Adapting APSIM Lucerne to the Western Australian environment

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Abstract

The APSIM Lucerne model has been tested in limited environments and it requires more rigorous testing before it can be used to interpret production in Western Australia. The model prediction of biomass growth rate was tested against observed data from seven sites located in Western Australia. Data sets were chosen for periods where there was no water stress. The results showed that the model generally over predicted the above ground biomass. Once an allowance was made for increased above ground biomass soon after cutting and reduced above ground biomass later in the plants development the model could satisfactorily predict the observed biomass growth. This behaviour is consistent with the idea that stored below ground carbohydrates are used after cutting to support initial biomass growth, followed by replenishment of these reserves later in the growth cycle at the expense of shoot growth. This is not currently simulated by APSIM and the incorporation of a dynamic crown carbohydrate pool to improve model performance is suggested.

Key Words

Lucerne, growth, modelling, biomass allocation, environment.

Introduction

Lucerne is regarded as a promising perennial pasture species combining profitable production and higher water use relative to annual species. The higher water use is necessary to reduce deep drainage below the root zone, the driving force behind groundwater rise and salinity. Currently 1.8 million ha of cleared farmland in Western Australia is affected by salinity and this area is predicted to double over the next 15-25 years unless new farming systems are introduced (1). Although initial experience with lucerne is promising, the potential impact needs to be fully analysed over a range of environments and soil types in Western Australia. Incorporation of experimental data into a simulation model offers the opportunity to interpret a change in farming system on production and water use.

The APSIM Lucerne model has been developed and tested in some environments (7) but it requires more rigorous testing before it can be used with confidence to interpret production and water use in Western Australia. APSIM simulates crop growth, soil water and N dynamics on a daily time step in response to weather (minimum and maximum temperature, radiation and rainfall), soil type and management information (sowing date, tillage, cutting dates) (6). This paper outlines initial testing and a suggested model improvement.

Materials and Methods

The model simulation of above ground biomass growth rate was tested against the observed data from seven sites ((4), (5), R. Latta and A. Lyons, pers. comm.) located in southern Western Australia. The sites had been established in 1995-1998 and only data from the second and third year of the trials were used in the comparison. The biomass growth rate was determined by sampling pasture dry matter after an average of 50 days of growth (Table 1) following cutting with a mower at a height of 2 cm above the ground. To eliminate the complication of water stress in the initial model testing, the comparison was limited to periods in late autumn- early spring. However, in spring for some data points APSIM indicated that the growth might have been affected by water stress. The lucerne pasture included a component of annual species (Table 1), however only periods that contained at least 60% lucerne as a percentage of the total pasture production was used in the analysis.

Biomass growth rate (BGR, g m^{-2} d^{-1}) in APSIM Lucerne is determined by the following function:

$$BGR = RUE * (1- e^{(-k * LAI)})* R$$

where RUE = radiation use efficiency (1.2 g MJ^{-1}) , k = extinction coefficient (0.8), LAI = leaf area index, and R = incident solar radiation (MJ m^{-2} d^{-1}). BGR is decreased if the average temperature is below 8 or above 25 ^{o}C. The biomass is partitioned between leaves and stem so the RUE is based only on above ground biomass. Partitioning to below ground biomass results in greater complexity and therefore was not included.

Observed and simulated data were compared using a mean error or bias (bias = mean (O-S)*100/mean O, where O is observed and S is simulated BGR). A negative value indicates an over estimation and a positive value indicates an under estimation. Secondly, precision was estimated by comparing the deviations of the simulated from the observed relative to the variation of the observed (precision = $(\Sigma O^2 - (((\Sigma O)^2)/n) - \Sigma (O-S)^2)/(\Sigma O^2 - (((\Sigma O)^2)/n))$, where n is the number of data pairs. The closer the value is to 1 the greater the precision.

Table 1. Summary of data from seven sites based on the time of year (A = autumn, W-winter, S = spring) including number of data pairs (n), mean day of cutting (start day, range in parenthesis), days of growth after cutting, incident solar radiation, maximum and minimum temperature, lucerne and total (lucerne and annual species) biomass growth rate.

