MODELLING THE IMPACTS OF GRASSLAND, FORESTRY AND SUGARCANE ON RUN-OFF AT THE UMZINTO RESEARCH CATCHMENTS

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Introduction

South Africa is generally a water-poor country, and the demand for this scarce resource is ever-increasing. This has implications for agriculture, with an increasing need to provide accurate assessments of the impacts that individual crop types have on water resources. As is the case with most crops and land uses, there is a lack of accurate data and knowledge of the influence of sugarcane production on the water resources of a catchment. Hence, together with other land uses, sugarcane is increasingly coming under the spotlight as possibly having a significant impact on water resources.

A cost effective and efficient method of assessing the impact of any crop on water resources is to develop credible simulation models that are able to simulate the run-off response from a catchment and which are sensitive to land cover, management practices and soil characteristics. The alternative to modelling is long term field monitoring experimentation, which produces results that are site specific, requires records to be kept over an extended period and is costly to maintain. An added advantage of adopting a modelling strategy to water resource impact assessments is that the modelling process clarifies existing knowledge of a particular physical process and highlights areas that require further investigation.

Objectives

The objectives of the research reported were to:

- verify, and where necessary improve, the simulation of run-off and sediment yield by the *ACRU* model from sugarcane fields under various management practices
- use the model to investigate the seasonal and annual trends in run-off from catchments under grassland, forestry and sugarcane production.

Simulating run-off from sugarcane fields

Run-off data from the four La Mercy catchments, monitored by the South African Sugar Association Experiment Station (SASEX), have been analysed and the effect of different sugar-cane management practices on run-off have been characterised (Smithers *et al.,* 1996). The *ACRU* model (Schulze, 1995), a daily time step physical-conceptual agrohydrological simulation model which has been widely verified, particularly in KwaZulu-Natal, was applied to the La Mercy catchments and daily stormflow volume, peak discharge and hydrograph shape as well as sediment yield simulated by the model were verified against observed data. As a result of the modelling, a Sugar Cane Decision Support System (SCDSS) was developed for the *ACRU* model (Smithers *et al.,* 1996). This incorporates knowledge gained from the modelling of the hydrology from sugarcane land covers under different management practices. Thus the results from application of the model to ungauged catchments with sugarcane land cover may be used with more confidence. Some results from simulating daily streamflow volumes from three of the La Mercy catchments are contained in Figure 1 and statistics of model performance are listed in Table 1.

Table 1
Observed versus simulated statistics for daily flows (mm) for the period 1984 to 1996.

	Catchment		
	101	102	103
Sample size	4 383	4 383	4 383
CONSERVATION STATISTICS			
Sum of observed values	1 198	1 872	1 639
Sum of simulated values	1 266	1 619	1 774
Variance of observed values	14,5	27,3	23,4
Variance of simulated values	16,4	18,3	19,0
Skewness coefficient of observed values	25,2	20,5	21,6
Skewness coefficient of simulated values	25,9	22,8	21,7
REGRESSION STATISTICS			
Correlation coefficient (Pearson's r)	0,84	0,91	0,90
Slope of the regression line	0,89	0,74	0,81
Y intercept of the regression line	0,05	0,05	0,10

Impact of grassland, forestry and sugarcane on run-off

The run-off from three land cover scenarios for three catchments (Catchments 1, 2 and 6) which form part of the Umzinto Research Project were simulated for a 52-year rainfall record

