

APSIM Kale appropriately simulates spring and autumn grown forage kale crops in Tasmania

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Abstract

Kale (*Brassica oleracea* var. *acephala*) is an important winter feed on many dairy farms in the temperate regions of Australia and New Zealand. A key challenge in lifting farm productivity and profitability is understanding the effects of biophysical factors on growth and development of this crop. Biophysical models help in this regard, and can be used to test new production practices, or identify efficiencies that can be gained over current agronomic practices. The objective of this study was to determine if the APSIM kale module appropriately simulated the growth and development of forage kale crops in Tasmania. The results of simulations using site-specific soil and climate data and crop management were compared with data collected from field experiments and commercial kale crops. Comparison of the modelled growth and leaf development to observations in the field showed the model appropriately represented both biomass accumulation and phenological development. Relationship between modelled and observed biomass (n = 35) explained 86% of the variation with a mean bias of -37kg DM/ha over the life of the crop. Relationship between modelled and observed number of leaves (n = 16) explained 93% of the variation with a mean bias of 0.4 leaves over the life of the crop. The APSIM kale module includes predictions of soil water and nitrogen use and once verified will allow more precise management scenarios to be tested and implemented for optimising productivity while minimising the environmental impact of dairy winter forage systems.

Key words

Biophysical modelling, forage crops, dairy systems

Introduction

Pasture growth is low during the winter months on dairy farms in the temperate regions of Australia and New Zealand due to cold temperatures and water logging. This period is also a time when many dairy farmers destock their milking platforms to reduce pugging damage and increase pasture biomass in preparation for calving at the beginning of spring (Nie *et al.* 2001). Consequently during winter dairy cows are often fed sources of forage other than pasture and animals are housed on feedpads or on adjacent blocks to the milking area. Forage kale (*Brassica oleracea* var. *acephala*) is one such forage source that is grazed during winter on dairy farms. Forage kale produces relatively high yields (between 9 and 12 tDM/ha; Gowers and Armstrong 1994) with a nutritive value that is suitable for feeding to dairy cows (a metabolisable energy content of 11.2 MJ/kgDM and a crude protein content of 9.7%; Westwood and Mulcock 2012). While kale crops are a popular option for dairy farms there are challenges around productivity and quality of feed as well as the fit of kale into forage systems.

Pasture based dairy farms are complex agricultural systems. The interaction between pasture and crop components and the use of supplementary feeds adds complexity in terms of nutrient management and the scheduling of grazing rotations and farm operations (Rawnsley *et al.* 2013). Biophysical and farm system models are used to understand the nature of these interactions. Currently available biophysical modelling tools for investigating dairy farming systems do not include a package for the simulation of winter forage crops. This study aimed to address this gap by evaluating the performance of a recent beta module for forage kale for the Agricultural Production System Simulator (APSIM) biophysical crop model (Holzworth *et al.* 2014) in representing the growth and development of kale crops grown on Tasmanian dairy farms.

Methods

Kale crop growth and phenology

Data was collated for the growth and phenology (number of leaves) of kale crops across five locations in Tasmania, Australia (Table 1). These crops covered a range of soil types, sowing dates and varying levels of input. The details of such are provided in Table 1.

Table 1. Details of Tasmanian grown kale crops used to evaluate the performance of APSIM kale.

Location	Soil type	PA-WC (mm)	Irr/dry	Cultivar	Sowing date	Plants per m	N Fert (kg/ha)	End date	No. of biomass obs.	No. of leaf obs.
Mawbanna	Red	171	Irr	Kestrel	2/2/10	11	76	19/6/10	4	5
Redpa	Ferrosol Podsol	178	Dry	Sovereign	7/3/10	28	137	19/7/10	5	5
Cambridge	Brown Sodosol	243	Irr	Sub zero	22/12/09	43	12	12/2/10	1	1
Stonehouse	Brown Sodosol	243	Dry	Sub zero	13/11/09	29	0	13/1/10	1	1
Elliott	Red Ferrosol	143	Irr	Kestrel	13/11/99	45	50	11/2/00	24	4

