Comparing forage biomass estimation between forager-mounted near infrared spectroscopy (NIRS) and rising plate-meter (RPM) techniques.

Jones, A. G.*; Irisarri, G.*; Takahashi, T.*; Rivero, M.J.*; Harris, P.*
*Net Zero and Resilient Farming, Rothamsted Research.

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Abstract

Quantifying the forage mass harvested per paddock is essential for informing late-season management decisions on grazing livestock farms. This information can be used to calculate winter feed budgets and thus support decisions such as area of land to defer for autumn grazing, and head of stock to sell before winter housing. However, there are practical limitations associated with existing measurement methods, which can influence the accuracy of forage biomass estimates. The purpose of the current study was therefore to compare biomass estimation from two alternative precision farming methods — near infrared spectroscopy (NIRS) integrated within-spout of a self-propelled forage harvester, against a rising plate meter (RPM). Data were collected from the North Wyke Farm Platform (NWFP) in South-West England. RPM readings were taken within seven days preceding harvest, and Harvester measurements taken at the point of harvest. Data from two paddocks were collected during 2021 (figure 2, points a and b) and two from 2020 (points c and d). Three of the sampled paddocks (a, c and d) contained permanent pasture and one (b) contained reseeded white clover and perennial ryegrass.

Paddocks c and d in figure 2 suggest a good correspondence between methods, demonstrated by proximity to the 1:1 line which passes through the origin. However, points a and b lie parallel to the 1:1 line, suggesting a systematic underestimation from the RPM. This underestimation could be linked to the tendency of grass to lodge at high yields, or due to an unquantified factor linked to the year of harvest, such as weather conditions which are known to indirectly influence RPM readings. With suitable calibration and consideration of practical limitations, forager mounted NIRS technology can provide valuable farm management data quickly, and at a relatively low cost compared to manual methods of biomass estimation.

Introduction

Key management decisions within grazing livestock systems, such as area of land to defer for autumn grazing, quantity of additional feed to purchase, or head of stock to sell before winter housing are reliant on knowing the forage mass harvested per paddock, as this information is key for calculating winter feed budgets (Oliveira et al., 2020). Accurate estimation of the quantity of forage harvested to be ensiled is thus essential, however many farming systems rely on visual estimates of herbage mass (HM) or less commonly through the weighing of silage trailers during harvest — estimates of silage quantity are therefore known to suffer from low accuracy (Stockdale, 1984). Alongside strongly fluctuating yields over time, sources of spatial HM estimation uncertainty on grasslands include the botanical composition of the pasture, where different species have different dry matter (DM) content and vertical structure, and overall pasture HM yield due to the tendency of grass to lodge (lie flat) at high yields. Recent decades have seen an increase in the interest and investment in precision farming (PF) techniques to estimate HM quickly and accurately, however there are practical limitations associated with many of the existing measurement methods and in particular the labour demand. To address this issue, use of a near infrared spectroscopy (NIRS) sensor array mounted within the spout of a self-propelled forage harvester (SPFH) was first evaluated by Digman and Shinners (2008), initially for the purpose of predicting DM, however it has since been adopted by multiple agricultural machinery manufacturers for measuring multiple parameters, including the yield of both grass and maize silage. Although this method is associated with a low labour input and is able to quickly provide accurate spatial information, previous studies have suggested that extreme conditions and sub-optimal species-specific calibration can have a substantial impact on the accuracy of yield predictions (Worek and Thurner, 2021). The purpose of the current study was therefore to investigate the suitability of using SPFH mounted NIRS (referred to as 'Harvester') for estimating mechanically harvested grass HM against the more conventional Rising Plate Meter (RPM) method.

Methods

Data were collected during the 2020 and 2021 growing seasons from the North Wyke Farm Platform (NWFP), a long-term cattle and sheep grazing experiment in South-West England (Figure 1; Orr et al., 2016). RPM sward height measurements were taken within seven days preceding harvest each year, using a Jenquip EC20 Bluetooth Electronic Platemeter (Figure 1), which were converted to HM using a calibration equation of HM = CSH(cm) x 140 + 500 (Klootwijk et al., 2019). Harvester measurements were taken at the point of harvest using a NIRS sensor array mounted within the spout of a SPFH. It should be noted that a misestimation of the slope and intercept of the calibration equation does not affect the correlation structure between RPM and Harvester readings, as this error can be corrected by linear transformation. Data from two paddocks were collected during the 2021 growing season (points *a* and *b* within Figure 1) and two from 2020 (points *c* and *d* within Figure 1). Three of the sampled paddocks (*a*, *c* and *d*) were a permanent pasture (PP) and predominantly composed (>60%) of perennial ryegrass (*Lolium perenne* L.), and one paddock (*b*) was a reseeded sward of white clover and perennial ryegrass (*Trifolium repens* L. & *L. perenne* L. - WCPR).

