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On field work operations of two smart tools that support decision-making in grazing management

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Abstract: *Optimising the feeding regime of livestock on pasture is an important topic and can be facilitated through the development of Precision Grazing Management tools. The focus lies on optimising yield and quality of pasture feed in return of saving costs on supplementary feed and labor. An established method to measure available feed on milking platforms is a georeferenced rising plate meter (RPM) that requires weekly farm walks across all paddocks. A new alternative is weekly grassland assessment with the help of unmanned aerial vehicles (UAV). They require an operator to program a flight grid and to analyse captured images downstream. This study modelled labor time requirements during the work operations on field of both methods. Therefore, a farm with a compact milking platform was simulated and compared to a farm with a milking platform consisting of three separate areas. Additionally, a grazing system with low and with high stocking density, meaning large versus small paddocks, was compared. The UAV method showed a lower labor input on field in all scenarios in the range of 15 to 80 minutes per measurement event compared to the RPM because preparation tasks needed to be performed only once before the flight mission. Contrarily, the RPM method demanded the operator to travel far distances across the paddocks and time for preparation before each new paddock, making it more suitable for grazing systems with few paddocks.*

Keywords: *labor time requirement, herbage measurement, rising plate meter, unmanned aerial vehicle*

Introduction

Agriculture is a profession with peak workloads occurring regularly. Especially during the vegetation period, the amount of work accumulates (Deming *et al.*, 2018) and time for regular monitoring, *e.g.* of animal health, plant health and growth can become scarce. Moreover, measuring available herbage is one of the three most time consuming grassland tasks in pasture-based dairy production besides slurry spreading and fertilizing (Deming *et al.*, 2018). As a result, many farmers did not yet firmly integrate it into their daily work routine although the benefits are remarkable. Thus, the market for automated monitoring solutions is growing. Many solutions have the potential to not only save working time and effort, but they can also help improving resource management in a profitable and sustainable way by supporting farmers in decision making. This is particularly important in grassland management. Although, the decision about when and how to use a grassland parcel is important for livestock farming, yet, the majority of farmers decide on the date for herbage cutting or grazing based on their subjective feeling and mostly only considering herbage quantity rather than quality. This can lead to a loss of quality in the silage produced or an inaccurate feed supply on pastures and as a consequence, to a loss of milk yield and high costs for feed concentrates (Ferraro *et al.*, 2012; Bell *et al.*, 2018). Nevertheless, there are smart tools to quantify feed availability on pasture. A minor number of farmers uses a rising plate meter (RPM); a tool to determine compressed sward height during weekly farm walks to objectify their decision. A new early phase method is the determination of available pasture feed by using unmanned aerial vehicles (UAVs). One possibility is that the UAV is mounted with a camera to capture multispectral images from 30 to 50 m above the grassland. Following this, the images can be analyzed for grassland characteristics, such as yield and crude protein concentration, via an online platform (www.grassq.com; Askari *et al.*, 2019). Both methods differ in physical and cognitive labor input. Furthermore, they vary in time requirement depending on the spatial structure of the milking platform which is the pasture area on a farm that is available for milk production via grazing dairy cows, as well as distances that need to be travelled on farm in order to perform the tasks.

The aim of this study was to compare two smart tools (RPM and UAV) regarding the working time requirement on field (excluding office tasks of the UAV method) in a grazing system with (i) two contrasting paddock sizes and (ii) two spatial distributions of the milking platform over the farm. The differences in work processes, required time, and skills when using the UAV and the RPM method as grassland assessment aids are discussed.

Method

Within this study, the work processes were modelled for the UAV and the RPM method in order to see general effects of travelling and preparation time on the overall required time on field. Therefore, two variants of fictional model farms were established. Elements of the work processes where the required time was unknown were investigated during field observations.

Modelling

In order to estimate the working time requirements a modelling approach based on the work element method (REFA, 1978) was used. For this method individual "work elements" will be defined and an associated "standard time" will be calculated. Subsequently, work processes can be modelled dynamically based on work elements, influencing factors, such as distances travelled, and a defined workflow model.

