A COMPARISON OF SOIL AND WATER LOSSES FROM CONVENTIONAL AND MINIMUM TILLAGE REPLANTING METHODS USING A RAINFALL SIMULATOR

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Abstract

A rotating-boom rainfall simulator is used to simulate a once in 10 years storm of about 63 mm h^{-1} for an hour. Soil loss and runoff from plots that were replanted using minimum tillage are compared with those plots that were replanted by conventional tillage. The results of the studies showed that sediment loads (soil loss) and water runoff are reduced under good minimum tillage conditions.

Introduction

Soil and water losses from sugarcane fields are a serious problem in many areas of the sugar industry. This problem is associated mainly with steep topography and shallow, erodible soils. Research on erosion following natural rainfall on fields planted to sugarcane is presently being carried out on runoff plots and small catchment areas (Platford[8]). Assessments of erosion losses caused by natural rainfall on such areas take many years (Hudson[2]). The main advantages of a rainfall simulator are that the speed and efficiency of research is greatly increased. Rainfall simulation tests show that it is feasible to measure comparative soil losses and runoff from arable lands subjected to a number of different agricultural practices (McPhee *et al*[3]; Smithen *et al*[10]).

Good crop cover can greatly reduce the amount of soil erosion. Using a rainfall simulator just after planting, runoff from high intensity storms in areas under minimum tillage has been found to be less than that obtained from areas under conventional tillage (Rawls *et al*[9]; Smithen *et al*[10]). Sugarcane produces more vegetation above the ground than most other crops grown in rows so it provides more protection to the soil against the impact from rainfall. An area that is being replanted is more vulnerable to highly erosive rainstorms (Platford[7]) and replant methods which reduce this vulnerability should therefore be practised.

Rainfall simulator trials were conducted by applying 63 mm of water in one hour on two separate occasions, 24 hours apart, to assess the effectiveness of minimum tillage on eight different sites which are listed in Table 1. Within each site there were four plots. Two of the plots were replanted using conventional tillage while the other two plots were replanted using minimum tillage techniques. The objective was to compare the two types of replanting technique on each site.

Experimental procedure

The rotating-boom rainfall simulator was built according to the design by Swanson.[11] The simulator is mounted on a two-wheel trailer chassis which has a central, vertical stand-pipe. This stand-pipe may be lowered during transportation. Ten pipes (booms) are attached to a central manifold which is rotated at a constant speed by a hydraulic motor driven by a petrol engine. Nozzles are placed on the underside of the booms in a flat fan spray pattern as shown in Figure 1. The spray pattern of the nozzles is directed vertically downward at right-angles to the direction in which the booms rotate. A strainer prevents any matter in the water which may clog the nozzles from entering the supply-line. A flowmeter measures the volume of water supplied, and a Saunders pressure valve is used to maintain a constant pressure of 42 kPa at the nozzles.

Table 1

Properties of the rainfall simulator sites

Site no	Slope %	Soil			Particle size distribution (mm)		
		Form	Series	Depth (mm)	Clay % <0,002	Silt % 0,002-0,02	Total sand % 0,02-0,5
1	25	Glenrosa	Trevanian	300	34	13	53
2	25	Glenrosa	Trevanian	300	33	14	53
3	17	Shortlands	Shortlands	>1200	68	13	19
4	25	Glenrosa	Williamson	300	29	12	59
5	6	Longlands	Waldene	500	37	8	55
6	8	Longlands	Waldene	500	37	8	55
7	17	Glenrosa	Williamson	300	19	16	65
8	15	Hutton	Clansthal	>1200	8	3	89