Evaluation of model performance

Simulations were developed in APSIM (version 7.6) with climate, soil and management parameters that reflected each of the crops. The modelled biomass and leaf number from these simulations were compared to the observed biomass and leaf number from the crops. Comparisons were made by plotting the modelled and observed values as scatter plots and tests for variance reported as the mean bias (as an indication of a bias in under or over predicting modeled values), R^2 and Pearson correlation coefficient (as an indication of the variance between modeled and observed values), model efficiency and mean prediction error (as an indication of how much of the variance in the observed data is explained by the model) and variance ratio and concordance correlation coefficient (as an indication of the deviation between the fitted line between the modeled and observed data and a 1:1 fit). Further details of these statistics are provided in Tedeschi (2006).

Long term simulation of kale crops across Tasmanian dairy regions

Long term (1974 to 2014 inclusive) simulations of kale crop growth were run for four locations that represent the major Tasmanian dairy regions (Bushy Park, Deloraine, Scottsdale and Edith creek). The locations were Bushy Park (black vertosol soil, 576 mm mean annual rainfall), Deloraine (brown kurosol soil, 951 mm mean annual rainfall), Scottsdale (brown dermosol soil, 1001 mm mean annual rain fall) and Edith creek (red ferrosol soil, 1106 mm mean annual rainfall). The following management was used in these simulations:

- The cultivar Kestrel sown into fully cultivated seedbeds on February 1 every year with 35 plants per m² established.
- Irrigated to the soils drained upper limit at sowing and then subsequently grown under rain-fed conditions.
- Fertiliser of 30 kgN/ha applied at sowing and a further 40 kgN/ha applied 45 days after sowing
- Grazed and terminated 140 days after sowing.

Results

A comparison of the model predicted values for biomass and leaf number to the observed values showed the model gave realistic representation of kale crop performance in Tasmania (Figure 2). Evaluation statistics for respective biomass and leaf number variables were: An R^2 of 0.86 and 0.93 and Pearson correlation coefficients of 0.93 and 0.96 indicating little variance between observed and modelled values. A mean bias of -37 kgDM/ha and 0.4 leaves indicating no major bias to under or over predicting yield and leaf number. A mean prediction error of 32% and 13% and a modelling efficiency of 0.85 and 0.91 highlighting a high amount of the variance in the observed data was explained by the model. Variance ratios of 0.97 and 1.02 and concordance correlation coefficients of 0.93 and 0.96 indicating little deviation from a 1:1 line of fit between the observed and modelled values.

The median yield at grazing from the long term simulations of kale crops was 7.4, 8.3, 8.4 and 7.6 tDM/ha for Bushy Park, Deloraine, Scottsdale and Edith Creek, respectively (Figure 3). The distribution in yields was similar at each locations and ranged between 6.5 and 8.9 t DM/ha at Bushy Park, 7.4 and 10.2 t DM/ha at Deloraine, 6.1 and 9.7 t DM/ha at Scottsdale and 5.8 and 9.2 t DM/ha at Edith Creek.

