Grass Cover Estimation for Precision Grazing Systems

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BACKGROUND - AVAILABLE TECHNOLOGY

Technologies for monitoring grass growth and yields in grazing systems

In rotational grazing systems the accurate estimation of grass covers is crucial to ensuring the grazing offered is sufficient to meet animal demands, whilst also maximising pasture utilisation and grazing efficiency. Farms employing routine grass measuring are associated with higher total grass productivity from their grazing platforms (Figure 1).

Despite this, only a small percentage (13.5%) of dairy farmers in NI regularly measure their grazing pasture covers (McConnell et al., 2020), and a key barrier to increasing the adoption of regular measuring has been identified as the perceived time and labour requirement to do so.

Current common measurement methods

The 'gold-standard' technique for measuring grass covers is to clip a sample from a known area to weigh, dry and re-weigh to get an exact figure for the amount of dry matter (DM) available. By taking multiple clips across a paddock an average estimate of the DM cover can be generated (3-5 clips would be the very minimum recommended for estimation across a 1-day paddock). However, this is a time-consuming process and a destructive sampling method making it less than ideal for frequent routine measurements, and significant variability in covers across some paddocks can mean that a well calibrated rising platemeter with a far higher number of readings taken will actually give a more accurate result at the paddock scale.

Rising plate meters were developed over 40 years ago, and reliable calibration equations have been developed to suit a number of sward types and climates in order to convert the 'compressed sward height' measurement taken by the platemeter into an estimation of the biomass cover. For swards in Northern Ireland the equation:
'Pasture cover (kg DM/ha) = Compressed Sward Height (cm) x 124 + 608'
has previously been optimised for grass and grass clover swards at AFBI Hillsborough (Dale, 2010).

A major drawback to both these approaches is the time required to conduct a walk of all the grazing paddocks to collect data, and then the time for accurate data recording (McConnell et al., 2020). This reportedly, and understandably, puts a lot of farmers off regular grass measuring. Unfortunately this is despite the clear benefits to be achieved in terms of maximising grassland productivity and grass quality when optimal grazing management strategies are implemented (McCarthy et al., 2016) and through the use of regular measuring and monitoring (Figure 1).

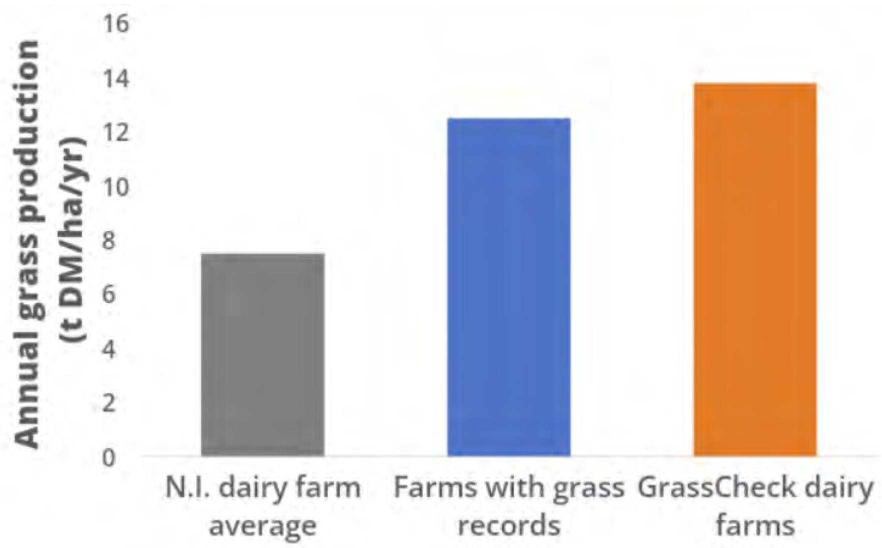

Figure 1: Grassland productivity on NI dairy farms as influenced by degree of recording

Many experienced grassland managers will 'eyeball' covers, but this approach is prone to larger errors and regularly checking these assessments against a platemeter or cut & weigh measure is always worthwhile.

