

RESEARCH INTO SOIL AND WATER LOSSES FROM SUGARCANE FIELDS

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Abstract

A research programme to measure soil and water losses from sugarcane fields is described. The programme consists of four separate projects, each with a particular objective, but all interrelated in order to produce recommendations for protective practices. A modelling approach will be used in some stages of the programme so that the data collected from a limited number of sites can be applied to other areas within the sugar industry.

Introduction

A research programme in the form of an inter-disciplinary co-ordinated project has been initiated by the Experiment Station to study the factors which contribute to soil and water losses from sugarcane fields. One way of summarizing the soil erosion process is by means of the Universal Soil Loss Equation (USLE) developed by Wischmeier:⁹

$$A = R \times K \times LS \times C \times P$$

Soil Rainfall Soil Topographic Crop Support
loss factor erodibility factor management practices

Modelling techniques also exist (Elwell,⁵ Kuh⁶) and they comprise similar components. If each of the factors can be measured or estimated for a given situation in the field, changing any of them would result in a change in the estimated soil loss. The depth of soil available on any site for crop growth may be limited, and it is necessary to decide how much soil loss can be tolerated. Once this has been established, then the equation becomes a useful modelling tool to test the effects of changes in the various factors. Whilst rainfall, soil erodibility and slope cannot normally be changed, combinations of values for the crop management and supporting practice factors, that meet the given requirement for acceptable soil loss, can be determined. Various terrace spacings, methods of crop management, field layouts and tillage techniques have been developed in the industry in order to control soil erosion and limit water losses. Each of these items can play a role in conservation. However, there are few data by means of which benefits of terrace banks and strip cropping can be compared, and the value of minimum tillage has yet to be determined. Information is needed also on the effects of the timeliness of operations carried out in cane fields, and on the protective effect of the crop and a trash blanket. The programme described here is intended to provide at least some of this information.

Values for each of the factors in the various soil loss prediction models which have been developed, such as those prepared in the USA and by Elwell and his co-workers for the Rhodesian highveld, have all been determined for local crops under local conditions, and they are not always applicable to sugarcane growing areas. Although the same modelling approach and principles can be used, it is always necessary to determine values for the factors under local conditions. At this stage it is difficult to decide on the final form of a model, so the four projects in the programme are intended to permit either the USLE or other modelling approaches to be used and compared.

Programme

The programme will be used to establish acceptable soil loss limits. Rainfall records will be analysed and experimentation

will be carried out on run-off plots and small catchment areas.

Acceptable soil loss limits (Factor A)

The objective is to establish acceptable soil loss limits for each of the different soil types in the cane belt. Soil parent material surveys have been done for all cane farms (Beater^{1,2,3}, Macvicar⁷). In conjunction with detailed soil analyses carried out by the Chemistry and Soils Department, a large data bank is available to use in setting acceptable soil loss limits. Soils with deep profiles, overlying parent material which is weathering rapidly can be assigned a greater value for A than shallower soils, overlying rock which is weathering slowly. The values shown in Table 1 are initial estimates for use in the USLE and indicate proposed limits.

TABLE 1
Acceptable annual soil loss values

Soil Series	BD g/cm ³ 1	Tons soil cm/ha 2	Average depth cm 3	Tons soil/ha (Col 2 × Col 3) 4	Acceptable loss t annum (Col 4 ÷ 1 000 years)
Clansthal	1,55	155	150	23 250	23
Hutton	1,55	155	100	15 500	15
Shorrock	1,50	150	150	22 500	22
Glendale	1,30	130	70	9 100	9
Shortlands	1,28	128	100	12 800	13
Arcadia	1,20	120	70	8 400	8
Rydalvale	1,25	125	50	6 250	6
Phoenix	1,44	144	50	5 100	5
Bonheim	1,02	102	60	6 120	6
Stanger	0,97	97	100	9 700	10
Griffin	1,10	110	100	11 000	11
Inanda	1,00	100	120	12 000	12
Cartref	1,50	150	70	10 500	10
Fernwood	1,52	152	150	22 800	23
Glenrosa	1,63	163	50	8 150	8
Rosehill	1,45	145	60	18 700	9
Trevanian	1,43	143	80	11 440	11
Williamson	1,71	171	50	8 550	9
Windermere	1,29	129	50	6 450	6
Waldene	1,65	165	30	4 950	5
Avoca	1,68	168	60	10 080	10
Kroonstad	1,60	160	50	8 000	8
Estcourt	1,60	160	30	4 800	5
Uitvlugt	1,70	170	30	5 100	5
Milkwood	1,20	120	40	4 800	5
Mispah	1,20	120	30	3 600	4
Katspruit	1,40	140	50	7 000	7
Balgowan	1,00	100	130	13 000	13
Wasbank	1,60	160	30	4 800	5
Mayo	1,20	120	70	9 400	9

