SHORT NON-REFEREED PAPER

VERIFICATION OF RUNOFF VOLUME, PEAK DISCHARGE AND SEDIMENT YIELD SIMULATED USING THE *ACRU* MODEL FOR BARE FALLOW AND SUGARCANE FIELDS

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Introduction

The Agricultural Catchments Research Unit (*ACRU*) model is a daily time step, physical-conceptual agrohydrological model (Schulze, 1975; Schulze *et al.*, 1995; Smithers and Schulze, 1995; Smithers *et al.*, 1996). It is a multi-purpose model with application in design hydrology among others (Schulze *et al.*, 1995; Jewitt and Schulze, 1999). The *ACRU* model, together with simulated outputs such as streamflow, soil water content and sediment yield, has been extensively verified against observed data in southern Africa and internationally (Schulze, 2008; Schulze, 2011). To verify is to determine the correctness of simulated output through comparison with observed data, hence model verification is a measure of the model's performance (Schulze, 2011). For simulations using a daily time-step model to be acceptable, the slope of the regression line of simulated vs observed values should be close to unity and the minimum acceptable coefficient of determination (R^2) should be 0.60 (Schulze and Smithers, 1995). In addition, model performance is examined based on its ability to generate reasonable key statistics like percentiles and extreme values (Rashid *et al.*, 2015), and maintain similarities in shapes and distributions of peaks between observed and simulated values (Kim *et al.*, 2014). Continuous assessment of the accuracy and sensitivity of models is vital in the prioritisation of model structure modifications and the identification of more efficient parameterisations (Merritt *et al.*, 2003).

The results reported in this paper are a component of a wider study whose aim is to develop updated design norms for soil and water conservation structures in the sugar industry in South Africa. The nomograph for the design of soil and water conservation structures in the sugar industry in South Africa was developed by Platford (1987), who used long-term annual soil loss simulated using the Universal Soil Loss Equation (USLE). However, erosion occurs on an event basis and Platford (1987) did not conduct any verification on the USLE prior to development of the nomograph. Therefore, the objective of this paper was to verify the runoff volume, peak discharge and sediment yield simulated by the *ACRU* model against observed data at the La Mercy catchments in South Africa, under both bare fallow and sugarcane land cover conditions and with various management practices.

Simulation of storm flow volume, peak discharge and sediment yield in the *ACRU* model

Storm flow is the runoff that is produced from a particular rainfall event, either at or close to the surface in a catchment, and which contributes to stream discharge within that catchment (Schulze, 2011). Runoff is dependent on interactions between rainfall intensity, antecedent soil moisture conditions and land cover, whereas peak discharge from a catchment depends on catchment slope, runoff volume, rainfall depth, rainfall intensity and area of catchment (Schulze, 2011). The algorithms for the simulation of runoff and peak discharge in the *ACRU* model are shown in Equation 1 and Equation 2 respectively (Schulze, 1995; Schulze and Schmidt, 1995; Schulze *et al.*, 2004).

$$Q_s = \frac{\left(P_g - I_a\right)^2}{\left(P_g - I_a + S\right)} \qquad \text{for} \qquad P_g > I_a \tag{1}$$

where

Q_s = stormflow depth (mm),
P_g = gross daily precipitation amount (mm),
I_a = initial abstraction prior to stormflow commencement (mm), and
S = potential maximum soil water retention (mm).

$$\Delta q_p = \frac{0.2083 A \Delta Q}{\frac{\Delta D}{2} + L} \tag{2}$$

where

Δq_p = peak discharge of incremental unit hydrograph ($m^3.s^{-1}$),
ΔQ = incremental storm flow depth (mm),
A = catchment area (km^2),
L = catchment lag time (h), and
ΔD = incremental time duration (h).

Sediment yield in the *ACRU* model is simulated using the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975), which is an empirical equation derived from the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965; 1978). The event sediment yield, Y_{sd} (t) is determined from stormflow volume for the event, Q_v (m^3), event peak discharge, q_p (m^3/s), soil erodibility factor, *K* (t.h.N/ha), slope length factor, *L*, slope steepness factor, *S*, cover management factor, *C*, supporting practices factor, *P*, and location specific MUSLE coefficients, α_{sy}, β_{sy}, as shown in Equation 3 (Hui-Ming and Yang, 2009).

$$Y_{sd} = \alpha_{sy} (Q_v . q_p)^{\beta_{sy}} K.L.S.C.P \tag{3}$$

Data and Methods

The study area was located at La Mercy, 28 km north of Durban in South Africa, on the site now occupied by the King Shaka International Airport. The research catchments were established by the South African Sugarcane Research Institute (SASRI), formerly South African Sugar Experiment Station (SASEX), and were monitored under bare cover and various sugarcane management practices. There were four small catchments numbered from south to north (Platford and Thomas, 1985), with Catchment 101 the southernmost catchment and Catchment 104 the northernmost catchment (Maher, 1990). A detailed description of the characteristics and management practices at the La Mercy catchments is presented by Platford and Thomas (1985).

The available data comprises of daily observed rainfall and runoff for the period 1978-1995, peak discharge for the period 1984-1995 and daily maximum and minimum temperature and A-pan data for the period 1978-1995. Historical information on the management practices at the La Mercy catchments for the period 1978-1988 was also obtained from studies reported by Haywood (1991).

