Applicability of APSIM AgPasture for modelling yield and nitrogen content of timothy grass in boreal conditions

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In high-latitude regions, the short growing season and long day length create narrow harvesting windows, increasing the need for accurate forage growth and quality estimations. Timothy grass (*Phleum pratense* L.) dominates in northern Europe, but simulating its growth dynamics remains challenging. Existing models often fail to reproduce seasonal biomass accumulation accurately in northern conditions (Korhonen et al. 2018). Key limitations include inadequate representations of temperature-dependent nitrogen cycling, winter damages, and plant competition. Many grassland models were developed for permanent pastures rather than northern silage production systems.

We evaluated APSIM AgPasture (Li et al. 2011), originally developed for perennial ryegrass, for simulating timothy biomass yield and nitrogen content in Finland. AgPasture represents perennial grasslands with repeated defoliation and regrowth cycles. Our aim was to assess how calibration improves the model's capability to replicate timothy growth and N dynamics, and identify critical limitations requiring further development for northern conditions.

Materials and methods

AgPasture was calibrated following the calibration protocol of Wallach et al. (2024), with 11 plant parameters selected based on sensitivity analysis. Calibration data came from a field experiment in Maaninka, Finland (63°09'N), providing multi-year observations of timothy yield under varying N fertilization levels (Termonen et al. 2020; Figure 1).

Management setup replicated experimental harvest and fertilization dates. Residual biomass after harvest was set to 3000 kg DM ha^{-1}, with 1500 kg DM ha^{-1} tested as alternative. Soil parameters were specified by layers based on measurements. Initialization used 700-year spin-up runs with grass rotation and 150 kg N ha^{-1} year^{-1} fertilization. Alternative approaches were tested for setting the soil temperature factor (Ceres Optimum Temperature). The values selected are the AgPasture default (32°C) and an optimized value estimated based on yield of non-fertilized experiment. ERA5 weather data for Maaninka (1940–2022) was applied.

Figure 1. Data used for model calibration and testing was from timothy grass (*Phleum pratense* L., cv. 'Grindstad') plot trials with varying nitrogen fertilization levels (0-450 kg N ha^{-1}; Termonen et al. 2020).

Results and discussion

The testing of AgPasture in boreal conditions critically evaluates a model originally developed for very different environments. The soil temperature factor proved important for nitrogen mineralisation and grass growth, particularly evident at low fertiliser rates. This indicates necessary parameter adjustments when applying the model outside its original area.

Calibration enhanced reproduction of yield responses to fertilisation, but systematic biases remained: underestimation of high yields and overestimation of low yields (Table1, Figure 2). Residual biomass settings (1500 vs. 3000 kg DM ha^{-1}) also markedly affected regrowth and plant N content dynamics. Observed interannual variability exceeded simulated variability throughout the experiment period.

Adapting soil temperature parameters for cold climates is essential for accurate nitrogen cycling simulation in northern grasslands.

	CeresOptT = 32	CeresOptT = 8.92
Optimized crop parameters (value)	RPR (1.24); GTO (15); LEC (0.5); GTEE (1.7); MRC (0.03); GRC (0.25); PNM (0.011); PNO (0.020)	RPR (1); GTO (19.81); LEC (0.5); GTEE (1.8); MRC (0.03); GRC (0.25); PNM (0.009); PNO (0.0152)
RRMSE Yield	0.444	0.337
RRMSE N amount	0.289	0.345
BIAS Yield	-925.61	-404.35
BIAS N amount	-1.49	8.46

Table 1. Optimized crop parameters, relative root mean squared error (RRMSE), and BIAS for the optimized parameter values, with 3000kg/ha residual biomass, and with ceresT = 32 -default value- and ceresT = 8.92 -optimized-.

RPR: ReferencePhotosyntheticRate; GTO: GrowthToptimum; LEC: LightExtinctionCoefficient; GTEE: GrowthTEffectExponent; MRC: MaintenanceRespirationCoefficient; GRC: GrowthRespirationCoefficient; PNM: pago_Nmin; PNO: pago_Nopt.

