Project Report: RCF Precision Grazing

GrassCheck 2018 - Grass growth and quality monitoring

June 2019

Report prepared by:

Eamonn Meehan, Debbie McConnell and Kathryn Huson

Agri-Food and Biosciences Institute, Agriculture Branch, Hillsborough, County Down, Northern Ireland BT26 6DR

Introduction

Grass production is central to the Northern Ireland (NI) agricultural economy and measurement of its production and quality throughout the growing season are fundamental to our understanding and optimal management of this resource. Since 1999, grass growth has been monitored over the duration of the grazing season at AFBI, Hillsborough and CAFRE, Greenmount and more recently a larger number of sites across NI as part of the GrassCheck project. This has provided a consistent, representative measurement of grass growth during the growing season for the past two decades.

It has been estimated that an additional profit of £334/ha/year could be achieved on NI dairy farms by improving grass utilisation by one tonne dry matter per hectare (t DM/ha; DAERA, 2016). Currently, performance of managed grasslands in NI remains sub-optimal with an estimated 7.5t DM/ha utilised on dairy farms, significantly behind levels achievable by modern day grass varieties (>12 t DM/ha; DAERA, 2016). Grass utilisation is dependent on grass production which in turn is dependent on a number of factors including location, weather, soil, sward management and grazing management. While the potential for grass production is influenced by some of these factors which are beyond the farmer's control, other limiting factors can be optimised (Table 1).

The absence of regular, robust measurement of growth rates and quality makes it difficult to improve grass growth and utilisation. The Sustainable Agricultural Land Management Strategy for NI (2016) has called for an increase in the uptake of 'sward assessment and grass utilisation measurement and recording' on grassland farms as one mechanism by which improvements in grass utilisation can be achieved. Within the UK, centralised data on grass growth and quality remain extremely limited, with few data sources. This continues to be a significant concern given the importance of grazed and ensiled grass in our livestock production systems.

Recording of sward measurements on NI grassland farms has been identified as one mechanism by which improvements in grass utilisation can be achieved. GrassCheck objectives addressed this by monitoring grass growth rates and grass quality in the 2018 growing season via plate meters at farm locations throughout NI in addition to the cut plots at CAFRE, Greenmount and AFBI, Hillsborough. The CAFRE and AFBI data were used to develop and publish weekly grass growth rate forecasts for the following 7-day and 14-day periods using the GrassCheck model.

This project has sought not only to provide robust grass growth and quality data to support grass growth rate forecasting but also to understand the variation in grass growing conditions across NI and encourage uptake of grassland measurement practices through publication of commercial farm data. The project was composed of two work packages (WP) where WP1 continues to provide data from AFBI-Hillsborough and CAFRE-Greenmount and WP 2 provides data from a wide range of farms across NI. Weekly grass growth and quality, both from the experimental plots (WP1) and the commercial farms (WP2) were included in the weekly farming press report. In addition to the 12 commercial dairy farms participating during the 2017 season, a further 8 dairy farms were recruited for the 2018 season.

Table 1: Factors affecting grass production in NI.

Influence on grass production		Opportunity to control
Location	Fixed effects	
County/ Townland		n/a
Altitude		n/a
Aspect		n/a
Weather	Becoming increasingly variable	
Temperature (soil/ air)		n/a
Rainfall		n/a
Light, (cloud cover)		n/a
Wind		n/a
Soil moisture		Can be affected by drainage
Soil		
Type	Fixed	n/a
Nutrient status		Analyse and optimise (RB209 guidelines)
pH		Analyse and optimise
Structure/ compaction		Analyse and optimise
Organic/ biotic components		Earthworms are a good indicator of healthy soil
Drainage		Address worst fields first
Compaction		Address worst fields first
Sward		
Species composition		Relative amounts of perennial ryegrass to other grasses, docks. Presence of ragwort
Variety choice		Diploid v tetraploid, maturity groups, mixtures
Ground cover		Reduced ground cover reduces grass production
Age		Productivity generally decreases with age
Reseeding		Regular programme of reseeding
Management		
Grazing		With all other conditions optimised, management of grazing will be most effective in improving utilisation

Objectives

The objectives of GrassCheck 18 were to:

1. Monitor grass growth rates and grass quality via cut plots throughout the 2018 growing season on the two long term sites at Greenmount and Hillsborough.
2. Monitor grass growth rates and grass quality on 20 commercial dairy farms across NI throughout the 2018 growing season.
3. Publish grass growth and quality information on a weekly basis in the farming press with complementary management notes.
4. Provide weekly 7-day and 14-day grass growth rate forecasts throughout the growing season using the GrassCheck model.
5. To identify key drivers behind grass growth and utilisation on commercial farms in N.I.