In a first step, the work processes and all corresponding work elements were identified for both, the RPM and the UAV method. The work processes were modelled using the model calculation system PROOF for forage production (last updated 2003, Agroscope, Taenikon, Switzerland, described in Riegel and Schick, 2005). A database containing over 3000 work elements that was obtained as a result of numerous studies on labor budget over the years formed the basis of the modelling process (Näf, 1996; Schick, 2005; Umstatter *et al.*, 2015).

Two grazing systems were modelled: ten small versus five large paddocks. Additionally, two model farm variants were compared: a compact and a spatially separated grazing platform. Figure 1 shows the model farms as schematic illustration and highlights the two variants of assumed spatial distribution of the milking platform covering 5 ha in each case.

In the following paragraph the modelling assumptions are described. The home points were assumed to be at the farm yard. This was the location where the UAV took off and landed. After a UAV took off it travelled to the targeted area of the milking platform where the programmed flight mission started. For this distance, a speed of 8.3 m/s was assumed. According to flight operators, the UAV generally needs to return to the home point for battery change after a flight duration of 20 min. For battery change a working time input of 1 min was assumed. For the operators, it was assumed that they do not use vehicles in both methods and walk all distances with a speed of 1.7 cmin per meter. This value originates from the work element database at Agroscope and is labelled as the work element "walking without load". The work element "actuating electric switch" with a required time of 2 cmin was used to model the procedure of taking an RPM sampling point in the field. As illustrated in Figure 1, it was assumed that the RPM operator sampled a paddock by walking in a W-pattern and taking 45 sampling points per paddock as recommended by the manufacturer.

The model estimations for time also depend on distances and paddock sizes. Table 1 presents the main influencing factors for modelling herbage measurements.

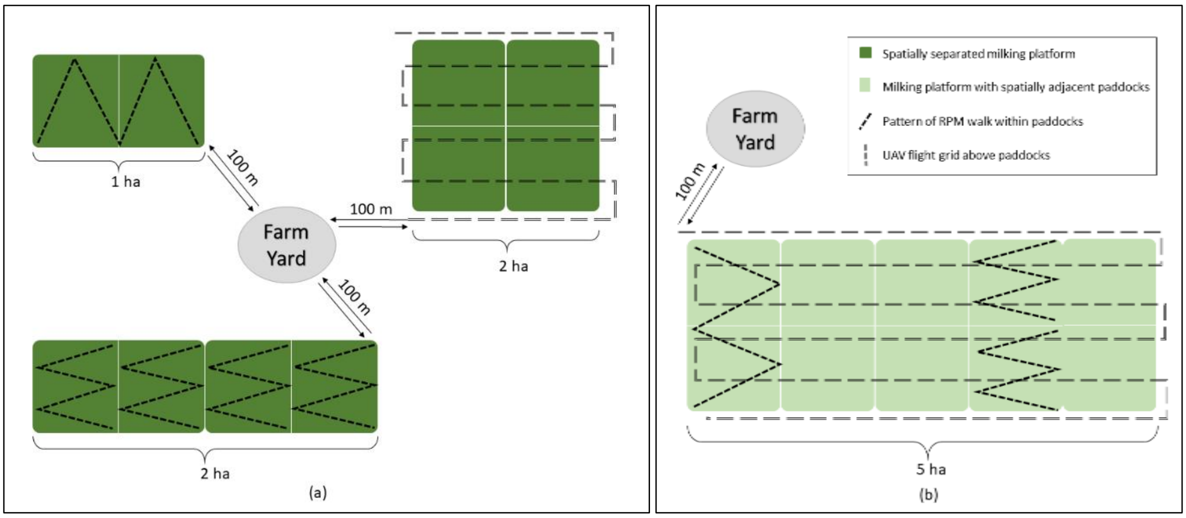

Figure 1. Schematic illustration of the model farm variants. *Dark and light green paddocks show the distribution of the milking platforms over the farm in two variants (a – spatially separated paddocks and b – adjacent paddocks). Unmanned aerial vehicle (UAV) flight and rising plate-meter (RPM) walk started at the farm yard.*

Adjacent milking platform area	5 ha
Spatially separated milking platform areas	1 ha 2 ha 2 ha
Number of paddocks within the overall milking platform	5 and 10
Paddock sizes	1 ha and 0.5 ha
Distance from farm yard to milking platform	100 m
Distance from paddock to paddock	10 m
Distance from operating person to home point of the UAV	6 m

Table 1. Main influencing factors for modelling.

