Satellite-based estimation of herbage mass: comparison with destructive measurements and UAV model's estimation

Sutter M., Cornu M., Aebischer P. and Reidy B.
Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL, Switzerland

Abstract

Regular estimation of herbage mass (HM) is a prerequisite for efficient pasture management. In addition to classical estimation using rising plate meters, remote-sensing methods using unmanned aerial vehicles (UAV) or satellites are available. Pasture.io has developed a model that estimates HM based on daily satellite data, herbage growth models and herbage-ingested input data recorded by farmers combined with artificial intelligence. This study compared the accuracy of Pasture.io HM estimations with UAV estimations and destructive measurements. Pastures from three Swiss farms were assessed regularly in May, June and July 2021. It was found that Pasture.io estimates HM with an error value RMSE 342 kg dry matter (DM) ha^{-1} while the UAV model's estimation showed a higher RMSE of 447 kg DM ha^{-1}. The results suggest that even in small pasture structures (mean paddock size: 1.2 ha), it is possible to estimate HM with reasonable accuracy based on satellite data and artificial intelligence.

Keywords: grassland, artificial intelligence, pasture, spectroscopy, remote sensing, pasture-based agriculture

Introduction

Grasslands comprise a large part of the Swiss territory. Although some farmers use tools, such as rising plate meters (RPM) to estimate herbage mass (HM) for pasture management, there is still considerable potential for optimization. New technologies have brought new estimation methods, including aerial photos taken by unmanned aerial vehicles (UAV) (Sutter *et al.* 2021) or satellites. The Pasture.io platform already offers comprehensive support for pasture management worldwide, including daily satellite overflights of pasture areas and estimations of herbage growth and HM on pastures. These estimations are based on artificial intelligence. The platform therefore promises the next level of automation in pasture management. Our study aimed to test this tool under practical conditions on Swiss dairy farms and compare it to RPMs and UAVs.

Materials and methods

Four paddocks on three different dairy farms were studied in May, June and July 2021. The pastures were measured weekly with an RPM and Pasture.io estimated the HM using artificial intelligence. The input data for the Pasture.io model are satellite data, weather data and the amount of herbage grazed. Herbage growth curves from previous years and similar sites were provided to enable Pasture.io to estimate HM. The Pasture.io model corrects its HM estimations based on the amount of herbage ingested by the grazing animals. Therefore, each day the farmers recorded which paddock was grazed on the Pasture.io platform. Herbage intake was estimated by the platform based on the number of animals, their milk yield, and the supplementary feeding in the barn.

In addition to RPM measurements and Pasture.io estimations, the areas were flown over in the same period with a UAV, and the HM estimated using a random forest model as described in Sutter *et al.* (2021).

The two HM estimation methods were compared with field measurements. Five experimental plots per paddock were cut with a lawnmower to height of 5 cm over an area of at least 1 m^2 and the mown herbage was dried at 105 °C for 48 hours to calculate the dry mass per hectare. This was done at a random time during regrowth. The mean value of these five measurements was defined as the paddock's dry matter yield (DMY). A total of 54 DMY measurements was available for the study. Pasture.io HM estimations were also available for these areas. Due to the prevailing weather conditions, not all paddocks could be surveyed with the UAV before field measurements were taken. There were therefore only 27 UAV HM estimations.

Results and discussion

The DMY measurements obtained from the experimental plots ranged from 322 to 2,225 kg dry matter (DM) ha^{-1}. The root-mean-square error (RMSE) for the Pasture.io estimations was 342 kg DM ha^{-1}, corresponding to a normalised root-mean-square error (NRMSE) of 39% (Figure 1A). A similar approach by Askari *et al.* (2019) based on the Sentinel-2 satellite data resulted in a RMSE of 600 kg DM ha^{-1} or NRMSE of 32%, thus achieving comparable values to our Pasture.io results. However, unlike Pasture.io, Askari *et al.* (2019) did not use artificial intelligence and additional input data. Our study was limited to the three months mentioned. However, since the Pasture.io model works with input data and artificial intelligence, it improves with increasing input data. In order to capture this development, investigations over several years would be necessary.

Estimation by UAV resulted in an RMSE of 447 kg DM ha^{-1} (NRMSE = 48%; Figure 1B). The deviation of HM estimation by this method was thus substantially higher, as observed in previous trials (Sutter *et al.*, 2021). One possible explanation for the poorer performance of the model could be related to the botanical composition of the pastures. Most of the pastures consisted of semi-natural multi-species grassland, whereas the model was trained on pastures with fewer species. It is also noticeable that both the estimations by Pasture.io and with the UAV model show the greatest deviations from the measurements on 4 July (Figure 1, squares). It is a great challenge to define five representative locations within a pasture area of >1 ha for field measurements. Unlike field measurements, the two models always estimate HM based on data from the entire pasture area. It is therefore possible that the field measurements were not

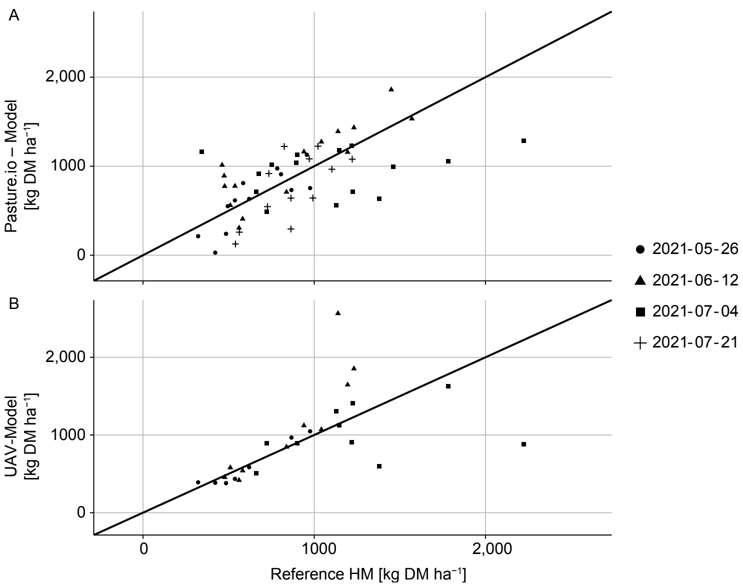

Figure 1. Comparison of the two herbage mass (HM) estimation methods with values measured in the field by cutting and weighing in May, June and July 2021 on pastures. The available HM was measured with a post-grazing height of 5 cm. (A) shows the estimation using the Pasture.io platform (n=54) and (B) shows the estimation using the UAV model (n=27).

representative enough for the whole area. Heterogeneity increases during exclusive grazing of areas within the pasture, which would support the hypothesis of a lack of representativeness in the field measurements.

Pasture.io was also compared to RPM measurements and both methods were found to estimate HM with similar RMSE (data not shown).

Conclusions

The average paddock size in the study was 1.2±0.46 ha. It thus seems possible to estimate HM adequately using satellite data, even on small farms as in Switzerland. However, further improvements of the Pasture.io model should be investigated within studies covering a more extended period.

References

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