Modelling Pasture Growth in the Mitchell Grasslands

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Abstract: The Mitchell grasslands are some of the most productive grazing lands in Australia. However, the decision making environment for graziers is often challenging and risky within the naturally high rainfall and pasture growth variability experienced. Many graziers adjust their stock numbers based on the amount of standing feed and expected rainfall. Pasture models are useful if they explain the majority of variability in measured pasture growth, because long time series of measured growth are usually unavailable. The WinGrasp pasture model has been used to successfully simulate pasture growth in other plant communities (e.g. spear grass), however it is yet to be validated using independent data on Mitchell grasslands. If the model is useful in simulating Mitchell grasslands, forecasts of pasture growth can be used to help make better management decisions. Pasture growth forecasts based on El Niño Southern Oscillation (ENSO) have the potential to be more useful than rainfall forecasts for graziers in western Queensland. The accuracy of WinGrasp to simulate and forecast the growth of Mitchell grass needs testing. In this paper we compare the output from WinGrasp to measured total standing dry matter (TSDM) data from long-term grazing trials at Toorak Research Station, Julia Creek in the northern Mitchell grasslands and Rosebank Research Station, Longreach in the central Mitchell grasslands of Queensland. Using observed data from independent sites, the model explained 64 to 81% of the variability of observed TSDM at the industry utilisation levels of 10-50% in the northern Mitchell grasslands and 74 to 84% in the central Mitchell grasslands. In the central Mitchell grasslands predicted TSDM was consistently lower than observed. This was most likely because of changes in botanical composition. We also compared the accuracy of using either measured or interpolated rainfall data in the model to predict TSDM. There was no significant difference between measured and interpolated rainfall data to predict TSDM. Therefore at these locations interpolated rainfall can be used with confidence when modelling pasture growth, however in more remote areas where there are fewer official recording stations interpolated rainfall should be used with more caution. The model was useful for predicting TSDM in the Mitchell grasslands, however further calibration is required to better simulate changes in pasture composition.

Keywords: *Pasture growth; Forecasting; Mitchell grass; WinGrasp*

1. INTRODUCTION

The grazing industry in northern Australia is important from an economic and resource point of view. The Mitchell grasslands are highly productive and are an important part of the northern Australian landscape occupying about 19% of Queensland (Phelps and Bosch, 2002). Major challenges for pastoral managers are the high degree of variability in rainfall and pasture growth and having the knowledge and skills to manage this variability. Pasture growth forecasts based on El Niño Southern Oscillation (ENSO) have the potential to be more useful than rainfall forecasts for graziers in western Queensland. Therefore if pasture growth in the Mitchell grasslands can be accurately modelled, forecasts of pasture growth can be used to make better management decisions (Park *et al*. 2001)

WinGrasp has been used to model various plant communities in northern Australia such as spear grass (McKeon *et al*. 1990). It uses historical climate data as input, and a suite of mathematical equations to simulate changes in pasture growth and yield through time (Clewett *et al*. 1998). Transpiration is the main driving variable in WinGrasp. Hence the water balance components including rainfall, runoff, infiltration, drainage, soil water storage and evaporation are central to the model (Clewett *et al*. 1998). A general set of pasture growth parameters suitable for native pastures in Queensland has been calibrated and validated (Hall *et al*. 1998).

Mitchell grass (*Astrebla* spp.) is tolerant of fire, heavy grazing and drought. Other species such as *Digitaria* spp. and *Dichanthium sericeum* come and go depending on climatic conditions and grazing management. Ideal long-term pasture utilization levels are between 10 and 30%, with levels up to 50% common for short periods. Under utilisation causes pastures to become moribund and over utilisation produces extreme pasture detachment.

In this paper we investigate how well WinGrasp explains the variation in total standing dry matter in the north-west and central-west Mitchell grasslands. These regions are remote, have high temporal and spatial rainfall variability and there are long distances between official climate recording stations. Because of this, we also compare the use of measured and interpolated rainfall data in modelling pasture yields.