Work Package 1: Plot activity

Materials and Methods

Field site description

The study was conducted on two grassland sites consisting of established perennial ryegrass (*Lolium perenne*) swards (approximately 324 m^2) at CAFRE Greenmount (54°22'N, 07°37'W) and AFBI Hillsborough (54°27'N, 06°04'W). Soils from both sites are classified as Stagnosols (WRB, 2014) and are representative of 60% of NI agricultural soils.

Plot areas were selected to be visually uniform and representative of the field, avoiding low lying areas, steep slopes, boundaries, shading and areas of poor sward composition or soil structure. Plot areas were assessed for soil fertility in January 2018, prior to fertiliser application, and pH status, P, K, Mg and S determined by standard laboratory methods. Nutrient deficiencies identified were addressed in accordance with RB209 The Fertiliser Manual 7th edition recommendations (DEFRA, 2000).

Each experimental area consisted of nine plots each measuring 5.0 x 1.5 m and surrounded by a 2.0 m discard area and a stock proof perimeter fence. The nine plots were divided into three series of three replicates and each randomly to one of three cutting sequences (Fig. 1).

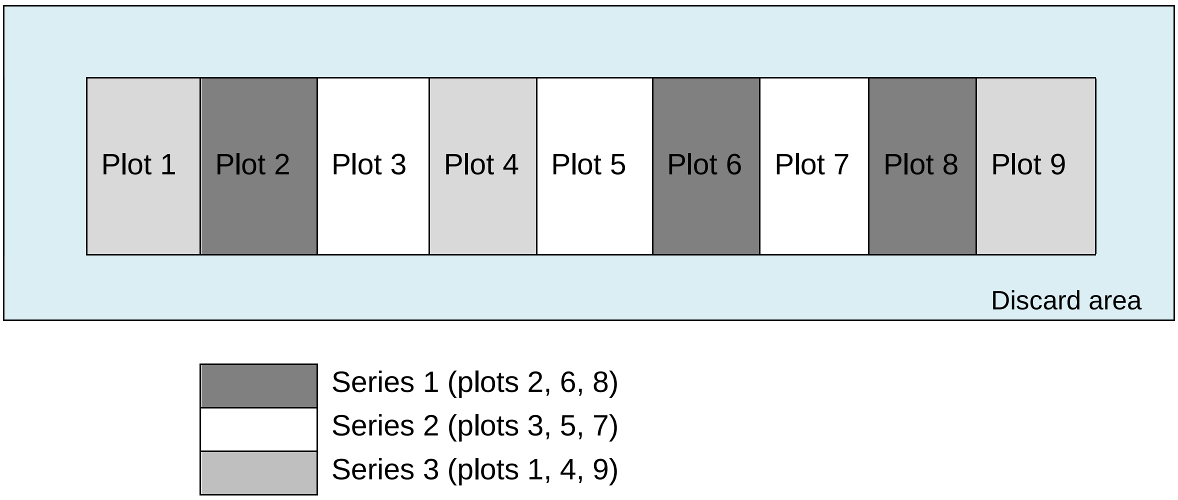


Fig. 1: The allocation of the nine plots into three series of three replicates.

Plot management

All plots were trimmed off during the week beginning 12th February and the over winter accumulated herbage on plots used the previous year was determined. First cuts for herbage mass measurements were cut on Monday 12th March 2018. Urea fertiliser was applied at a rate of 28 kg N per ha, immediately following cutting. Throughout the season, all plots received 270 kg N/ha with rate and form of fertiliser matched to plant demand and stage of season (Table 1). Fertiliser recommendations (Table 2) were in accordance with The Fertiliser Manual (RB209) 7th edition (DEFRA, 2000). Fertiliser was weighed for each individual plot and applied by hand post cutting.

