161

Back to the future – site, science and sustainability

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Abstract

Inter-annual rainfall variability across Queensland, Australia, is among the highest in the world. This variability coupled with episodic periods of drought and flood and highly variable forage supply pose major challenges for grazing management in Queensland. Since the mid-1990s, researchers have successfully used historical and current pasture data with the GRASP biophysical model to simulate pasture growth in the grazing lands of northern Australia. The FORAGE online system provides a unique combination of pasture modelling (GRASP model), remote sensing and climate forecasts to support grazing land and environmental management decisions. Here we look 'back to the future' to build on previous research, transfer our past knowledge and experience in modelling grazing systems to new researchers, and use the traditional, highly valued but resource-intensive site data to improve the GRASP land type models used in the FORAGE decision support system. Four fenced sites were established in regionally dominant Brigalow softwood scrub and Brigalow blackbutt buffel grass (*Cenchrus ciliaris* cvv. Biloela, Gayndah) pastures. We use detailed soil, pasture and rainfall measurements collected over three years (2020 – 2022) to represent key biological and physical pasture processes in the GRASP model. Across the years, the sites varied in rainfall (3 – 138% above long-term median), average buffel grass dominance (69 – 98% of total yield), peak pasture yield (2742 – 4343 DM kg ha^{-1}) and sward nitrogen yield (19 – 34 kg N ha^{-1}). We use this data to improve the FORAGE modelled estimates of long-term buffel grass pasture productivity in the broader Brigalow softwood and Blackbutt land type pastures in central Queensland. This will inform grazing and environmental land management decisions that promote both sustainable natural resource use in grazing lands and profitable grazing industries.

Introduction

Grazing with beef cattle and sheep is the dominant land use in Queensland, Australia, occupying nearly 86% of Queensland's 173 million hectares. Gross value of production from cattle and calves was estimated to be $6.6 billion and 35% of Queensland's primary industry commodities in 2024 – 25 (Queensland Government 2024). Almost 25% of the Queensland herd (~2.5 million cattle) grazes over 11.1 million ha in the Fitzroy Basin (MLA 2022).

Buffel (*Cenchrus ciliaris* L.) grass is an introduced strongly tufted, erect (60 – 100 cm tall), perennial, summer-growing grass that occurs on range of soil types containing reasonable fertility. The productivity, adaptation and drought tolerance of buffel grass make it the most widely established sown pasture in Queensland, estimated to be 'dominant' on 5.8 million ha (Peck et al. 2011), and a major contributor to the Queensland grazing industry.

The considerable inter-annual and decadal rainfall variability experienced in Queensland (Klingaman et al. 2013), and associated major temporal variability in forage supply, pose a major challenge for the sustainable and profitable management of grazing businesses (O'Reagain and Scanlan 2013). Since the mid-1990s, researchers have successfully used historical and current pasture data with the point-based GRASP model (McKeon et al. 2000) to simulate pasture growth in the grazing lands of northern Australia. The GRASP pasture growth model has been calibrated for over 100 native pasture sites across Queensland (Day et al. 1997) and has been widely used in the rangeland environments to predict year-to-year variability in forage supply and to estimate safe carrying capacities in the highly variable climate of northern Australia (e.g. Day et al. 1997; Walsh and Cowley 2011; Whish et al. 2014). However, there is little site data to predict pasture growth of long-term established buffel grass pastures in Queensland.

The Queensland Government developed an operational online information system – FORAGE – to facilitate decision support for grazing and environmental land management practices (Zhang and Carter 2018). The FORAGE system provides land managers with property-scale information relating to rainfall, ground cover, soil erodibility, land types, tree density, seasonal climate outlooks and pasture growth simulated using the GRASP grazing system model.

