A NEW APPROACH TO DESIGNING THE WIDTHS OF PANELS IN SUGARCANE FIELDS

By G. G. PLATFORD

South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe 4300

Abstract

The construction of a nomograph to compute widths of panels in sugarcane fields is described. (A field of sugarcane, ie the area always treated similarly at any one time, may comprise more than one panel.) Rainfall erosivity, soil erodibility and land slope are used as fixed parameters. Tillage, strip replanting, terrace banks and trash mulching are rated according to their effect on soil loss. These variables are included as options in the design of field width. Soil loss modelling based on the Universal Soil Loss Equation (USLE) modified for sugarcane is used to predict trends in soil losses. Results from rainfall simulator work, and from runoff studies on plots and small catchments are used to construct the nomograph. The effects on field width of changes in the options are included as examples.

Introduction

In South Africa, sugarcane is often grown in adverse climatic and topographic conditions as well as on a variety of soils. Rainfall varies widely in amount, intensity and distribution throughout the year. The soils in the sugarcane growing areas are mostly granular, leached and often have high rates of erosion once the natural vegatation is removed. A management system to control the runoff and associated soil and nutrient loss is therefore essential. Traditionally, protection for cropped land in areas of high rainfall has been provided by building water-carrying terrace banks across the hillside at a slight gradient. These banks intercepted any accumulated runoff water before it could build up to a dangerous volume or velocity. The controlled flow of water could then be discharged into prepared grassed waterways which were designed to accommodate the expected flow. Sugarcane is not always grown on the relatively gentle slopes for which this system of control was designed and which were mainly concerned with annual crops and rotational cultivation. Until 1983, physical protection in the form of terrace banks was the only recognised way of providing soil conservation for agricultural land in South Africa. The spacing of the banks depended on the ground slope and soil type. This method, when applied to steep slopes with erodible soil, was not adequate to control runoff during heavy storms and this was particularly apparent during the period when land was conventionally tilled prior to replanting sugarcane.

As long ago as 1965 in the United States the protection provided by the growing crop was given cognizance. The Universal Soil Loss Equation (USLE) (Wischmeier[6]), an empirical predictive model for calculating long term average soil loss, was developed and it incorporated allowances for the crop and crop management practices. By including these factors a land and crop management system could be designed, taking account of the protection provided to the land by the crop. Strip planting, rotational crops, reduced tillage and other management practices could, in certain instances, provide sufficient protection so that terrace banks could be excluded. It has now been recognised in the sugar industry that the growing sugarcane crop gives protection against raindrop splash for much of the life of the plant.

The trash mulch left on the ground after the sugarcane has been harvested, as well as the canopy provided by the foliage of the standing crop, play important roles in soil protection, weed control and water infiltration. The recommendations previously given to growers specified water-carrying terraces and grassed waterways as the major methods of control, but took the protection provided by the growing crop into account. In addition, it was emphasised that further protection could and perhaps should be achieved by strip planting, minimum tillage and trash mulching on moderate to steep slopes with erodible soils.

The conservation of Agricultural Resources Act of 1983 allows for crop-related factors to be considered when designing a protection scheme. By allowing for the effects of tillage practices, strip planting and surface mulching as well as control structures, the conditions required to protect a particular area could be more flexible and realistic. The implications of the 1983 Act are considerable because, although crop factors are now part of the official recommendations, there are not many threshold values that have been set based on measured results from research projects. Some values have been established on the basis of continuing erosion research, but field experience and observation have been used to supplement these data.

Soil and water losses result from the interaction of many variables. If a decision is to be made on a suitable panel width, taking into account the acceptable crop management practices for each site, all of the possible combinations of the variables must be assessed. A nomograph is described which gives the panel width that should be used with each combination of variables. A nomograph is a graphic description of the many calculations needed to solve the interaction between a number of variables (Dent[1]). Results from trials involving rainfall simulation, runoff plots and small catchment projects have been used to construct the nomograph described here.

