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Adaptation and evaluation of a mechanistic grass growth simulation model for grass-based systems

Hurtado-Uria C.^{1,2}, Hennessy D.¹, Delaby L.³, O'Connor D.² and Shalloo L.¹

¹ Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland

² Cork Institute of Technology, Cork, Co. Cork, Ireland

³ INRA, AgroCampus Ouest, UMR 1348, Physiologie, Environnement et Génétique pour l'Animal et les Systèmes d'Élevage, F-35590 Saint-Gilles, France

Corresponding author: Deirdre.Hennessy@teagasc.ie

Abstract

An accurate grass growth model would be a valuable tool in anticipating grass growth and grass utilization at farm level. Ideally, a grass growth simulation model must be accurate, dynamic, use realistic input parameters and incorporate meteorological data. The objective of this study was to parameterize the grass growth model developed by Jouven *et al.* (2006) to increase its accuracy of grass growth simulation in the south of Ireland. The model was parameterized using an optimization technique where a number of the parameters in the model were optimized with the objective function of minimizing the root mean square error (RMSE). Both meteorological and grass growth data for the period 2005 to 2009 were included in the optimization process. During validation the Jouven Model was compared to the Adapted Model. RMSE was reduced from 20.45 kg DM ha⁻¹ day⁻¹ with the Jouven Model to 14.62 kg DM ha⁻¹ day⁻¹ with the Adapted Model. MSPE was reduced from 476 to 183. The proposed changes to the Jouven Model improved grass growth simulation in the south of Ireland. The adapted version of the Jouven Model can be used for grass growth simulation; albeit without perfect simulation.

Keywords: grass growth, model, adaptation, simulation

Introduction

Budgeting grass supply allows farmers to minimize the quantity of purchased feed required in the diet of grazing livestock. Forecasting grass growth and hence reducing volatility around grass supply will be a key feature of profitable milk and meat production systems in the future. An accurate model to simulate grass growth would be a valuable tool in anticipating and planning grass growth and grass utilization at farm level. Three grass growth models were evaluated by Hurtado-Uria *et al.* (2013). The model developed by Jouven *et al.* (2006) (hereafter referred to as the Jouven Model) was shown to have the greatest potential to simulate grass growth in Ireland; however, Hurtado-Uria *et al.* (2013) concluded that the model would require adaptation and parameterization to improve its grass growth simulation. The objective of this study was to parameterize the Jouven Model to increase its grass growth simulation accuracy in Ireland using data from 2005 to 2009.

Materials and methods

The Jouven Model is described in detail by Jouven *et al.* (2006). The model combines functional and structural components. In the model a site is described by its nitrogen (N) index (Bélanger *et al.*, 1994), water holding capacity (WHC) and grassland community. Only above-ground grass growth is modelled. To parameterize the Jouven Model for Irish conditions, the Solver Tool pack for Microsoft Excel was used in association with Moorepark

meteorological and grass growth data from the 2005-2009 period (Hurtado-Uria *et al.*, 2013). The optimization procedure was applied with the objective function set to minimize the root mean square error (RMSE) of observed versus predicted grass growth, by adjusting a number of parameters. A number of constraints were included to ensure both inputs and outputs were sensible in the optimization process. Herbage production was modelled for the period 2005 to 2009 using climatic data from Teagasc, Moorepark (hereafter referred to as Moorepark). The grazing season was divided into three periods: spring (January to April), mid-season (April to August) and autumn (August to November). Modelled data were compared with grass growth measured at Moorepark for 2005-2009 (Hurtado-Uria *et al.*, 2013) using RMSE (Jin *et al.*, 2005) and mean square prediction error (MSPE) (Rook *et al.*, 1990) as measures of fit.

Results and discussion

The Adapted Model simulated total herbage production for the years 2005 to 2009 with more accuracy than the Jouven Model (Figure 1). The random variation of the MSPE was 0.905 for the Adapted Model compared to 0.482 for the Jouven model, and R^2 (0.87) was improved for the Adapted Model compared to the Jouven model ($R^2=0.66$). The Adapted Model simulated the seasonal herbage production in the spring for the years 2005 to 2009 with more accuracy than the Jouven Model. The Jouven Model undersimulated grass growth in all years (data not shown). The best fit for the Adapted Model was achieved in spring with a MSPE of 25 kg DM ha⁻¹ day⁻¹ ($R^2=0.89$) with the random variation making up the greatest component of the MSPE and the mean bias was zero (Table 1), and was poorest in mid-season. The Adapted Model reduced the RMSE from 16.36 kg DM ha⁻¹ for the Jouven Model to 12.84 for the Adapted Model).

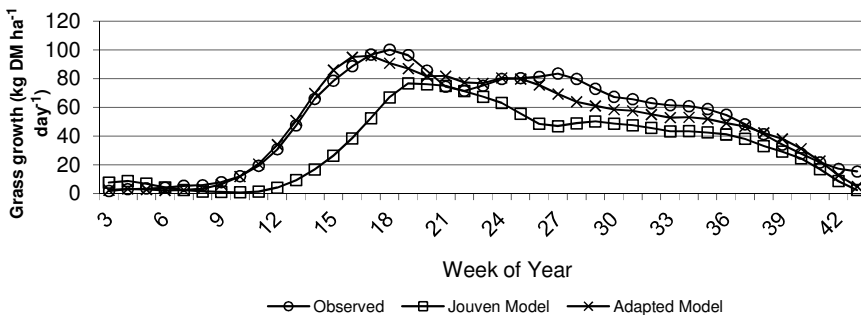


Figure 1. Average grass growth (kg DM ha⁻¹ day⁻¹) simulated by the Jouven Model, the Adapted Model and measured grass growth data for the average of 2005-2009 at Moorepark.

Table 1 Mean square prediction error (MSPE) and R^2 of the Adapted Model for five years (2005-09) and for spring (January-April), mid-season (April-August) and autumn (August-November).

| Period | Model version | Proportion of MSPE | | | MSPE | R^2 |
|------------|---------------|--------------------|-----------|--------|------|-------|
| | | Mean bias | Line bias | Random | | |
| Total | Adapted | 0.034 | 0.060 | 0.905 | 152 | 0.87 |
| Spring | Adapted | 0.000 | 0.106 | 0.894 | 25 | 0.89 |
| Mid-season | Adapted | 0.034 | 0.177 | 0.789 | 221 | 0.43 |
| Autumn | Adapted | 0.072 | 0.120 | 0.808 | 166 | 0.72 |

Several parameters were changed, including the initial biomass of green vegetative material (reduced from 650 to 300 kg DM ha⁻¹) and initial biomass of dead vegetative (from 560 to 300 kg DM ha⁻¹); bulk density of green vegetative material was increased from 850 to 1200 g DM m⁻³; minimum temperature threshold (reduced from 4°C to 0°C), and maximum temperature threshold (reduced from 20°C to 18°C); the initial and end of reproductive

growth temperatures changed from 600°C d to 725°C d and from 1200°C d to 975°C d, respectively.

Conclusion

The Adapted Model improved grass growth simulation in the south of Ireland. This improvement was achieved with changes on the parameters used by the model, thus making the adaptation possible for other locations. The adapted version of the Jouven Model can be used for grass growth simulation; however, further changes to the model could be made around the functions of the model.

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