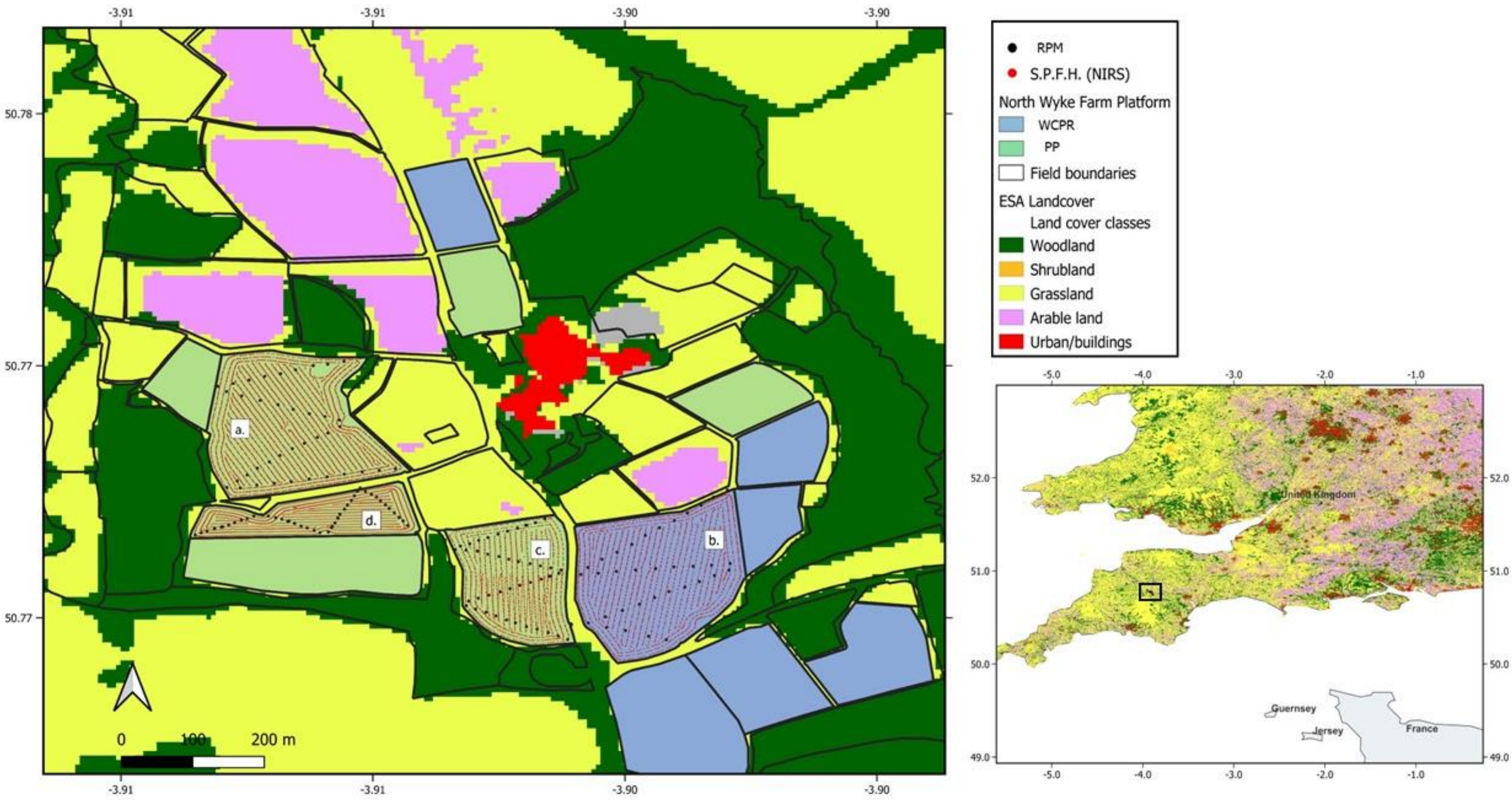

Figure 1. Maps showing regional location of the study site (right), and local position of sampled paddocks (left), alongside land-use classifications and sampling routes of both RPM (black) and Harvester (red).