Table 2: Plot management key dates and nitrogen fertiliser* application in 2018**.**

Series 1 cutting date	Series 2 cutting date	Series 3 cutting date	Nitrogen application rate (kg N/ha)	Fertiliser type
Pre-season trim 12 February			28	Urea (46% N)
12 March			28	
3rd April	19 March		35	Chalk N (27% N)
23rd April	9th April	26 March	35	
14th May	30th April	16th April	35	
4th June	21st May	7th May	25	
25th June	11th June	29th May	25	
16th July	2nd July	18th June	25	
6th Aug.	23rd July	9th July	17	
27th Aug.	13th Aug.	30th July	17	
17th Sept.	3rd Sept.	20th Aug.		
8th Oct.	24th Sept.	10th Sept.		
	15th Oct.	1st Oct.		
		22nd Oct.		

Fertiliser application: only series 1 shown*

Table 3: Application rate of P and K fertiliser according to soil index

P or K index	**1**	**2-**	**2+**	**3**	**4 and over**
kg/ha P_2O_5 required	120	90	90	20	0
Kg/ha K_2O required	330	320	200	110	0
Triple super phosphate - (kg/ha)	261	196	196	43	-
Muriate of potash - (kg/ha)	550	533	333	183	-

Meteorological measurements

A met-office weather-station located at AFBI Hillsborough recorded daily rainfall, mean, minimum and maximum air temperature, and percentage of cloud cover.

The forecasted meteorological parameters required to run the model and obtain the weekly grass growth simulation were provided by www.metcheck.com. Further monthly data were obtained from the Met Office (www.metoffice.gov.uk/climate/uk/summaries/datasets)

Soil moisture measurements

Soil moisture measurements were taken on a weekly basis at each site. Six soil core samples (2.5 cm of outer diameter by 7.5 cm length) from the area surrounding the plots were taken. Gravimetric soil moisture was determined by oven drying samples at 100 ºC for a 24 hour period.

Grass measurement

Grass measurements were performed weekly on a three week rotational series therefore, one of the three series was cut each week. Series 1 grass measurement cuts began on 12th March 2018, Series 2 on 19th March and Series 3 on 26th March. Plots were cut with a self-propelled cutting bar (Agria, Denmark) to a height of 4 cm. Mower cutting height was checked at regular intervals by measuring the height of the cutting bar above the ground when the mower was sitting on a level concrete surface, and switched off. All herbage mass for each plot was collected and weighed. Herbage from the discarded area of each plot was harvested and removed from the plots following the grass cut measurements.

Supplementary herbage height (cm) measurements were also recorded at AFBI Hillsborough by a rising platemeter (RPM, Jenquip; New Zealand). A total of eight RPM readings per plot where taken on a weekly basis from each plot before and after harvesting. Grass DM cover was calculated using the following equation [1]:

$$[1]\ \text{RPM cover}\ \left(\text{kg}\frac{\text{DM}}{\text{ha}}\right) = (\text{ herbage height x } 316) + 330$$

Grass quality measurement

Herbage quality was measured weekly. Four grass samples were obtained for each series at cutting. Three samples of 250g each were used to determine the gravimetric grass dry matter content by oven drying at 85 °C for 24 hours, a fourth sample was collected for herbage quality analysis. Dry matter (DM), crude protein (CP), metabolisable energy (ME), acid detergent fibre (ADF) and water soluble carbohydrates (WSC) were determined on fresh samples by near infrared spectroscopy (NIRS) by the Hillsborough Feed Information System at AFBI.

Grass growth rate calculations and forecasting using the GrazeGro model

Grass growth rate was calculated weekly as a function of the herbage mass harvested from each plot, herbage DM content and the plot area harvested.

