

EXECUTIVE SUMMARY

1. BACKGROUND AND OBJECTIVES

The current area under sugarcane production in South Africa is some 400 000 ha. There is increased need to quantify the impact of sugarcane production on water resources. This impact could include reduction in stream flow, modification in flood size (volume and peak) and impact on sediment yield and water quality.

In 1992 a joint project between the Water Research Commission, Illovo Sugar Ltd and the South African Sugar Association was initiated to address these issues. The main aims of the project were:

- To measure water yield and quality from steep catchment areas planted to a commercial timber crop.
- To measure the changes in water and sediment yield and water quality when the forested area is planted to sugarcane, requiring different management and slope preparation methods.
- To compare results from the above areas with runoff from natural grassland.

2. METHODOLOGY

Initially the project focussed on measuring hydrological response from eight small catchments, located at Umzinto (70 km south of Durban), undergoing a land use change from timber to sugarcane. Various factors resulted in limited data being collected from the catchments during the project. Accordingly, emphasis of the project was placed on use of a hydrological model, validated using available data for sugarcane catchments, to meet project objectives.

The *ACRU* model (Schulze, 1995) was selected as an appropriate model since it is a physical, conceptual model which has been widely tested over the past 15 years for a wide range of land uses including timber, sugarcane and grassland. The model was verified for sugarcane using data collected of the period 1977 to 1995 at four catchments located at La Mercy. The model was then applied for various land use scenarios to the Umzinto catchments.

3. RESULTS AND CONCLUSIONS

The major results and conclusions from the study are given below in three sections which focus in turn on:

- (i) Hydrological trends and relationships evident from the data collected from sugarcane catchments and plots.
- (ii) Adequacy of hydrological simulations using the *ACRU* model when compared with observed data.
- (iii) Assessment of the impact of changing land use (sugarcane, timber and grassland) on catchment hydrology based on model scenarios.

3.1 Hydrological Trends and Relationships

Based on hydrological data collected from runoff plots and research catchments the following trends were evident:

- Soil type and slope have a marked impact on runoff, especially under bare fallow conditions.
- On average, there was a 60% reduction in soil loss and 34% reduction in runoff from plot experiments when minimum tillage as opposed to full tillage methods were adopted.
- Average annual runoff as a percentage of rainfall from plots under sugarcane ranged from 1 to 20 per cent depending on soil conditions.
- Average annual soil erosion from sugarcane plots ranged from 21 t ha⁻¹.an⁻¹ to less than 2 t ha⁻¹.an⁻¹.
- Annual runoff as a percentage of rainfall from four catchment experiments varied between 0 and 25 per cent of annual rainfall. Typically, runoff response is less than 5% when annual rainfall was less than 850 mm, and rose to above 25% when rainfall exceeded 1 200 mm.
- Generally a few large storm events produce most of the runoff. During such storms more than 50% of rainfall can run off.
- Rainfall intensity and soil moisture conditions have a major influence on runoff response.
- Soil loss declines to a greater extent than runoff as sugarcane cover increases.
- Runoff appears to be mostly affected by soil type (infiltration rate), storm intensity and antecedent moisture conditions.
- Crop cover and management practices such as strip cropping, minimum tillage and trash retention appear to reduce runoff and soil loss to a greater extent than conservation structures such as contour banks and waterways.
- No signs of excessive wash-off of nutrients or minerals from the catchments were evident.

The above results illustrate how variable hydrological response is on small catchments and how local soils, rainfall and crop management practices will affect this response. Recommendations in terms of catchment management thus need to be site specific.

3.2 Hydrological Simulation using the *ACRU* Model

Based on validation of the *ACRU* model using observed daily data from four sugarcane catchments the following results and conclusions can be made:

- The *ACRU* model adequately simulated runoff volume from sugarcane catchments.
- A decision support system to improve estimation of the *ACRU* model parameters for sugarcane catchments was developed.
- Certain events were not well presented by the model. This was ascribed to an inadequate representation for the events of:
 - rainfall intensity (*ACRU* is a daily model)
 - initial abstractions prior to runoff occurrence
 - land preparation and crop management practices.