These have been arrived at by using average soil depths. Variations in depth will occur from site to site within the same soil type and the user of the equation will have to bear this in mind when compiling a working model.

1. Rainfall Erosivity Project (Factor R)

An industry-wide map of the potential of rainfall to cause erosion is being compiled. After storms of high intensity rainfall, rills and sediment deposits are often observed in the field, while lesser storms cause little visual damage. Whether or not the heavier storms play the major part in the erosion process has still to be determined. Rain is known to act in two ways in

causing soil loss. Firstly, the energy in falling raindrops breaks up surface aggregates on impact, detaches them from the surface and leaves them available to be transported by the second phase, surface run-off. Water which cannot infiltrate becomes surface run-off, moving the detached particles down the slope. American data (Wischmeier¹²) has shown that the total energy of a rainstorm multiplied by the greatest thirty-minute intensity gives a parameter (EI_{30}) which, if summed over a year, is closely related to average annual soil loss. Rhodesian information (Stocking¹⁰) suggests that under tropical conditions total annual rainfall energy can be used.

As the cane belt is neither tropical nor temperate both parameters are being considered. Long term monthly records from rainfall stations with returns longer than twenty years have been analysed. These have been supplemented with data from SA Weather Bureau records and a total Rainfall Energy map has been produced (Figure 1). Five rainfall intensity recorders have been installed at the plot sites mentioned in Appendix 1 so that rainfall intensity distribution throughout the year can be recorded. The recorded data are being analysed by computer so that an Erosion Index map may be drawn to show areas of equal erosivity, and to provide values of R to be used in the USLE.

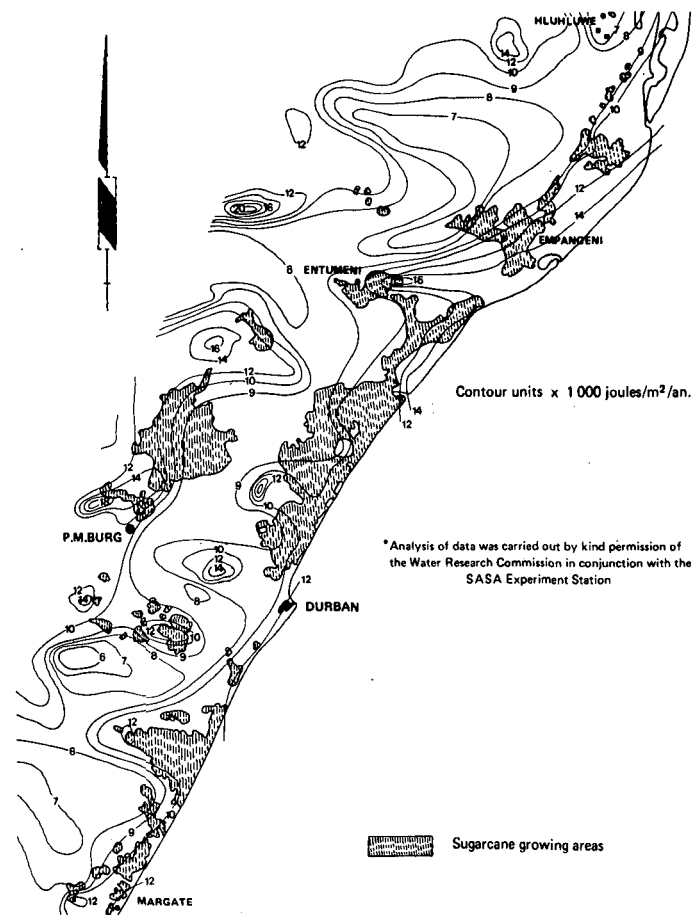


FIGURE 1 Total annual rainfall energy for rainfed sugarcane areas.