The overall milking platform comprised five hectares in both variants of spatial distribution (adjacent or spatially separated). This area contained either five or ten paddocks which had a size of either 1 ha or 0.5 ha, hereafter referred to large and small paddocks, respectively.

Field observations

The work element database did not contain all work elements that were required for modelling the work processes of the RPM and the UAV methods. Especially work elements where the operator used smart devices or assembled the UAV were not recorded in the database because these tasks are not yet widely adopted on farms. In order to estimate the missing work elements, videos were taken during RPM farm walks and UAV flights in 2018 and 2019.

In total five RPM farm walks were observed. The farm walks were performed by two experienced operators with a semi-automated RPM (Grasshopper, G2 Sensor, TrueNorth Technologies, Shannon, Ireland) according to the manufacturer's recommendations. The size of each paddock was determined beforehand by walking along the fences and measuring the position of the corner posts with the GPS module of the RPM. This operation was not considered in this study, because it was performed only once a year and is not part of the regular work process of assessing grassland on a weekly basis.

In case of the UAV method, we took videos of six flights which were performed by two experienced operators. The UAV flight missions were performed 50 m above-ground by a quadcopter (DJI Phantom 4 Pro+, DJI, Shenzhen, China) equipped with a multispectral camera (Parrot Sequoia sensor, Parrot SA, Paris, France). The planning of flight missions took place via a smart device application in the field before take-off. Settings for the multispectral camera were entered in a second application on the smart device as there was no link developed yet for communication between the two applications. The flight speed during the capturing mission was set to 3 and 5 m/s and the UAV automatically adjusted it according to wind speed. The flight grid for image capturing depended on the targeted overlap of images (80%) and the flight height.

At present, the on-field work process of the UAV method yields only the captured images and does not provide the operator with measurement results in real-time. The UAV method, in its current development stage requires a follow-up work process to analyse the images in the farm office in order to get a feed quantity prediction. Within this study, only the on-field work processes on-site were considered, as it was assumed that rapid analyzing solutions will be available in the near future.

Based on the video material, work elements were identified and their working time requirement was measured. To do so the video analysis software Meza (Version 8.8, Drigus Systeme GmbH, Dortmund, Germany) was used, which offers time study preparation, execution and evaluation. A mean of the required time was noted for each work element measured and used for modelling.

Results

Table 2 shows all work elements that were identified within the work processes in the field. The mean required time, the so called standard time used for modelling is given. Preparation tasks from "installing UAV and supplies" until "starting UAV" as well as the finishing tasks such as "uninstalling UAV and supplies" took more time compared to the preparation and finishing tasks of the RPM method. These tasks and their standard time is only considered once within the model for the UAV work process. However, for the RPM method the operator repeats some elements each time he or she samples a new paddock, for example typing or choosing the name of the new paddock and the number of sampling points. Nevertheless, the required time for W-pattern walks across the paddocks stood out the most because it was performed per paddock and depended on paddock length and width.

The working time requirement modelled in manpower minutes (MPmin) for the on-field operation of measuring herbage is shown in Table 3. With the given flight speed of the UAV the required time for over-flying the same area was much lower compared to the RPM method. The results in Table 3 show that 14.5 to 79.7 MPmin were additionally required for using an RPM compared to a UAV for assessing a five-hectare milking platform. The size, and consequently the number of paddocks made no difference in working time requirement for the UAV method. However, the RPM work process took 48.5 and 30 MPmin per 5 hectares longer for ten small paddocks compared to five larger paddocks. Additionally, measuring paddocks that were spatially distributed over the farm on three areas, appeared to have a minor positive effect on required working time with the RPM method compared to measuring one spatially adjacent area (around 2-3 MPmin and 21 MPmin less). The UAV work process was found to require around 14 MPmin more for a milking platform that was spatially separated.