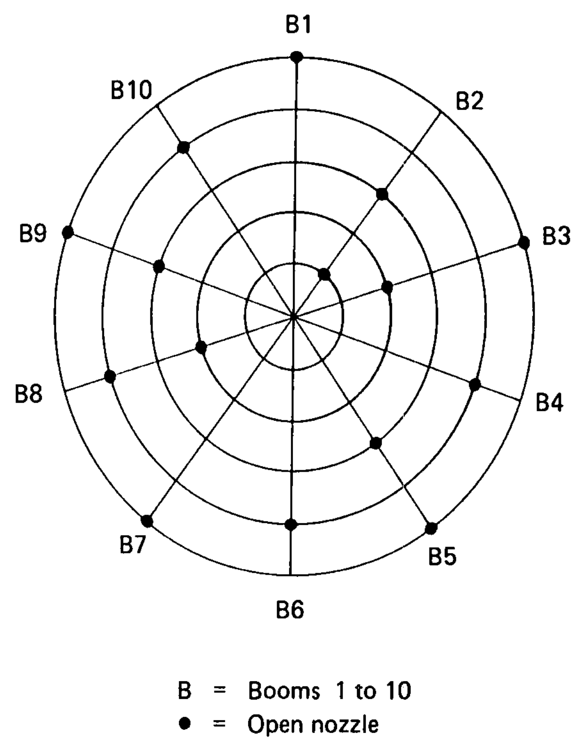

FIGURE 1 Layout of the nozzles of the rainfall simulator (after McPhee *et al.*[3]).

The erosive characteristics of natural rainfall must be known before a simulated rainfall apparatus can be designed. The major characteristics are intensity, droplet-size, distribution, and the velocity of the falling droplets (Meyer[5]). Meyer and McCune[4] selected the Spraying Systems Company 80100 vee-jet nozzle for the rainfall simulator. This nozzle was found to have the best combination of droplet-size, drop velocity, and intensity. The kinetic energy produced is approximately 75 % of the kinetic energy of natural rainfall with an intensity of 63 mm ha^{-1}. Platford[7] determined a coefficient of uniformity of 94% for this rainfall simulator.

The four plots of 10,67 m by 1,8 m, were arranged lengthwise up and down the slope as shown in Figure 2. Unplasticised polyvinyl chloride (PVC) boards, each 1,5 m by 0,2 m, were placed in an overlapping arrangement around the plots to a depth of 100 mm to prevent runoff leaking into and out of the plots. At the lower edge of the plots, a steel sill-plate was placed on an excavated soil face so that the top edge of the plate was horizontal and 20 mm below the soil surface. Closed-type collection chutes were attached to the sill-plates.

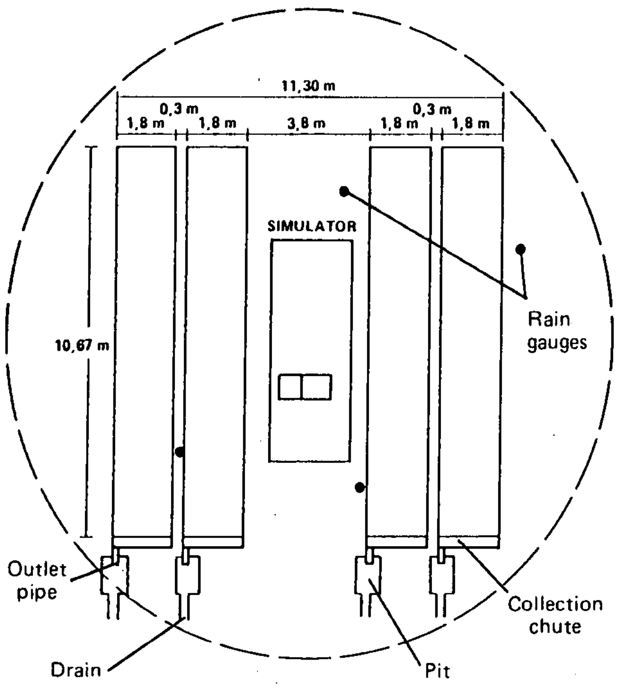

FIGURE 2 Layout of the plots for the rainfall simulator sites (after McPhee *et al*[3]).

The plots were replanted using either conventional or minimum tillage methods in each alternate plot. When the ratoon cane had grown to a height of approximately 400 to 700 mm, or to the 4th to 8th leaf stage of growth, the minimum tillage replant plots were sprayed with the chemical Roundup at a rate of 8 l ha^{-1}. Three weeks after spraying, once the cane had died, planting furrows, 150 mm deep and 1,4 m apart, were prepared manually in the interrow and seedcane was planted. At the same time, the old stools in the conventional tillage replant plots were removed by hand-hoeing. The bare soil was tilled using a small self propelled rotary hoe until a suitable tilth and seedbed were prepared. Seedcane was planted in the same way as the minimum tillage replant plots.