Period	n	Start day	Days of growth	Incident Radiation (MJ m^{-2} d^{-1})	Temperature (^{o}C)	Lucerne BGR (kg ha^{-1} d^{-1})	Total BGR (kg ha^{-1} d^{-1})
A-W	9	120 (98-141)	51(41-66)	10.3	19.0/9.1	10	14
W	8	173 (155-204)	55(29-70)	10.9	16.0/6.1	10	13
W-S, S	7	224 (182-266)	45(30-69)	15.3	17.7/6.5	24	29

Results and Discussion

APSIM Lucerne generally over-estimated the growth rate of lucerne over the late autumn-early spring period compared to the observed measurements and the precision was low (Fig. 1a). A greater over-prediction and less precision occurred in the late autumn to late winter period compared to late winter-early spring (Fig. 1a). The major difference between the winter-early spring period and the autumn-winter and winter periods is radiation rather than temperature, suggesting that the problem in the simulation prediction lay in incorrect utilisation of radiation (Table 1). The biomass growth rate in APSIM Lucerne is simulated using constant RUE for the whole growth cycle. Low LAI after cutting means that for the first 10-14 days after cutting BGR is low (< 0.1 g/m^2), then it increases exponentially to reach a maximum of >15 g/m^2 depending on radiation and when it is harvested. There was evidence that the length of time between harvests was influencing the bias (Fig. 2a) indicating that the use of constant above ground biomass RUE was a simplification. Other workers have shown that measured above ground biomass RUE varies seasonally (3). However, this variation was due to the extent of partitioning of assimilates between above and below ground (3). It is also known that lucerne utilises stored carbohydrate from below ground biomass for initial growth after cutting and subsequently stores carbohydrate once flowering is reached (2). To determine if the observed BGR was being influenced by a dynamic storage of carbohydrates the following analysis was performed. For each growth period the observed RUE was computed by dividing the observed BGR by the simulated radiation interception. This observed RUE varied exponentially as a function of the number of days of each growth period (Fig. 2b). The relationship shows that the computed RUE was higher than the current model value of 1.2 g MJ^{-1} for growth periods up to 40 days but was consistently under the model value for longer periods (Fig 2b).

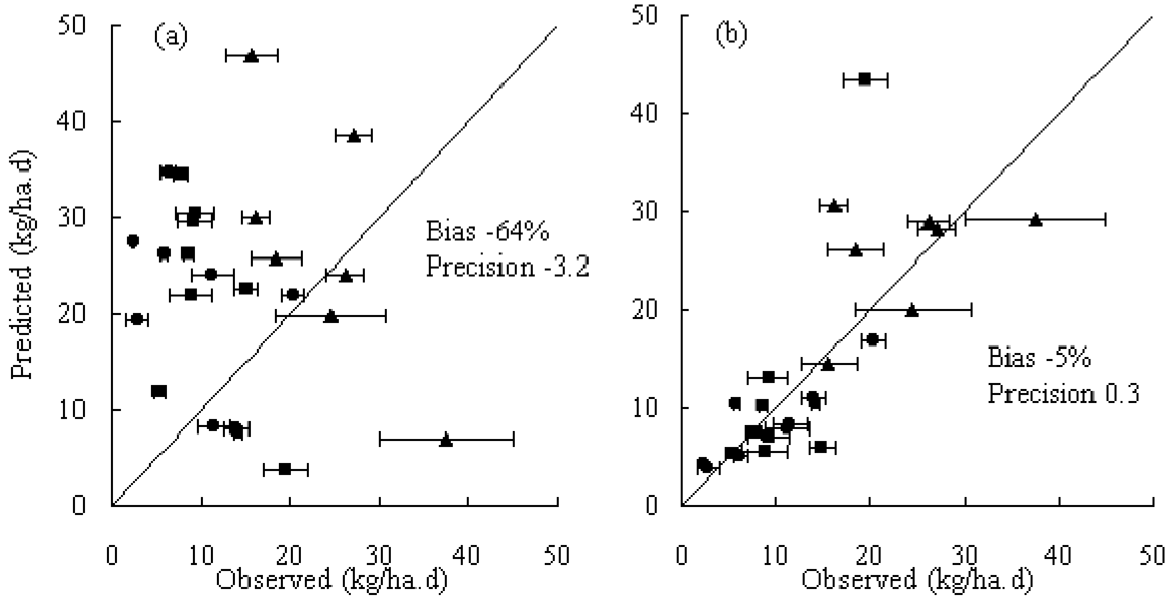

Figure. 1. Observed (bars represent standard error) compared to predicted lucerne growth rate for (a) original model parameters and (b) adjusted model parameters for different times of the year (circle, autumn-winter; square, winter; triangle, winter- spring and spring)