Seven day and 14 day forecast grass growth rates were calculated using the GrazeGro model (Barrett et al., 2004), a herbage growth model constructed for use in a decision support system (Mayne et al., 2004). Model validation against independent historical European data showed output predictions to be sufficiently accurate to make it a useful aid for on-farm decision-making processes (Barrett et al., 2005).

GrazeGro is primarily based on plant physiological processes at the leaf and tiller level. The model accounts for reproductive growth, growth response to soil nitrogen, and changes in herbage quality in the form of CP and organic matter digestibility (OMD). Grass growth is determined as the balance of the supply (source) and demand (sink) of carbon allocation. Both supply and demand process are largely dependent on the temperature and solar radiation and hence on the photosynthetic rate and leaf production. When the demand is consistently greater than the supply, a negative carbon balance results and the plant draws from the reserve pool. Otherwise growth proceeds and reserves are replenished when supply is greater than the demand. Inputs required to run the model are daily photosynthetically active radiation (PAR), mean air temperature, mean rainfall, and rate of nitrogen fertilizer application in the sward. The PAR was estimated [2] by the mean average daily cloud cover from 2005 until 2012 ($\overline{\mathrm{X}}_{\mathrm{long}}$) and the average daily cloud covered measured at the weather station ($\overline{\mathrm{X}}_{\mathrm{meas}}$).

$$[2]\ \text{Mean daily PAR} = \frac{\overline{\mathrm{X}}_{\mathrm{long}} + (50 - \overline{\mathrm{X}}_{\mathrm{meas}})}{100 \times \overline{\mathrm{X}}_{\mathrm{long}}}$$

All the above parameters were used to calculate the simulated herbage production on weekly basis. After the simulated period, the actual measured on site meteorological parameters were inputted to the model and the next simulation started.

Model outputs were assessed on a weekly basis by an AFBI scientist and forecast growth rates were generated. In situations where projected forecasts from the model alone were deemed to be extreme outliers i.e. significantly different from expected at that time of year, a correction factor was applied. This correction factor took into account the performance of the model in the previous weeks relative to actual measured data. The estimated herbage by RPM on the plots to be harvested at Hillsborough one week later was also considered.

Dissemination of results

All data produced on a Monday were collated by mid-day Tuesday to allow for appropriate grass growth rate forecasts to be generated. Grass growth rates (measured and forecast) were published weekly throughout the season in the local farming press, on the AgriSearch website and on social media. This information was accompanied by technical guidance notes.

Results and Discussion

Meteorological data

The average mean temperature for Northern Ireland in 2018, (using Met Office monthly data) was 9.2 °C which was similar to the 30 year (1988-2017) average of 9.1 °C. February and March were colder than average (although this was not statistically significant) however June, at an average monthly air temperature of 14.9 °C, was the warmest recorded in NI since records began in 1910.

Total annual rainfall during 2018 (1084mm) was marginally less than the 30 year average (1157mm), facilitated by low rainfall totals during the summer and autumn months (Fig 2). At the AFBI Hillsborough site, drought conditions were evident during June and July with a total of 0.3mm of rainfall recorded in the 23 day period between 21st June and 14th July, and a mean daily air temperatures peaking at 21 °C on 29th June. Monthly meteorological data can therefore be deceptive when viewed in retrospect with regards to effects on grass growth - most of the 66.1 mm of rain recorded at AFBI-Hillsborough, or 81 mm recorded for NI as a whole (Met Office) in July 2018 occurred in the last few days of the month following a prolonged warm dry period with poor grass growth. The combined effects of warm air temperatures and reduced precipitation led to loss of moisture from the soil (Fig. 4). Other meteorological data were within normal parameters for 2018.

