LAND USE ON STEEP SLOPES ON AN ESTATE ON THE SOUTH COAST OF NATAL

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Abstract

The cane growing area of the South Coast of Natal has problems of steep, long run slopes which require specific solutions. It is not sufficient to think that the use of specialised machinery will be a panacea to all problems. The solution lies in the development of a complete farming system into which specialised techniques of field layout, land preparation, planting, harvesting and transport are incorporated, bearing in mind that any such farming system tends to be less flexible, less adaptable to technological advance and more sensitive to escalating costs than farming systems applied to more favourable terrain.

Introduction

The Sezela estate of C. G. Smith Sugar Limited has 8 420 ha of land under cane, of which 70% is steeper than 15% slope and 24% steeper than the accepted limit of mechanisation with conventional wheeled tractors, viz., 32% slope. As these slopes often exceed a run of 300m from top to bottom, efficient cane farming requires an application of layout techniques which are exacting in both design and application.

The terrain imposes constraints that require that the canegrower be meticulous with the design and implementation of field layouts, with special attention given to the finishing touches, to ensure that:

(a) run-off is led off crest roads onto terraces
(b) run-off volume from crest roads is reduced by mitre drains spaced between terraces at approximately one third of the vertical interval of terraces.
(c) high or low spots that might cause overtopping of terraces are eliminated.
(d) no ponding is allowed to develop in terraces just before reaching the waterways
(e) there is a positive slope into waterways between terraces, i.e. no shoulders are allowed to develop during either shaping or grassing.
(f) special attention is given to waterway/terrace crossings, notably the upper and lower road embankments, by stone cobbling if this is necessary.

Furthermore, it is necessary to embody the above considerations into an overall farming system, which, because of the strict constraints of the terrain, does not only not allow much variation in design, but is also very expensive to adapt if a change is made in design criteria. Therefore it is important to establish and clearly define the objective of the planned layout and the design criteria to be used.

Objective and Design Criteria

The objective of the land use plan for this estate is to achieve and maintain a profitable and efficient cane farming system, which will conserve soil and water, maintain production according to defined labour use and output standards, with the maximum and most efficient usage of machinery that can be achieved.

The basic criteria to achieve this are:

All fields replanted, except those that already meet the following specifications, should be re-designed for easy and efficient access, improved harvesting efficiency, faster and more efficient field-to-loading zone haulage and conservation of soil and water.

The specifications are:

Terrace gradients: A standard gradient of 1:100 is used, with the first 50m from the crest road and the final 50m at the waterway being at 1:50 to lead runoff water off the cambered crest road and ensure a quick outflow from the terrace into the waterway. This terrace gradient may be varied according to special soil or management requirements, but should not be flatter than 1:200. Experience has shown that it is hazardous to accumulate water in terraces, without controlled release; therefore the gradients are designed to dispose of run-off as quickly as possible without causing scouring in the terrace channels. Grassed and mown, these channels are more stable and resistant to erosion than bare ground.

Terrace spacing: The most practical spacing for efficient hand cutting of cane on steep slopes and for strip cropping and in-field haulage operations on this estate has been found to be a surface spacing of 30m to 40m, measured on a slope face approximately midway between the crest line and waterway in part of the field which is steep but reasonably representative of the whole field. This gives the minimum spacing of terraces in the field. Care should be taken not to measure terrace spacings on isolated and unrepresentatively steep sections of the field. This spacing gives a vertical interval between 10m (on a 32% slope) and 15m (on a 15% slope).

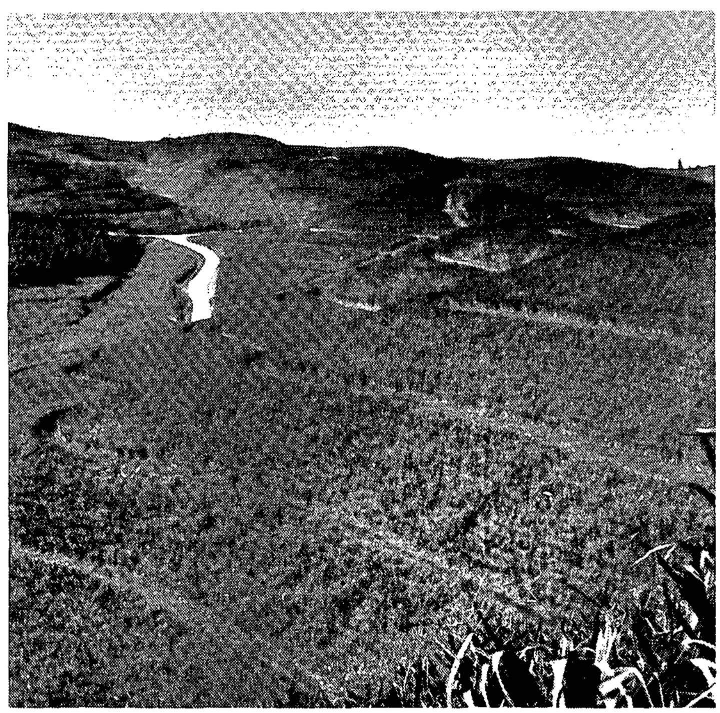

Figure 1: Layout showing spacing of roads.

