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Grass biomass assessment in Wallonia (Belgium) based on satellite imagery and a grass growth model

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Abstract

In Wallonia (Belgium), grasslands cover 367 200 ha and represent the dominant land cover class (47% of utilized agricultural area). Grassland yields are fluctuating according to different factors such as the pedoclimatic region, the floristic composition, the intensification level as well as management, especially in the context of climatic change. A multi-approach concept based on a large reference field data set, satellite imagery and a grass growth model (GGM) is being developed in the frame of the SUNSHINE project. The objective is to co-construct a Decision Support Tool (DST) adapted to breeders' needs. Intensive field campaigns in grassland parcels have been conducted in 2022 to calibrate/validate the GGM and information extracted from satellite images. Satellite remote sensing (RS) offers opportunities for large-scale monitoring and quantification of grass production across and within fields. This study aims to assess the potential of Sentinel 2 (S2) images to monitor grassland growth. Grass height *in situ* observations were related to Leaf Area Index (LAI) derived from ten S2 images acquired between May and October. Coupling the GGM with RS data allows estimation and prediction of grass growth with an RMSE between 367 and 482 kg dry matter ha^{-1} on a daily step, fitting this to breeders needs.

Keywords: Sentinel-2, grass growth model, grasslands yield

Introduction

The management of grasslands is complex and a great challenge in a changing climate. In the case of grazed parcels, farmers need to adjust their practices regularly depending on the spatial and temporal distribution of available grass biomass. This information is usually estimated from time-consuming *in situ* observations or measurements (e.g., with a rising plate meter). Remote sensing (RS) data could be used to help farmers to adapt their practices (Dusseux *et al.*, 2022). Satellite optical sensors provide region-scale spatial information on the status of the vegetation and could be used to map within-field heterogeneity. However, cloud cover can hamper the efficiency of the system, and RS data cannot be used to predict the status of vegetation. On the other hand, process-based dynamic crop models, relying on sets of ecophysiology-related mathematical equations, can predict the productivity of crops using weather forecasts, but due to their formalism they do not account for every factor that can affect plant growth. Moreover, crop models provide field-wise information, whereas in the case of grazing, more detailed (paddock-wise) information is required. Coupling crop models with RS data can provide a tool to estimate and predict the growth of grasslands at field and paddock-scale. In this study, the coupled use of the ModVege grass growth model (Jouven *et al.*, 2006) and leaf area index (LAI) extracted from Sentinel 2 (S2) satellite data (Weiss *et al.*, 2020) has been evaluated to estimate and predict the dry matter yield of grassland fields.

Materials and methods

Field data were collected over 16 farms located in six different Walloon pedoclimatic regions in 2022. From 56 monitored grassland fields, the only five monitored mowing fields (three temporary grasslands: CO1, CR2, DF4 and two permanent grasslands: RA3, VI4) were considered for this study (Fig. 1). Areas of fields are between 1.2 ha (RA3) and 3.0 ha (CR2) and dominant plant species is perennial ryegrass (*Lolium perenne* L.) and tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh). The field measurements consisted of geolocalized compressed sward height (CSH) measured weekly (50–65 measurements per ha) using an electronic rising plate meter (RPM).

The ModVege model is used in this study to simulate in daily time steps the growth of a homogeneous field of grass based on soil and plant traits, farming practices and weather data.

Bottom of atmosphere (Level 2A) optical RS data were obtained from the S2 constellation, which provides open-access 10m resolution multispectral images with a high revisit frequency (approximately 2.5 days for Belgium). The number of cloud-free images available in 2022 over monitored fields is DF4 -12, CR2-15, RA3-32, CO1-34 and VI4-36. The LAI values per field were calculated for all cloud-free available S2 images.

ModVege and LAI-S2 models were calibrated and validated using independent samples of field data. The calibration (n=21) of the ModVege was based on data collected on seven micro-plots (9 m^2) monitored over three cutting events in the period spring to mid-summer. The calibration parameter employed is a plant coefficient (Kc) used to adjust the evapotranspiration of the gras. The coefficient is adapted monthly using data from the Grassim model (Kokah *et al.*, 2023).