Soil and Water Losses

Sugarcane is a perennial crop that in many cases is not harvested annually. Because it can ratoon, a number of crops can be harvested before replanting is necessary. The cycle usually lasts for 8 or 10 years. When replanting is to take place, the soil is particularly vulnerable to erosion by rainfall because a bare surface has to be tilled for the new crop, and there are then large areas of disturbed soil which can be eroded by even moderately heavy storms. Once replanting has taken place, the crop material begins to accumulate, canopy begins to develop, and roots help to bind the loose soil. Within 3 to 4 months after planting, crop factors become significant in reducing soil vulnerability to erosion. As further soil stabilisation and crop development take place, very little active erosion normally occurs. After the crop is harvested, soil protection due to the presence of the crop is reduced, but even if the crop is burnt prior to harvesting, sufficient crop debris usually remains to provide good surface cover. The roots and stubble form small ridges across the slope and the soil surface is stabilised. Under these conditions very little soil loss occurs.

It has been established from measurements on runoff plots and small catchments that 85 to 90 % of average annual soil losses occur during the period when replanting takes place. It is important to control losses at this stage if overall soil loss is to be limited. If the amount of soil disturbance can be reduced either by killing the crop chemically or by chipping it out, the erosion hazard can be reduced significantly. Care must nevertheless be exercised to ensure that an adequate amount of organic material is present to protect the soil. Even then, if deep interrow cultivation is required, large amounts of loose soil can be available for transport during storms of high intensity which do occur regularly at the time when minimum tillage is most beneficial.

The USLE

The Universal Soil Loss Equation (USLE) is used to calculate long term average annual soil losses as follows:

A	=	R	×	K	×	LS	×	C	×	P
Soil loss		Rainfall erosivity		Soil erodibility		Topographic factor		Crop management		Practices factor

It is an empirical equation derived from the analysis of data obtained from runoff plots. If an acceptable soil loss for a particular site is A, then R, K and slope (S) are fixed. The equation can then be solved for either a field length (L) with known crop management and practices, or for crop management and practices when the field length is defined. The factors are described as follows and the values are given in Figure 1.

A. Acceptable soil loss: even when undisturbed, natural vegetation exists, erosion does take place. Once the natural vegetation is removed and the soil is disturbed by agricultural practices, however, the rate of erosion generally increases.

```
          USLE       =             R  *     K  *     LS  *    C  *    P
      ===========                Rainfall   Soil     Slope/   Cover  Practices
                                 Erosivity Erodibility Length

EROSIVITY
==========
Code       R  value
         1 Coast              350
         2 Inland             300
         3 Midlands           250

ERODIBILITY
===========
Code       Erodibility   K value              ===========
         1 V.high            0.65          Shallow fine grained sandy soils
         2 High              0.42          Shallow coarser grained loamy sands
         3 Moderate          0.28          Moderately deep coarse grained loams
         4 Low               0.22          Deep sandy loams,mod. deep sandy clay loams
         5 V.low             0.15          Deep sandy clay loams and stronger

COVER CODE
==========Average annual cover

Code
         1 September plant                 Coast SEPT plant        0.09
         2 September plant                 M/lands SEPT plant      0.12
         3 February plant                  Coast FEB plant         0.11
         4 February plant                  M/lands FEB plant       0.15

PRACTICES
=========                          SELECT PRACTICE
Code       Type                                         ========= Value
    P1     Contour plough          --------------                  0.85
           Up/down plough          --------------                  1.00
           Plough +disc            --------------                  0.95
           Min tilled(chemical)    --------------                  0.15
           Min tilled (chipped)    --------------                  0.25

    P2     Strip plant(terraces)   --------------                  0.70
           Strip plant             --------------                  0.25

    P3     Terrace banks           --------------                  0.90
           Spillover roads         --------------                  1.00

TRASH CODE
==========                                                       Value
         1 Trash                   --------------                  0.80
         2 Burnt scattered tops    --------------                  0.90
         3 Burnt,reburnt           --------------                  1.00
```

FIGURE 1 Estimated values for input into the USLE modified for sugarcane management practices.

