms and shallow and medium-deep Vertic Inceptisols*

Landform	1997 Shallow	1997 Medium-deep	1997 Mean	1998 Shallow	1998 Medium-deep	1998 Mean
			Chickpea			
Total dry matter yield (kg ha⁻¹)						
Flat	1850	2240	2050	1490	2300	1900
BBF	1980	2700	2340	1830	2630	2230
Mean	1915	2470	2195	1660	2470	2065
	L	**S**	**LS**	**L**	**S**	**LS**
CD(0.05)	NS	424.7		NS	456.4	
Seed yield (kg ha⁻¹)						
Flat	1000	1150	1070	860	1300	1080
BBF	1060	1370	1210	970	1420	1200
Mean	1030	1260	1140	915	1360	1140
CD(0.05)	NS	213		NS	236.6	
			Pigeonpea			
Total dry matter yield (kg ha⁻¹)						
Flat	2890	2975	2930	5260	5590	5430
BBF	2960	2945	2950	6200	6530	6360
Mean	2920	2960	2940	5730	6060	5895
CD(0.05)	NS		NS	872.2	NS	1166
Seed yield (kg ha⁻¹)						
Flat	640	580	610	1210	1230	1220
BBF	650	540	590	1380	1385	1380
Mean	650	560	600	1295	1290	1390
CD(0.05)	NS	NS	NS	NS	NS	NS

Table 3. *Total system productivity [seed yield (kg ha^{-1})] of soybean+chickpea in sequence and soybean/pigeonpea intercropping systems grown on BBF and flat landforms on shallow and medium-deep Vertic Inceptisols*

Landform	Shallow Soybean+chickpea	Soybean/pigeonpea	Mean	Medium-deep Soybean+chickpea	Soybean/pigeonpea	Mean	Total mean
1997							
Flat	2040	1320	1680	2000	1320	1660	1670
BBF	2120	1480	1800	2410	1240	1830	1810
Mean	2080	1400	1740	2205	1280	1740	1740
L*	S*	C*	LS*	LC*	SC*	LSC*	
CD(0.05)	NS	NS	190.4	NS	263.2	262.4	379.5
1998							
Flat	2580	2130	2350	2850	2390	2620	2510
BBF	2630	2290	2460	3000	2480	2740	2610
Mean	2605	2210	2410	2930	2430	2680	2560
CD(0.05)	NS	236.4	242.9	332.8	328.6	262.4	379.5

Soybean + chickpea = Soybean and chickpea in sequential system
Soybean / Pigeonpea = Soybean and pigeonpea in intercropping system

by a large number of medium intensity long duration storms and, therefore, relatively high runoff events recorded in all the land management and cropping systems. A total of 30 runoff events were recorded in this season and total seasonal runoff from the BBF system was considerably lower (226 mm) when compared with the flat system (287 mm) on both the shallow and medium-deep soils (Table 4). On the shallow soil, the total seasonal runoff was 251 mm on BBF landform treatment and 283 mm on the flat landform configuration. Similarly on the medium-deep soil, the total seasonal runoff during the rainy season was 200 mm on BBF landform and 290 mm on flat. On an average total runoff from the medium-deep soil was 28% of seasonal rainfall, whereas on shallow depth soil it was 31% of the seasonal rainfall. The average runoff from flat treatment was 33% of the seasonal rainfall and on the BBF landform was 26% of seasonal rainfall was lost as surface runoff. The reduced runoff in case of BBF landform was due to higher retention time on soil because of slow movement of water in furrows laid across the slope (0.4%) for the rainwater enabling more infiltration in soil as compared to the flat landform treatment.

Nitrate N concentration in the runoff water varied from 2.4 to 9.6 mg L^{-1} during the entire crop-growing period where as for different events the amount of NO_3-N lost in the runoff ranged from 0.01 to 2.53 kg N ha^{-1}. The highest N concentration was observed at 64 DAS of the crops. The total nitrate - N lost in the season was 14.4 kg ha^{-1} in the medium-deep soil under flat landform and 9.3 kg ha^{-1} in medium-deep soil under BBF landform. The reduced NO3-N loss in case of BBF landform was due to reduced runoff as compared to the runoff from the flat landform treatment (Table 4).

The BBF system reduced soil loss when compared with flat landform system in both the shallow and medium-deep depth soils. However, flat landform treatment had no effect on soil loss in shallow and medium depth soils. On an average, amount of soil lost in runoff was high in the flat form (5.35 t ha^{-1}) than the BBF (3.08 t ha^{-1}). Several workers such as Singh *et al.* (1999), Gupta and Sharma (1994) and Srivastava and Jangawad (1988) reported similar results.

Table 4. *Effect of landform and soil depth on runoff, soil loss and NO_3^--N in Vertic Inceptisols (BW7) during rainy season in 1998.*

Parameters	Treatments Shallow	Flat Medium -deep	Mean	Shallow	BBF Medium-deep	Total mean	mean
Runoff (mm)	283	290	287	251	200	226	257
Soil loss (t ha^{-1})	5.3	5.5	5.4	3.4	2.7	3.1	4.3
NO_3^--N loss (kg ha^{-1})	12.6	14.0	13.3	10.3	9.3	9.8	11.6

Rainfall during rainy season 1998 = 862 mm

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