Two rainstorms were applied at 63 mm h^{-1} to the plots for one hour on two consecutive days, usually within one week after planting. Runoff and sediment samples were collected in one-litre bottles at regular intervals during the storms, and the times taken to fill the bottles were recorded.

The contents of each sample bottle were weighed in the laboratory to obtain the mass of the sediment. The time taken to fill the bottles was used to calculate the rate at which soil loss and water runoff had occurred.

Results and discussion

The two main elements of the erosion process are soil detachment and the transportation of this loose soil. Considerable erosion is not possible unless both these processes occur (Zaslavsky[12]). Land use and treatment of the soil surface can reduce the volume of direct runoff that occurs during individual storms either by increasing the infiltration rates, by increasing the surface storage or both (Anon[1]). Infiltration increases if the runoff velocity is reduced and this can be achieved either by decreasing the slope of the land or by increasing the roughness of the surface. Surface roughness can be increased by conventional tillage practices such as ploughing, or by increasing the vegetative or residue cover. Practices such as contour ploughing or the construction of terrace banks to increase surface storage generally reduce the total volume of runoff and thereby increase infiltration (Rawls[9]).

A summary of the slopes and soils at the eight rainfall simulator sites is given in Table 1. Hydrographs (Figures 3 and 4) were plotted for each storm and the total soil loss and runoff were calculated. A summary of the runoff and soil loss of the first and second simulated rainstorms is shown for each site in Table 2. There was more runoff and sediment lost from the minimum tillage replant plots than from the conventional tillage replant plots only on Site 1 (second test) and on Sites 3 and 4. The principal reason for the unexpected results on Sites 3 and 4 was the poor residue cover on the minimum tillage replant plots. The ratoon cane was at the 4th leaf stage of growth when Roundup was applied. There were bands of compacted soil along the cane rows where the infiltration rate was clearly less than in the cultivated interrows. As a result the volume of water available for runoff was greater in the minimum tillage replant plots than in the conventional tillage replant plots. The poor cover provided by a crop sprayed at the 4th leaf stage was not able to restrain and store the runoff water sufficiently and the detached soil particles were carried down the slope.

The more vegetative growth from the ratoon crop there is at the time the plant is killed chemically, the greater will be the possibility of conserving soil and water. This was supported by the results obtained from Site 1 and Site 2, where the soils and slope were similar. The results of the different tillage replant practices obtained from the second rainstorm should be used for comparative purposes because the first rainstorm was used in all instances to standardise antecedent moisture conditions. The amounts of soil lost from the conventional tillage replant plots were approximately the same for both sites immediately after planting. The runoff from the different plots on Site 1 (sprayed at the 5th leaf stage) was approximately the same (about 77 %), but there was less runoff from the minimum tillage replant plots than from the conventional tillage replant plots on Site 2 (51 % v 94 %) because there was a better mulch on Site 2, which had been sprayed at the 7th to 8th leaf stage.

Table 2

Summary of runoff and soil losses of the simulated rainstorms

Site no	Soil	Treatment	Residue cover (%)	Leaf stage when sprayed with Roundup	Storm 1 Intensity (mm h⁻¹)	Storm 1 Soil loss (t ha⁻¹)	Storm 1 Runoff (5)	Storm 2 Intensity (mm h⁻¹)	Storm 2 Soil loss (t ha⁻¹)	Storm 2 Runoff (%)
1	Gs17 Trevanian	Min tillage replant Conv tillage replant	- -	5	60,0	0,4 0,1	6,2 1,6	56,5	7,2 11,1	76,3 78,8
1	Gs17 Trevanian	Min tillage replant (simulation 10 wks after replanting) Conv tillage replant	- -	5	62,9	12,2 4,9	34,7 10,0	60,9	13,8 11,1	90,8 71,5
2	Gs17 Trevanian	Min tillage replant Conv tillage replant	68 9	7-8	57,7	1,2 6,9	47,5 60,0	60,8	0,8 11,4	50,9 94,3
3	Sd22 Shortlands	Min tillage replant Conv tillage replant	38 5	4	63,7	0,0 0,0	1,1 0,0	64,8	0,2 0,0	5,1 0,0
4	Gs16 Williamson	Min tillage replant Conv tillage	29 3	4	61,8	0,7 0,1	5,8 1,1	68,0	6,5 2,0	39,1 24,7
5	Lo12 Waldene	Min tillage replant (simulation 6 wks after phosphogypsum applied) Conv tillage replant	36 5	5	48,0	0,3 2,5	27,1 56,6	60,0	0,8 4,4	67,1 88,6
6	Lo12 Waldene	Min tillage replant Conv tillage replant	- -	5	58,6	1,4 3,3	45,0 51,5	62,0	3,4 8,6	69,4 87,9
7	Gs16 Williamson	Min tillage replant Conv tillage replant	- -	5	55,6	0,2 4,9	3,9 46,8	56,2	4,1 15,7	22,1 96,5
8	Hu24 Hutton	Min tillage replant Conv tillage replant	49 5	6	62,8	0,0 6,4	0,9 29,3	57,4	0,1 16,4	3,7 60,5