2. MATERIALS AND METHODS

Observations of total standing dry matter (TSDM, kg/ha) were completed using a dry weight rank technique (BOTANAL, Tothill *et al*. 1992), at Toorak Research Station, Julia Creek and Rosebank Research Station, Longreach (Table 1). Two trials were completed at Toorak (utilization and pasture capability (PC)) and one at Rosebank (pasture capability (PC)). Each trial contained treatments that were either ungrazed or grazed by Merino sheep. At Toorak utilization and Toorak PC trials the grazed treatments were stocked at the end of each growing season according to pasture utilisation level (Table 1). The Rosebank PC trial was completed in three stages. In Stage 1 (Jan 91-May 93) the average stocking rates in the three grazed paddocks were similar (2.3 hd/ha or between 20 to 50% utilisation); in stage 2, paddocks were destocked (May 93-May 95), and in stage 3 (May 95-Nov 97) the stocking rates were 0.66, 0.32 and 0.16 hd/ha in paddocks G, M and P respectively (Table 1).

Data from the Toorak and Rosebank PC trials were independent of that used to calibrate the model, and data from the Toorak utilization trial was quasi-independent. TSDM was modelled using WinGrasp (McKeon *et al.* 1990, Cobon and Clewett, 1999) and compared with observed TSDM. The pasture model was calibrated using observed exclosure data from an independent trial conducted at Toorak between 1986 and 1988, and observed data from the Toorak utilisation trial between 1984 and 1999 (Ken Day, unpublished data). Some important parameter values from the calibrated parameter file used to run the pasture model in WinGRASP are shown in Table 2.

Daily climate data for Toorak and Rosebank was sourced from the SILO data drill (Jeffrey *et al*. 2001). These files contained interpolated rainfall. New climate files were created by replacing interpolated rainfall with that measured at the Toorak and Rosebank homesteads. Distances from the respective homesteads were three kms to the Toorak utilisation trial, eight kms to the Toorak PC trial and one km to the Rosebank PC trial. The interpolated and measured climate files were used in WinGrasp to calculate TSDM, and calculated values were compared with observed data from the three trials.

Table 1. Treatments used for comparing observed TSDM and modelled TSDM

Location	Treatments	Timing
Toorak utilisation trial Homestead location: 141° 46' 7" E 21° 4' 5" S	0% utilization (no domestic animals or large herbivores) 10% utilisation 20% utilisation 30% utilisation 50% utilisation 80% utilisation	May 1982 – October 2002
Toorak PC Trial Homestead location: 141° 46' 7" E 21° 4' 5" S	1. Ungrazed (no domestic animals) 2. Grazed at 22% utilization (6 reps) 3. Data from grazed paddocks combined (CGrz)	May 1991 – April 1998
Rosebank PC Trial Homestead location: 144° 15' 28" E 23° 31' 35" S	1. Ungrazed Z (no domestic animals) 2. Grazed G 3. Grazed M 4. Grazed P 5. Data from grazed paddocks combined (CGrz)	January 1991 – November 1997

2.1 Detachment rates

The default percentage detachment of standing dead material is shown in Table 2. These levels were adjusted for some years in the Toorak utilisation trial to better represent changes in pasture composition that occurred on-site. From 1995 to 1997 there was a high proportion of bull Mitchell grass (*Astrebla squarossa*) in all treatments except the 80% utilisation. As bull Mitchell is more resilient than curly (*A.*

lappaceae), hoop (*A. elymoides*) or barley (*A. pectinata*) Mitchell, there is less detachment of dead material. The default detachment levels were therefore too high and yield was being underestimated. Because of this, the detachment rates in the model were reset to a quarter of the default values in Table 2, between 1995 and 1997.

Table 2. Default parameters used in the WinGrasp model (winwool3.mrx).

Default parameters	Value
Maximum N uptake (kg/ha/yr)	30
N at minimum growth (%)	0.9
Standing dead material detaching (%)	1st Dec – 30th Apr = 45 1st May – 30th Nov = 57
Transpiration efficiency (kg/ha/mm water@20hpa)	25
Initial basal area (%)	5
Green biomass yield at 50% of green cover (kg/ha)	1750
Plant available water capacity (mm)	Layer 1 (0-10cm) = 25 Layer 2 (10-50cm) = 100 Layer 3 (50-100cm) = 85
Soil water index required to support full green cover	1
Soil water index at which above-ground growth stops	0.4

Conversely, high detachment rates were parameterised in the Toorak utilization trial under high sheep densities due to the trampling of pastures. The yields for all treatments were visually assessed and outliers identified. It was observed that some of the estimated yields were much higher than the predicted values. Closer scrutiny revealed that in each of these years the sheep density for each treatment was greater than 4.3 sheep/ha. This resulted in an overestimation of yield during these years. The detachment rate for wet and dry seasons was increased to 85% and 90% respectively for years within treatments where this stocking threshold was exceeded. The adjustment was made for the 50% utilisation in 1998 and the 80% utilisation in 1998 and 2002.