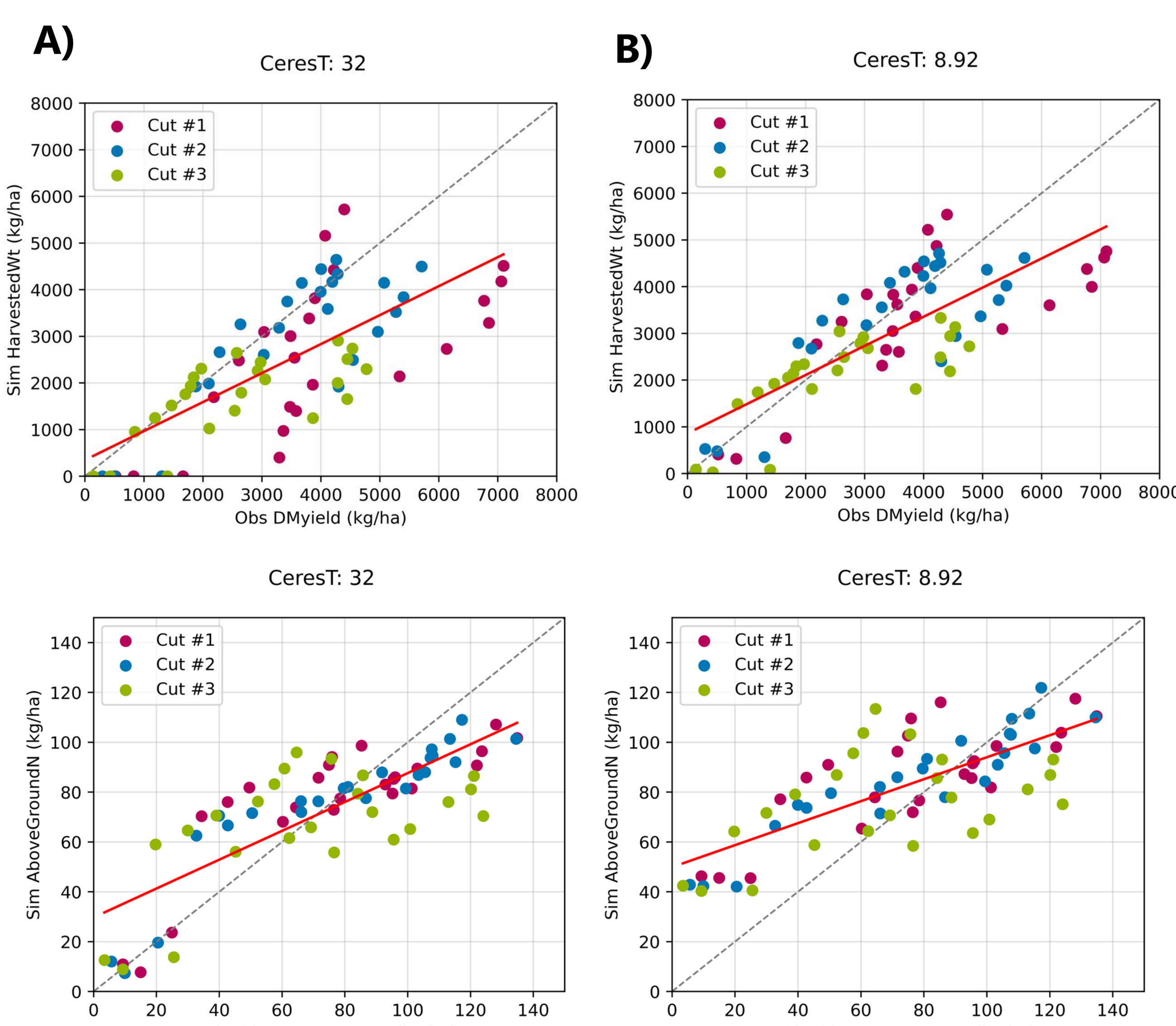

Figure 2. Scatter plots of measured and simulated harvested biomass DM and N yields by cuts. Optimized crop parameters, with 3000 kg ha^{-1} residual biomass, and with ceresT = 32 -default value- (A) and ceresT = 8.92 -optimized- (B).

Conclusions

While calibration improved APSIM AgPasture's simulation of timothy yield and nitrogen content, persistent errors indicate that applying the model beyond its original context requires careful local parameterization and process adjustments. Further empirical work and model testing are required to accurately predict soil nitrogen processes and their temperature responses in northern conditions.

iCROPM 2026
"Crop Modelling for Agriculture and Food Security under Global Change"
February 2-4, 2026 Florence, Italy

This study was funded by the European Agricultural Fund for Rural Development and the Just Transition Fund ('Kestävyyttä nurmesta', 'N-Fiksu'), European Regional Development Fund (ERDF; 'BioEconData'-project), as well as by INTEGRITY project funded by The Development Fund for Agriculture and Forestry (Makera).

Co-funded by the European Union