New technologies for grass measurement

A research project with experiments carried out at AFBI Hillsborough between 2018 and 2021 aimed to evaluate some of the new and emerging precision tools and technologies for measuring grass covers on grazing pastures, whilst requiring a lesser time commitment than those traditional approaches. These new techniques have been proposed to also provide more precise data to inform grassland management decisions in greater detail. These tools range in their current costs and stage of development, but have all shown promise in previous research studies.

GROUND-BASED TECHNOLOGIES

Smart platemeter

The Grasshopper platemeter which uses micro-sonic measurements to determine a compressed sward height value. The GrassHopper is GPS enabled and can automatically detect the paddock being measured once all the fields have been mapped within the GrassHopper App. The bluetooth connectivity sends readings straight to a mobile phone or tablet, and from there results can be uploaded to the linked pasture management software and a current grazing wedge is automatically created.

Figure 2: Grasshopper rising plate meter

Other smart platemeters such as the Jenquip EC20 are available, that use the traditional height measurement but are also GPS and Bluetooth enabled to speed up and simplify data collection, with automatic uploads to your pasture management software and generation of the current grazing wedge whilst you complete the farm walk.

C-Dax trailed pasture meter

This kit uses a different approach to measuring the amount of biomass present in a pasture. As can be seen in the picture (Figure 2), the trailed pasture meter hitches to a quad bike or ATV to be towed around grazing paddocks, taking continual readings of the standing height of the sward which passes through the centre of the unit. This measurement is taken as the grass passes through laser beams at 0.5 cm height intervals spanning the centre of the pasture meter unit.

Figure 3: C-Dax trailed pasture meter

REMOTE SENSING MEASUREMENTS

The Normalized Difference Vegetation Index (NDVI) is calculated by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs) using the following equation:
NDVI = (NIR-Red)/(NIR + Red).

Generated values may range from -1 to +1, with higher values associated with healthy vegetation because of the high absorbance of red light and reflectance of near-infrared light by chlorophyll.

The Green Normalized Difference Vegetation Index (GNDVI) is generated in the same way but uses visible green light instead of visible red and near infrared. Both NDVI and GNDVI have previously been used in pasture biomass estimation (Poley and McDermid, 2020). Two approaches were tested involving remote sensing via cameras mounted on an unmanned ariel vehicle (UAV/drone) which utilised the NDVI and GNDVI from plot and paddock-scale studies. Satellite-based remote sensing utilised a proprietary equation involving reflectance data.

DJI P4M UAV with network RTK and Pix4Dfields

The DJI P4M (phantom4 multispectral) drone was launched in late 2019 and combines a multispectral camera with in-built light sensor and a highly accurate positioning system (real-time kinematic positioning, RTK) allowing it to carry out repeatable missions and collect images from the same areas for comparison between different flights. Pix4Dfields software was used to generate orthomosaics, processing for radiometric calibration using the light sensor data and calculating the NDVI and GNDVI values ready for export into a spreadsheet for analysis. The performance of the radiometric calibration step means that images from different flights on different dates could be reliably compared, even when completed in very different light levels, eg: bright sunshine compared to an overcast day.

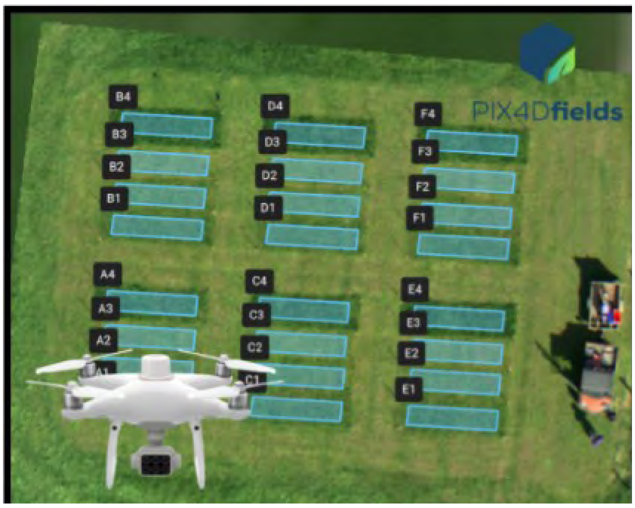

Figure 4: Paddock layout for UAV

Figure 5: Drone image of plot trials

MiGrass satellite estimations

Satellite-based estimations of grass covers were obtained from the 'MiGrass' function within the Precision Decisions online portal (Precision Decisions, UK) for a paddock study at AFBI Hillsborough and from a number of participating GrassCheck farms during 2019 and 2020. Grass covers are calculated within the MiGrass platform using a proprietary equation based on different multispectral reflectance values and is owned by Precision Decisions.