Results and discussion

The ModVege validation was conducted on the five mowing parcels considered for this study in 2022: n=122, RMSE=481.5 kg, R^2=*0.76.*

The LAI values extracted from S2 images acquired simultaneously with CSH field measurements for the 56 grassland parcels in 2022 (n=117) were used to calibrate a linear model (n=79, without the five mowing fields). The validation result using an independent sample, including the five considered parcels, for n=38 is RMSE=366.9 kg, R^2=*0.78.*

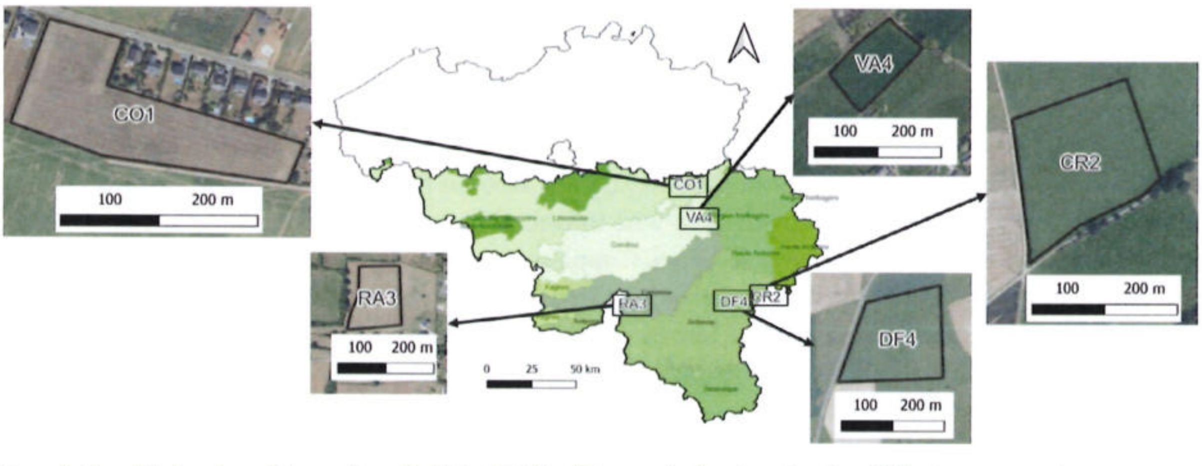

Figure 1. Map of the locations of the monitored fields in 2022. The different pedoclimatic regions from Wallonia are presented.

The simulated values of dry matter (DM) are presented in Figure 2. The CSH values were converted to DM using the formula: kg DM ha^{-1}=215 kg DM cm^{-1} ha^{-1}(Lefèvre *et al.*, 2022).

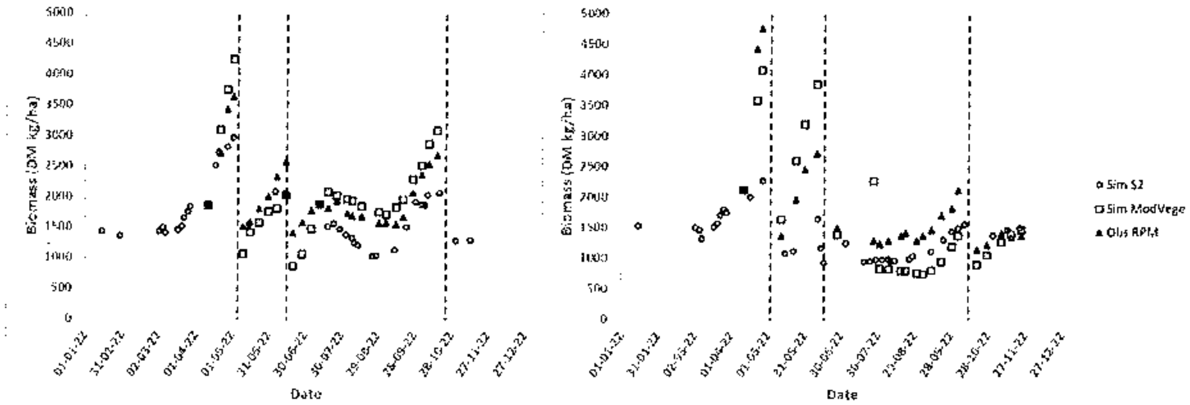

Figure 2. Example of dry matter (DM) temporal development for two grass parcels in 2022. The reference values (from CSH) and results from S2 and ModVege are presented for VI4 (left) and CO1 (right) fields. The mowing dates are presented with dot lines.

A better DM estimation from ModVege than LAI-S2 can be observed during the spring-summer period when S2 values are underestimated for higher values of biomass. A possible explanation could be the saturation of LAI estimated from S2 for high values of biomass.

Conclusion and perspectives

This study demonstrated that Sentinel-2 images provide quantitative information of the biomass status in Wallonia grasslands. The coupling of RS estimates with a grass growth model allows the obtaining of grass biomass information daily. Better calibration of models (RMSE <400kg) and an adapted coupling method between RS and ModVege will be tested using an enlarged data set.

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