Soil depth and texture determine the acceptable rate of soil loss for any particular soil. One can afford to lose more soil from a deep profile than from a shallow profile. Generally, the values for acceptable soil loss range from 4 to 12 $t\ ha^{-1}\ a^{-1}$.

R. Rainfall erosivity: this factor represents the long term average annual amount of rainfall energy. It is calculated by adding the maximum 30 min intensity of each storm in excess of 12 mm during the year. Isolines for rainfall erosivity have been prepared for southern Africa by Smithen and Schulze[3] (Figure 2). For the areas under sugarcane, the coastal region around Richards Bay shows the highest value and this gradually decreases in southerly, westerly, and northerly directions.

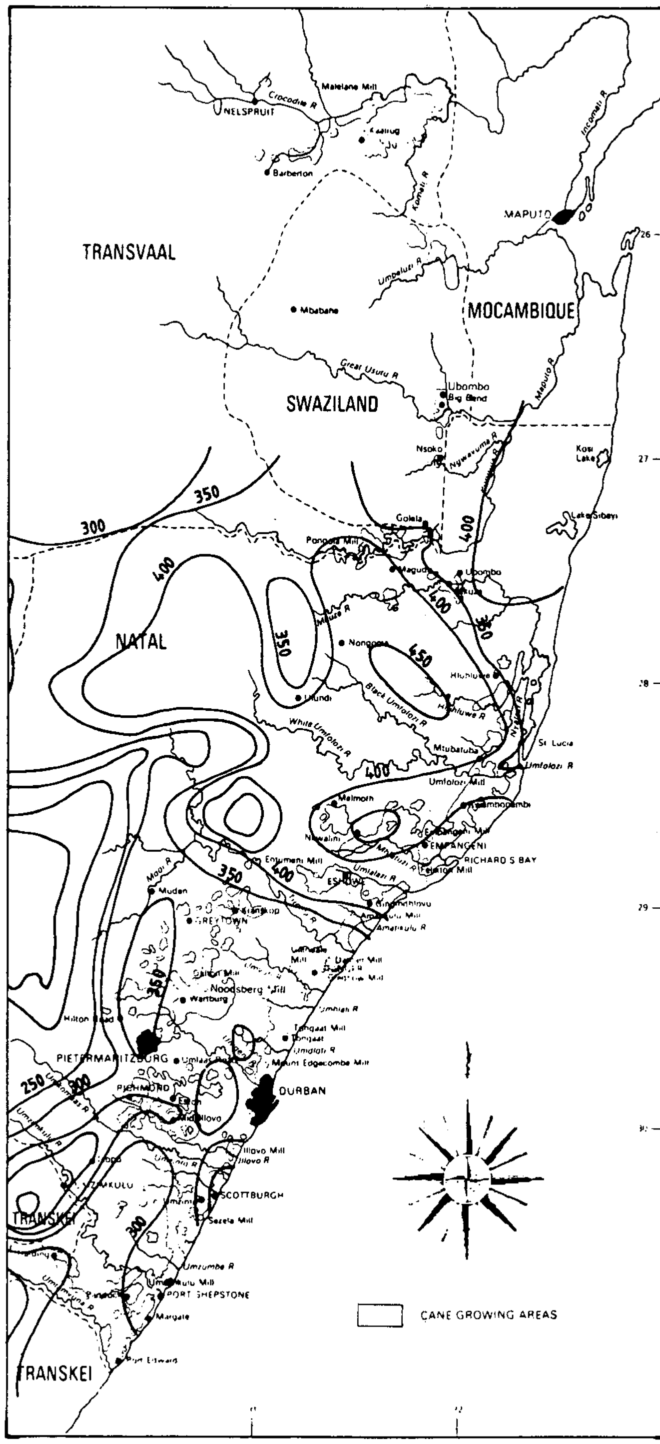

FIGURE 2 Rainfall erosivity values for a portion of the sugarcane areas.