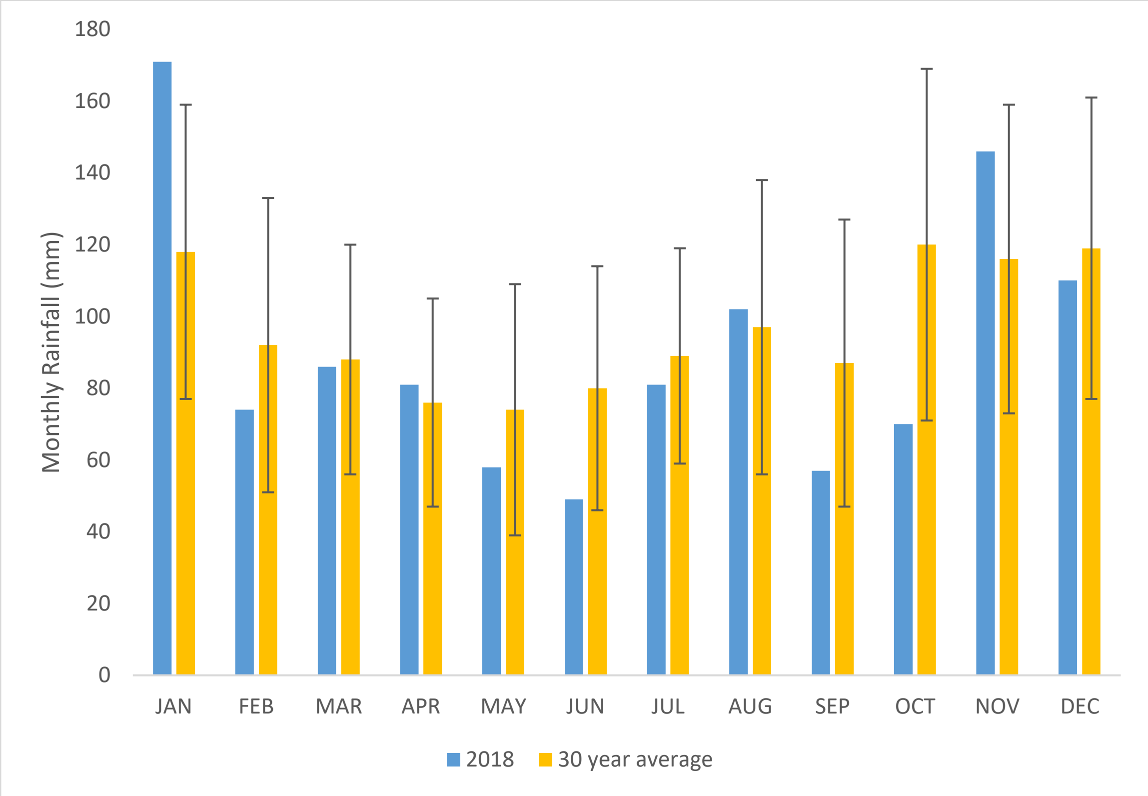


Fig. 2: Monthly rainfall in 2018 compared with 30 year average (1988-2017). Error bars are s.e.