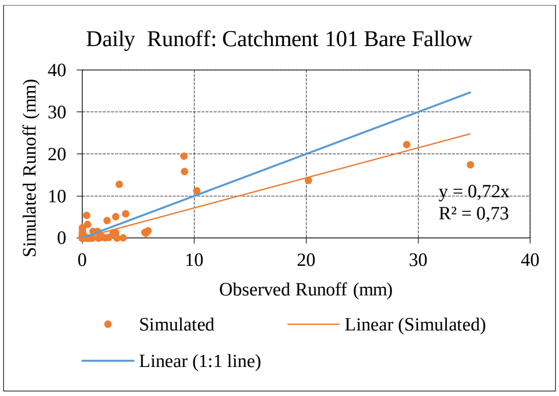
Daily rainfall, together with various *ACRU* parameters representing the catchment characteristics and the management practices at the La Mercy catchments, were used as input into the *ACRU* model to simulate storm flow, peak discharge and sediment yield and the results compared against respective observed events (i.e. plots of simulated events vs observed events). Runoff was verified under both bare fallow conditions for the period 1978-1984 and sugarcane land cover conditions for the period 1985-1995. On the other hand, peak discharge and sediment yield were only verified under sugarcane cover conditions, since there was no observed peak discharge and sediment yield data available under bare fallow conditions. The daily rainfall and the various *ACRU* parameters used in the simulations are documented by Otim (2018).

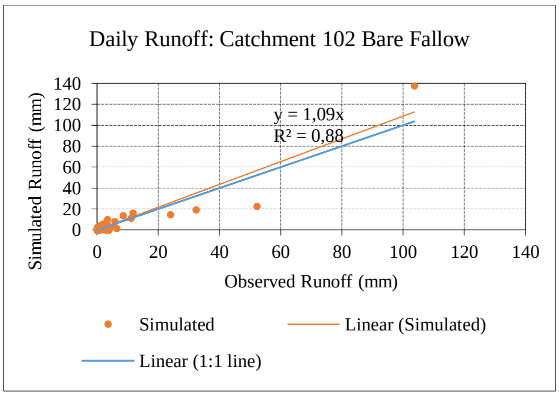
Results and Discussion

The simulated vs observed runoff plots under bare fallow conditions are shown in Figure 1. From the results, the association between the simulated and observed runoff is generally good, as shown by the slopes and the R^2 coefficients of the regression lines (i.e. slopes of regression lines close to unity and $R^2 \geq 0.6$).

Similarly, under sugarcane land cover conditions, the simulations were reasonably good and the slopes of the regression lines for simulated vs observed runoff are 1.23, 0.90, 0.93 and 0.72 for Catchments 101, 102, 103 and 104, respectively while the respective R^2 coefficients are 0.97, 0.93, 0.94 and 0.90.

In relation to peak discharge, the slopes of the regression lines are 1.01, 0.64, 0.70 and 0.53 for Catchments 101, 102, 103 and 104 respectively while the respective R^2 coefficients are 0.82, 0.78, 0.80 and 0.61. In addition, the association between simulated and observed sediment yield events was also good and the slopes of the regression lines were 0.75, 1.05, 0.86 and 1.33 for Catchments 101, 102, 103 and 104 respectively, while the respective R^2 coefficients were 0.82, 0.87, 0.90 and 0.98.





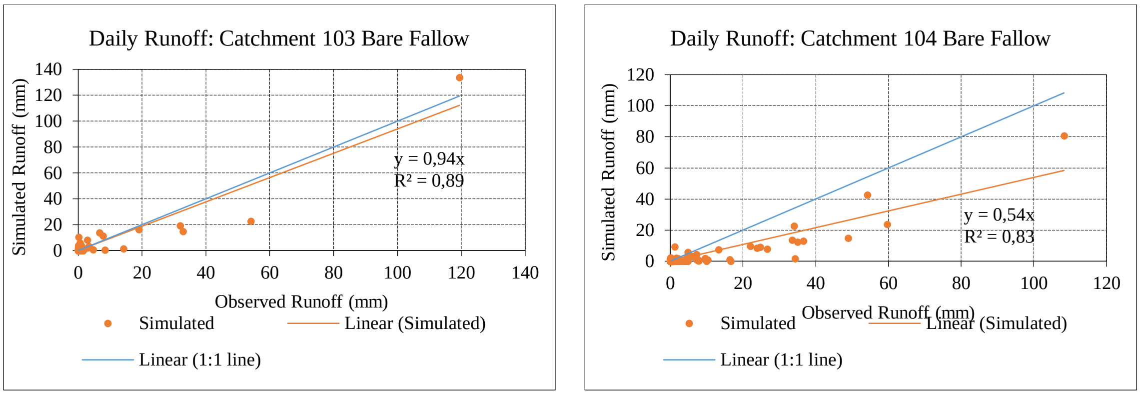


Figure 1. Simulated vs observed daily runoff volumes simulated from the La Mercy catchments under bare fallow cover.

Conclusions

Based on the results from this study, it is concluded that the *ACRU* model is suitable in the simulation of runoff volume, peak discharge and sediment yield from catchments under both bare fallow and sugarcane land cover and with various management practices in South Africa. Therefore, the *ACRU* model can be applied with confidence in the development of updated design norms for soil and water conservation structures in the sugar industry in South Africa.

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