	Work element	Frequency of occurrence	Unit	Standard time (cmin) per unit
Rising plate meter (RPM):				
Determining paddock size	-		-	-
Herbage measurement in the field	Walking without load	recurring	m	1.7
	Turning on RPM	1 per adjacent area	Qty.	12.3
	Turning on smart device	1 per adjacent area	Qty.	64.0
	Setting up measurement in app on smart device*	1 per paddock	Qty.	82.3
	Plate calibration°	1 per adjacent area	Qty.	23.7
	Sampling RPM point	45 per paddock	Qty.	2.0
	Finishing sampling in app on smart device^{+}	1 per adjacent area	Qty.	32.8
Unmanned aerial vehicle (UAV):				
Determining paddock size	-		-	-
Herbage measurement in the field	Walking without load	recurring	m	1.7
	Installing UAV and supplies	1	Qty.	324.0
	Radiometric calibration of camera§	1	Qty.	122.6
	Setting up camera software on smart device$^{\#}$	1	Qty.	106.3
	Flight planning on smart device$^{\infty}$	1 per flight	Qty.	151.8
	Starting UAV	1 per flight	Qty.	136.0
	UAV take-off to 50 m flight height	1 per flight	Qty.	34.3
	UAV flight between home point and capturing area	1 per flight	m	0.2
	UAV capturing	1 per flight	ha	196.8
	UAV landing from 50 m flight height	1 per flight	Qty.	88.0
	UAV landing manually at runway	1 per flight	Qty.	19.5
	Battery change	1 $^{!}$	Qty.	100
	Uninstalling UAV and supplies	1	Qty.	205
Reading memory card	-		-	-
Image processing	-		-	-
Image analysis for grassland assessment	-		-	-

Table 2: Work elements of the operation "herbage measurement in the field" and their mean standard time per unit (n = 5 for RPM, n = 6 for UAV)*. Tasks in grey were not considered in this study; *typing/ choosing paddock name, entering an estimate for dry matter concentration of herbage, choosing the number of sampling points; °automated calibration for maximum distance from ultrasonic sensor to plate by lifting RPM off the ground; $^{+}$Confirming completion of sampling, checking measurement result, uploading data to platform; §initiating calibration process on smartphone application, lifting UAV off the ground, holding UAV above calibration target until calibration is completed; $^{\#}$entering image resolution, time laps between single shots; $^{\infty}$choosing flight grid, capturing area, flight speed, time-lapse between shots of internal camera; $^{!}$only if flight duration (time between take-off and landing) is ≥ 20 min; if so, a second flight is required;*

	One adjacent milking platform		Three spatially separated areas	
	Five large paddocks	**Ten small paddocks**	**Five large paddocks**	**Ten small paddocks**
Rising plate meter (RPM) (MPmin)	53.5	102.0	51.1	81.1
Unmanned aerial vehicle (UAV) (MPmin)	22.3	22.3	36.6	36.6
Differences (RPM-UAV) (MPmin)	31.2	79.7	14.5	44.5

***Table 3. Mean working time requirement in manpower minutes (MPmin) for measuring herbage once by using a rising plate meter (RPM) and an unmanned aerial vehicle (UAV) on a milking platform of five hectares.** The milking platform contained either spatially adjacent or separated paddocks and consisted of either paddocks of 1 ha (large) or 0.5 ha (small).*

The work element "walking without load" had a great impact on the required working time for the RPM method. This element came into effect when modelling the W-pattern walk across the paddocks while sampling RPM points and during travelling distances from farm yard to the milking platform and from paddock to paddock. Overall, travelling accounted for 27 to 29% of the total time required. Even more pronounced was the share of time for the W-pattern walk together with RPM point sampling which was 57 to 62%.

As a side-result, it was identified that a maximum area of nine hectares can be overflown before battery needs to be changed for this specific UAV with a flight height of 50 m, flight speed of 3 to 5 m/s in mission and 8.3 m/s travel speed.

Discussion

This study gives an overview of the working time requirement needed for introducing smart tools to measure herbage such as the RPM or the UAV approach.

Murphy *et al.* (2018) already determined the time requirement for the RPM tool. The sampling procedure took slightly less time (5.4-9.6 MPmin per hectare) as in this study but did not include the preparation and finishing tasks. The authors found that a lower sampling number reduces labor input. As sampling an RPM point takes slightly more time than walking without load (2.0 cmin versus 1.7 cmin, Table 2), our model supports these findings. On the other hand, Murphy *et al.* (2018) indicated that a lower sampling number would increase the estimation error of the tool and thus lead to profit loss. Which is why, for our model it was decided to stick to the manufacturers recommendation to use 45 sampling points per paddock. To our knowledge, for UAV flights above pastures, no comparable labor study was available.