2. Run-off plot project (Factors K and C)

In this project soil erodibilities are being determined by measuring soil loss from run-off plots. Dimensions and layout of the duplicated plots are shown in Figure 2.

After soil erodibilities have been established, a sugarcane crop will be grown on one of the pair of plots and its effects on soil and water losses measured. The second plot will be kept under a continuous weed-free fallow as a control. The

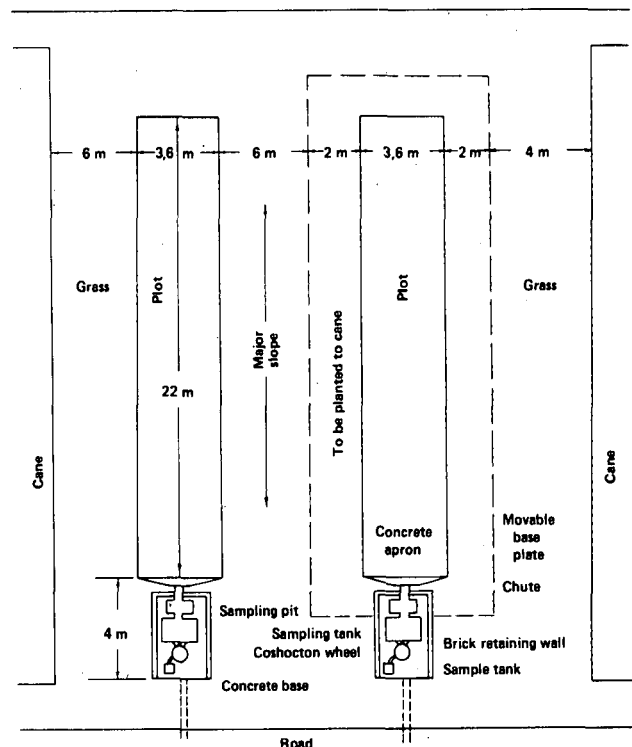


FIGURE 2 Site layout for run-off plots.

effects of crop management practices such as burning or trashing, weed control by cultivation or herbicide application, minimum tillage or ploughing, can also be studied on these plots.

Five sites have been selected (see Appendix 1) for the project. They cover a wide range of topography and soil types. Soil textures range from heavy clay to light sand, and the land slope varies from site to site.

Each plot is bounded by 300 mm wide asbestos boards which protrude 150 mm above the ground. These boards exclude run-off from outside the plot and prevent soil splash from entering or escaping from the plot. The fallow plot area of 80 m² is kept in a tilled condition by means of a small self-propelled rotary tiller, worked up and down the length of the plot. When necessary, herbicide is applied by knapsack sprayer to control weeds. The sampling equipment is situated in a pit below the concrete apron at the lower end of the plot, and is illustrated in Figures 3 and 4. The tanks are made of fibreglass and the Coschocton wheel (Parsons⁹) of mild steel. The concrete apron is covered by a galvanised iron sheet, not shown, to prevent it from contributing to run-off. Soil washed off the plots flows across the concrete apron, through the chute (see Figure 4) and into the first sample tank. A coarse horizontal screen removes leaves, stalks and roots and the slurry passes into the tank. A vertical screen holds back any large particles or aggregates, allowing only fine suspended material into the main sample tank. A spring balance with supporting legs is used to determine the mass of this first tank complete with coarse sample. A portable water pump with a capacity of 1 000 litres per minute is used to stir the slurry in the main tank before samples are taken. If very heavy storms cause the main tank to overflow through the flume, this flow rotates the Coschocton wheel. The vertical slotted vane on the spinning wheel cuts through the flow from the flume and every rotation extracts a one percent sub-sample, which passes into the sealed sub-sample tank. All samples are then analysed in the laboratory to determine specific soil mass in grams per litre of sample, which is then converted to total loss. Rainfall for each run-off event is measured by means of an intensity rain gauge on the site.