Here we look 'back to the future' to build on previous research, transfer our knowledge and experience in modelling grazing systems to new researchers, and use the traditional, highly valued but resource-intensive site data to calibrate buffel pasture GRASP models at four locations within 75 km from Emerald (23°31´S and 148°09´E), central Queensland. In this paper we outline the systematic approach for buffel grass model calibration, review the calibration results and extend the site models over time. We briefly discuss the use of the buffel site calibrated models across similar soil types and pastures, and the potential use of calibrated models to improve the FORAGE modelled estimates of long-term buffel grass pasture productivity in the broader Brigalow softwood and Blackbutt land type pastures in central Queensland.

Methods

Paired SWIFTSYND sites were established on the regionally dominant Brigalow blackbutt (sites 'A', 'B') and Brigalow softwood scrub (sites 'C', 'D') (State of Queensland 2022) buffel grass (cvv. Biloela, Gayndah) pastures at three grazing properties within 75 km from Emerald, central Queensland.

Fenced (to exclude livestock, wildlife and feral grazers) 30m x 30m sites were established during November (B, C, D) and December (A) 2019 on good condition buffel grass pastures that were established approximately 15 years previously. Preparation of the sites each year involved using brush cutters to remove dead material to 5 – 10 cm and remaining litter before spring rains.

The extensively cleared, Brigalow blackbutt sites (A, B) were established on hard setting, sandy clay loam to medium clay (brown sodosol) soils, whilst the Brigalow softwood scrub sites (C, D) were established on periodically cracking, light – medium clay to medium heavy clay (black vertosol). All sites were densely covered with medium tall (34 – 40 cm) Gayndah dominant buffel pastures, with the taller (~1.0 – 1.5 m) Biloela buffel grass a third of the pasture sward at the D site (Table 1).

Detailed pasture measurements were collected four times a year over 2020 – 2021 period using the methodology of Day and Philp (1997). Following the declaration of 'La Niña' an extra year of sampling

(2022) was undertaken at all sites to optimise the capture of potential growth when not water-limited. The measurements taken at each site provide the minimum information required to determine pasture and soil parameters for the pasture growth model GRASP. Site measurements included pasture yields and composition (‘Gayndah’ buffel, ‘Biloela’ buffel, ‘Other grasses’, ‘Legumes’, ‘Dicots’), heights, grass basal area, cover and plant nitrogen (N) content. Climate files for each site were obtained from SILO (Jeffrey et al. 2001) and combined with site-specific daily rainfall data (tipping bucket rain gauge). Soil water, Colwell phosphorus content, soil profiles and bulk density measurements were also collected at each site. In this paper we used three years of data in the calibration of ‘B’ and ‘D’ sites, and only the first two years of data in the calibration at ‘A’ and ‘C’ sites.

The GRASP model was used to simulate pasture production at the fenced buffel pasture sites through calibration using GRASP Calibrator (version 1.33 Build 7177). A systematic approach for model calibration (Scanlan et al. 2008), and the adjustment of parameter values to achieve the ‘best fit’ between model and site data, was employed to ensure key biological and physical pasture processes were well represented in the GRASP model. The latest versions of GRASP CEDAR (version 2.1.04 date 30/11/2023) and CEDAR default parameter file (cedardefault_v_2_1_03.prv dated 19/1/2024) were used. Long-term (1876 – 2024) annual (1 Oct- 30 Sep) ‘Year Type’ seasonal analysis for rainfall and pasture growth percentiles were derived for each calibrated site model using historical climate data.

Results

Site description

Annual rainfall (Jan – Dec) varied across the sites with the B and D sites receiving less rainfall than A and C sites during the study, however, all sites received rain in 2021 and 2022 that was well above (31 – 138%) their long-term median annual rainfall (Table 1). The long-term average annual rainfall and year-to-year variability (co-efficient of variation) for the sites ranged from 579 mm and 0.36 at B site to 619 mm and 0.40 at A site.

