ABSTRACT

Research determining soil and water losses from sugarcane lands has helped us to set field recommendations for Land Use Plans. A nomograph is used to determine panel spacings and field management practices for both gentle and steep slopes. The application of the method to farms with a wide range of soil types and slopes is discussed. A field design and management plan is detailed. Methods to assess possible productivity improvements are described with special reference to cane haulage for three farms producing about 18,000 t per year. Implementation of the Land Use Plan is discussed, using existing field records to determine priority areas.

Key words: Sugarcane, farm planning, erosion control, water control, transport rationalization.

INTRODUCTION

In the sugarcane growing areas of South Africa there are many soil, slope, elevation and climate variations. Generally the conditions are not fully suitable for best crop growth. Rainfall is variable during the summer months from September to March, and storms of high intensity occur. Soils are often erodible and also vary within the farm boundaries. Better growing conditions may occur in the valley bottom areas compared to the crest lines and hillsides. Sugarcane is a very good conservation crop and despite the adverse climatic factors grows where most annual crops could not be grown.

To gain best returns from a farm unit under these conditions it is essential to provide protection and to apply the best agronomic practices for the land type. The best land use practices on different parts of the farm are presented in the form of a Land Use Plan (LUP). The plan is developed using a nomograph and provides a basic protection pattern over the farm based on catchment units and crop management. Haulage and access roads of various types are then integrated into the plan. The crop is bulky, heavy and difficult to move over steep terrain. Haulage costs are high in relation to the other production costs so the selection of
correct equipment and the correct routing after harvesting are vital. Assessments of proposed field row lengths and differing transport systems are undertaken to ensure that the most suitable system with the best available equipment is used. An implementation programme is needed to ensure the estimated benefits can be achieved and included in the LUP report.

The Nomograph

As data on soil and water losses became available from a research program (Platford), they showed that the major sediment yields occurred during the replanting periods, when soils were ploughed and cultivated. It was seen that a single protection practice such as the provision of water runoff control banks in a tilled field would not be sufficient to prevent large scale soil losses on steep slopes. For the flatter areas conventional tillage and graded terrace banks with grassed waterways are effective. As the range of soil types, slope, aspect and elevation is large throughout the sugar industry a set of recommendations was needed to include these differences. The original recommendations given for spacing of banks were modified from those designed by the Department of Agricultural Development for annual crops. A nomograph (Dent) was developed to allow for the different variables of soil type, slope, crop and management factors (Platford) (Figure 1).

The nomograph was designed to keep expected long term average annual soil losses to less than 20 t/ha/annum. Various slope limits were set for tillage methods because of the severe soil losses which occur on sloping ground. On highly erodible soils it was estimated from the data that unacceptable soil losses would take place on slopes over 12%. For the soils more resistant to erosion, the slope limit appeared to be 22%. Slope and soil erodibility are specific for each site and these form the starting point for entry into the nomograph. Various combinations of soil protection options are available; the result of the different options sets a panel width between either terrace or spillover roads. One or a number of panels can be incorporated into a field depending on the management practices selected. Using this technique the grower can have some choice in practices while still complying with the soil protection required under the Conservation of Agricultural Resources Act (1983).

MATERIALS

Aerial photographs

Most of the sugarcane areas are regularly photographed from 4,600 m. With a normal focal length of 150 mm in the camera a contact print with a scale of 1:30,000 is produced. Enlargements with an approximate scale of 1:6,000 are
FIGURE 1. SASA nomograph used to determine panel widths between roads in sugarcane fields.

used to identify specific fields, streams, wet spots, erosion gullies and other ground objects. Although photographs are useful for visual effects, their main function is to produce stereoscopic models for survey and topographic maps for individual growers.
G.G. PLATFORD AND E. MEYER

Soil maps

Large areas of the sugarcane belt have soil maps or soil parent material maps (Beater\(^1\)). These are used in the first assessment of soil type to be expected on the farm which is being planned. This information is vital together with the slope and aspect to set protection patterns. Most soil maps have been produced at a scale of 1:6,000.

Quota maps

Individual quota maps produced from aerial photographs, are at a scale of 1:6,000. They show the farm boundaries, field roads, buildings and the positions of areas where there is no sugarcane grown. Each field has a number specified by the grower and a measured area. They are used to control the position of allocated quota area and for management decisions and cane yield analyses.

Formline maps

Developed from aerial photographs they show topographic detail in the form of contours. The shape and spacing of the contours (lines of equal elevation on the ground) allow the planner to judge and assess the topography of the farm. Quota maps are true to scale and can be used to measure ground lengths and areas.