Default detachment parameters were used for the Toorak and Rosebank PC trials as the observed data showed no increase in the level of bull Mitchell, and sheep numbers did not exceed the 4.3 sheep/ha threshold.

2.2 Predicted TSDM vs observed TSDM

WinGrasp was used to model predicted annual TSDM on the 31st May each year for both measured and interpolated climate files at all three trials. Regressions between the observed and predicted TSDM were calculated for all treatments.

Predicted (monthly) TSDM (using measured and interpolated rainfall) was plotted with observed TSDM. These time series' gave an indication of the extent to which the observed yields matched those that the model predicted, and whether there were any differences between using measured and interpolated rainfall data.

2.3 Significance tests

Regressions between the observed data and the modelled output from WinGrasp were calculated using GenStat (Anonymous 2000). Simple linear regression analysis was used to test the significance of individual regression equations, the slope and the intercept (constant). Simple linear regression analysis (with groups) was also used to test for differences in TSDM from using measured and interpolated equations.

3. RESULTS

The predicted TSDM matched well the observed for the Toorak utilization and Toorak PC trials (Figure 1a,b). However the predicted values in the Rosebank PC trial are consistently less than the observed values (Figure 1c). The predicted values match the observed for the Toorak utilisation and Toorak PC trials. However the predicted values in the Rosebank pasture capability trial are consistently less than the observed values.

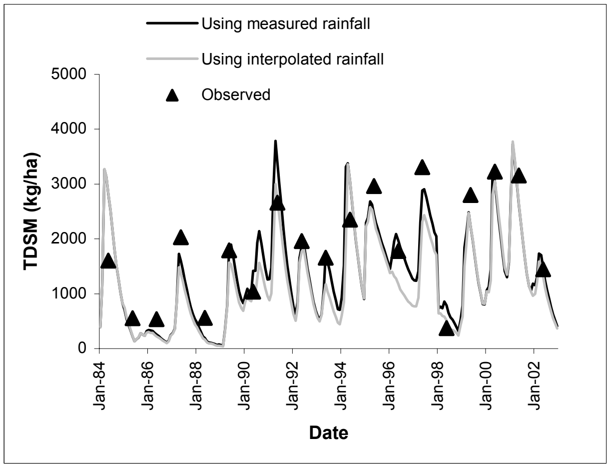

Figure 1a. Time series comparing modelled TSDM, using either interpolated or measured rainfall, with observed values for the Toorak utilisation trial (30% utilisation).

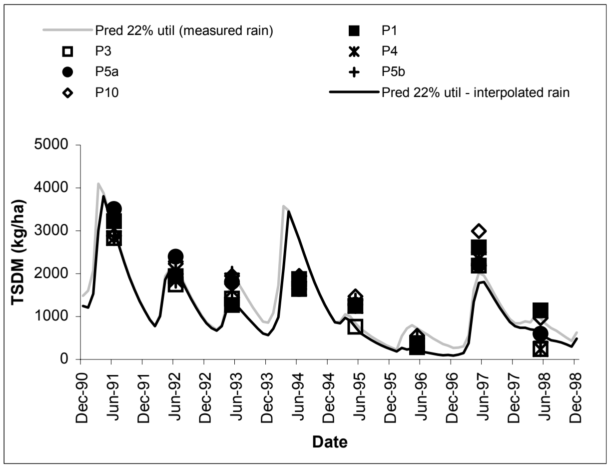

Figure 1b. Time series comparing modelled TSDM, using either interpolated or measured rainfall, with observed values for the Toorak pasture capability trial (grazed treatments).