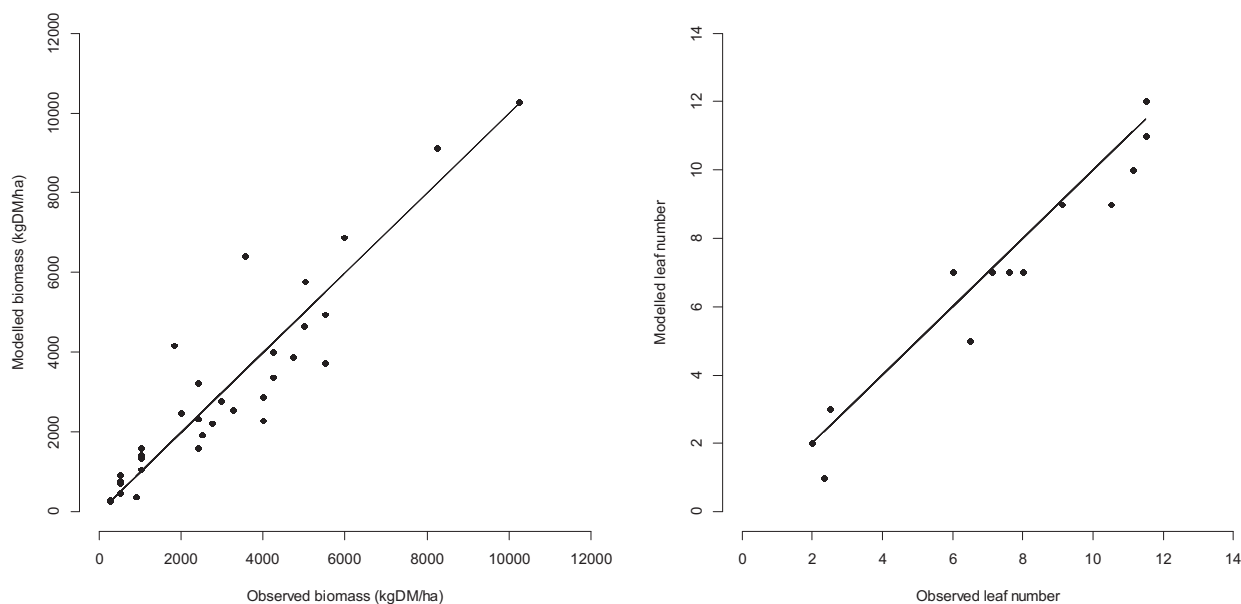


Figure 2. Scatter plots compare the observed and modelled values of biomass and leaf number of forage kale across five locations in Tasmania. The line represents a perfect 1:1 relationship between the observed and modeled values.

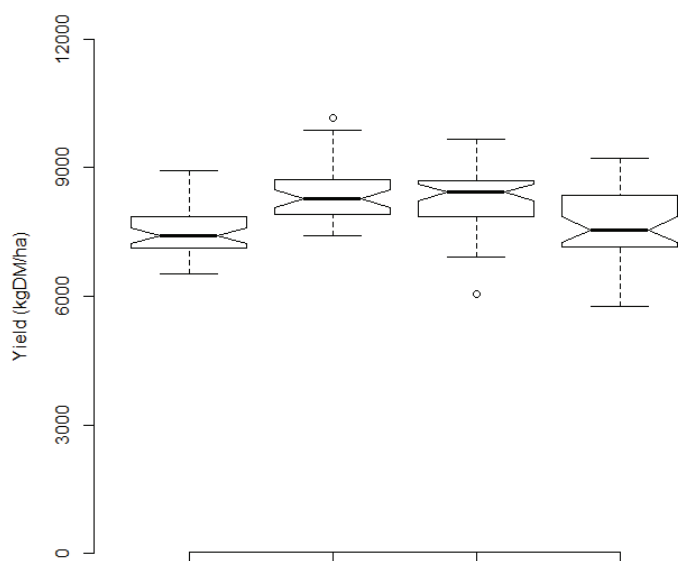


Figure 3. Notched box and whisker plots of simulated kale crop yield over 40 years for four major dairy locations in Tasmania.

Discussion

The summary statistics indicate that the performance of APSIM kale in simulating kale crops grown in Tasmania was similar to or better than the performance of APSIM in simulating the growth of other annual forage crops (e.g. oats, maize, forage rape, forage sorghum; Pembleton *et al.* 2013) and lucerne (Pembleton *et al.* 2011) at similar locations. It was also similar to the performance of DairyMod/SGS (Johnson *et al.* 2008) in simulating pasture growth in Tasmania (Cullen *et al.* 2008; Rawnsley *et al.* 2009). The yield predictions from the long-term simulations of forage kale growth across four major dairy locations were consistent with locally observed yield. The relatively small distributions in forage yields in these simulations reflect the impact that a single irrigation at sowing has on the yield distribution of summer sown, rain fed forage crops in a winter dominant rainfall environments (Harrison *et al.* 2013). This study has shown that the forage kale module in APSIM appropriately represents the growth and development of kale crops

grown in Tasmania. As this module is capable of predicting soil water and nitrogen use it will become an important tool in the simulation of winter forage systems to explore management options that optimises their biophysical, economic and environmental performance in the context of a whole farm system.

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