Predicting Vegetative Cover, Runoff and Soil Moisture for Assessing Land Degradation in Australia's Northern Territory

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Summary   The runoff parameter in a pasture growth model called GRASP was optimised using data from different pasture cover conditions in the Northern Territory of Australia. A relationship between cover and runoff, thus obtained, was utilised in repeat simulations for the same situations. Although total cover and total profile soil moisture were predicted well by the model for all situations, the runoff predictions for all cases but for the low cover situation was poor compared to those from the static cover option. This deficiency is suspected to be attributable to the inadequacy in the provision for drainage in the model and/or the ability of the model to handle the growth of improved pasture. The enhancements and rectifications incorporated in the APSIM model currently being developed are aimed at addressing these issues.

1.   INTRODUCTION

Over a third of the Northern Territory (NT) of Australia lies within the Semi Arid Tropics, with cattle production being the dominant agricultural industry in the region. The region, however, experiences extremely erosive rainstorms having the potential to cause significant damage to poorly managed lands.

A good understanding and knowledge of the dynamics of and interactions between soil, plant, water and climate, accommodated in a computer simulation model, will facilitate sustainable development and management of the land resources of the region. Collaborative work between the Conservation Commission of the Northern Territory (CCNT), Northern Territory Department of Primary Industry and Fisheries (NTDPI&F), Queensland Department of Primary Industries (QDPI), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Agricultural Production Systems Research Unit (APSRU) (Dilshad et al. 1994a) is producing such a model, called APSIM (McCown et al. 1993).

One of the modules in the APSIM model will be a pasture productivity sub-model called GRASP developed by QDPI (McKeon et al. 1993).

The aim of this study was to optimise the runoff parameter in GRASP for sub-catchments with different, reasonably static vegetative cover, in order to obtain a relationship that accounted for the effect of cover on runoff. The relationship thus obtained was then used in repeat simulations, using the dynamic cover runoff option and any improvements in the predictive ability of the model was examined while deficiencies, if any, were identified.

2.   MODEL BACKGROUND

GRASP (McKeon et al. 1993) is a model for simulating native pasture production. It was designed to simulate aspects of grass production and to predict soil moisture, pasture growth and animal intake, on a daily time step.

Yee Yet (1994) showed that for four rangeland conditions in Central Queensland the model predicted soil moisture well but not runoff for high grass cover. The model was, therefore, modified to include the Williams-Ritchie water balance method (Littleboy et al. 1995), with a cover-runoff parameter relationship, to obtain better runoff predictions (Yee Yet 1994). This modified version of the model has been used for the present study.

3.   THE SITE

The study area was situated at the Douglas Daly Research Farm (DDRF), 250km southwest of Darwin at a latitude of 13°51' and longitude 131°12'. Five experimental sub-catchments (SC), each 20m long and 5m wide, were located within four catchments ranging in size from 4.1ha to 7.8ha, and on slopes of less than 2% (Dilshad et al. 1994b). SC 1,2,3 and 4 were located on catchments with improved pasture *(Eurochloa mosambicensis)* and SC5 was in a native woodland *(Heteropogon contortus* dominated) catchment.

In the 1994/95 wet season, SC1 was maintained bare and scalded (about 3% mean projected cover). SC2 and SC3 were mown regularly to obtain mean projected cover of about 50 to 60% and, SC4 and SC5 were left ungrazed after being burnt in September 94.

More than 90% of the historic annual rainfall in the region is recorded over the five month period from November to March (Williams et al 1985). These are the only months when mean monthly rainfall exceeds mean monthly evaporation (Lucas 1984). Historic mean annual rainfall for the study area is 1200mm.

Table 1: Optimised curve numbers for the sub-catchments with static cover option

SC	CN	Sample no.	Mean Cover	Profile Depth (mm)	Observed - Average	Observed - Std Dev	Predicted - Average	Predicted - Std Dev	Predicted Observed	r²	RMSE
					Runoff (mm)						
1	87	67	3	-	4.35	8.80	4.89	8.74	1.12	0.90	3.83
2	73	81	52	-	4.15	9.00	4.35	7.57	1.05	0.68	5.04
3	70	81	58	-	3.70	7.15	3.82	7.06	1.03	0.57	4.95
4	42	27	63	-	0.54	0.76	0.54	1.41	0.99	0.73	0.73
5	45	81	40	-	0.71	2.51	0.89	2.30	1.23	0.05	2.98
					Soil Moisture (mm)						
1	87	8	3	1500	434.00	27.00	467.00	36.00	1.08	0.60	43.24
2	73	8	52	1500	437.00	53.00	459.00	42.00	1.05	0.80	32.99
3	70	8	58	1500	411.00	47.00	431.00	37.00	1.05	0.94	24.16
4	42	3	63	1500	406.00	47.00	418.00	55.00	1.03	1.00	13.86
5	45	8	40	1700	514.00	53.00	522.00	50.00	1.02	0.85	23.57

The soils in the Douglas Daly district are generally Kandosols (Isbell 1993). Kandosols are well drained and have low water holding capacities (Dilshad et al 1995). Top soil textures are mainly sandy loam, loamy sand and light sandy clay loam (Howe 1995). The soil structure is weak at best. The soils are highly erodible in their natural state and even more so when stripped of their protective vegetative cover (Howe 1995).