Terrace sizes: The standard terrace is 3m wide, with a 0,30m deep reverse slope and 1:2 grassed backslopes above and below the terrace.

Waterway sizes: The standard waterway is 5m wide with the centre 1m flat, and side slopes 1:3,5, the depth being 0,60m (grassed). For catchments in excess of10ha the width should be increased by 0,4m per additional hectare of catchment up to a maximum width of 10m, the side slope flattened to 1:4 and the depth increased to 0,75m.

In-field haulage: Critical tractor-trailer haulage gradients are:
i) hauling uphill — 1:12
ii) hauling down-hill — 1:7,
and the distance from field to loading zone should not exceed one kilometre.

Wet areas: Should be drained according to the specifications detailed in the S.A.S.A. Experiment Station Standard Drainage Drawing 47/1, using corrugated slotted drainage tubes laid in a sand envelope, 1m below the soil surface. The lateral tubes are 63/50mm diameter (maximum length 125m). The collector tubes are 88/75mm corrugated, non-slotted, the length depending on the number of laterals they serve. These collectors discharge into the main drains.

Main drains: Open trenches are 1,5m deep, the top width 4,0m, and the bottom width 1,0m. The 45° angle of repose of the drain side (1:1 slope) may have to be reduced to 27° (1:2 slope) in highly saturated soils to prevent the sides slumping and filling in the drain.

In all layout operations, but in particular drainage of flat areas, land planning to achieve a smooth, even surface pays dividends.

Design Considerations

Efficient cane haulage is possibly one of the most difficult problems to solve in layout design. The options for Hilo road routes are few and it is therefore important to site these roads first along routes that will give easily negotiable grades and facilitate drainage and road maintenance, and then to locate the loading zones, considering accessibility from both Hilo and in-field roads.

The key to in-field access is to use negotiable crestlines and valley bottoms for main in-field haulage routes, with critical tractor-trailer haulage gradients in mind. Connect crest and valley with standard gradient terrace roads or, if this is not possible, use diagonal roads with maximum gradients of 1:12 or 1:7, depending on the direction of haul. The diagonal roads should be used only if no other solution can be found as they complicate in-field management and present difficult drainage problems. In steep vee-shaped valleys, the sharp, difficult-to-negotiate turns at the junction of terrace and valley bottom roads can be avoided by constructing a short road looping across the valley and back again, or by twin roads parallel to the drainage line. If there is a flat area in the valley bottom where drainage is necessary it is important to site these roads as cut-off roads at the slope break, or, more important, above the seepage line to avoid wetness problems when hauling along them in wet weather.

Figure 2: Valley bottom showing twin cut-off and interconnecting roads.

As a combination of negotiable crestlines and valleys constitutes the key to solving access problems in steep areas, so do hydraulically stable and well protected waterways provide the key to successful conservation layouts. In fact waterways are, without doubt, the most important single factor in a conservation layout, and therefore merit care and attention.

It is accepted that it is easier to control small rather than large volumes of water, and experience has taught us that it is folly to compromise on the size and number of waterways in a layout on steep land. Not only is it easier to dispose of runoff in small volumes in several waterways rather than to concentrate it in a few super-waterways, but also the probability of design error and failure is considerably reduced.

Stabilisation of waterways is vitally important and the cheapest and most effective method is grassing. Where an extra hard-wearing surface is required, cobble-stoning, grouted with soil into which grass is planted, is very successful.

In theory, it is advisable to establish and stabilise waterways before they are expected to carry run-off, but in practice they are often established last of all in a layout, and grass is planted after the cane. Where substantial land levelling has to be undertaken prior to establishing a waterway this practice is understandable but waterway shaping and grassing should be the first step in developing a conservation layout, even to the length of completing this job a season in advance.

Grassing Waterways

There are three very useful techniques of grassing waterways, each of which has its application.