K. Soil erodibility: local values for individual soils have been determined experimentally from the results of trials on runoff plots. Soil erodibility values represent the amounts of soil loss which are expected to occur from a unit of rainfall erosivity. For highly erodible soils the K values are between 0,5 and 0,7. Soils with high silt and fine sand contents, and containing little organic matter, comprise this category. Soils with high clay contents that have high organic matter content and have good structures have K values between 0,05 and 0,1. K values have been determined experimentally for relatively few soils, but statistical analysis has shown that certain physical and chemical components of the soil can be used to estimate the K value (Wischmeier, Johnson and Cross[5]).

LS, Topographic factor: both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The LS factor is defined as the ratio of soil loss per unit area of field compared with the loss from a plot 22,3 m long on a 9 % slope. Soil losses increase as the length and steepness of the slope increase. Values for LS for different land slopes and lengths can be determined from Figure 3.

C. Crop management: the C factor is defined as the ratio of soil lost from the land under specified conditions compared with the soil lost from a continuous area of land that is fallow and clean-tilled. The crop and its management cannot be assessed separately. The effectiveness of the crop canopy and residues of the crop left in the field also depends on the occurrence of erosive rains during the different growth stages of the crop. Values for C can be obtained from prepared tables in which the type of crop, its stage of development, and the rainfall erosivity during each stage of development, are taken into account. For the sugarcane crop that is perennial, has a large canopy and provides considerable above-ground residues, the C factor is conservatively estimated to be between 0,05 and 0,15.

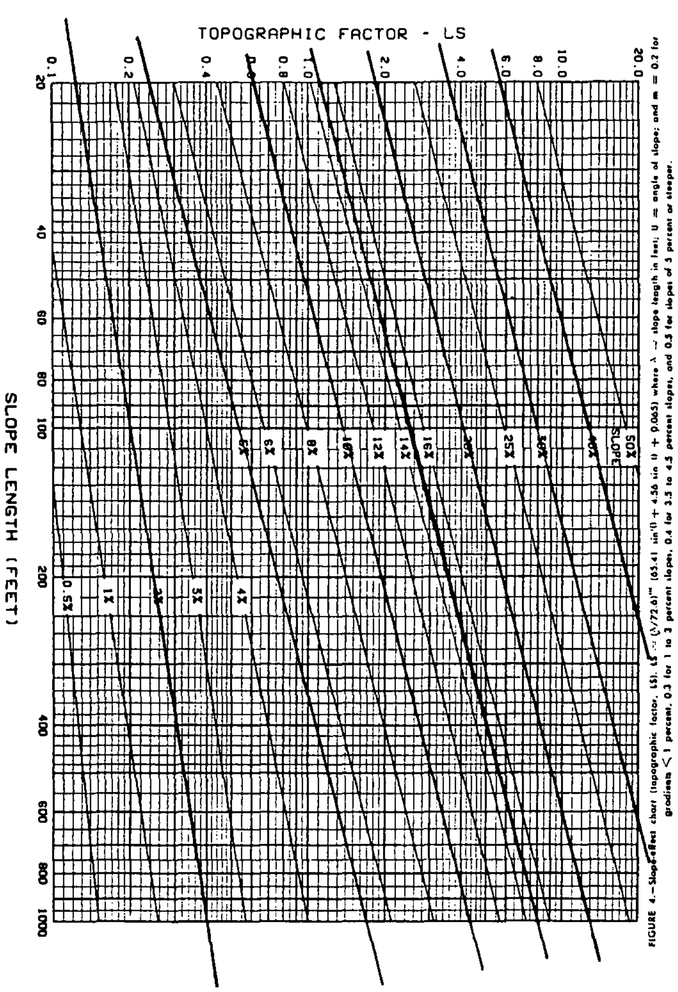

FIGURE 3 Values of LS to represent the combined effects of slope and length.

P. Practices: on sloping land that is cultivated, particularly where erosive rains occur as they do in the tropics and subtropics, practices which help to limit erosion are needed at certain times of the year. Practices such as strip planting, contour tillage, reduced tillage, and the construction of water-carrying terrace banks may be necessary.