4.   MODEL CALIBRATION

A key parameter in the Williams-Ritchie water balance method is the curve number (CN) described by Littleboy et al. (1995). The model pasture growth parameters were first calibrated for standing dry matter (SDM) and cover using data measured from SWIFTSYND (Day and Philp 1993) trials at DDRF in the 1992/93 season (Peel et al. 1995). It was then further calibrated using the model without any effect of cover on runoff. The criteria for optimising CN was to minimise root mean square error (RMSE) and average error, while simultaneously examining correlation between each predicted and observed value and the ratio of total predicted to total observed values. The same criteria were used for examining soil moisture in conjunction with runoff. This exercise was done for all five SCs using data from the 1994/95 season. The SDM and cover were checked to be comparable to those measured. Optimised CN for each SC corresponded to the mean projected cover for the period of simulation.

5.   RESULTS AND DISCUSSION

The optimised curve numbers together with the values of the statistical criteria used to check the agreement between measured and observed values are given in Table 1. Some of the observations for SC1 were discarded because of a sink-hole that appeared in January 1995. Optimisation for SC4 was done only for the period November to December 94 as the

predicted SDM and cover did not agree well with the measured values beyond that period. Based on the optimised values presented in Table 1, a cover-CN relationship was derived as shown in Figure 1. There is a scatter of the optimised values of CN. However, these optimised values for CN based on daily runoff comparisons are valuable.

Employing the model with dynamic cover effect, and using the cover-CN relationship obtained above, simulations were repeated for each SC. The predicted total cover, soil moisture and runoff for the five SCs are presented together with their observed counterparts in Figure 2. The corresponding values for the criteria used for the optimisation are given in Table 2.
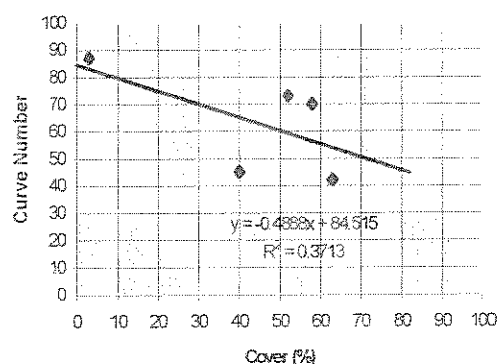