During the relatively drier 2020 growing season, peak pasture and N yield were greatest at the Brigalow blackbutt B site (Table 1). During the wetter year (2021) the peak pasture yield was greatest at the Brigalow softwood scrub C site, however, a similar peak pasture yield and the highest N yield was reached at the Brigalow blackbutt A site (Table 1). Peak pasture production during the 2021 growing season was broadly reflected in the similar or lower sward N yields compared to the drier year.

Site calibration

The GRASP model was used to simulate pasture production at the four buffel pasture sites through calibration using GRASP Calibrator and the adjustment of parameter values to achieve the ‘best fit’ between model and site data. Calibration commenced using the Queensland Government’s Brigalow blackbutt and Brigalow softwood scrub land type parameters used in the FORAGE online system (Zhang and Carter 2018).

The average annual rainfall at the four buffel pasture sites during the study (2020-2022) was in the long-term 60-100th percentile for all sites (Table 1). The four calibrated buffel pasture models when compared with observed (measured) data were a good to very good fit for pasture yield (Total Standing Dry Matter, TSDM kg ha^{-1}, Fig. 1 & Table 2), fair to moderate fit for soil water, with none to moderate agreement for N yield in TSDM (Table 2).

Long-term median annual pasture growth was highest at the Brigalow blackbutt B site, with pasture growth at the other sites being 2% (D), 6% (A) and 10% (C) less than site B (Table 2). The long-term median pasture growth for the calibrated models was higher than the respective FORAGE Brigalow blackbutt land type models but lower than the respective FORAGE Brigalow softwood scrub land type models (Table 2).

Discussion & Conclusions

Detailed pasture production data collected at the Brigalow blackbutt and Brigalow softwood scrub buffel grass pasture sites was successfully used to calibrate the GRASP model. Model calibration included adjustment of the Queensland Government's Brigalow blackbutt and Brigalow softwood scrub land type parameters values to achieve the 'best fit' between model and site data.

Table 1. Annual rainfall, average % Gayndah buffel grass composition of total pasture yield, average Grass Basal Area (%GBA), peak pasture yield Total Standing Dry Matter (TSDM) and pasture sward nitrogen content for peak yield (kg N ha^{-1}) for the paired GLM Brigalow blackbutt ('A', 'B') and Brigalow softwood scrub ('C', 'D') land type buffel (*Cenchrus ciliaris* cvv. Biloela, Gayndah) pasture sites.

GLM Land type	**Site annual rainfall mm (Percentile annual rainfall 1889-2024)**			**Average Gayndah buffel composition total yield (%)**	**Average Grass Basal Area (%GBA)**	**Peak yield TSDM (kg ha^{-1})**			****Sward nitrogen for peak yield (kg N ha^{-1})**	
	2020	**2021**	**2022**			**2020**	**2021**	**2022**	**2020**	**2021**
Brigalow blackbutt sites										
*A	631 (60)	1367 (100)		96	17	2686	4317		29.9	30.2
B	598 (60)	787 (90)	853 (100)	98	13	3314	3062	3178	33.8	19.0
Average				97	15					
Max						3314	4317	3178	33.8	30.2
Brigalow softwood sites										
*C	588 (60)	923 (100)		98	22	2742	4343		24.4	26.1
D	576 (60)	725 (90)	849 (100)	69	12	2484	3708	3452	27.8	23.0
Average				84	17					
Max						2742	4343	3452	24.4	26.1