- Good estimates of peak discharge were achieved with the model when using actual rainfall intensity data. Catchment response time was generally under-estimated. Use of design rainfall distributions resulted in over-estimation of peak discharge.
- Hydrograph shape was reasonably well represented by the model. Increasing catchment response time provided better representation of catchment storage.
- Estimation of sediment yield using the modified USLE equation did not prove successful. Generally sediment yield was over-estimated. Varying the cover parameter improved estimates but it was concluded that the role of sediment transport and deposition was not well represented by the model.
- Local land management practices such as crop cultivation, repair to waterways and contour banks can have a major impact on timing and magnitude of sediment yield. Flushing out of previous deposits during a large flood will also play a role.

3.3 Modelling the Impact of Grassland, Forestry and Sugarcane

The *ACRU* model was used to simulate the impacts of *eucalyptus grandis*, sugarcane and grassland on water yield at Umzinto. The results of the model runs are site specific and limited by the assumptions and adequacy of how well the model represents the real world processes. The *ACRU* model is however hydrologically sensitive to land use changes and has been widely verified for grassland, sugarcane and timber. Based on the model runs, the following conclusions can be made:

- Afforestation had a greater impact on stream flow than sugarcane at Umzinto.
- The impact of land cover on runoff is least when soils are shallow and is exacerbated as the soil thickness increases.
- Differences between runoff response under different land covers is smallest during wet years and seasons.
- On thin soils the runoff simulated from grassland and sugarcane land covers were similar. On thicker soils runoff from grassland generally exceeded that from sugarcane.
- Use of stochastic rainfall series did not provide good representation of runoff conditions during high and low flow periods.

4. RECOMMENDATIONS

Owing to the limited hydrological data recorded from the Umzinto catchments over the project period, no direct comparison between measured water yield and water quality under different land uses could be made. Nevertheless, the project objectives were addressed in an indirect way by using a widely recognised hydrological model, which was validated using hydrological data from a range of sugarcane catchments and runoff plot requirements.

The resulting improvements in *ACRU* model representation for sugarcane will be of great assistance in assessing the impact of sugarcane, relative to other land uses in other parts of the sugar industry where no gauged data is available.

Furthermore, the project allowed preparation of a data base containing hydrological information from sugarcane catchment and plot experiments, which will be invaluable for further research studies.

The major recommendations emanating from the project are highlighted below.

4.1 Data Collection

A crucial aspect in the successful collection of data is frequent analysis and use of the data. This enables any problems in data acquisition methods to be detected and corrected timeously. Based on analyses undertaken in the project, various improvements for further data collection and processing have been identified.

4.2 *ACRU* Model Development and Application for Sugarcane

Useful guidelines have been developed during this study for improved estimation of parameter values for use in the *ACRU* model for sugarcane catchments. Further refinements to model structure for application to sugarcane is recommended, namely:

- The method of simulating initial rainfall abstractions should be investigated, especially as they are related to antecedent moisture conditions.
- Further research is required into identifying the factors affecting runoff concentration times under various management practices.
- Further research into the use of regional rainfall intensity distributions based on actual daily rainfall amount is required.
- A more detailed investigation is required into integration of the factors affecting sediment yield on sugarcane catchments into the *ACRU* model. Factors that need to be addressed include the role of soil moisture status on soil erodibility, variation of crop and management factors through the year and sediment transport within a catchment.

4.3 Other Water Research

The study focussed on the Umzinto catchments to indicate the impact of different land covers (timber, grassland and sugarcane) on hydrological processes. It is recommended that more generalised investigations be initiated to determine whether the trends evident vary between regions and climatic regimes. Catchment attributes that influence these trends also need to be further investigated.

Further work needs to be undertaken on the appropriateness of using stochastic rainfall series in simulating hydrological response.

This study has focussed only on rainfed sugarcane. The impact of irrigated sugarcane on water resources should be investigated on a regional scale.

Finally, further research is required on the water quality characteristics of surface and subsurface flow from sugarcane catchments.

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The Steering Committee responsible for this project consisted of the following people:

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