How accurate is the Grasshopper® system in measuring dry matter quantity of Swiss and Danish grassland?

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Abstract

The interest in pasture-based dairy systems in Europe increases, as it is a cost-effective way to provide feed. The precise estimation of feed on pastures is complex and laborious. The Grasshopper® system promises a solution. It is a semi-automated rising plate meter to estimate herbage quantity of grasslands. The system measures compressed sward height and calculates the available dry matter (DM) ha^{-1} using a conversion equation. The herbage density differs among grassland usage, herbage composition and geographical regions. Therefore, we tested the Grasshopper® in Switzerland and Denmark and compared the herbage quantity estimations with laboratory results. We collected fresh herbage samples at four locations in Switzerland and at three locations in Denmark during summer and autumn 2018. The samples were oven-dried at 60 °C and the quantity of DM ha^{-1} was calculated. The results indicate a more correct herbage quantity estimation of the Grasshopper® with its original equation for Danish pastures compared to Swiss grassland. As a conclusion, we suggest implementing region-specific herbage density estimations and known seasonal quality changes for the Grasshopper®.

Keywords: Grasshopper®, rising plate meter, pasture management, real-time measurement

Introduction

The utilisation of the amount of feed on pastures can only be optimised if it is quantified properly. In many countries where pasture-based dairy production is not yet widespread or farms have site-specific limits of intensification, farmers usually estimate forage quantity by visual observation. This method is prone to error. Moreover, a big challenge is not only the sward height estimation but also the constantly changing forage quality within the vegetation period. Hence, to be able to manage pasture precisely, we need to automate herbage quantity and quality measurements in real-time in the field, at low costs and with management tools that support farmers' decision-making.

Sward height measurements are commonly performed using rising plate meters (RPM, e.g. Jenquip, Feilding, New Zealand) in high pasture, grassland-rich countries, such as New Zealand and Ireland, and are therefore considered to be the "method of choice". Subsequently, standard equations to convert compressed sward height measurements into feed quantity estimates are used. Previous studies have shown that the conversions may vary considerably between geographical regions and between seasons (Schori *et al.*, 2013; Defrance *et al.*, 2004). MacAdam & Hunt (2015) pointed out that the correct conversion is also affected by plant species growing on the pasture. The authors recommend using specific conversion factors for different species. This is not always applicable because grasslands often consist of mixtures of species. There is the possibility to create one's own conversion equation to determine dry matter quantity within a paddock that represents the farm or even field specific conditions. However, this method would be relatively complex and laborious for farmers. Furthermore, for intensive grazing systems, determining the allocated paddock size is of importance.

A further development of RPMs is the combination of herbage quantity linked to the georeferenced location of compressed sward height (CSH) measurements (Grasshopper®, G2 Sensor, TrueNorth Technologies, Shannon, Ireland). The Grasshopper® is able to predict the available feed and provides a paddock management tool on a mobile device, in combination with a cloud based database that allows farmers in field decision making. Additionally, the Grasshopper® acts as a decision support system by using its feed calculation tool to reset fences for grass allocation. In this regard, the system has to be reliable in estimating herbage quantity on pastures.

While McSweeney *et al.* (2018) found the ultra-sonic method of the Grasshopper® to be accurate in grass height measurement. There is very little research on the accuracy of herbage quantity estimations of the Grasshopper® system applicable for Swiss and Danish grasslands. Therefore, we evaluated the commercially available system.

Material and methods

Experimental design

Herbage was sampled at four locations in Central Switzerland with three replicates each at two observations, counting 24 in total. The same procedure was performed at three locations in Denmark with 20 observations in total during summer and autumn 2018. Due to a severe drought in Switzerland two observations are missing, leading to a total of 42 Grasshopper® observations (Table 1). The locations differed in altitude and herbage composition, considering that they represented permanent grassland and temporary ley in parts for Switzerland and permanent pastures for Denmark. All experimental plots in Switzerland were managed in order to simulate a grazing situation with an average pasture growth of two weeks.