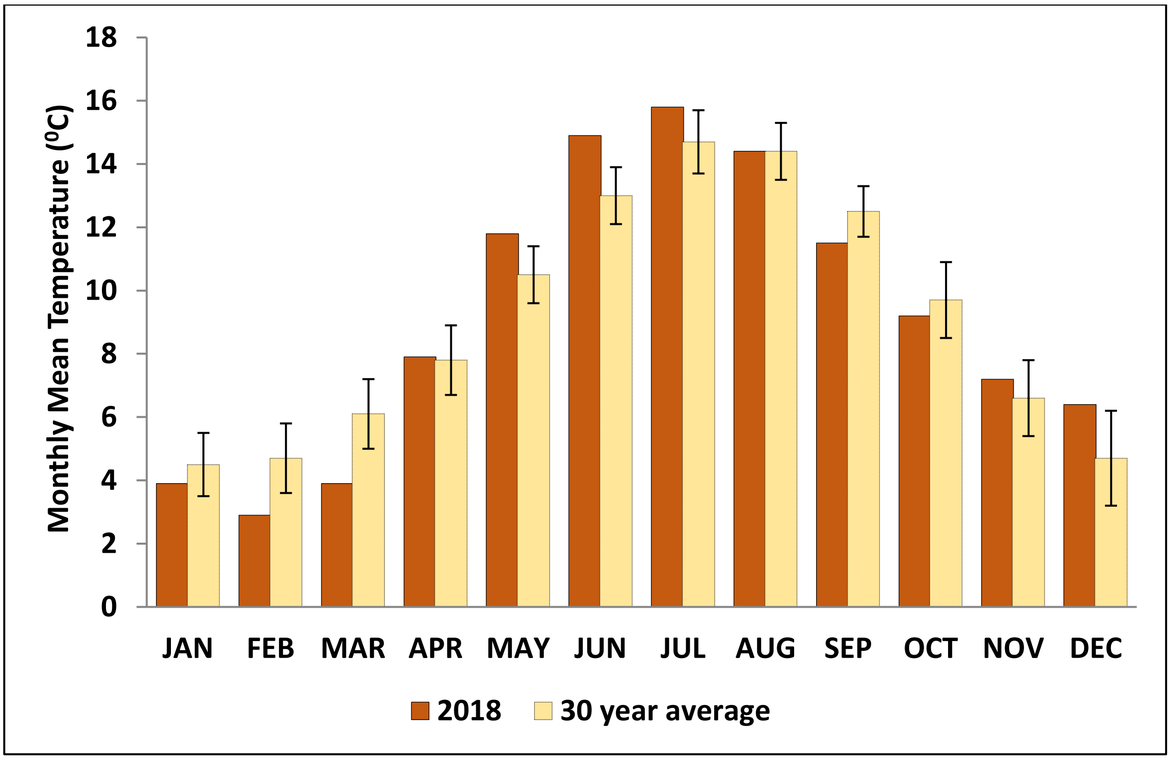


Fig. 3: Monthly mean air temperatures in 2018 compared with 30 year average (1988-2017). Record breaking June temperature (14.9 °C) was higher than the long term average (13.0 °C). Error bars are s.e.

Soil moisture conditions

The grass growth curve at Hillsborough declined sharply at the end of May reflecting the declining soil moisture content from a maximum of 41% at the end of April to a minimum of 19% in the second week of July (Fig. 4). This low productivity was maintained into August and correlated closely with the soil moisture especially when the soil moisture content was at or below 30%.

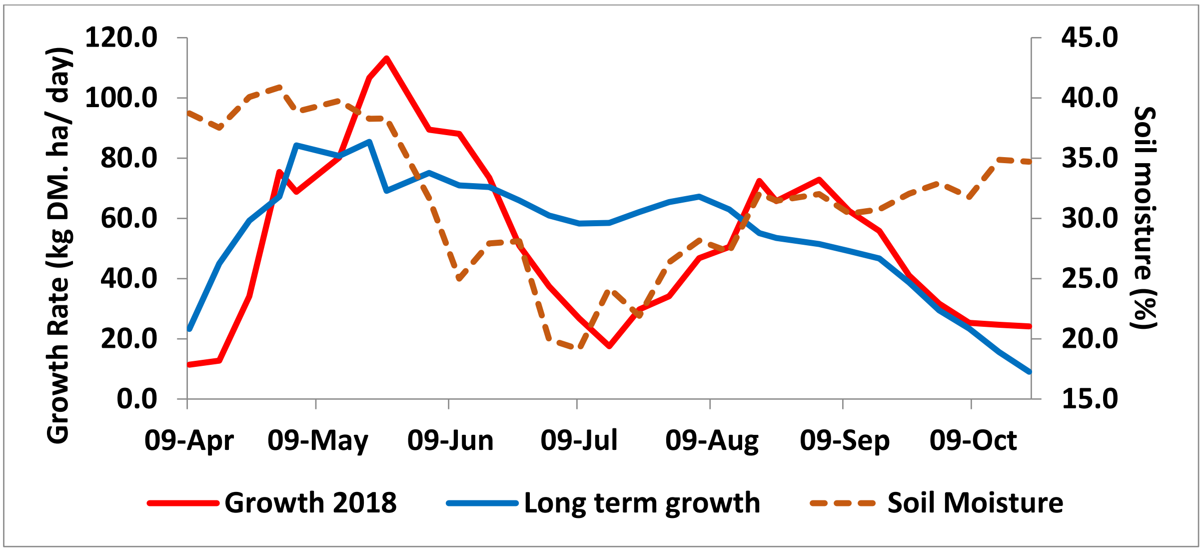


Fig. 4: Grass growth rate at Hillsborough in 2018 compared with soil moisture conditions and the long term (2008-2017) average grass growth rate.

