Developing a predictive model for grass growth in grass-based milk production systems

Paillette C.A.[1,2], Delaby L.[3], Shalloo L.[1], O'Connor D.[2] and Hennessy D.[1]
[1]*Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland;* [2]*INRA, Physiologie, Environnement, Génétique pour l'Animal et les Systèmes d'Elevage, 35590 St. Gilles, France;* [3]*Cork Institute of Technology, Bishopstown, Cork, Ireland*

Abstract

In temperate regions grazed grass is the most economical means of feeding dairy cows. Grass growth is highly variable within and between years. A model capable of simulating daily grass growth depending not only on weather conditions but also on N fertiliser application and farm management would provide valuable information allowing farmers to make better management decisions around supplementation, silage making, fertilisation and grazing. The Moorepark Grass Growth Model (MGGM) is a mechanistic grass growth model developed to take into account weather, soil water and soil N dynamics. The response of the model to weather conditions, frequency of harvesting, initial soil N content and N fertiliser application was evaluated. The responses from the model were comparable with published studies. The MGGM responded coherently to grass harvesting and N fertiliser application and can predict the grass growth rate taking into account management and weather.

Keywords: grass growth model, soil N, fertiliser N, cutting frequency

Introduction

There is increased interest in grass growth prediction due to the low cost of grazed grass as a feed for ruminants in temperate regions (Finneran *et al.*, 2012). In a context of increasing food demand due to global population growth and the need for economic sustainability of grass-based farms, predictive grass growth models can improve the decision-making process at farm level. In temperate climates grass provides the cheapest feed for dairy cows (O'Donovan *et al.*, 2011). Grass growth is highly variable both within and between years (Hurtado-Uria *et al.*, 2013). Existing grass growth models were developed around specific questions, location or to answer key management based decisions. The objective of this study was to develop and evaluate a mechanistic model capable of simulating grass growth in a pasture-based system through the linkage of grass growth model (Jouven *et al.* 2006; Hurtado-Uria, 2013) and a soil N model (Paillette *et al.*, 2014). An internal validation of the model was undertaken to evaluate the capacity of the model to respond to changes in N fertiliser application, different initial quantities of soil mineral N and number of annual herbage harvests.

Materials and methods

This study involved the creation of a dynamic and mechanistic grass growth model (the Moorepark Grass Growth Model; hereafter referred to as MGGM) by adapting an existing grass growth model (Jouven *et al.*, 2006 as adapted by Hurtado-Uria, 2013) and combining it with a soil N and water model (Paillette *et al.*, 2014) (Figure 1). The model described by Jouven *et al.* (2006) was adapted and validated for use in Irish cut grass pastures (Adapted Jouven Model; Hurtado-Uria, 2013). Briefly, the Adapted Jouven Model describes the sward as a homogeneous community characterised by its density, temperature thresholds (minimum, optimum and maximum temperature for growth, and cumulative temperature range for reproductive growth) and leaf composition (specific leaf area, percentage of laminae and leaf lifespan). The sward is divided into green and dead plant material for both vegetative and reproductive parts. The soil N and water model (Paillette *et al.*, 2014) describes the soil water stock (l ha^{-1}; in top 1 m of soil) depending on soil type, precipitation and evapotranspiration, and soil mineral and organic

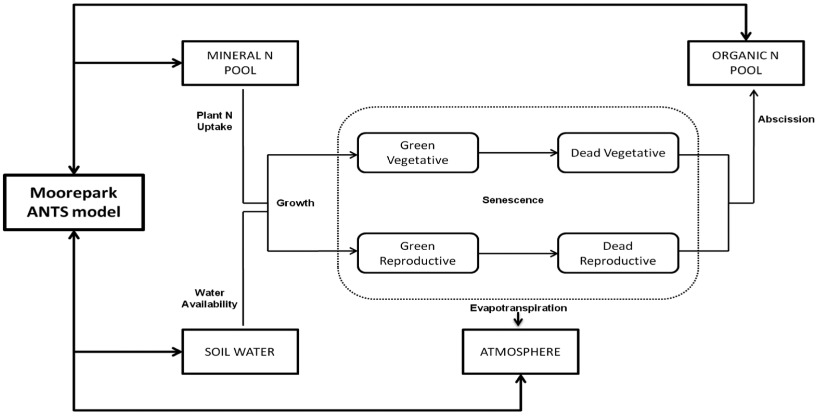

Figure 1. Schematic representation of the Moorepark Grass Growth Model.