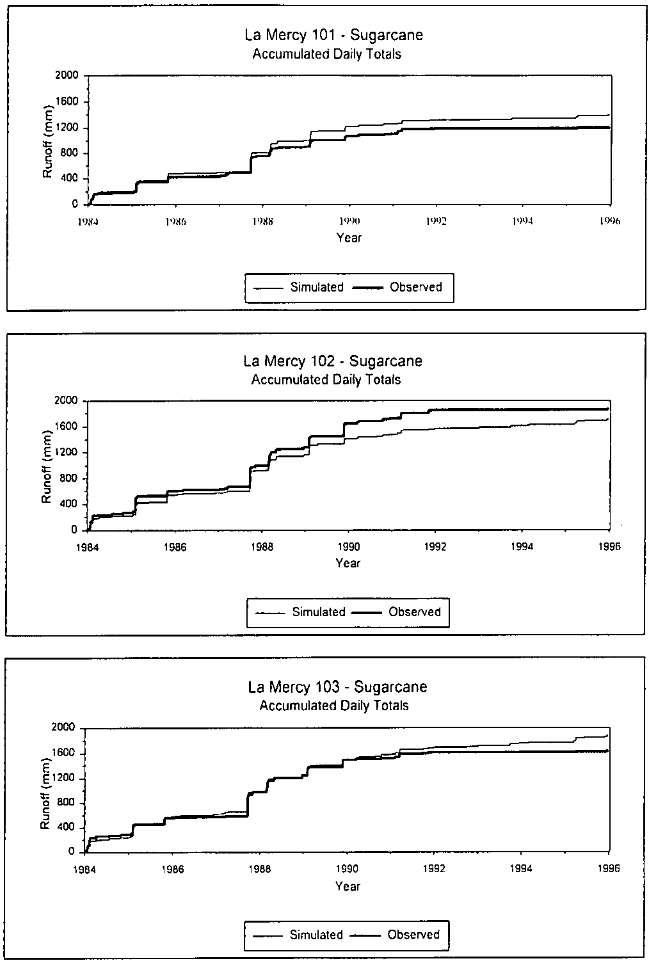

Figure 1. Simulated and observed run-off, La Mercy catchments (after Smithers *et al.*, 1996).

(1942-1993) using the *ACRU* model. The land covers simulated were grassland (assumed to be in pristine condition), a 5-year old forest of *Eucalyptus grandis* and sugarcane. All land covers were assumed to cover the entire catchment. The run-off from *E. grandis* was simulated as having had site preparation of intermediate intensity prior to planting (i.e. deep ripping, but no ploughing) and the run-off from sugarcane was simulated for intensive soil preparation prior to planting and to contain conservation structures. Real climate and soils data from the three catchments were input to the model, and input vegetation variables were based on published values, the SCDSS and expert knowledge (Smithers and Schulze, 1996). The depths of the soils in the catchments were 0,75 m (Catchment 1), 0,95 m (Catchment 2) and 0,60 m (Catchment 6).

On all three catchments, the largest volume of run-off was simulated from the grassland cover and the least from the forest land cover (Figure 2). Median (50%), 5% (equivalent to 1:20 dry year) and 95% (equivalent 1:20 wet year) non-exceedance levels of monthly totals of daily run-off simulated from the three catchments for forest and sugarcane land covers, expressed as a percentage of the run-off simulated from the grassland cover, are depicted in Figure 3. The simulated results indicate that the differences in the impact of the different land covers on the run-off simulated from a catchment are least when the soils are thin, and are exacerbated as the soil thickness increases. In addition, for months in which median totals of daily run-off occur, it was noted that run-off from the sugarcane scenario was similar to or exceeded that from the grassland during the winter (low flow) months on catchments that had thinner soils. This is postulated to be the result of increased rainfall infiltration and hence larger winter base flows under sugarcane. During periods with above normal monthly totals of daily run-off (i.e. 95% non-exceedance), the run-off simulated from the different land covers were very similar.

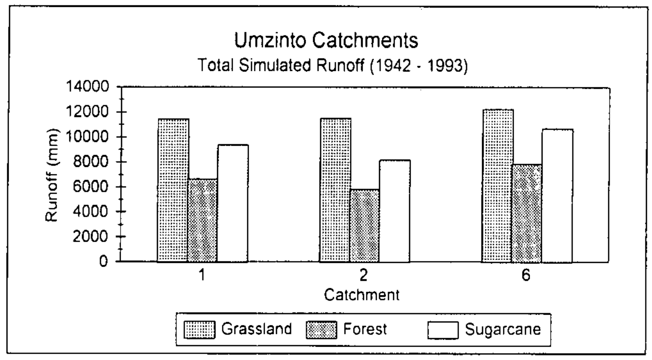

Figure 2. Total run-off simulated for the three land cover scenarios from three Umzinto catchments for the period 1942 to 1993.

Conclusions

Smithers *et al.* (1996) demonstrated that the *ACRU* model is capable of adequately modelling the run-off volume, peak discharge and hydrograph shape from small catchments under sugarcane production in KwaZulu-Natal.