Soil moisture, which is both weather dependent and field specific, was highly correlated with weekly growth data especially in the summer period (Fig. 5). The decline in soil moisture content from 25th May was followed by a decline in the following week's grass growth. A correlation of 90% was demonstrated during 2018 between weekly grass growth (21st May – 20th August) and weekly average soil moisture from the week preceding the grass growth measurement (14th May - 13th August; Fig. 5). The R^2 value of 0.81 suggests that 81% of the variance in grass growth during this period can be explained by the low soil moisture. This information will also be useful in future modelling.

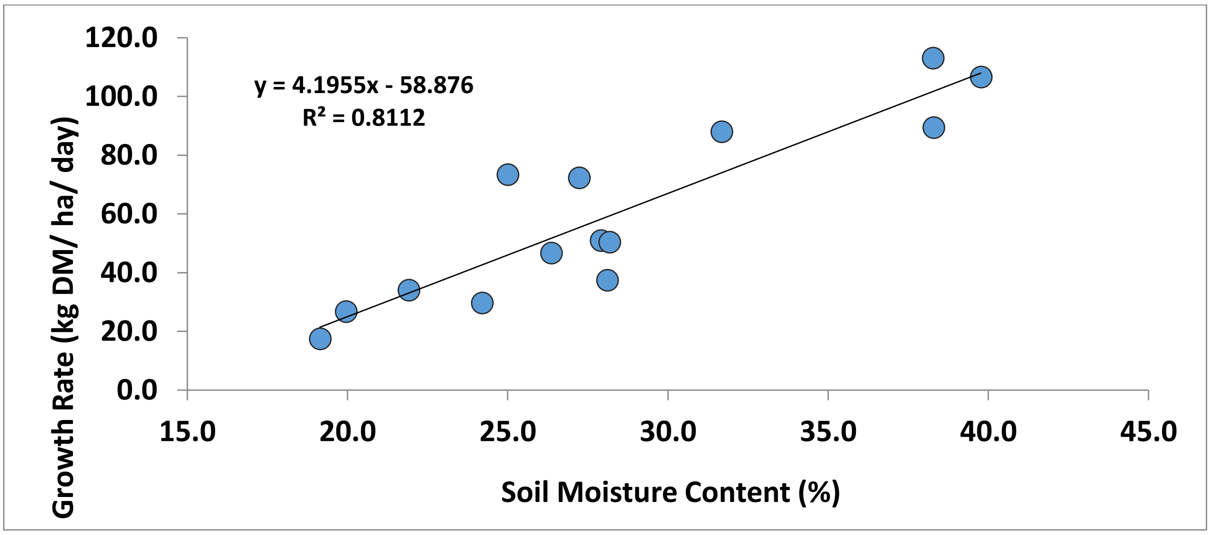


Fig. 5: Correlation during 2018 between published GrassCheck weekly growth data (21st May – 20th August) and weekly average soil moisture (Greenmount and Hillsborough combined) from the week preceding grass growth measurement (14th May - 13th August).

The soil moisture graph (Fig. 6) largely reflects the grass growth curve recorded by GrassCheck from mid-May to mid-August (Fig. 4). The Hillsborough sites were 4% drier on average than the Greenmount sites (30% moisture at Hillsborough, 34% moisture at Greenmount) and grass production was 19% higher at Greenmount. The equation from figure 5 would predict a 24% higher growth rate at Greenmount during this period which is broadly in keeping with the expected variance of growth rate due to soil moisture differences.