Stabilised waterways for the safe disposal of accumulated runoff are also important. In sugarcane agriculture the inclusion of these practices is especially relevant. Large amounts of soil can be lost during replanting. Minimum tillage, strip replanting and terrace banks in combination or individually can greatly reduce soil losses. For sugarcane lands, the P factor can make a significant contribution in the USLE to limit the value of A. It has been modified here to represent the ratio of the amount of soil lost when individual or combined practices are used, to the amount of soil lost when no conservation practices are used.

When considering a replant procedure based on minimum tillage and strip replant, a further constraint must be added. Because the estimates of soil loss are based on 10-year frequency storms, and more severe storms can occur, no more than three adjacent panels should be replanted at any one time, even when minimum tillage is being practised. This provides a further degree of soil protection that has been found to be necessary.

The Nomograph

For a number of years soil conservation recommendations have comprised terrace bank spacings, taking land slope and soil conditions into account. The spacings have been based on the assumptions that a conventional ploughing or disc harrowing will be used to kill the old crop and normal seedbed preparation for replanting will follow. Terrace spacings were sometimes adjusted to permit easier handling and transport of the crop. This generally resulted in road banks being closer than required for protection on flat slopes, and further apart on steep slopes. To compensate for this on steep slopes, certain crop management practices had to be stipulated.

The 1983 Conservation of Agricultural Resources Act specifies the methods by which conservation can be effected. Hence the new approach to planning conservation of sugarcane lands takes into account all of the options which could be used by growers to protect their land. The choice of certain practices may be based on relative costs. When these costs change, the most economical conservation practices may be different. It should be understood that, if management practices change, the adequacy of conservation measures may be jeopardised.

The method now used for preparing recommendations starts with the soil erodibility and slope on a particular site. For sugarcane, a number of variables can then be considered. Field width (W) can be considered as a function of the method of tillage (T), whether or not strip planting is practised (SP), whether or not conservation terraces are to be used (B), and whether the crops are to be burnt or trashed (M). This can be represented in an equation as follows:

$$W = f\ (T.SP.B.M)$$

Different combinations of these factors give different solutions to this equation. A nomograph has been developed to facilitate the procedure.

Construction

The nomograph is constructed using the soil erodibility and slope curves that had been established previously. They appear in the top right-hand corner of Figure 4. Consideration is given to the three major variables in the other three quadrants of the nomograph. These are tillage, strip replanting, and terrace banks. Trash mulching is included as a final consideration. The 45° lines in each quadrant represent the original standard recommendations, *viz.* conventional tillage, no strip replanting, and terrace banks. The alternative lines in each quadrant account for the maximum effect that the various crop management factors can have. The slopes and positions of these lines are dependent on how much they reduce soil losses compared with the original standard practices. To an extent, subjective judgement has had to be used in placing these lines, but results from rainfall simulator trials have been helpful (Table 1).

Predictions of soil loss ($t\ ha^{-1}\ a^{-1}$) were prepared for all the possible combinations of factors, using the modified USLE (Table 2), and these have been used to prepare the nomograph.