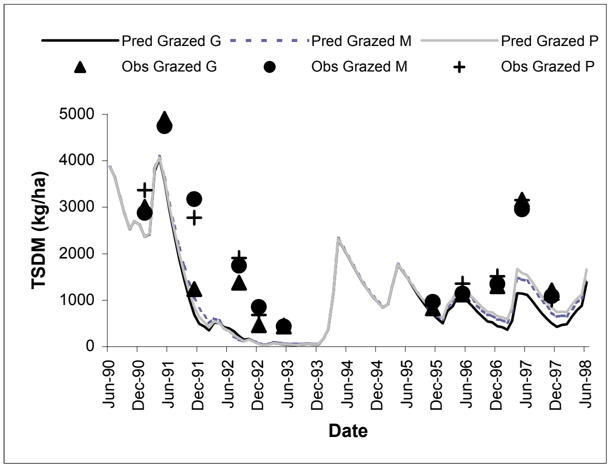

Figure 1c. Time series comparing modelled TSDM, using interpolated rainfall, with observed values for the Rosebank pasture capability trial (grazed treatments).

The regression equations (y = observed kg/ha, x = predicted kg/ha), r^2 values and significance levels (P=0.05) are shown in Table 3. The model explained more than 60% of the observed TSDM for all treatments except the 0% and 80% utilisation in the Toorak utilisation trial. Whilst there were no significant differences between equations based on measured or interpolated rainfall, the constant was significantly different from zero on nine occasions for interpolated rainfall but only seven occasions for measured rainfall.

Table 3. Regression of observations of TSDM (kg/ha) from WinGrasp model predictions and pasture trials using measured and interpolated rainfall. For each treatment, the model for the first equation uses measured rainfall, whereas the second was interpolated rainfall.

Treatment	Constant	Slope	n	r^2
TOORAK UTILISATION TRIAL				
0%	1365 ^{ns} 1416 ^{ns}	0.415 ^{ns} 0.501 ^{ns}	19 19	0.48 0.22
10%	439 ^{ns} 484 ^{ns}	0.799 *** 0.910 ***	19 19	0.65 0.67
20%	258 ^{ns} 542 ^{ns}	0.815 *** 0.904 ***	19 19	0.70 0.72
30%	210 ^{ns} 450 ^{ns}	0.792 *** 0.938 ***	19 19	0.71 0.78
50%	185 ^{ns} 602 *	0.731 *** 0.827 ***	19 19	0.60 0.61
80%	266 * 583 *	0.805 ** 0.547 **	19 19	0.41 0.42
TOORAK PASTURE CAPABILITY TRIAL				
UnGr P2	-85 ^{ns} 392 ^{ns}	0.779 * 0.674 *	7 7	0.71 0.73
Grz P1	327 ^{ns} 609 ^{ns}	0.788 * 0.715 **	8 8	0.68 0.73
Grz P3	-141 ^{ns} 220 ^{ns}	0.870 ** 0.757 **	8 8	0.81 0.80
Grz P4	119 ^{ns} 436 ^{ns}	0.794 * 0.690 **	8 8	0.70 0.71
Grz P5a	92 ^{ns} 465 ^{ns}	0.921 ** 0.812 **	8 8	0.72 0.72
Grz P5b	270 ^{ns} 607 ^{ns}	0.811 ** 0.705 **	8 8	0.76 0.75
Grz P10	596 ^{ns} 886 *	0.730 * 0.641 *	8 8	0.64 0.65
CGrz	211 ^{ns} 537 ***	0.819 *** 0.721 ***	48 48	0.69 0.70
ROSEBANK PASTURE CAPABILITY TRIAL				
UnGrz	1496 ** 1155 *	0.921 ** 0.981 **	10 10	0.67 0.59
Grz G	907 ** 576 *	1.095 *** 1.175 ***	10 10	0.81 0.84
Grz M	1067 ** 785 *	1.031 *** 1.050 ***	10 10	0.79 0.74
Grz P	997 ** 665 ^{ns}	1.236 *** 1.248 ***	11 11	0.84 0.80
CGrz	990 *** 672 ***	1.123 *** 1.161 ***	31 31	0.81 0.79

ns = not significant
* = significance level <0.05 but >0.01
** = significance level <0.01 but >0.001
*** = significance level <0.001

4. DISCUSSION

4.1 Predicted vs observed data

The general parameter set for the northern Mitchell grasslands that was calibrated using data collected at Toorak explained between 64 and 81% of the variation in total standing dry matter (TSDM) observed in independent studies from the Toorak PC trial. Using quasi-independent data from the Toorak utilisation trial, the general parameter set explained 65 to 78% of the variation in observed TSDM of paddocks stocked at industry utilisation levels (10 to 50%). However, there were occasions where the default detachment rates needed adjusting to better represent observed values. For example, in the 50% utilisation treatment (using measured rainfall), when the default parameters were not adjusted the r^2 value was 0.3938. By decreasing detachment in 1995, 1996 and 1997 to better account for a shift in pasture composition to bull Mitchell, and increasing detachment in 1998 to better account for extreme trampling, the r^2 value was 0.6036. For the general parameter set in the model to be accurate, its use should be restricted to utilisation levels within industry levels (10 – 50%). Extremely high (80%) utilisation was poorly predicted ($r^2 = 0.41$) because TSDM was being over estimated. In addition, 0% utilisation from both domestic animals and large herbivores was poorly predicted ($P = 0.1$) due to pastures becoming moribund.