Ortho-photographs

These are modified aerial photographs with the form lines or contours drawn on them using special techniques and are free of distortion. They have the visual appeal of a photograph with the accuracy of a map but the expensive method of production has limited their production.

Data bases

Field Record System (FRS). A large number of growers submit records of field results to this service. The data related to field numbers on the quota map is analyzed for yield trends and is available to make management decisions. Where farms to be planned have this data it can be included in the planning process.

Fertilizer Advisory Service (FAS)

The results of soil and leaf sample analyses if available are identified by quota map field number. This information can be integrated into the data base used for deciding on best land use.
Geographic Information System (GIS)

The above types of data have been used in a GIS (Plattford\textsuperscript{\textregistered}) for the sugar industry. A Digital Terrain Model (DTM) has been included in the GIS to allow all the information to be referenced to the topography. Software modules are used to design transport routes at specific gradients to reach set positions for loading zones requiring flat sites and water control structures.

METHODS AND RESULTS

A request to prepare a Land Use Plan and assess the transport options for a group of three farms in the Eston area of the Natal Midlands was received from the Extension Department of the Experiment Station using the existing Specialist Advisory Service (SAR). The request covered three separate farms, two of which were on one quota (Elsinore and Hope Valley) and the third (Maxwilton) which had recently been purchased. (Figure 2).

FIGURE 2. Relative locations of the three farms planned and assessed for cane haulage efficiency.
All three farms had been planned but the change in ownership required some re-assessments of field works, field boundaries and of the cane haulage systems. The detailed planning method used was the same on all farms and the plan for Maxwilton farm is used as an example.

The steps taken in the preparation of the LUP were:

- A physical plan to suit the surface was prepared
- Site visits to fit the plan to the ground
- New field boundaries were proposed
- Comparisons were made of existing and proposed systems
- An implementation program was set

Preparation of a physical plan

The detail from the soils maps and formline maps with crest and drainage lines were drawn onto an existing quota map. Catchment sizes were measured for each waterway (mostly dry) and watercourse (mostly wet). Slopes were measured along crests, down representative hillsides and along the waterways. Soil types were examined and classified into: erodible, moderately erodible and resistant to erosion. These boundaries were then marked on the same map. Field areas and crests with slopes greater than 10% were circled and possible diagonal roads at a constant 10% gradient marked for possible extraction routes. Using the photograph and formline maps as a guide, possible wet valley bottom lands were marked. With the use of a nomograph, road spacings for each of the defined hillside blocks were established. A series of water-carrying terrace banks were designed to intercept any run-off water and carry it across the hillside to the grassed waterways or existing watercourses. The capacity of the banks was detailed in the specifications attached to the maps. These terrace banks were used as the basic framework for new fields. The required capacity and shape for each individual grassed waterway was calculated. Each of the watercourses and streams were examined on the photograph; on the contour map and marked for possible stabilization works and notes were made on the map to inspect sensitive areas such as possible wetlands. The rough drawing then showed all the proposed works and the embryo LUP was ready for field checking (Figure 3).

Modification

Arrangements were made to visit the grower and to inspect the farm to check the proposed plan on the ground. The need to modify the plan with the growers own preferences was discussed. The principles to be applied in the plan such as strip planting, reduced or minimum tillage replanting, trashing or burning at harvest and watercourse, streambank and wetland protection were outlined. A record was then made of crop and field details and all existing farm operations with the
FIGURE 3. Terrace banks, grassed waterways and extraction roads form the framework of the Land Use Plan.

Field details

Existing field boundaries were marked clearly with a dark pen on a quota map (Figure 4).

Many fields have terraces and waterways within the field boundary, which may be suitable for inclusion in the final plan. The existing estimated replanting program was recorded. Where the field information was available details were noted on a copy of the quota map. Where no record was available the grower estimated the value of the crop. Fields were graded into the current year's harvest with an estimated cane age or those fields which would only be cut the following season. These two sets were then split into three categories: good, moderate or, bad depending on the crop condition. As most plans entail reshaping field boundaries this information is essential to make sure that any change does not radically affect cash flows or predicted estimates. This was needed for the later stages of planning when implementation programs were set.
FIGURE 4. Existing field shapes and sizes shown on a Quota Map for the farm Maxwilton.