In Denmark, the Grasshopper® measurements were performed on six fields with an area of 4.2–7.6 ha, whereas the experimental plots in Switzerland had an area of 2.2 m times 5 m. An unvegetated border of approximately 15 cm width surrounded these plots (Figure 1).

Sensor technology and usage

The Grasshopper® system is a partly automated RPM. It represents an RPM with a mounted sensor that recognises the distance of plate lift and is able to georeference each measurement with an integrated GNSS-receiver module. The sensor is connected to a mobile device via Bluetooth and visualises the measurements in the Grasshopper® App (Version 3.03).

Figure 1. The present study is part of a larger experiment in Switzerland. One of the experimental plots of interest is shown here (marked plot)

Table 1. Description of experimental sites, observations, and available Grasshopper® samples

Experimental site & country		Altitude (m, above sea level)	Observation date	No. of sampled plots / fields
Malters Tal	CH	470-480	18 Jul. 2018	3
			28 Aug. 2018	3
Malters Berg	CH	680-690	6 Aug.2018	1
			13 Sept. 2018	3
Schwarzenberg	CH	880-910	6 Aug. 2018	3
			13 Sept. 2018	3
Sigigen	CH	780-800	7 Aug. 2018	3
			14 Sept. 2018	3
Farm 40167	DK	25-100	29 Aug. 2018	1
			6 Sept. 2018	1
			12 Sept. 2018	2
			19 Sept. 2018	3
			26 Sept. 2018	2
			3 Oct. 2018	3
Farm 24029	DK	25-100	29 Aug. 2018	1
			6 Sept. 2018	2
			12 Sept. 2018	2
Farm 26279	DK	25-100	29 Aug. 2018	1
			6 Sept. 2018	1
			12 Sept. 2018	1

Using the Grasshopper® system, we measured the geolocation of each corner in order to map the experimental plot (Figure 1) and fields. Subsequently, we randomly took samples within each area using the Grasshopper®. The system asked to input dry matter (DM) content and a value for the post-grazing sward height residual. The pre-settings were defined as follows: 25% DM content and 50 mm post-grazing residual for Switzerland, and 17% DM content and zero mm post-grazing residual for Denmark.

During the sampling, the Grasshopper® App recorded CSH measurements in real-time and calculated the available feed quantity within the defined area (DM kg ha^{-1}). To evaluate the accuracy of the Grasshopper®, its estimates were compared to laboratory measurements that were based on cutting fresh herbage samples in the field.

Fresh herbage sample collection

From each Swiss experimental plot, one square metre was cut at 50 mm above ground. In Denmark, three quadrats of herbage were randomly cut in each field at 40 mm above ground and fresh weight was determined. Following this, the samples were oven-dried in the laboratory at 60 °C, weighed and the DM content as well as the DM ha^{-1} was calculated and assumed as gold standard method, referred to as laboratory measurements.

Data analysis

The herbage quantity determination in the laboratory were compared to the Grasshopper® estimations for Swiss and Danish grasslands. No conversion calibration was done for the system, because we wanted to detect the standard equation of the system. Therefore, the measured CSH were plotted against the estimated herbage quantity. Following this, the conversion equation was derived through regression analysis.

Results and discussion

The amount of herbage on Danish pastures was generally higher than in Switzerland. Figure 2 shows that the Grasshopper® detected these differences with its original conversion equation for estimating DM ha^{-1}. The system tended to overestimate herbage quantity on Swiss grasslands. This could be caused by differences in the herbage composition of both countries. Another reason is that for Denmark, laboratory samples were cut at 40 mm above ground but the post-grazing residual was set to zero mm, because pre-tests on Danish pastures showed that the pre-setting of zero mm of post-grazing residual resulted in best estimates for herbage quantity during September.