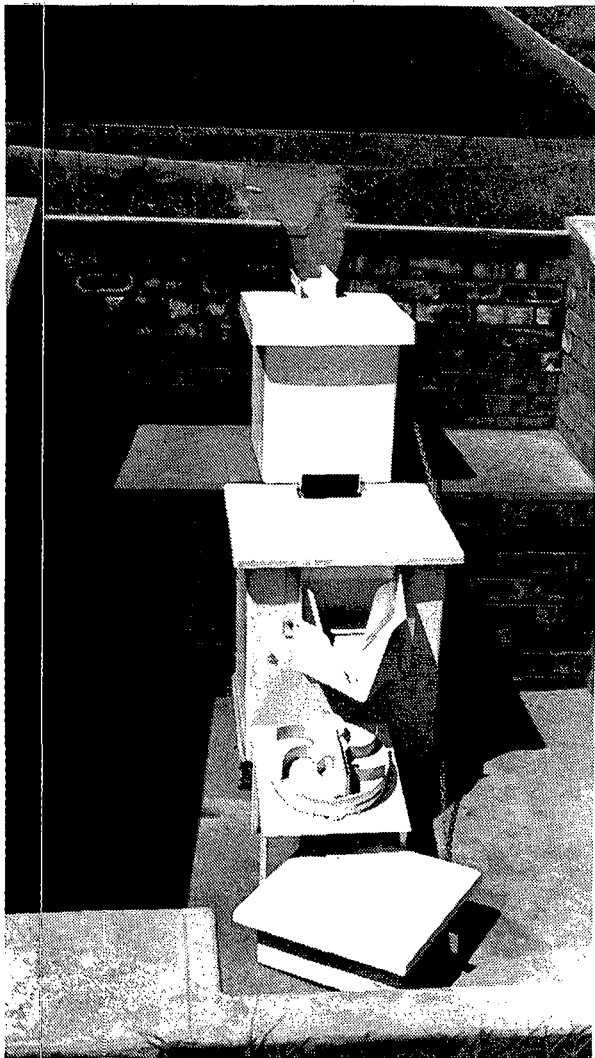


FIGURE 3 Sampling equipment in pit at base of plot.

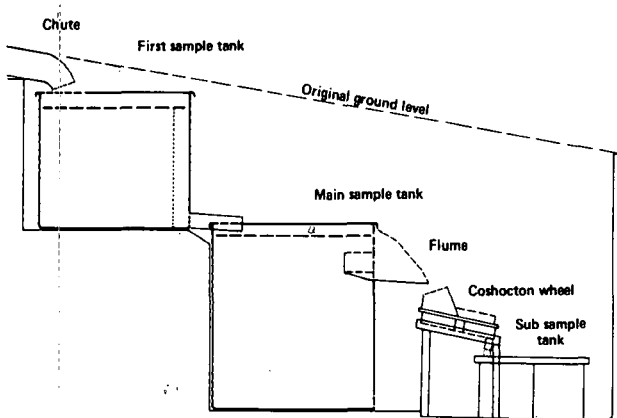


FIGURE 4 Section through sampling equipment.

K factor

By using the procedure described above the amount of soil and water lost from the known plot area can be measured and related to the rainfall. The amount of soil lost per annum can be related to the total annual rainfall energy and expressed in terms of soil erodibility per unit of erosivity. This procedure will establish the K factor for each site.

As there are a limited number of sites, it will be necessary to use a complementary approach and to determine the reliability of predictions of K by the nomograph method (Wischmeier¹³). This involves the use of soil physical properties to assign K factors as shown in Table 2.

TABLE 2
First approximate soil erodibility values
(0,05 resistant soil, 0,31 erodible soil)

Soil Series	K factor	Soil Series	K factor
Rydalvale . . .	0,05	Cartref . . .	0,16
Trevanian . . .	0,05	Glenrosa . . .	0,18
Inanda . . .	0,07	Avoca . . .	0,18
Shortlands . . .	0,10	Milkwood . . .	0,18
Clovelly . . .	0,10	Phoenix . . .	0,21
Farningham . . .	0,13	Griffin . . .	0,21
Arcadia . . .	0,14	Williamson . . .	0,21
Bonheim . . .	0,14	Shorrockes . . .	0,21
Uitvlugt . . .	0,14	Fernwood . . .	0,23
Rosehill . . .	0,14	Kranskop . . .	0,23
Glendale . . .	0,15	Estcourt . . .	0,29
Stanger . . .	0,15	Waldene . . .	0,31
Clansthal . . .	0,16		

K factors have been determined for the soils which occur at the run-off sites from laboratory analyses. These will be compared with the values determined empirically and, if necessary, modifications will be made to the nomograph to suit local conditions.