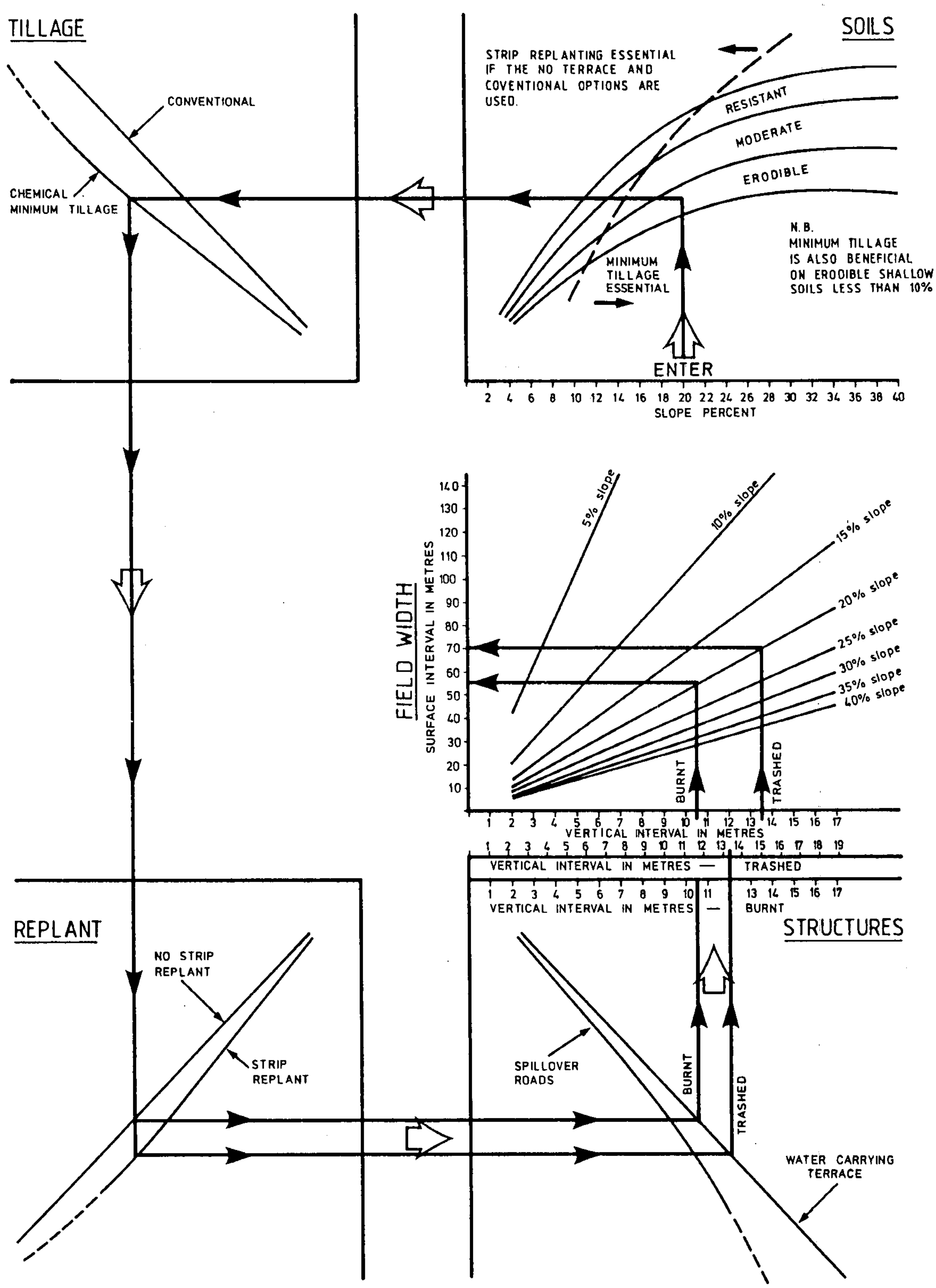

FIGURE 4 Nomograph to compute widths of panels in sugarcane fields.

Table 1

Summary of soil losses and runoff from rainfall simulator trials comparing conventional tillage and chemical minimum tillage

Site	Soil	Slope (%)	Tillage	Soil loss t ha^{-1} a^{-1}	Runoff (%)
La Mercy	Waldene	6	Conventional Minimum	4,4 0,8	89 67
La Mercy	Waldene	8	Conventional Minimum	8,6 3,4	88 69
Darnall	Williamson	17	Conventional Minimum	15,7 4,1	96 22
Cornubia	Clansthal	15	Conventional Minimum	16,4 0,1	60 4

Certain constraints have been included with the nomograph. From predictions of soil loss (Williams[4]) and using 20 t ha^{-1} a^{-1} as an acceptable soil loss, it has been possible to indicate the conditions of slope and soil erodibility under which erosion, even with terrace banks, would be excessive and therefore unacceptable (see broken line, top right quadrant of Figure 4). There are also some government restrictions which apply on slopes of more than 20 % in certain cases.