Results and Discussion

The mean annual precipitation at the NWFP site was 1132 mm and 1059 mm for 2020 and 2021 respectively, with an average daily air temperature of 10.74 °C and 9.75 °C respectively. The paddocks dominated by perennial ryegrass (PP paddocks) with lower average yield values (from 2020) had a good correspondence between the RPM and SPFH methods, as demonstrated by proximity to the 1:1 line which passes through the origin (Figure 2, points c and d). However, on high-yielding PP paddocks there was an indication of a systematic underestimation from the RPM. This underestimation is likely to be linked to the tendency of grass to lodge at high yields, which impacts the accurate functioning of the RPM device (Murphy et al., 2021). For the WCPR paddock (point *b*), this underestimation is likely to be linked to the pasture species-specific calibration used for the RPM although, judging from the high level of variation amongst Harvester readings (vertical line for point *b*) the yield estimate from the Harvester may also be underestimated through the use of a generic equation intended for predominantly perennial ryegrass swards (Murphy et al., 2021; Worek and Thurner, 2021). Alternatively, as paddocks *a* and *b* were both measured during the 2021 grazing season, the reduced correspondence between methods could be due to unquantified and confounding factors affecting RPM readings which are known to show variability across years (Michell, 1982). Weather conditions and sward reproductive development stage are the most notable of these potential factors, as they can influence the relative proportions of leaf, stem and dead material within the sward, and thus the density of DM in any given area (Nakagami and Itano, 2014; Klootwijk et al., 2019).

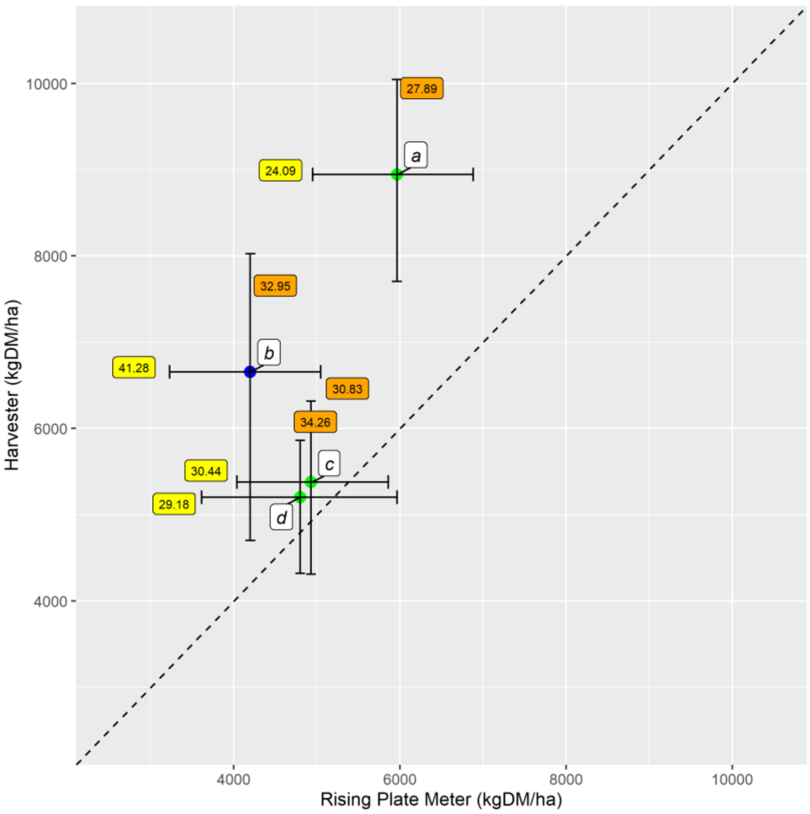

Figure 2. Average estimated biomass on four paddocks, using Harvester and RPM. Paddocks *a* and *b* sampled in 2021 and paddocks *c* and *d* were sampled in 2020. Error bars denote interquartile range, coloured labels describe coefficient of variation for each paddock— orange for RPM, and yellow for Harvester.

Conclusions

With suitable calibration, forager mounted NIRS technology can provide a high level of valuable farm management data quickly, and at a comparably low labour requirement when compared to manual methods of biomass estimation. Although the initial outlay for the farm is greater, this makes the technology a more attractive option, especially under conditions where lower-cost technologies are known to provide less accurate estimates. As with the case with any adoption study, challenges remain on quantifying the trade-off between the cost of data collection and the economic value of accuracy (and precision) of forage biomass estimation, as this requires additional knowledge regarding the cost and efficacy of real-time, data-driven interventions (Jones et al., 2021). Nevertheless, the present study provides an initial insight which will be refined and updated via the on-going collection of the NIRS-RPM data at the experimental site, alongside the use of drone and satellite spectral data for concurrently estimating forage biomass.

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