N stocks, taking into account N fertiliser application, N recycled during grazing, N exchanges with the atmosphere (volatilization and organic N deposition), N lost through leaching, N mineralization and immobilization, plant N uptake and abscission. Model inputs are soil properties, sward details, farm management (e.g. N fertiliser application, grazing management), and weather data (e.g. temperature, rainfall, solar radiation). Outputs from the MGGM include growth rate (kg dry matter (DM) ha^{-1} day^{-1}), plant N uptake (kg N ha^{-1}) and biomass (kg DM ha^{-1}), as well as the N and water stocks and N losses.

The model was evaluated with six annual N fertiliser levels (0, 100, 200, 300, 400, 500 kg N ha^{-1} year^{-1}) applied in six or eleven applications, and cutting (>4 cm) 6 and 11 times per year. Fertiliser N was applied on 16 February and the day after each cut (for all but the last cut of the year) as 1/6 or 1/11 of total annual N fertiliser at each event. For each management, two initial soil mineral N contents (150 and 250 kg N ha^{-1}) and two years (2010 and 2013) of weather data were tested (the weather data was collected at Teagasc Moorepark, Co. Cork, Ireland, latitude 50°07' North, 8°16' West). Results were compared with published data.

Results and discussion

Frequency of cutting resulted in differences in biomass harvested and average daily growth rate (Table 1). Over all simulations predicted quantity of biomass harvested was 3 Mg DM ha^{-1} greater on paddocks harvested six times compared to paddocks harvested eleven times (11,533 and 9,587 kg DM ha^{-1} year^{-1}, respectively). Average growth rate was 5.4 kg DM ha^{-1} day^{-1} (17%) lower with eleven compared to six harvest events. The decrease in grass growth rate and DM yield described by the MGGM with increasing frequency of defoliation agrees with Pontes *et al.* (2007) as well as the trend reported by Herrmann *et al.* (2005). Total biomass harvested increased with increasing N fertiliser application. Herbage production at 0 N kg N ha^{-1} was 6,416 kg DM ha^{-1}, similar to Hennessy (2005), and increased to 15,088 kg DM ha^{-1} at 500 kg N ha^{-1}. Reid (1970) reported productivity of around 14.5 Mg DM ha^{-1} year^{-1} from grass only pastures receiving 560 to 896 kg N ha^{-1} year^{-1}. Average grass N content was higher under an eleven cut system than under a six cut system, similar to Pontes *et al.* (2007).

Conclusions

The MGGM responded coherently to harvesting and N fertiliser application. To be useful as a management tool, a grass growth model must at least be able to predict the trend of grass growth. The MGGM allows the exploration of the effect of different N fertiliser application or harvesting patterns on grass growth rate.

Table 1. Total biomass mass harvested, average daily grass growth rate, average herbage N content per kg dry matter (DM), average soil N content and end of year soil N content for simulations with different initial soil N contents, different frequencies of defoliation, different levels of N fertiliser application and different yearly weather conditions.

		Total biomass harvested (kg DM ha^{-1})	Average daily growth rate (kg DM ha^{-1} day^{-1})	Average herbage N per kg growth (kg N kg DM^{-1})	Average soil N content (kg N ha^{-1})	Soil N content at the end of the year (kg N ha^{-1})
Initial soil N content (kg N ha^{-1})	250	10,046	31.7	0.045	202	140
	150	8,201	26.3	0.046	154	129
Number of cutting events	6	10,106	31.7	0.044	180	137
	11	8,142	26.3	0.047	176	131
N fertiliser application rate (kg N ha^{-1} year^{-1})	0	5,430	17.6	0.047	112	68
	100	6,472	21.4	0.047	140	97
	200	8,040	26.0	0.046	165	121
	300	9,796	31.1	0.045	189	145
	400	11,626	36.4	0.044	216	172
	500	13,378	41.5	0.043	245	204
Year	2010	9,266	29.1	0.045	175	135
	2013	8,982	29.0	0.045	180	134

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