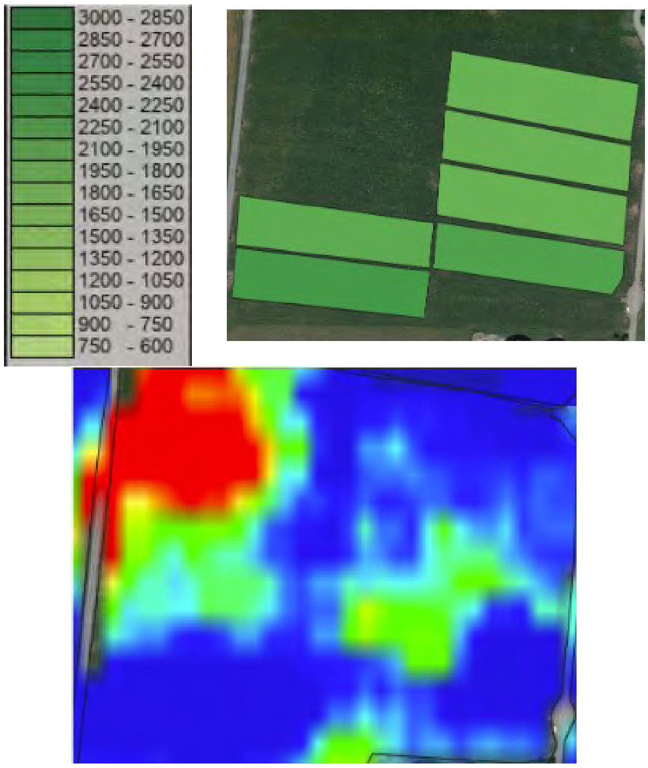

Figure 6+7: MiGrass satellite measurements

Experiments carried out

All trials were undertaken at the Agri-Food and Bioscience Institute (AFBI) research farm, Hillsborough, Northern Ireland. Two sets of plot experiments were carried out to assess all but the satellite remote sensing estimates, as the resolution achievable makes these only utilisable in trials at the paddock or field scale.

In the first plot experiment in the autumn of 2018, a total of 192 plots were established to capture 4 different grass growth stages (7, 14, 21, and 28 days regrowth after cutting) in six replicate blocks. Plots were established on a predominantly (>80%) perennial ryegrass (Lolium perenne) pasture. Initial cutting dates were staggered to ensure all 4 stages of regrowth were cut simultaneously to mitigate against any effect of varying grass dry matter (DM), weather conditions or light levels on the date of measurement.

- Aerial images were collected by a DJI Phantom 4 UAV equipped with a Sentera High-Precision NDVI Single Sensor camera (Sentera, MN, USA), at a flying height of 25m. Sentera Field Agent software generated NDVI values for individual plots/paddocks.

- Each plot was then measured with a single lengthways pass at 5-20 km/h (the manufacturers defined operating speed bracket) with the C-Dax trailed pasturemeter.

- A total of 30 platemeter drops were recorded, as per industry recommendations, using a standard rising platemeter (Jenquip EC09) with a ratchet counter and a previously optimised conversion equation (Grass Cover = CSH (cm) x 124)+608) was used to generate kg DM/ha readings (Dale, 2010).

- With the GrassHopper rising platemeter software, grass DM for the calculation of herbage biomass was set as a default of 17%, and once each plot location had been mapped into the software, a total of 30 drops were recorded across each plot, as with the standard platemeter.

- Total plot yields were calculated from the fresh herbage mass >4 cm, and oven DM% of plot sub-samples. Herbage biomass <4 cm in height was assumed to be 1500 kg DM/ha.