C factor

This factor in the soil loss equation represents the ratio of soil loss from a field cropped under specified conditions to the loss from a continuously bare fallow. The C factor incorporates a number of effects which cannot easily be separated but which can be measured together by growing a crop and varying the management techniques. The effect of the crop on soil loss throughout the year changes as the crop develops. Rainfall distribution also plays an important role, for the majority of storms which produce run-off occur during a few months. If these storms occur during the early stages of crop growth, there will be greater soil loss than if the crop were at full canopy. The effects of different crop stages on run-off during periods of high rainfall will be measured and the effects of leaf canopy on rainfall energy will be assessed by using splash cups. With the data available the USLE can be compared with other models.

3. The Small Catchment Project (Factor P)

This project is designed to measure the effect on run-off and soil loss of field layout systems where terrace banks carrying run-off to prepared grass waterways will be compared with a strip-cropped layout with spill-over roads.

Sites

Four adjacent catchments, ranging in size from 3 to 6 ha, have been selected for this purpose on the Experiment Station farm at La Mercy. Slopes vary from 4% to 40% while the Rydalvale and Milkwood series soils are derived from Dolerite and Middle Ecca parent materials.

A centrally located intensity raingauge records rainfall continuously. A type H flume, 1,37 metres deep, with a pressure bulk type water depth recorder, has been built at the base of each catchment area. A standard raingauge has also been placed next to each flume as a check on the amounts recorded by the central intensity raingauge. A rising and falling stage soil sampler is being manufactured for installation at each flume to measure the amount of sediment washed off the catchment.

As run-off passes through the measuring flume, depth readings are recorded continuously and from these run-off intensity and amount can be calculated. The sediment sampler will extract run-off samples at particular stages, and analyses of these will be converted to total sediment load and soil loss in tons per hectare.

P factor

All four catchments will initially be in a bare fallow condition, ploughed up and down the slope as illustrated in Figure 5.

At least ten run-off events are required during the bare fallow condition to establish a relationship between catchments. After this calibration procedure has been carried out the various treatments will be implemented. The treatments to be compared are terrace banks with grassed waterways and strip cropping with spillover roads. It will be necessary to have one catchment under a continuous fallow to act as a control, and another under continuous cane, without structures, so that the effects of the crop can be measured and the value of the treatment alone can then be calculated.

4. The Variable Length Plot Project (Factor LS)

It is necessary to check the validity of the LS factor under conditions in the cane belt for areas with steep slopes as most of the work done elsewhere applies to slopes of less than 20%. It is important to clarify what happens if these data are extrapolated to steeper slopes. Eventually, it is intended that plots of different length will be laid out and run-off and soil loss measured.