Examples (see Figure 4)

Design: a field has a slope of 20 %; the soil is classed as erodible; minimum tillage will be used, a strip replanting programme is to be carried out, and terrace banks will be built. The cane will be cut green, leaving a trash blanket.

To use the nomograph enter the known slope of 20 % and move to the erodible soil category. (Note: this point lies to the right of the dotted line which indicates that minimum tillage is **essential**).

Move to the left horizontally to the Tillage quadrant and locate the interception with the **chemical minimum tillage** line.

Move vertically down to the Replant quadrant and intercept the **strip replant** line.

Move horizontally right into the Structures quadrant and intercept the **water-carrying terrace** line.

Move vertically up to read Vertical Interval (VI) for Trashed cane of 13,5 m.

Enter the separate section of the graph, immediately above the Structures quadrant, with the value for VI that has been determined, ie 13,5 m.

Move vertically to the slope of 20 % and at this intercept move horizontally left to find a Panel Width of 70 m.

If strip planting is not carried out and the crop is burnt at the time of harvest a 10 m Vertical Interval or 52 m Panel

Table 2

Soil loss predictions by the Universal Soil Loss Equation (USLE)

Select cover code for area: 3: Coast FEB plant
Select trash code : 2: Burnt scattered tops
Enter rainfall erosivity: 350,00

Slope (%)	Soil erodibility	Code	Soil loss (t ha^{-1} a^{-1})											
			Water-carrying terraces						No terraces					
			Length (m)	LS factor	Strip		No strip		Length (m)	LS factor	Strip		No Strip	
					Conven-tional	Minimum tillage	Conven-tional	Minimum tillage			Conven-tional	Minimum tillage	Conven-tional	Minimum tillage
5			65	0,8	11,04	1,66	15,78	2,37	200	1,4	12,30	1,85	30,75	6,15
10			60	1,9	27,26	4,09	38,94	5,84	200	3,5	31,60	4,74	78,99	15,80
15			55	3,5	49,14	7,37	70,20	10,53	200	6,6	59,50	8,92	148,74	29,75
20			50	5,3	75,42	11,31	107,74	16,16	200	10,6	95,77	14,37	239,42	47,88
25	High	1	45	7,4	104,66	15,70	149,51	22,43	200	15,5	140,09	21,01	350,22	70,04
30			40	9,5	135,28	20,29	193,26	28,99	200	21,3	192,06	28,81	480,16	96,03
35			35	11,7	165,52	24,83	236,46	35,47	200	27,9	251,22	37,68	628,05	125,61
40			27	12,9	183,45	27,52	262,07	39,31	200	35,2	317,01	47,55	792,52	158,50
45			20	13.6	193,65	29,05	276,65	41,50	200	43,2	388,81	58,32	972,03	194,91
5			74	0,8	5,08	0,76	7,25	1,09	200	1,4	5,30	0,79	13,25	2,65
10			65	2,0	12,22	1,83	17,46	2,62	200	3,5	13,61	2,04	34,03	6,81
15			60	3,6	22,11	3,32	31,59	4,74	200	6,6	25,63	3,84	64,07	12,81
20			55	5,6	34,07	5,11	48,68	7,30	200	10,6	41,25	6,19	103,13	20,63
25	Moderate	3	50	7,8	47,52	7,13	67,89	10,18	200	15,5	60,35	9,05	150,86	30,17
30			45	10,1	61,81	9,27	88,30	13,25	200	21,3	82,74	12,41	206,84	41,37
35			40	12,5	76,22	11,43	108,89	16,33	200	27,9	108,22	16,23	270,55	54,11
40			33	14,3	87,37	13,10	124,81	18,72	200	35,2	136,56	20,48	341,39	68,28
45			25	15,3	93,27	13,99	133,24	19,99	200	43,2	167,49	25,12	418,72	83,74
5			80	0,9	2,83	0,42	4,04	0,61	200	1,4	2,84	0,43	7,10	1,42
10			70	2,1	6,79	1,02	9,71	1,46	200	3,5	7,29	1,09	18,23	3,65
15			65	3,8	12,33	1,85	17,61	2,64	200	6,6	13,73	2,06	34,33	6,87
20			60	5,8	19,06	2,86	27,24	4,09	200	10,6	22,10	3,32	55,25	11,05
25	Low	5	55	8,2	26,70	4,01	38,14	5,72	200	15,5	32,33	4,85	80,82	16,16
30			50	10,7	34,90	5,24	49,86	7,48	200	21,3	44,32	6,65	110,81	22,16
35			45	13,2	43,31	6,50	61,87	928	200	27,9	57,97	8,70	144,93	28,99
40			40	15,7	51,53	7,73	73,61	11,04	200	35,2	73,16	10,97	182,89	36,58
45			30	16,7	54,73	8,21	78,19	11,73	200	43,2	89,73	13,46	224,32	44,86