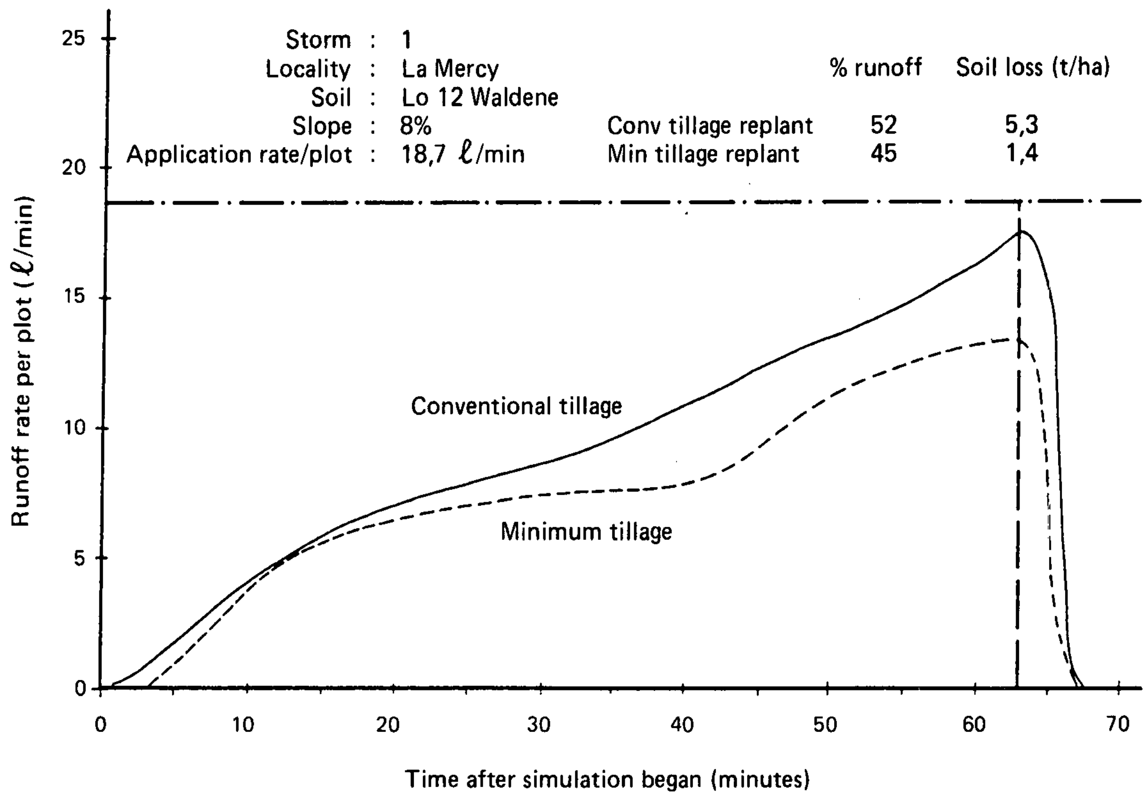

FIGURE 3 Runoff hydrograph for the first storm at La Mercy.