Figure 1: Cover - CN relationship obtained with the static cover option for the five SCs
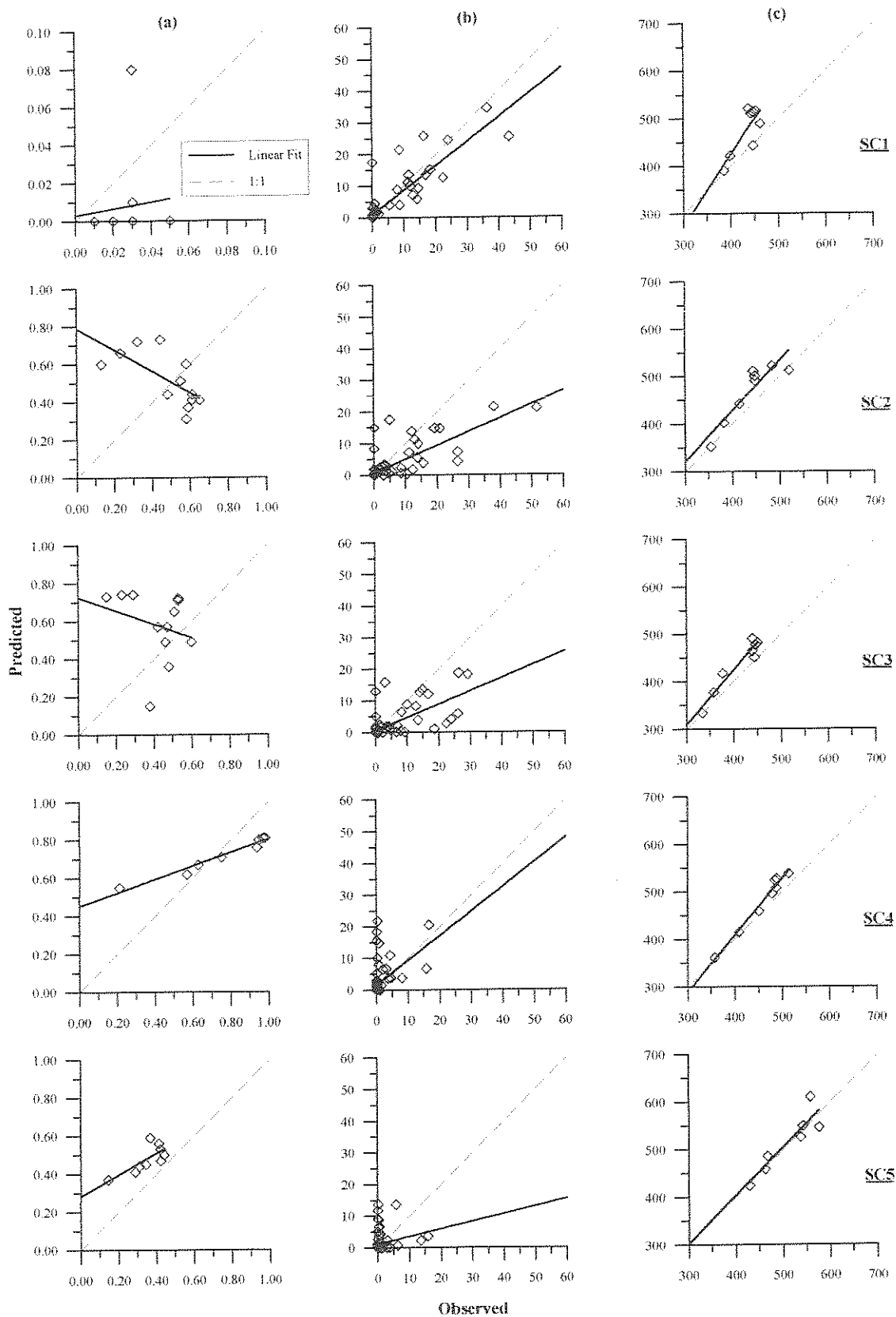
Figure 2: Observed and Predicted (a) total cover (fraction), (b) daily runoff (mm) and (c) total profile soil moisture (mm) for the five sub-catchments, with the dynamic cover effect

Table 2: Results obtained using the dynamic cover option

SC	CN	Sample no.	Mean Cover	Profile Depth (mm)	Observed - Average	Observed - Std Dev	Predicted - Average	Predicted - Std Dev	Predicted Observed	r^2	RMSE
					Runoff (mm)						
1	85 at	67	3	-	4.35	8.80	4.30	7.70	0.99	0.77	3.84
2	zero	81	52	-	4.15	9.00	2.52	5.10	0.61	0.58	6.25
3	cover	81	58	-	3.70	7.15	2.08	4.43	0.56	0.46	5.50
4		81	63	-	0.78	0.76	2.20	4.80	2.81	0.20	4.54
5	reduces	81	40	-	0.71	2.51	1.24	3.03	1.77	0.04	3.55
	to 45										
	at 80%				*Soil Moisture (mm)*						
1	cover	8	3	1500	434.00	27.00	476.00	51.00	1.10	0.65	52.36
2		8	52	1500	437.00	53.00	467.00	62.00	1.07	0.83	38.85
3	and	8	58	1500	411.00	47.00	437.00	56.00	1.06	0.92	30.79
4	stays	8	63	1500	459.00	52.00	479.00	62.00	1.04	0.98	23.91
5	const	8	40	1700	514.00	53.00	519.00	60.00	1.04	0.83	23.49

The scatter in the cover-CN relationship may be due to a number of reasons including inadequacy in the model for drainage of water from the soil profile, the need for improvement in the model to handle improved pasture growth or the variation in the history of the Scs.

There was hardly any cover in SC1 which was well predicted by the model. The predictions for SC4 and SC5 are a little higher than the corresponding values. For SC2 and SC3, where the cover was manipulated, the scatter seen is a result of comparatively dramatic changes in observed cover immediately being mown.

The runoff prediction for SC1 was good. But the model under-predicted runoff for all other cases. However, total profile soil moisture for all the cases was well predicted by the model.

6. CONCLUSIONS

The GRASP model used for this study performed well in the prediction of total profile soil moisture, satisfactorily in the prediction of total cover and poorly in predicting daily runoff. Therefore, some improvements are required in the model to simulate the conditions studied.

The work currently underway at collaborating agencies described previously will facilitate the use of advanced, physically sound water balance methods and improvements in the handling of the pasture growth module. Such a model will address deficiencies in the sub-models while retaining strong features, so as to get better predictions from simulations of systems as complex as the one being addressed.

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