Width would be required. If the requirements were to be determined by the standard method, using only slope, soil erodibility, and conventional tillage as criteria, the Vertical Interval would be 10,5 m and the Panel Width would be 55 m.

Checking

The nomograph can also be used to check the adequacy of existing panels and crop management systems.

Suppose that a panel is 60 m wide, strip replanting is carried out, and there are spillover roads, ie no water-carrying terraces. The cane is burnt at harvesting and conventional replanting is carried out. The panel is on a slope of 15 % and the soil is a shallow Waldene series, being highly erodible.

Enter the nomograph in the separate Panel Width segment at 60 m and move horizontally right to intercept the 15 % Slope line. Moving vertically down, this corresponds to a VI of 8,8 m. Entering the Structures quadrant at 8,8 m on the burnt line VI, continue down to meet the Spillover Roads line. At this intercept move horizontally left to the Strip Replant line. Move vertically to intersect the Conventional line in the Tillage quadrant. Project the line from this intercept across the graph into the Soils quadrant. Draw a line vertically at 15 % Slope to intersect the projected line from Tillage. This intersection must fall in the Erodible soil grouping if the existing conditions on the field are to be acceptable. In this example the intersection falls well above the correct erodibility category. Other practices should therefore be introduced to limit erosion to an acceptable amount. Available options are minimum tillage, terrace banks, and trashing. Of these three options the most effective in this example would be to introduce a minimum tillage replant programme.

Discussion

The introduction of the nomograph permits panel widths to be determined quickly for each of the combinations of options which are available to a sugarcane grower. It enables the power to combine management practices and structures to his best advantage. Because crop management practices affect the results obtained from the nomograph, it must be understood that the vertical intervals apply only to the particular crop management practices that are chosen. If minimum tillage were to be replaced by conventional tillage, the proposed specifications would no longer be suitable.

Conclusion

The nomograph provides a means of integrating all of the factors that need to be considered when designing conservation plans for sugarcane fields. Until more data become available caution must be used when intercepts occur at the extremes of the lines which account for tillage, replant and structures. The correct assessment of soil erodibility for each site is critical. While only three categories of soil erodibility are given, interpolation within the limits is acceptable if carried out by experienced personnel.

REFERENCES

1. Dent, MC (1982). The nomograph - an effective aid to agricultural exentsion. *Agricultural eng in SA* Vol 16: 45–49.
2. Platford, GG (1979). Research into soil and water losses from sugarcane fields. *Proc S Afr Sug Technol Ass* 53: 152–157.
3. Smithen, AA and Schulze, RE (1982). The spatial distribution in Southern Africa of rainfall erosivity for use in the Universal Soil Loss Equation. *Water SA* Vol 8 No 3, July 1982.
4. Williams, JR and Berndt, HD (1975). Sediment yield prediction based on watershed hydrology. *Trans ASAE* Vol 20 No 6: 1100–1104.
5. Wischmeier, WH, Johnson, CB and Cross, BV (1971). A soil erodibility nomograph for farmland and construction sites. *Journal of Soil and Water Conservation* 26: 189–193.
6. Wischmeier, WH and Smith, DD (1978). Predicting rainfall erosion losses - a guide to conservation planning. UA Department of Agriculture. Agriculture Handbook 537.