Sodding: An expensive technique, but justified on the highly erodible Recent Sands (Clansthal and Fernwood series) and Table Mountain Sandstone-derived soils (Cartref and Trevanian series). Without a mechanical sod-cutter this becomes prohibitively expensive. Sods should be pegged into the ground to prevent movement before the sods knit with the soil surface.

Broadcasting cuttings: also an expensive technique, but very effective in that it produces an overall cover quickly under all conditions.

Seeding: undoubtedly the cheapest and quickest method of planting waterway grasses, but has the disadvantages that it takes longer to stabilise than either sodding or broadcasting seedlings.

Grass species suitable for seeding waterways are *Cynodon dactylon* (ngwengwe) and *Axonopus compressus* [1, 2] (carpet grass).

The technique used for seeding waterways is to mix the grass seed with clean, dry river sand, two volumes of sand to one of seed, and to broadcast by hand. The seeding rate used for *Cynodon dactylon* was 50 kg/ha, but this was found to be extravagant, and 25 kg/ha (compared with 15 kg/ha for pastures) would be satisfactory.

If there is a likelihood of heavy rain within a month of seeding, additional protection of the waterway should be provided by means of cane-top revettes[3]. In the same manner, a waterway grassed by broadcasting cuttings should be protected by revettes, but the erosion hazard is not as serious as with seeding, and waterways have been successfully grassed in this way without the additional expense of revetting.

Figure 3: Seeded waterway three months after seeding.

On steep terrain meticulous attention to detail in the abovementioned operations cannot be over-emphasised, as mistakes can be disastrous.

Land Preparation

Steep caneland laid out in the manner described above presents a problem when it has to be prepared for replanting. Ploughing with crawler tractors becomes very difficult and although oxen may be used, they are slow and inefficient.

TABLE 2

A comparison of conventional land preparation and minimum tillage

	Conventional tillage*	Minimum tillage**
Field size	23,1 ha	23,9 ha
Soil type	Mayo series	Mayo series
Time of cutting	June/July 1977	May 1977
Age at cutting	20 months	18 months
Yield: i) tc/ha	125,7	107,7
ii) tc/ha/mth	6,3	6,0
iii) ts/ha/mth	0,81	0,81
Costs /ha ***	R192,95	R136,85

* Includes new conservation layout
** No improved conservation layout
*** Costs are those incurred from the time of cutting the previous crop, up to and including the drawing of furrows, but do not include planting operations.

TABLE 1

Comparison of waterway grassing technique

Method	Sodding	Broadcasting cuttings	Seeding
Area of waterway treated	80mx5m	330mx5m	1 000mx5m
Soil Series	Cartref	Glenrosa	Glenrosa
Labour used to dig grass and transport	1 driver 2md*	1 driver, 3 md 1 conductor, 3md 1 charge hand 24md 17 labourers 357md	Nil
Planting	1 Induna:2md 11 labourers 22md	1 Induna:24md 6 labourers 144md	5 labourers 125md
Equipment used	Ford County & sod cutter: 2 hours Ford 5 000 & G.P trailer:16 hours	Ford 5 000 & G.P. trailer:25 hrs	Nil
Material Planted	Sods	Grass root cuttings	**Cynodon dactylon** seed
Stabilisation period	Instant	1 week	3 weeks
Planting rate, m^2/day	120	68,75	200
Labour used, m^2/md	16	5,14	40
Tractor usage m^2/hr	13,3	66	Nil
Cost per m^2	R0,29	R0,34	R0,07

md = man day

It is here that the work done by the S.A.S.A. Experiment Station and others [4, 5, 6, 7] on Roundup and minimum tillage makes a significent contribution. The replanting of cane without ploughing is not only feasible, but an economic proposition and the results obtained are satisfactory, as is shown in Table 2.

The data in Table 2 indicate that there is no significant difference between cane grown on conventionally prepared land compared with cane grown under minimum tillage. In fact, there is probably some advantage accruing to the minimum tillage field as it lacked a conservation layout.

A comparison of conventionally preparing land against minimum tillage revealed that a cost saving of 35% was obtained with minimum tillage. Other advantages are:

(i) efficient elimination of the old crop, using only 8 ℓ Roundup per ha.
(ii) time saved between cutting the final crop and replanting.
(iii) reduction of sheet and rill erosion.

In regard to the latter, it has been observed during the 1977 season that, in a storm with an intensity of 28mm per hour (14mm fell in 30 minutes), no visible erosion took place on a recently planted minimum tillage field, whereas on a conventionally prepared field in the same area on similar soils, considerable rill erosion took place.