This study showed, that a larger number of small paddocks did not affect the labor time requirement for a UAV flight, although it increases the requirement for an RPM farm walk. This might be explained by the relatively long task of “setting up measurement in app on smart device” which was performed each time before a new paddock was sampled. Therefore, in terms of labor input, the RPM is the preferred method for grazing management systems with longer allocation duration on large paddocks and low stocking densities. The findings by Gillespie *et al.* (2008) stating generally higher labor requirements in rotational compared to continuous grazing systems can be a result of the here described walking distance impact.

Contrarily, the paddock size does not affect the time needed in the field for applying the UAV approach, because independent of paddock sizes and location of fences the UAV captures the whole milking platform area. On the other hand, the analysis for single paddocks needs to be performed subsequently at an office work place. The required time for this will most probably increase with the number of paddocks, because the geolocation of each paddock has to be defined during the next steps of image analysis.

Travelling distances have an important impact on labor input. In this study, this was investigated in comparing milking platforms that consisted of spatially spread paddocks and adjacent paddocks. In case of the UAV method, it was found that the labor requirement was lower for the compact milking platform (Table 3), because additional time was needed to travel from the farm yard to the single areas of the milking platform. In case of the RPM method, a large share of the required time was needed for walking distances across and between paddocks. Therefore, required time for this method strongly depends on walking speed of operating personnel.

In general, our findings have shown that the UAV method has the potential to save labor. This can be explained to a large extent by the flight speed of the UAV and by the fact that, compared to the RPM method, the operation does not depend on human walking speed and endurance. As long as the UAV is visible to the operator he or she does not need to travel. However, although the task of monitoring the UAV does not seem sophisticated because automated flight missions are usually programmed in advance, it does require significant human attention and interaction (De la Torre *et al.*, 2016).

Despite of the promising results of the UAV method, it should be pointed out that at present additional time needs to be taken into account for battery changes in between capturing far afield or larger areas than the ones of this study. More importantly, additional time is required for downloading and processing the images in the office as well as analysing the resulting farm maps. While with the RPM method a decision can be made in nearly real-time in the field, for the UAV method a considerable part of the work is performed in the farm office until receiving the prediction results. Today, a one-day delay is expected for the decision making due to image processing. In addition, the predictive quality of decision-support platforms is still questionable. However, development is in progress and it is worthwhile to follow the future development.

The modelling study gave a good overview of the work processes of both smart farming tools. During the undertaking of the study, it was found that the work element method has its limitations for studying Smart Farming Applications. It is crucial for the work element method to define the start and end points of a work element. However, this is especially difficult for tasks performed on a smart device because the screen is not always visible as a result of sun reflection. In addition, the variation tends to be larger for work elements depending on technical functionality or environmental conditions, such as availability of GPS connection and wind strength such as the work elements “Starting UAV” and “UAV landing manually at runway”. However, for comparing different model scenarios, the method proved to be very useful.

Conclusion

The UAV method was found to require less time in the field compared to the easy-to-use RPM method. Moreover, the grazing system (five large versus ten small paddocks) had no impact in terms of labor input for the UAV method. Contrarily, for the RPM the walking time for traveling and sampling purposes affected the required working time strongly. In addition, the preparation tasks before sampling a new paddock also had a high impact on the labor requirements for the RPM. These tasks contained steps such as typing in or choosing the paddock name, entering an estimate for dry matter concentration of the biomass, and choosing the number of sampling points. This resulted in additional 14.5 MPmin at minimum for an RPM farm walk compared to the UAV method. In terms of labor-savings on field, the RPM method is more favourable for milking platforms with few paddocks. In general, the RPM method is physically more demanding, includes fewer working tools, and the technical principles are very intuitive to understand. In contrast, the UAV method requires more cognitive skills. For example the capabilities of operating the drone, the optical sensor, and the calibration skills. In addition, there are the subsequent image analysis activities. Further studies are needed to determine workload during these work processes and to identify approaches whereby these developments can simplify tasks and thus support technology adoption in practice.

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