Objectives and targets

On this farm most of the production area was situated on the crest and hillsides where expected yields were similar. There was no valley bottom cane, which is normally of higher yield potential, because there is little flat land along the watercourses. The estimated annual crop to be cut from this section of the combined farms is about 12,000 tons. The Daily Ratable Delivery is close to 85 tons/day. With an estimated yield of 43 tons/ha/annum a field of 5 to 6 ha would take about three days to harvest. The target size for the fields was therefore set at 5 ha.

New field boundaries

The roads and terraces of the LUP set the framework for the new fields. New field boundaries are shown in Figure 5. These fields are much longer and narrower than the existing fields and are designed to provide strips of crop at different ages across the hillsides. Diagonal extraction roads and other access
panels are combined into suitable new field shapes.

The new field layout system will provide much greater protection to the soil. As there are more roads and terraces in the proposal, a check is needed to evaluate the efficiency of the new fields and the loss of ground due to the extra roads. Both manual and mechanical work in the field are improved if average row lengths are increased, as most field operations follow the row. Existing and proposed row lengths in the fields are measured and compared to see if the new fields give a greater row length and hence better efficiency (Murray and Meyer). The Field Machine Index (FMI) is a measure related to row length and shows the production time as a ratio to total time (production time plus turning time) for a specific field. This index is adjusted by a weighting factor based on field size. The sum of these weighted values gives the FMI for the layout system in question (Table 1).

FIGURE 5. After the basic Land Use Plan has been prepared horizontal panels are combined into suitable new field shapes.

Assessment of systems
TABLE 1. Summary of changes in field efficiency with changing row lengths.

FIELD MACHINERY INDEX (FMI) = \( P/P + T \)

\( P = \text{PRODUCTION TIME} = \text{AVE. ROW LENGTH/SPEED} \)

\( T = \text{TUERNING TIME} \)

Speed = 135 m/min  
Turning time = 1.25 min

<table>
<thead>
<tr>
<th>Field No</th>
<th>Area (ha)</th>
<th>Row Lgth (m)</th>
<th>FMI</th>
<th>FMI x Area</th>
<th>Field No</th>
<th>Area (ha)</th>
<th>Row Lgth (m)</th>
<th>FMI</th>
<th>FMI x Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>1.5</td>
<td>60</td>
<td>0.26</td>
<td>0.39</td>
<td>1.</td>
<td>2.2</td>
<td>180</td>
<td>0.52</td>
<td>1.144</td>
</tr>
<tr>
<td>12.</td>
<td>2.4</td>
<td>120</td>
<td>0.42</td>
<td>1.008</td>
<td>2.</td>
<td>1.6</td>
<td>210</td>
<td>0.55</td>
<td>0.88</td>
</tr>
<tr>
<td>602.</td>
<td>0.7</td>
<td>48</td>
<td>0.22</td>
<td>0.154</td>
<td>66.</td>
<td>1.7</td>
<td>300</td>
<td>0.64</td>
<td>1.088</td>
</tr>
<tr>
<td>604.</td>
<td>1.4</td>
<td>240</td>
<td>0.59</td>
<td>0.826</td>
<td>67.</td>
<td>2.2</td>
<td>450</td>
<td>0.72</td>
<td>1.584</td>
</tr>
</tbody>
</table>

Ave. row lgth: = 156 m  
\( \text{Ave. FMI:} \) = 0.51  
\( \text{FMI x Area:} \) = 0.72

IMPROVEMENTS % = PROPOSED-EXISTING/EXISTING \times 100 = 42%

Haulage systems assessment

Existing system

Figure 2 shows the position of the loading zones currently used. At present all cane is burnt before harvest, cut by hand and stacked into 4.5 ton bundles. Chained bundles are loaded into a contractor’s road haulage vehicle by communally-owned cranes over a 24 hour period for transport to the mill. Cane is transported from Elsinore and Hope Valley to Zone 48. Maxwinton cane goes to Zone 107. Both zones are outside the property boundaries. One 58kW 2WD tractor/double stack, walking beam, self loading trailer and one 45kW 2WD tractor/single stack self loading trailer are used. The routes used to transport cane to the loading zones were measured on the map and yields estimated for each field. The product of these two items is expressed as [ton-kilometers] on the effort required to move cane over the actual distance. The sum of all the products gives a measure of the effort needed to move cane over the existing road infrastructure (Table 2).
TABLE 2. Existing infield cane haulage distances.