Data collection at the paddock scale was conducted weekly in late summer 2019 from 6 x 0.4 ha paddocks (33.5 x 120 m). Measurements were taken as above, but with 6 x lengthways passes made of each paddock with the C-Dax trailed pasturemeter, and the C&W approach was adapted to use three 0.5 m2 quadrat clips per paddock, with DM calculated for each clip to obtain an estimate of average paddock kg DM ha-1.

Satellite-based estimations of herbage biomass from the 'MiGrass' function within the Precision Decisions online portal (Precision Decisions, UK) were included with paddock measurements. Paddocks were grazed to a target post-grazing residual of 1700 kg DM/ha by lactating dairy cows 10 days prior to week 1 of data collection, and 0-2 days after week 2 and week 5 measurements.

For week 5, no MiGrass data was available for comparison due to cloud cover. All UAV imagery was taken at approximately midday, and prior to all other measurements to ensure images were of an untouched sward. Data was analysed to compare measurements to ground-truth data.

Figure 8: Trial plots at AFBI Hillsborough

In the second plot experiment, a total of 24 trial plots were established in March 2021 on a perennial ryegrass pasture at the Agri-Food and Bioscience Institute (AFBI) research farm, Hillsborough, Northern Ireland. Plots were established in 6 replicate blocks of 4. Initially, all plots were cut to a standard residual of approximately 1200 kg DM/ha using an Agria mower with the cutting bar height at 4 cm. Each following week for 3 weeks one plot in each of the 4 replicate blocks was cut using the same equipment so that four weeks after the initial trim, each replicate block of plots had a plot with 7, 14, 21 and 28 days of grass regrowth.

This was designed to be representative of covers within a rotational grazing system. Four weeks from the initial trim, the plot area was overflown with a DJI P4M drone (DJI, China) equipped with RTK positioning, an inbuilt spectral sunlight sensor and a multispectral camera. The camera pitch was 90°, and flights were conducted at a 25m height. The RTK positioning data was obtained through a network-RTK link using the Ordnance Survey of Northern Ireland RTK network. Immediately after plot images had been collected, eight platemeter measures were taken of the biomass cover on each plot using a Jenquip EC10 platemeter, before each plot was cut using the Agria mower and fresh biomass yields recorded.

A subsample of the fresh biomass was collected from each individual plot and oven-dried at 60°C for 48 hours to determine the dry matter (DM) content of the pasture, and subsequently calculate the DM yield at cutting. Following plot cutting, a further 8 platemeter measures were taken of each plot to estimate the post-cutting cover. This process was then repeated for 6 consecutive monthly harvests from April-September 2021 at 28-day intervals, with the exception of the August harvest which was delayed by 7 days (14, 21, 28 and 35 days regrowth) due to adverse weather conditions preventing a UAV flight for image capture.

The multispectral images captured during each flight were processed and orthomosaics generated using the Pix4DFields software package (Pix4D, Switzerland). Radiometric calibration was automatically performed using in-flight data captured by the spectral sunlight sensor. NDVI and GNDVI indices generated using Pix4DFields were compared to the total biomass yields (corrected for the platemeter estimated post-cut residual) recorded at each harvest. The relationship between plot DM yields and both the NDVI and GNDVI average values was modelled via a non-linear regression analysis.

Results

In 2018, harvested plot yields ranged from 1598-2740 kg DM ha-1, and in 2019 paddock estimates ranged from 1282-3081 kg DM ha-1, as determined by C&W. In the 2021 plot study harvested plot yields in this experiment ranged from 1072 to 3696 kg DM/ha, again representative of biomass covers found in rotational grazing systems.

All of the technologies evaluated showed some level of positive correlation with the actual plot yields or C&W paddock cover estimates, though with varying levels of accuracy. These are summarised in Table 1.

In these studies, none of the technologies tested could out-perform the already well-known platemeter technology for accuracy of grass cover estimations, with both platemeters recording up grass covers with 79% accuracy compared to the control yields measured.