The Rosebank PC trial provided independent data from the central Mitchell grass system. The general parameter set, calibrated using data collected in the northern Mitchell grasslands explained 74 to 84% of the variability in observed TSDM. However, it consistently underestimated observed TSDM (interpolated rainfall 920kg/ha, measured rainfall 1160 kg/ha). It's likely that the central Mitchell grasslands are more fertile, which is supported by higher long-term carrying capacities of the central-west (0.7-0.8 dry sheep equivalent per hectare) compared to the north-west (0.6-0.7 DSE/ha). Furthermore, climate variability and livestock management can change pasture composition, which may not be reflected by processes represented in the model. Rosebank had good years in 1989 (827mm) and 1990 (665mm) and in May 1991 the average combined yield of *Dichanthium sericeum* and *Digitaria* spp. was 920 kg/ha (18% of TSDM), after being absent in the pasture sward in January 1991. The combined yield of these species remained between 20 and 30% of TSDM until May 1993, despite falling to 190 kg/ha during the drier than normal conditions after May 1991. By the end of the drought they had gone from the sward. These species were not present in these amounts at Toorak when the model was parameterized. It is likely that these pasture species partition more moisture and nutrients into shoots rather than roots, compared to Mitchell grass (Greg McKeon, personal communication). This may explain the model's underestimation of TSDM at Rosebank. The disappearance of *Digitaria* spp. and *Dichanthium sericeum* during the 1991 to 1995 drought supports the suggestion they partition relatively less moisture and nutrient into roots compared to Mitchell grass.

The difference between observed and predicted detachment during the dry season (May–Nov) and observed and predicted pasture growth during the wet season (Nov-May) demonstrated that is was unlikely that either growth (average predicted growth was 80% of observed growth) or detachment (average predicted detachment was 86% of observed detachment) rates in the model could fully explain the errors in predicted TSDM. Further work is required on the fertility of the central Mitchell grass system, the partitioning of water and nutrients of different species into roots and shoots and its effect on changing pasture composition.

4.2 Interpolated vs measured data

The strong correlation between measured and interpolated equations suggests interpolated data from SILO can be successfully used to predict TSDM in the north and central Mitchell grasslands. This is of great value where actual rainfall data cannot be accessed, or is unavailable for the time period of interest. Some caution should be exercised in interpreting predicted TSDM from interpolated data, however, as the risk of overestimating TSDM at low levels (in dry years) is greater than with measured data. The interpolated data set resulted in nearly 30% more instances of the constant (C) in the regression being significantly higher than zero. In these instances, there is a risk of yields being consistently overestimated, particularly during drier years.

There may also be a risk in using interpolated rainfall data in the far western Mitchell grasslands (eg. Windorah or Boulia districts), where there are fewer official climate stations.

5. CONCLUSIONS

WinGrasp was a useful tool to model TSDM using the general parameter set in the northern Mitchell grasslands. Moribund pastures and major changes in pasture composition pose problems for model calibration. In some years changes in pasture composition to high quantities of the more structurally robust bull Mitchell required lower detachment rates. In contrast, higher detachment rates were required to simulate the effects of trampling at high sheep densities. Simulations of TSDM outside industry utilisation levels (10–50%) should be considered with caution. Extreme stocking rates and pasture detachment rates need to be better parameterized.

In the central Mitchell grasslands, the general parameter set developed for northern areas underestimated TSDM. Its unlikely that this difference can be explained solely by errors in pasture growth and detachment, and more likely to be due either to higher soil fertility in central Mitchell grass areas compared to northern, or to differences in water and nutrient partitioning due to changes in pasture composition. This requires further investigation.

Errors from using interpolated rainfall data are likely to be less than those that arise due to insufficient parameterisation of detachment rates.

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