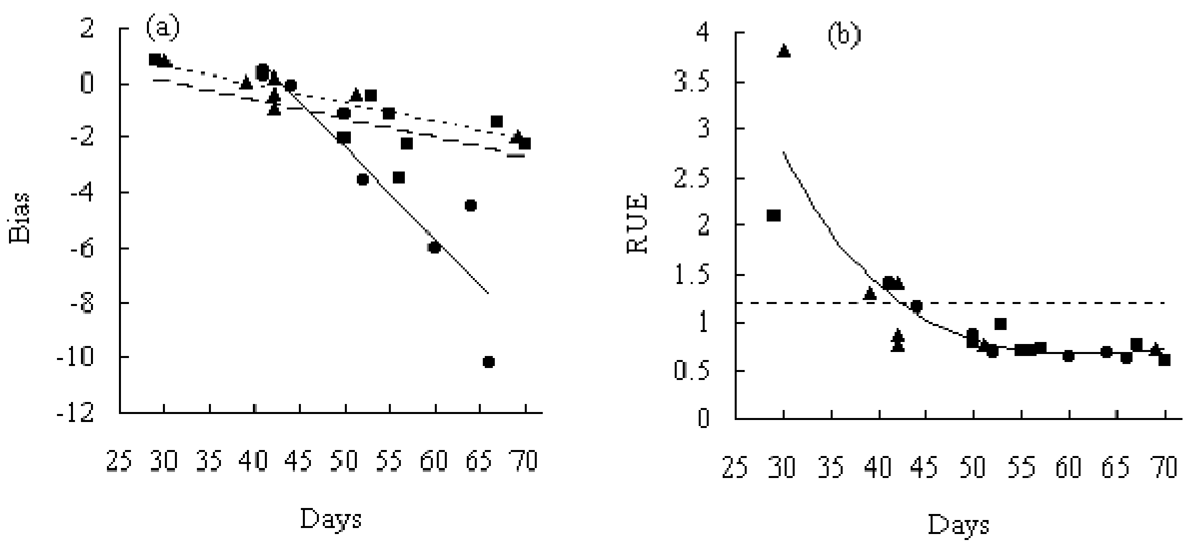

Figure. 2. The relationship between days of each growth period (from one cutting to the next) and (a) the bias between observed and simulated and (b) the observed radiation use efficiency (RUE, g MJ^{-1}) determined by dividing the observed biomass growth rate by the simulated radiation intercepted, with the current APSIM RUE shown as the dotted line. The symbols are the same as Fig. 1. The regression equations are (a) for autumn-winter (—) bias = 14.5-0.34*days r^2 =0.9, for winter (- - -) bias = 2.2-0.07*days r^2 =0.4 and for winter-spring (---) bias = 2.6-0.07*days r^2 =0.8 and (b) for all points (P<0.001), RUE = -1.2+26.6*0.93^{days} + 0.02*days r^2 =0.7. The curves were fitted by GENSTAT.

The RUE adjusted as a function of days after cutting greatly improved the relationship between simulated and observed growth rates (Fig. 1b). However, not all the variation was explained because of errors around the observed values (Fig. 1b) and the pastures contained a component of annual species, which was excluded in the analysis but would have used light in the system. Further more the number of data pairs at a cutting length of 30 days were limited and variable resulting in inaccurate predictions at some data points in Fig. 1b (for example the observed and predicted data pairs of 20 kg ha^{-1} d^{-1} and 43 kg ha^{-1} d^{-1} respectively), and there was no observed data to verify water stress (water stress might have occurred in some of the spring periods). Never less the improved relationship between simulated and observed biomass growth rate indicates that the model would benefit from a dynamic below ground pool of carbohydrate allowing biomass to be deposited and retranslocated to the above ground biomass as a function of crop ontogeny. Further data are required including sampling between cutting times to verify this conclusion and to determine if seasonal differences influence the storage dynamics.

Conclusions

The APSIM Lucerne model can satisfactorily predict the observed biomass growth data during low water stress periods once an allowance is made for increased above ground biomass production soon after harvest and reduced above ground biomass production later in the plants development, compared to simulated biomass growth using a constant above ground radiation use efficiency. Further research and testing is required before the model should be changed to include a parameter that allows carbohydrates to be stored from and then retranslocated to the above ground biomass before and after cutting, respectively. The model will also be tested over periods were there is water stress before being used to interpret a change in farming system on production and water use.

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