The correlation between the UAV-obtained vegetation indices and grass covers up to around 2000 kg DM/ha, but saturation effects in the measured reflectance values highlight a key limitation of this approach for use across grazing platforms (Figure 2).

Table 1: Correlation of grass measurement equipment yield estimates compared to actual plot yields

Equipment	Highest correlation
GrassHopper Platemeter	79%
C-Dax trailed pasturemeter	63%
NDVI	68%
GNDVI	69%
Standard plate meter	79%
MiGrass satellite measure	48%

The trailed pasturemeter also gave a respectable correlation of 63%, but this is still significantly lower than that obtained from the platemeters, and the bespoke equation generated in this project mould need further validation for use across NI farms, as the manufacturer provided equations based on NZ swards where the equipment was developed. These equations did not prove accurate for swards at AFBI Hillsborough.

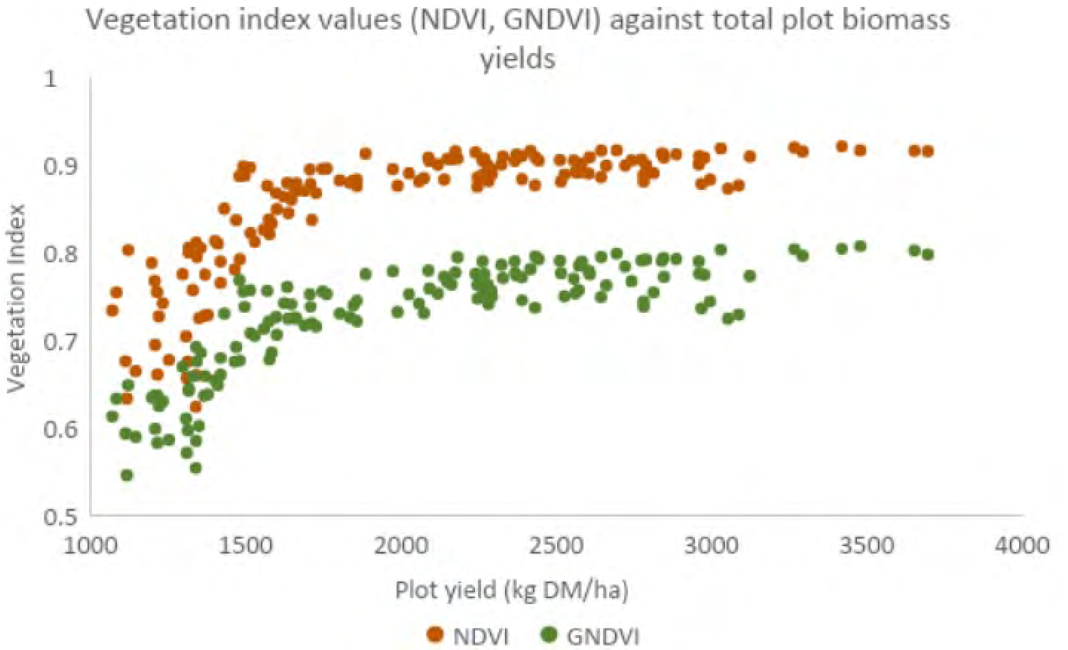

Figure 9: Vegetation index values (NDVI and GNDVI) plotted against the recorded total plot biomass yield.

With the wide variation in accuracy and the application of each of these different approaches, the main advantages and drawbacks of each are summarised in Table 2. For all of these methods of pasture cover estimation consistency and repeatability are key.

- When using a rising platemeter a minimum of 30-50 'plonks' are needed per paddock to get a reliable reading, but ensuring the same route is walked each time, with readings being taken every couple of steps (there is no maximum limit on the number of readings that can be taken) will produce the best estimation.

- With the trailed pasture meter then following the same route would also be advised to maximise the repeatability of herbage estimates for each paddock.

- Accurate mapping of paddock boundaries at the start of the season, with the exclusion of the immediate areas around drinkers/gates and any hedges or trees are key to getting the best measurement from remote sensing technologies (UAV or satellite-based).