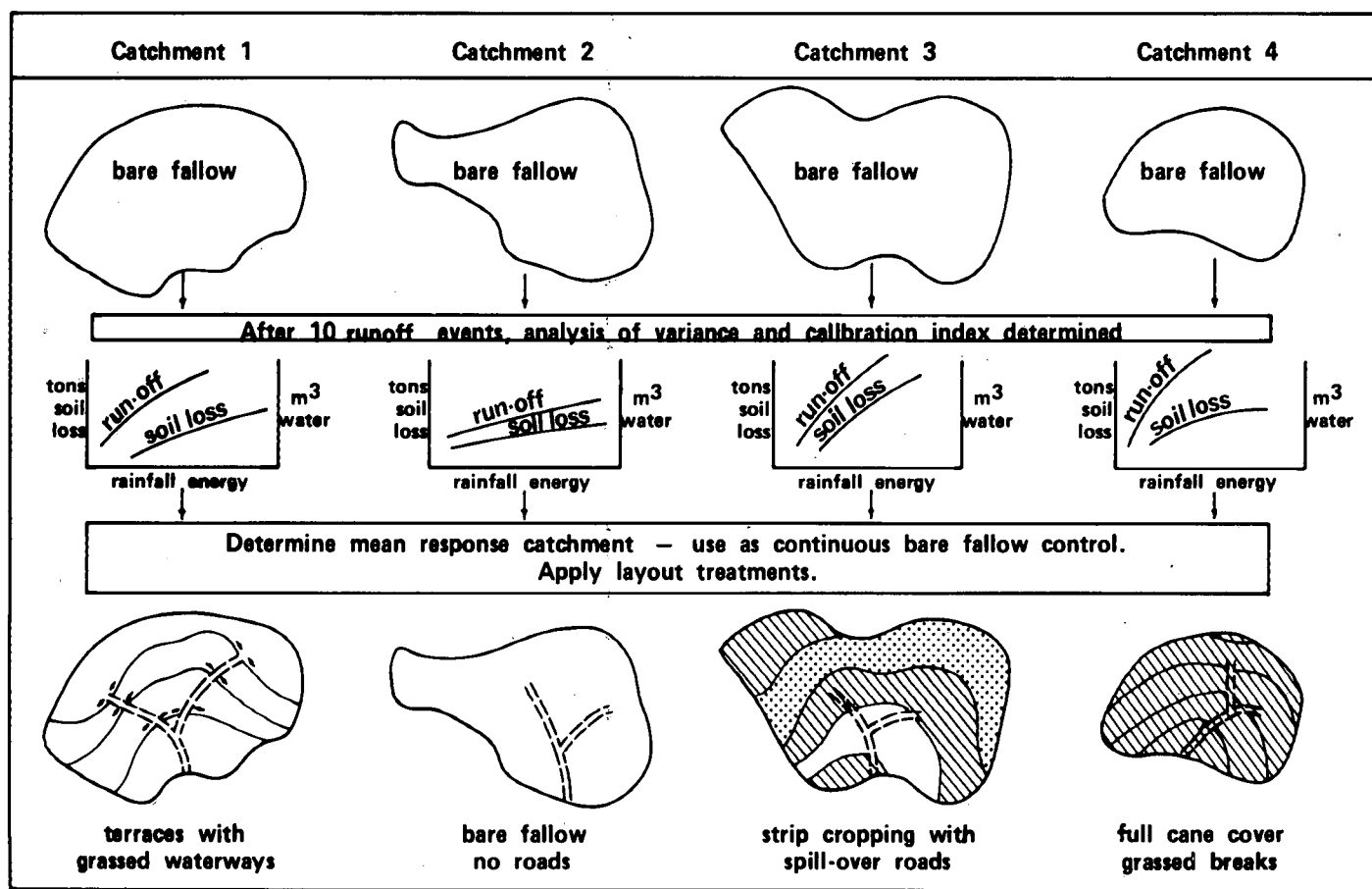
Discussion

All of the work being done is concerned with the USLE and its variations. Criticism is levelled at the use of this

equation under South African conditions because it was developed elsewhere. The equation nevertheless, explains the erosion process fairly well, despite the possibility of its being incomplete. It will be used as a starting point and will be modified in the light of local experience, if necessary. As the industry is concerned with sugarcane alone, the determination of the values of the various factors, using experimental plots, will be simpler than it would be where many crops and practices need to be evaluated.

The acceptable soil losses that have been proposed are based on some assumptions that different soil horizons, in different soils, are available for crop root development. Generally, where topsoil and subsoil have similar textures they have both been included when estimating soil depth and for some soils, such as those of the Glenrosa form, even some of the weathering rock has been included. The figures quoted refer to average depths and should be modified in the light of observations made on any particular site. Only after data have been accumulated for a number of decades will it be possible to confirm whether or not 1 000 years is an acceptable estimate of soil life.