<table>
<thead>
<tr>
<th>Estate</th>
<th>Total area (ha)</th>
<th>Annual (tons)</th>
<th>Zone No.</th>
<th>Ave. (kms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elsinore</td>
<td>157.9</td>
<td>6,187</td>
<td>48</td>
<td>2.48</td>
</tr>
<tr>
<td>Hope Valley</td>
<td>38.0</td>
<td>1,489</td>
<td>48</td>
<td>6.29</td>
</tr>
<tr>
<td>Maxwilton</td>
<td>250.7</td>
<td>9,824</td>
<td>107</td>
<td>3.51</td>
</tr>
<tr>
<td>Total</td>
<td>446.6</td>
<td>17,500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Proposed systems

After examining the topographic map additional loading sites are possible at the positions shown in Figure 2.

Option 1

Cane loads of 9.0 tons from the various farms to be transported to the nearest of four new loading zones (1, 2, 3, 4). A 58kW 2WD tractor double stack self loading trailer combination is used. The grower's Mobamech crane is used to load contractor’s road haulage vehicles over 24 hours (Table 3).

Option 2

Cane from Elsinore is transported to Zone 4, cane from Hope Valley and Maxwilton is sent to Zone 1. One 58kW 2WD tractor/double stack self loading trailer hauls cane to both zones. The grower’s Mobamech crane loads contractor’s road vehicles over a 24 hour period (Table 3).

The implementation of multi-transloading options 1 and 2 would substantially reduce cane transport cost. A reduction of about 50% of infield distance is expected by restating loading zones as seen in Table 3. Transloading and road haulage costs from zones to the mill will increase in options 1 and 2. The increase in relation to the overall main road costs is small and is outweighed by the large saving in field to zone costs. Option 1 is slightly more favorable than option 2 (Table 4).
TABLE 3. Field to loading zone transport efficiency.

GROWER: HD STAINBANK.
FARMS: ELSINORE, MAXWILTON AND HOPE VALLEY

<table>
<thead>
<tr>
<th>Field No.</th>
<th>Size (ha)</th>
<th>Zone No.</th>
<th>Dist. (km)</th>
<th>Total tons</th>
<th>Total t/km</th>
<th>Zone No.</th>
<th>Dist. (km)</th>
<th>Total tons</th>
<th>Total t/km</th>
<th>Zone No.</th>
<th>Dist. (km)</th>
<th>Total tons</th>
<th>Total t/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.8</td>
<td>48</td>
<td>2.52</td>
<td>110</td>
<td>276</td>
<td>4</td>
<td>0.90</td>
<td>110</td>
<td>99</td>
<td>4</td>
<td>0.90</td>
<td>110</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>5.6</td>
<td>48</td>
<td>2.46</td>
<td>219</td>
<td>540</td>
<td>4</td>
<td>0.84</td>
<td>219</td>
<td>184</td>
<td>4</td>
<td>0.84</td>
<td>219</td>
<td>184</td>
</tr>
<tr>
<td>264</td>
<td>4.0</td>
<td>107</td>
<td>4.20</td>
<td>157</td>
<td>658</td>
<td>2</td>
<td>0.84</td>
<td>1.57</td>
<td>132</td>
<td>1</td>
<td>2.10</td>
<td>157</td>
<td>329</td>
</tr>
<tr>
<td>265</td>
<td>4.0</td>
<td>107</td>
<td>4.20</td>
<td>157</td>
<td>658</td>
<td>2</td>
<td>0.84</td>
<td>157</td>
<td>132</td>
<td>1</td>
<td>2.10</td>
<td>157</td>
<td>329</td>
</tr>
<tr>
<td>266</td>
<td>1.6</td>
<td>107</td>
<td>3.96</td>
<td>63</td>
<td>248</td>
<td>2</td>
<td>0.60</td>
<td>63</td>
<td>38</td>
<td>1</td>
<td>1.86</td>
<td>63</td>
<td>117</td>
</tr>
</tbody>
</table>

Totals: 447 17500 59167 17500 16192 17500 24114
Ave. infield haul: 3.38 km 0.93 km 1.38 km
### TABLE 4. Estimated total annual haulage costs.

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infield haul</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.0 ton unit</td>
<td>R63.15/h 51,467</td>
<td>R64.69/h 55,245</td>
<td>R59.70/h 60,416</td>
</tr>
<tr>
<td>4.5 ton unit</td>
<td>R49.39/h 40,895</td>
<td>R1.60/t 28,000</td>
<td>R1.97/t 34,475</td>
</tr>
<tr>
<td><strong>Transloading</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road haulage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 48</td>
<td>R11.14/t 85,511</td>
<td>R12.30/t 54,661</td>
<td>R12.30/t 139,150</td>
</tr>
<tr>
<td>Zone 107</td>
<td>R11.89/t 116,807</td>
<td>R12.54/t 65,747</td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>R12.46/t 20,260</td>
<td>R11.43/t 70,717</td>
<td>R11.43/t 70,717</td>
</tr>
<tr>
<td>Zone 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>322,680</td>
<td>301,105</td>
<td>304,758</td>
</tr>
</tbody>
</table>

### Implementation

Once the benefits of the plan have been assessed, the terraces, waterways and roads are created in a planned implementation program which ensures a smooth transition to new field numbers.