- With UAV systems, real-time-kinematic positioning can now offer cm-level accuracy for drone positioning, meaning that flight data can be compared without the need for as much adjustment during processing, and radiometric sensors can calibrate the sunlight levels during each flight, meaning the VI values produced can be compared between flights conducted in differing light levels (eg: cloudy or sunny days).

Table 2: Evaluation of a range of equipment available for grass measurement

Grass Measurement Technology	Advantages	Drawbacks	Current readiness (2022)
GrassHopper Platemeter	GPS location to auto-recognise paddocks being measured Data upload from mobile to cloud and in-field view of covers and grass wedge Paddock mapping with plate meter	Some confidence with mobile technology required More costly than other (less high-tech) plate meter systems Specific management software required	On market
C-Dax trailed pasture meter	Operating speed 5-20 km/h, faster than walking. Automated data-upload and generation of grass wedge	Purchase of specialist software required, and investment in equipment Ground must be trafficable with an ATV Equations for UK/ROI swards require further validation.	On market, no UK/ROI distributors at present

Grass Measurement technology	Advantages	Disadvantages	Current readiness (2022)
UAV-mounted multispectral camera imaging to generate NDVI and GNDVI vegetation indices	Large areas covered in single flight Visualisation of sward heterogeneity Data collection can be automated	Operation must comply with latest CAA drone pilot laws, registration and certification required Reflectance saturation from higher covers (>2000 kg DM/ha) reduces accuracy Weather conditions limit opportunities for data collection – currently drones cannot operate in high winds or any rain. Radiometric calibration and highly accurate positioning (RTK) required for repeatability of flights and comparison of data between different dates.	Technology on market, but costly at present. Data analysis software is available but no current product offers automated conversion of VI values to herbage biomass, and specialist interpretation and data processing is required.
Standard plate meter	Established, reliable method	Time consuming to manually record data	Multiple options on market, including 'smart' options comparable to the GrassHopper but compatible with different pasture management software packages.
MiGrass satellite measure	Fully automated, with pre-processed data available online	Data availability limited by dates and times of satellite passes: daylight hours and cloud-free days required Challenging to tie-in with grazing events Lowest level of accuracy when tested within this project	On market

Conclusions

Different vegetation indices obtained with unmanned aerial vehicles (UAVs) and multispectral cameras have shown strong correlations with pasture biomass in some studies. However, complex photogrammetry processing and the saturation of reflectance from the dense grazing swards generated through good grassland management remain a barrier to the utilisation of this technology on-farm. In practical terms, whilst these approaches show some promise, further development is required before they will be available as commercial packages. Whilst the process of image collection with a UAV may be speedier than platemetering paddock, associated issues such as licencing and training requirements, planning and subsequent image processing do not currently seem to offer the significant time savings which are desired.

The GrassHopper smart platemeter trialled did the job of recording grass covers equally well to the older style traditional platemeter, whilst making data recording and interpretation much simpler and faster through the automated upload and processing. Interpreting automatically processed data from the trailed pasture meter was equally straightforward, and the operation via ATV offers an attractive alternative to using a platemeter, although accuracy remains a concern and the equipment requires a greater cost outlay.

Satellite-derived estimations of grass cover were rapid and easy to obtain, although cloud cover and the irregularity of satellite passes was limiting for data collection. The overall accuracy of the satellite platform tested was low in this trial, but this was highly variable within the study.

With coming improvements to allow data collection regardless of cloud cover, and combined with ground-truthed measurements on a proportion of the grazing platform these remote sensing estimates may well offer more rapid access to grass cover estimate for farmers, with a number of commercial packages currently available to purchase.

Smart plate meters are able to provide the best data accuracy currently but can be more time consuming than other options. Use of CDax measurement equipment provides relatively accurate data but is pricey compared to other options. Drone and satellite tech still needs further development, and drones in particular may be limited but reflectance saturation.

Summary

Grass measuring and close attention to grazing management is clearly worthwhile! Evidence from numerous studies including the GrassCheck project in NI indicates grassland productivity is higher in rotational systems where routine measuring and adaptable management is adopted, and improvements in grass quality can also be achieved relative to continuous grazing or set-stocked systems.