These facts present sufficient grounds to postulate that no land of 25% slope or steeper need be ploughed for the purpose of re-establishing cane, once it has been laid out according to the described techniques.

There are, however, disadvantages with using Roundup and minimum tillage.

(i) The timing of Roundup sprays is critical in terms of the stage of growth of the ratooning cane. It must be approximately 40cm high, with maximum tillering and there must be hot sunny weather at spraying, with no rainfall for at least eight hours after spraying. Planting should not be delayed more than three weeks after spraying.

(ii) Roundup does not kill the stubble left when cutting high with the last harvest. The eyes on these stalk bases germinate to become sickly cane plants and a nuisance, and they are more difficult to remove than dead cane plants.

(iii) Dead crop residues, while affording protection to the soil from wind and water erosion, leave the re-planted field very untidy and interfere with subsequent herbicide spraying for weed control. It is often advantageous to remove these residues by burning just before planting.

(iv) If used for early season planting, difficulty is experienced in furrowing out cane rows under dry conditions in heavy soils. This difficulty could possibly be overcome by using a rotavator/ridger implement (already in existence) behind a small crawler tractor.

To date 382 ha have been planted using Roundup and minimum tillage.

Harvesting and Cane Haulage

Land laid out according to the conservation principles described above is ideal for adaptation to a system of trashing and strip cropping – the ultimate in conservation – in that only 40m wide strips of land are left bare of the protection of a crop canopy on a steep hillside. More important is that at the stage of re-establishment of the cane only these strips will not have the protection of any vegetation during the two or three month cane re-establishment period.

Strip cropping has been tried and, apart from the need for some adjustment in the management of the cutting and in-field haulage operations, it has been found to be a practical proposition on steep fields with slopes in excess of 30%, and with crop yields varying from 110 to 155 tc/ha. It has been accepted that all fields with land slopes exceeding 15% should be strip-cropped.

Among the adjustments that were required in management were:

(i) Cutting system changes motivated by a large variability in stack weights, which varied during the 1977/78 season from 2,7 to 4,1 tons. The reason appeared to be tasking difficulties and an alternate system of tasking was tried, viz. an area tasking based on estimated cane yield and a block of cane lines, length depending on cane yield, stretching from one in-field road to the in-field road above. In a field yielding 114 tc/ha and a total crop of 2 793 tons the average stack weight achieved was 4,5 tons. Cutters were finishing their tasks between 30 minutes and one hour earlier than with the previous system, and they expressed a preference for the new system. These results represent a 25% increase in cutter efficiency or 13% increase in Hilo payloads.

(ii) The in-field haulage system, because strip cropping facilitates building stacks on the bank just above the lower in-field road, and points to the need, together with the improved in-field access, for a change from rear-loading trailers to side loaders.

Three other factors point to the need for change:

(i) Poor cable performance (an average of 583 tons per cable from April to December, 1976) caused by hauling the stacks up onto the in-field trailers.

(ii) A test run for 11 days to compare rear loading and side loading trailers, without the benefit of a farming system designed for the machine. The results showed a 35% increase in in-field haulage efficiency by using the side loader.

TABLE 3

Comparison of side loader and rear loader

Trailer	No. of loads	Total tons	Tons per day
Side-loader	219	799	73
Rear-loader	171	582	53

(iii) Widely variable Hilo payloads. An analysis of 12 670 Hilo loads involving 264 315 tons during the 1977/78 season showed that only 49% were in the range 19 to 23 tons per Hilo required by the haulage contractor, while 27% were in the range 9 to 18 tons, incurring possible minimum charge penalties, and 24% were in the range 24 to 36 tons, incurring possible over-load penalties.

Conclusion

To date some 2 260 ha of the estate have been redesigned according to the techniques described. Table 4 gives a comparison of rainfall and yield data for the seasons under discussion, showing a gradual increase in ts/ha/month.

TABLE 4

Rainfall and yield data, 1975/76 to 1977/78

Season	Rainfall for previous season mm	Tons cane/ hectare cut	tc/ha/mth	ts/ha/mth
1975/76	1 111,1	95	4,9	0,64
1976/77	1 474,2	107	5,4	0,65
1977/78	1 253,9	103	5,2	0,66

Experience has shown that the layouts and techniques discussed are undoubtedly beneficial, not only in terms of increased yields, but also in cane-farming efficiency. Furthermore, while each improved technique has contributed towards an overall improvement in cane-farming efficiency and profit margins, no individual improvement has been achieved to the exclusion of any of the others, and the potential production of the estate will only be achieved, at the level of present knowledge, when all these techniques have been correctly implemented.

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