*Only first 2 years data **2022 data being analysed

The four buffel calibrated models produced reasonably good fits (R^2 0.84 – 0.92) to observed TSDM data, aligning with the R-squared (R^2 0.92) achieved for a model calibration of buffel grass site near Moura, central Queensland (Peck et al. 2017). Poor to moderate agreement of the four calibrated models to soil water (R^2 0.15 – 0.70) and N yield of standing dry matter (R^2 0.0 – 0.66) were achieved during this study. Discrepancies between observed and predicted values of soil water are likely to be due to difficulties accessing sites during the wet periods and sampling dry, crumbly soils, rather than any site-specific impediment. The poor to moderate fits of modelled data to measured N yield at the three of the four Gayndah-dominant buffel pasture sites (A, B, D) were worse than that achieved for the calibrated Brigalow softwood scrub buffel grass model (R^2 0.57) at Moura where Gayndah buffel contributed only 22% of pasture yield (Peck et al. 2017). The higher observed than predicted N yields achieved during this study could be due to the ability of Gayndah buffel to respond quickly to rain and flower early whilst the flowering plant continues to produce extra N-rich leaves and new shoots. GRASP has a relatively simple calculation of N limitation so both the limitations of soil fertility and climate can be represented in simulations of pasture growth. The observed high N yields as an indicator of pasture quality are also an important driver of animal production. Further work is required to develop a dynamic N sub-model in GRASP that will enable representation of buffel grass species that exhibit high N yields in simulations of pasture growth and animal production.

The long-term (1890 – 2024) median pasture growth for the four calibrated buffel grass models (4739 – 5022 DM kg ha^{-1}) was slightly higher than the simulated long-term (1995 – 2014) annual pasture growth (4166 DM kg ha^{-1}) of grazed buffel grass pasture near Moura (Peck et al. 2017). The long-term median pasture growth for the calibrated buffel grass pasture models were approximately 10% more than FORAGE Brigalow blackbutt buffel but 30 – 35% less productive than the FORAGE Brigalow softwood scrub buffel model. Further consideration of site-specific characteristics and the adequacy of the study sites to represent the broader Brigalow softwood scrub and Brigalow blackbutt buffel pastures in central Queensland is required.

This work has provided an opportunity for a senior researcher to successfully transfer their knowledge and experience in modelling grazing systems to a new researcher, and demonstrate the value of the traditional, resource-intensive site data to calibrate buffel pasture GRASP models to inform and improve the FORAGE modelled estimates of buffel grass pasture productivity in central Queensland.

Table 2. Linear relationships (R-squared) between observed and predicted Total Standing Dry Matter (TSDM kg ha^{-1}), soil water for layers 1 (0 – 10 cm), 2 (10 – 50 cm) and 3 (50 – 100 cm), and nitrogen yield (kg N ha^{-1}) for the four Brigalow blackbutt and Brigalow softwood scrub buffel pasture calibrated models. Long-term (1876 – 2024) annual (1 Oct – 30 Sep) seasonal analysis 'All Years' median pasture growth (kg ha^{-1}) simulated for each calibrated buffel site model and for FORAGE Brigalow blackbutt and Brigalow softwood scrub land type models.

GLM Land type	**TSDM (kg ha^{-1}) R^2**	**Soil water layer R^2**			**N Yield (kg N ha^{-1}) R^2**	**'All Years' median annual pasture growth (kg ha^{-1})**	**'All Years' median annual pasture growth for FORAGE Brigalow blackbutt and Brigalow softwood scrub (kg ha^{-1})**
		1 (0-10 cm)	**2 (10-50 cm)**	**3 (50-100 cm)**			
Brigalow blackbutt sites							
***A**	0.92	0.51	0.33	No data	0.29	4739	4430
B	0.84	0.44	0.30	No data	0.0	5022	4600
Brigalow softwood sites							
***C**	0.92	0.30	0.47	0.70	0.66	4515	6970
D	0.86	0.27	0.15	0.56	0.56	4928	7028