Therefore, if time and labour availability limit options for grass measuring across the whole grazing platform, farmers may still consider measuring a subset of paddocks. Investment in smart plate meter technologies is likely to be beneficial to make this as quick and easy as possible.

Advances in remote sensing technologies should in future improve the accuracy and utilisation of these approaches, but they will require a combined approach with regular ground-truthing.

For tips on successful platemetering, cut & weigh sampling and information on available calculators to help you make the most of your grazing see the appendices for more details.

Appendices

Cut and weigh protocol

Cut-and-weigh can be an accurate way to assess herbage mass in grass paddocks and can be used when grass covers are high (eg: silage fields) as covers over 4000/4500 kg DM/ha can't be measured accurately using a plate meter.

To calculate grass covers using a cut-and-weigh approach use the following protocol:

- Place a 0.5 m x 0.5 m quadrat (this can be a square made of wood/wire/plastic piping/etc in 0.5 m lengths) on an area that is representative of the grass cover across the field. Do this at a minimum of 3 locations across the field. More cuts = greater accuracy.

- Other sizes of quadrat can be used. The quadrat size affects the 'number of quadrats per hectare' figure that is used as a multiplier in the equation below, so make sure to adjust this if you use a different quadrat size.

Quadrat size	Number of quadrats per hectare
0.25 m x 0.25 m ($0.0625\ m^2$)	160,000
Circle, 36 cm diameter ($0.1\ m^2$)	100,000
0.25 m x 0.5 m ($0.125\ m^2$)	80,000

Figure 10: Number of quadrats per hectare for a range of quadrat sizes

- Where grass overlaps the edge of the quadrat try to pull through to the inside any leaves from tillers rooted inside the quadrat, and pull out any leaves from tillers rooted outside of the quadrat.

- Knock the water off wet grass and using shears cut all the grass within the quadrat to the target grazing or cutting height (recommended around 4 cm, 1500 kg DM/ha).

- Collect all cut grass into a pre-weighed bag.
- The following equation is used to calculate the DM yield in the paddock:

Weight of grass (kg) x grass DM% x 40,000 = kg available DM/ha in the paddock

Example: Grass cut within the quadrat weighs 200g (0.200 kg) (Remember to subtract the weight of the empty bag), and grass DM% = 16% (0.16) (See below for how to calculate DM%)

0.200 kg x 0.16 x 40,000 (there are 40,000 quadrats in a hectare) = 1280 kg DM/ha grass yield available above the grazing/cutting target.

1280 + 1500 kg DM/ha = 2780 kg DM/ha total grass cover.

Calculating grass DM%

To get an accurate measurement it is important to get the DM% used in the calculation equation as accurate as possible. You can use an estimate of grass DM%, but it is better to use the DM value from a very recent grass quality analysis from this field, or preferably to dry a portion of the grass sample to calculate its DM as follows:

- Place a microwaveable container/bag onto kitchen scales and tare/'zero' them
- Mix the grass cuttings well and take a small handful from the sample bag
- Place this handful into the microwaveable container/bag on the scales and record the weight (weight 1)
- Set the microwave timer for 1 minute and microwave the container + sample
- Remove the sample and bag/container from the microwave and place back on the scales without adjusting them, and record the weight (weight 2)

- MIX THE SAMPLE (important to avoid burning in the middle) and repeat until the ‘weight 2’ remains constant for two readings. Use this weight in the calculation below:
- Dry matter % = weight 2 (dry) / weight 1 (fresh) x 100
- Use the calculated DM% in the grass yield calculation as a decimal value (in green on page X)

Value of Grass

- Grass remains the cheapest feed available for beef, dairy and sheep in NI and GB
- Significant potential to increase grass land performance on farms.

- Estimated typical utilised grass yields: **4.5-7.5 t DM/ha/year**

- GrassCheck plots 20+ yr average = **11.6 t DM/ha/year**

- GrassCheckNI farms 2019-2021 average = **12.2 t DM/ha/year**

- 1 tonne extra grass dry matter utilised = **margin +£204 - £334/ha** (Mayne, 2016)


Grasshopper

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