On all three catchments, the largest volume of run-off was simulated from the grassland cover and least from the forest cover. However, during dry years and on catchments with thinner soils, the winter baseflows simulated from the sugarcane cover may exceed that simulated from the grassland cover as a consequence of the increased rainfall infiltration modelled under sugarcane. The simulated results also indicate that the differences in the impact of the different land covers on the run-off simulated from a catchment are largest during dry years and negligible during wet years.

The different land cover scenarios simulated at Umzinto have shown the effect of soil thickness on the impact of different land covers on catchment hydrological responses. However, within a small region, it has also shown that the impact of different land covers on catchment run-off can vary between neighbouring catchments. It is thus recommended that more generalised investigations be instigated to determine whether any regional and climatic trends exist, and to identify catchment attributes that may be used to identify sensitive catchments in which changes in land cover may have a significant impact on the catchment water resource.

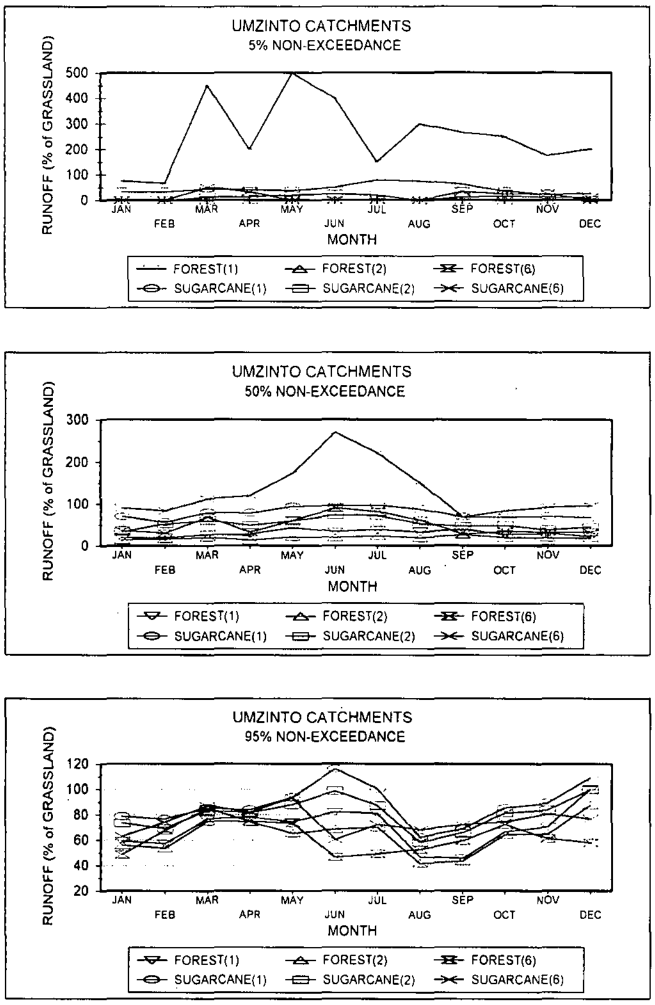

Figure 3. Frequency analysis of monthly totals of daily run-off for forest and sugarcane land cover scenarios, expressed as a percentage of runoff from grassland scenario (after Smithers and Schulze, 1996). (1) = Catchment 1; (2) = Catchment 2; (6) = Catchment 6.

Acknowledgements

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REFERENCES

Schulze, RE, 1995. *Hydrology and Agrohydrology: A Text to Accompany the ACRU 3.00 Agrohydrological Modelling System.* Water Research Commission Report TT 69/95. 552 pp.

Smithers, JC and Schulze, RE, 1996. Modelling the impacts of grassland, forestry and sugarcane on runoff at the Umzinto research catchments. *ACRU*cons Report No. 12, Department of Agricultural Engineering, University of Natal, Pietermaritzburg. 26 pp.

Smithers, JC, Mathews, P and Schulze, RE, 1996. The simulation of runoff and sediment yield from catchments under sugarcane production at La Mercy, using the *ACRU* model. *ACRU*cons Report No. 13, Department of Agricultural Engineering, University of Natal, Pietermaritzburg. 60 pp.