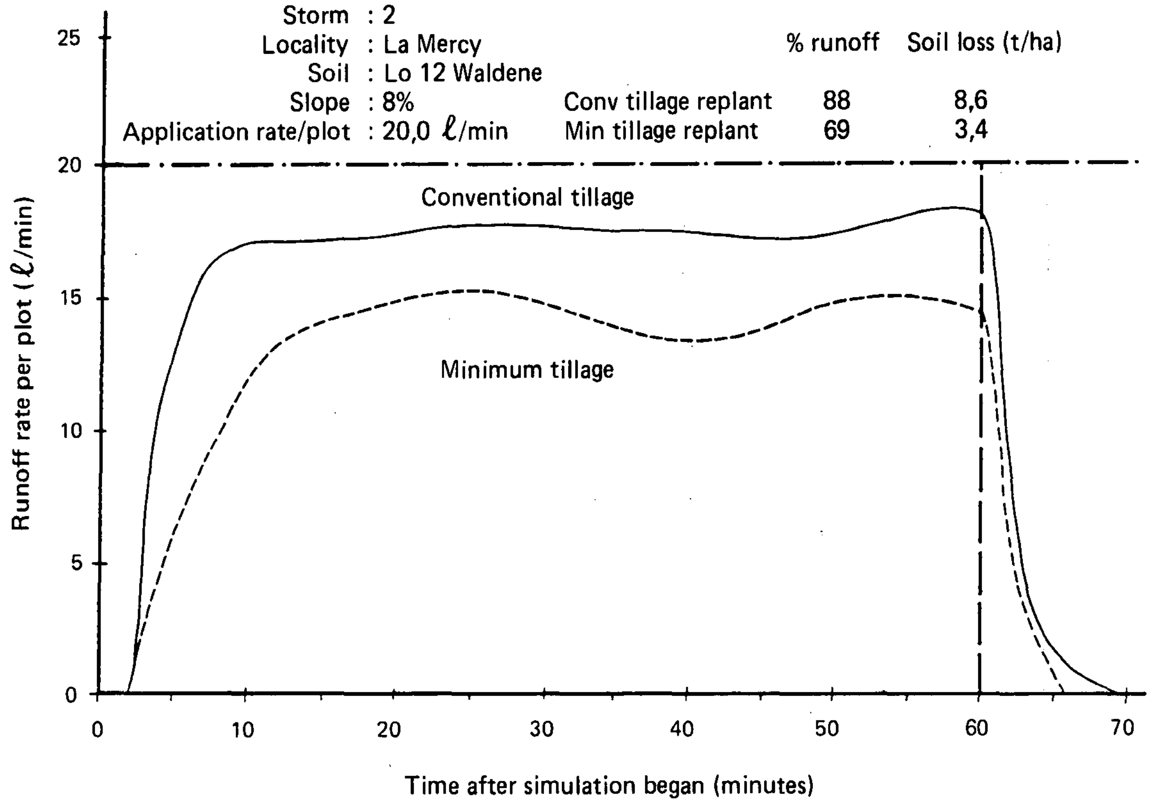

FIGURE 4 Runoff hydrograph for the second storm at La Mercy.

In comparing the first and second tests on Site 1, it should be noted that when the first test was done (immediately after planting) the minimum tillage plots enjoyed the advantage of the mulch from the dead previous crop. When the second test was done (10 weeks later) the mulch had largely decomposed, and the conventional tillage plots enjoyed the advantage of the more friable condition of the soil. These preliminary results should not be extrapolated to conditions which differ from those under which the tests were conducted in terms of soils and crops. Instead it should be noted that, excluding the results for Sites 3 and 4 which were sprayed at too early a stage (4th leaf), the average reduction in soil loss due to minimum tillage was 60 %, and the reduction in runoff was 34 %.

Conclusion

Useful comparative results have been obtained in a relatively short time. It is possible to reduce both water runoff and soil loss from sugarcane fields by practising minimum tillage methods. To obtain satisfactory reductions, the ratoon crop should not be killed chemically before it has reached the 6th leaf stage of growth and as much trash and residue as possible should be left on the surface.

Research will continue on minimum tillage replant plots, where the sugarcane has grown to the 6th leaf stage. Simulator trials need to be carried out at different stages of the replant cycle to ascertain where the largest differences in water and sediment losses occur.

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