Further, the correlation between the Grasshopper® estimates for herbage quantity and the laboratory measurements indicate differing results. The Swiss data resulted in a Pearson correlation coefficient of $r = 0.57$ while the Danish data correlate with $r = 0.77$. According to Taylor (1990), such correlation coefficients can be interpreted as weak for Swiss data and moderate for Danish data. The Grasshopper® has a standard error of prediction (SEP) of 100.1 DM kg ha^{-1} for Swiss data and a slightly better SEP of 79.7 DM kg ha^{-1} for Danish data.

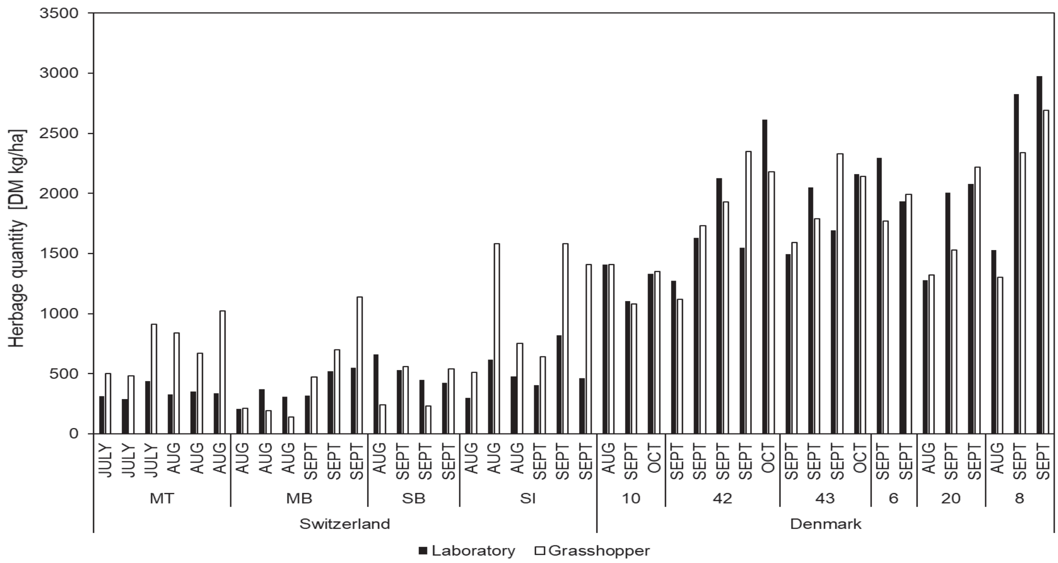

Figure 2. Comparison of dry matter quantity (DM kg ha^{-1}) on pastures estimated by Grasshopper® and measured by cutting and weighing, referred to as laboratory measurements. Field identifications are abbreviated as: Malters Tal, MT; Malters Berg, MB; Schwarzenberg, SB; Sigigen, SI; Farm 40167 includes Fields 10, 42 and 43; Farm 24029 includes Fields 6 and 20; Farm 26279 includes Field 8

Figure 3 shows compressed sward heights plotted against herbage quantity and the conversion equations that have been used by the Grasshopper® and the laboratory. The Grasshopper® conversion equations showed a linear relation and differed for Swiss and Danish conditions:

- $y = 38x - 1765$ for Switzerland (1)
- $y = 27x - 1017$ for Denmark (2)

where y is dry matter in kilograms per hectare and x is CSH in cm.

Contrarily, the laboratory measurements resulted in different equations to explain the relation between CSH and the actual amount of DM:

- $y = 5.9x + 59$ for Switzerland (3)
- $y = 24x – 628$ for Denmark (4)