The project to measure the factor R has led to a study of the relationship between rainfall energy and rainfall intensity. Although R is stated in terms of EI_{30} there does appear to be some correlation between total storm energy and maximum thirty minute intensity.* The production of EI_{30} or iso-erodent



Comparisons :

- A. Catchments 1 & 2 — difference due initially to terraces, later to cane growth and terraces. Therefore deduct effect of 4 (full cane) to measure effect of terraces alone.
- B. Catchments 3 & 2 — difference due initially to strip cropping + cane later. Therefore deduct effect of 4 (full cane) to measure effect of strip cropping.

FIGURE 5 Schematic drawing of the small catchment project

*Schulze, R. E. Personal communication.

lines depends on long term intensity records which are not yet available. It has therefore been more convenient at this stage to consider the total rainfall energy. Erosion is dependent on natural rainfall and soil erodibility factors estimated from the experimental plot data will therefore take some time to be established.

Studies in Hawaii (Dangler⁴) have shown that erodibility values can be determined with a fair degree of accuracy by means of a "rainulator". It was also shown that it is important to take antecedent soil moisture content into account as this can affect soil erodibility significantly. Limited data (Thompson and Gosnell¹¹) which might possibly be utilised in the soil loss equation are available.

The effects of crop management factors such as burning or trashing, and minimum tillage or ploughing, will be measured on the run-off plots. One item which is often overlooked is the timeliness of all operations and it will be possible to take this factor into account on the experiment plots. Once full canopy has been reached the cane will be cut, even if trash has to be imported to make up the required amount. The shortening of the crop cycle will allow data to be accumulated more rapidly.

In the catchment studies, care has been taken to ensure that only treatment effects will be measured. It is essential to keep the treatments simple and to avoid the complications caused by too many variables. The common layout types which are expected to give the greatest response have been used and modifications of layouts, such as parallel terraces (a variation of the conventional terrace bank layout), have been avoided.

The data accumulated from the small plots for soil erodibility and crop management factors, together with information obtained on layout practices from the small catchments, will be used in a model to estimate soil losses. Changes in cropping practices, terrace spacings and other conditions can then be studied by means of the model to determine their effect on soil losses.

The programme has only recently commenced, so no conclusions can be drawn at this stage. Valuable experience has

been gained, however, and some significant short-comings in the original concepts have come to light. These are being investigated and corrected.

Acknowledgements

Help in the preparation of the run-off plots and the sampling equipment by members of Experiment Station staff is gratefully acknowledged. The help given by Dr. R. Schulze in assessing research catchment problems and in processing rainfall data has been of great value.

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Appendix 1 **Run-off Plots — Soils**

		PLOT 1 Mount Edgecombe	PLOT 2 CFS	PLOT 3 La Mercy	PLOT 4 Shakaskraal	PLOT 5 Mtunzini
Parent material		DOLERITE	RECENT SANDS	MIDDLE ECCA SEDIMENTS	DWYKA TILLITE	MIDDLE ECCA SANDSTONE
Soil form		ARCADIA	HUTTON	SWARTLAND	LONGLANDS	LONGLANDS
Soil series		RYDALVALE	CLANSTHAL	SWARTLAND	WALDENE	WALDENE
Slope		16%	16%	35%	24%	9%

Appendix 2 **Run-off Plots — Grading analyses**

LOCATION	PER CENT					NOMOGRAPH					
	CLAY <0,0002 mm	SILT 0,002 to 0,02 mm	FINE SAND 0,02 to 0,2 mm	MEDIUM SAND 0,2 to 0,5 mm	COARSE SAND 0,5 to 2,0 mm	SILT & V.F. SAND 0,002 to 0,10	SAND 0,1 to 2,0	O.M. %	Structure	Perm.	Approximate K value
PLOT 1 MOUNT EDGECOMBE	32	13	41	11	3	36	32	3-4	Fine granular to medium coarse	Moderate to slow	0,05
PLOT 2 CFS	9	4	61	25	1	32	58	0-1	Fine granular	Rapid	0,16
PLOT 3 LA MERCY	46	18	26	5	5	38	14	2-3	Granular	Slow to moderate	0,18
PLOT 4 SHAKASKRAAL	23	12	44	14	7	43	34	0-1	Fine granular	Slow	0,29
PLOT 5 MTUNZINI	18	10	56	14	3	46	36	1-2	Fine granular	Slow	0,29