A transparent overlay of the proposed new fields is placed on the existing quota map with the boundaries highlighted. The state of the existing crop and the proposed replanting program as recorded on the farm visit, are used to determine where work can be started. In harvested fields, waterways and terrace roads can be marked or partly built. Diagonal extraction roads which may be needed for improvements to the haulage routes can be treated in the same way. For the areas to be replanted new works can be pegged, marked and partly built. The list of fields, i.e., good, moderate and poor producers, is examined on the map and the poor yielding fields are placed at the top of the action list if they are to be harvested in the current season. With the target amount of land to be replanted, the possible areas which can be replanted within the budget are marked. A close check must be made on the amount of new cane needed to keep the cutting cycle balanced. Fields or portions of fields were selected to achieve the new boundary structure and new allocated field numbers. In some cases it was necessary to look at the state and quality of a field adjacent to a poor field to see if a portion could be combined with it for a new field. Some fields with different varieties and age resulted. This will be rectified at the next replant. Although the crop cycle in some fields is probably in excess of ten years there is no need to wait that long to
achieve full implementation of the new plan. With prudent selection of areas to be replanted and harvested it could be implemented in two to three years. Some finished work on Maxwilton is shown in Figure 6.

FIGURE 6. Part of the completed field work showing water carrying terraces and grassed waterways. Some of the terraces will form new field boundaries.

CONCLUSIONS

Using a logical step by step approach the preparation of a Land Use Plan ensured that all aspects of protection and production were optimized. Based on the topography and the soil type of this farm, a network of water control roads was used to develop a field layout system for the best protection and optimum production. Crop management techniques were included in the selection of a suitable field layout. The layout provides long, relatively narrow fields of cane of differing age, across the hillside slopes. An analysis of the measured distances to loading sites, positioning of loading zones and diagonal extraction roads, combined with equipments requirements, showed the best haulage method and equipment for this farm. The implementation method causes a change in the field numbering system but the change-over period need not be longer than two to three seasons.
REFERENCES


PLANIFICATION DE L'UTILISATION DES SOLS
DANS L'INDUSTRIE SUCRIÈRE SUD-AFRICAINE

G.G. Platford et E. Meyer
South African Sugar Association Experiment Station
Mount Edgecombe, South Africa

RESUME

Les recherches pour déterminer les pertes de sols et d'eau dans les terres sous canne à sucre nous ont aidées à faire des recommandations pour des plans d'utilisation des sols. Un nomographe est utilisé pour la détermination des espacements et des pratiques de gestion des champs pour les pentes douces et fortes. L'application de la méthode aux exploitations avec une grande variété de types de sols et de pentes est discutée. Les détails de la planification et de la gestion des champs sont donnés. Des méthodes pour évaluer des améliorations possibles de productivité avec l'emphasis sur la manutention des cannes pour trois exploitations produisant environ 18,000 tonnes de cannes par an sont décrites. L'exécution des plans d'utilisation des sols, utilisant des données existantes sur les champs pour déterminer les emplacements prioritaires est discutée.

Mots clés: Canne à sucre, contrôle de l'érosion, contrôle de l'eau, rationalisation du transport.
RESUMEN

Las investigaciones que se han realizado para determinar las pérdidas de suelo y agua en tierras dedicadas al cultivo de la caña de azúcar, nos han ayudado en nuestras recomendaciones para la planificación del uso de tierras. Se ha preparado un nomograma para determinar el especiamiento de lotes, así como para prácticas administrativas, tanto para pendientes moderadas como pronunciadas. Se explica la aplicación de un método para trabajar con diversos tipos de suelos y pendientes. Se detallan diseños de campo y planificación administrativa. Se describen métodos para evaluar mejoras en la productividad con referencia especial al transporte de caña en tres fincas que producen 18,000 t de caña por año. Se discute la implementación de un plan para el uso de tierras empleando antecedentes de campo para determinar prioridades.

Palabras claves: Caña de azúcar, planeación de fincas, control de erosión, control hidráulico, racionalización del transporte.