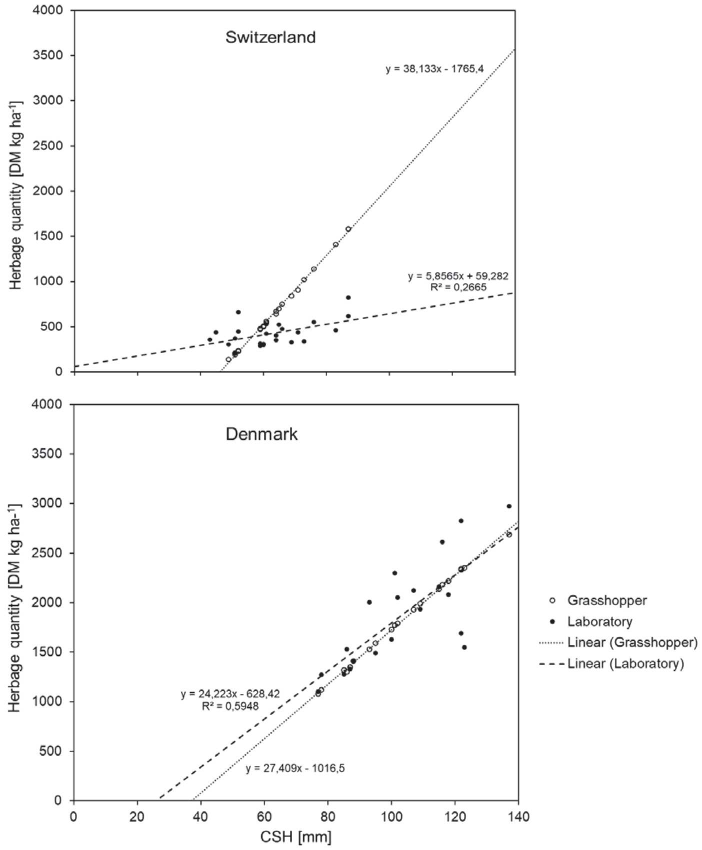

Figure 3. Compressed sward height (CSH) plotted against herbage quantity. The regression lines show the conversion equations used by the Grasshopper® system (dotted line) and the dashed line that explains the laboratory measurements

For Danish grasslands, the Grasshopper® estimate is close to the equation based on laboratory measurements. For Switzerland, where we measured lower sward heights, the estimation of herbage quantity differed strongly with the laboratory measurements. One reason may be that the Irish growth conditions, on which the Grasshopper® is based, are more similar to Danish conditions than to Swiss conditions. However, the conversion equations could also differ because of the pre-settings that we made in the Grasshopper® App before taking the measurements. The equations above are derived from the pre-setting of 25% and 17% DM content as well as 50 mm and 40 mm post-grazing residual for the Swiss and Danish data, respectively. We suggest analysing the data further in order to correct the defined value for DM content.

The findings demonstrate the need to adapt the DM quantity estimations for different regions. The accuracy of the Grasshopper® system may be better for taller swards or grass-rich locations. However, the analysis needs to account for different proportions of herbs and clover at different locations. In the field, users of the Grasshopper® should have the option to adapt the algorithm according to herbage density and herbage composition. For example, Skovsen *et al.* (2017) developed an App that detects the proportion of clover, grasses and herbs due to image analysis after taking a photo in the field. For Switzerland, Schori *et al*. (2013) developed equations to convert RPM measurements into herbage quantity depending on grassland usage and the proportion of herbs. In a next step, we should check if the conversion equations of Schori *et al*. are more accurate than the Grasshopper® equations in estimating herbage quantity. Additionally, the Grasshopper® has to be evaluated during spring and early summer.

Conclusions

The Grasshopper® estimated the DM quantity more accurately on Danish grasslands than on Swiss grasslands. For diverse Swiss grasslands the system is not yet sufficiently precise to rely on it for pasture allocation decisions. At this point, it cannot substitute for visual observations and experience of farmers to determine the available feed on pastures in regions with diverse species composition. In areas with more defined grass-rich species, the Grasshopper® has the benefit of being a rapid and user-friendly system.

Hence, there is considerable potential for the Grasshopper® in supporting pasture allocation and feed ration balancing if there is a possibility to combine it with farm-specific measurements, possibly with implementing clover and herb proportions of pastures and areas where feed losses have occurred.

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