*Only first 2 years data

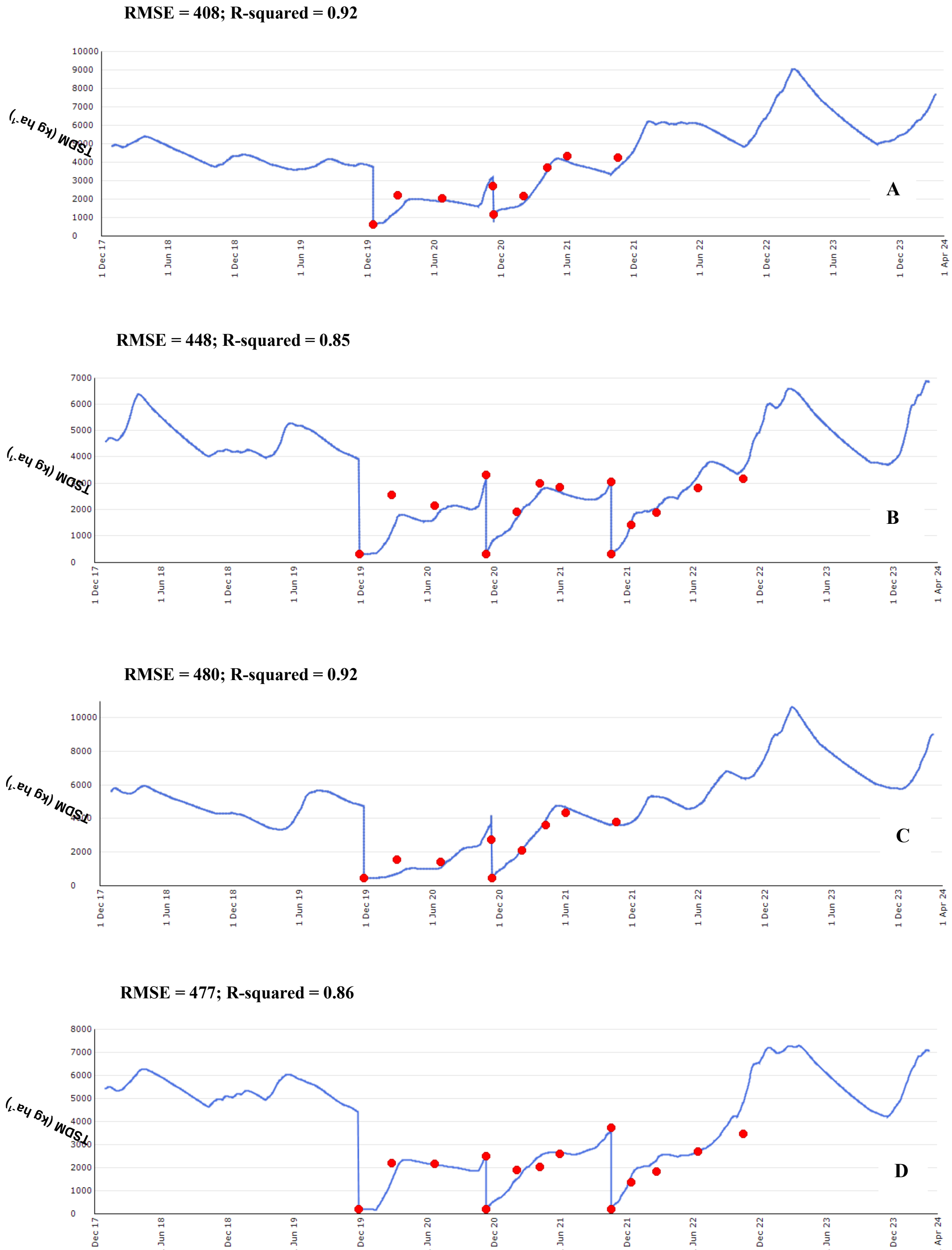

Figure 1. Time series for Total Standing Dry Matter (TSDM) kg ha^{-1} (observed red circles and predicted blue line) for the GRASP calibrated Brigalow blackbutt ('A' and 'B') and Brigalow softwood scrub ('C' and 'D') buffel pasture sites. X axis December 2017 to April 2024. Y axis TSDM (kg ha^{-1}). Linear regression

statistics (R-squared and root mean square error (RMSE)) are provided. Note: Only the first two years of data used in model calibration for 'A' and 'C' sites.

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