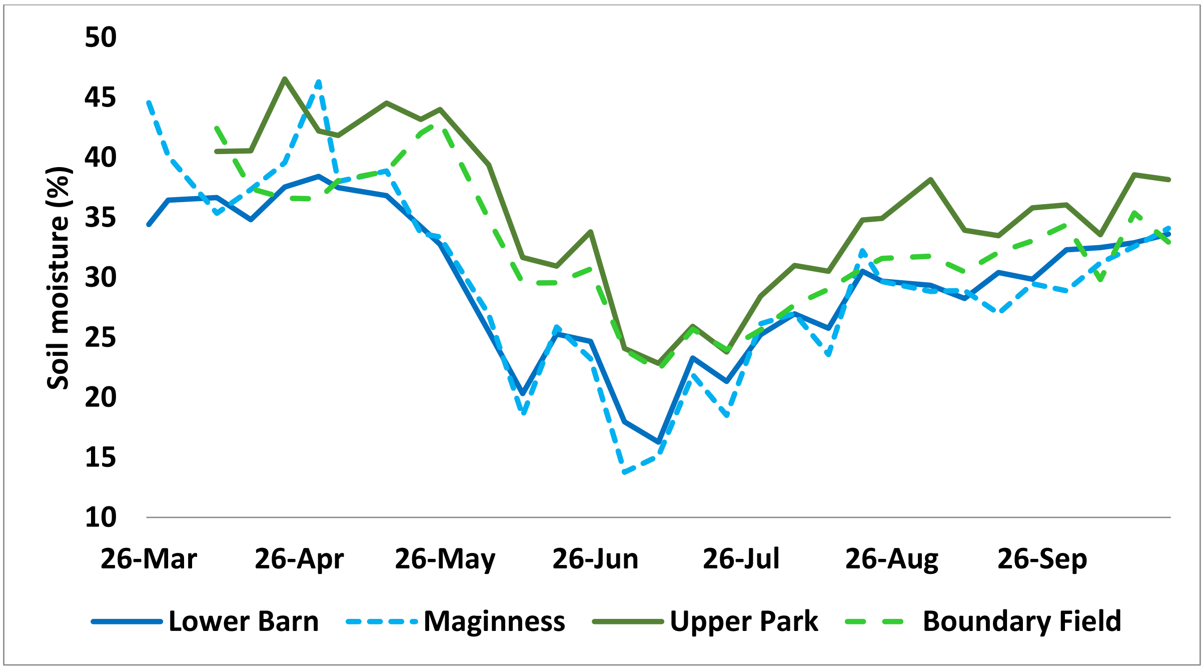


Fig. 6: Soil moisture (%) for two fields at each of two sites in 2018. Blue lines refer to Hillsborough sites and green lines refer to Greenmount sites.

Grass growth

Annual yield of grass dry matter production in 2018 across the four GrassCheck sites was 10.8 t DM/ha, a decrease of 0.6 t DM/ha from the long term GrassCheck average (11.4 t DM/ha; 2008 – 2017). Following a relatively cold February and March, grass growth began to increase rapidly from late April until late May, surpassing the 10 year average for daily kg DM/ha growth during this period as indicated in fig. 4. The combined yield for Spring 2018 was 4.3 t DM/ha compared to the long term average yield for these months of 3.7 t DM/ha (2008-2017). Following the significantly reduced growth during the warm dry months of June and July, grass productivity returned to normal in August with a combined summer yield (June, July, August) of 4.6 t DM/ha compared to the long term average of 5.8 t DM/ ha for this period (Fig. 4). The reduction in yield as indicated by the graph is associated with the reduced soil moisture (Fig. 5) and illustrates how dependent grass production is on regular rainfall maintaining soil moisture levels.

Mean monthly air temperatures (Fig. 3) indicated that February and March were colder in 2018 than average which resulted in reduced early season growth. In April 2018 only 1003 kg DM/ha were produced (Fig. 7), a reduction of over 30% from the average of 2460 kg DM/ha. By May, monthly grass production had increased to 2859 kg DM/ ha, 383 kg higher than the long-term May monthly average yield of 2476 kg DM/ ha. Similarly in June grass production was 148 kg DM/ha above the long-term average June yield. In general, warm air temperatures will support grass growth, but the absence of rain and ensuing loss of soil moisture (Figs. 4, 5, 7) meant that by July monthly grass growth had decreased to 902 kg DM/ha from an average of 1892 kg DM/ha equating to a reduction of 52% from the 2008-2017 average July yield. Following rainfall and therefore increased soil moisture, grass production returned to approximately average values by August 2018 (Fig. 4).

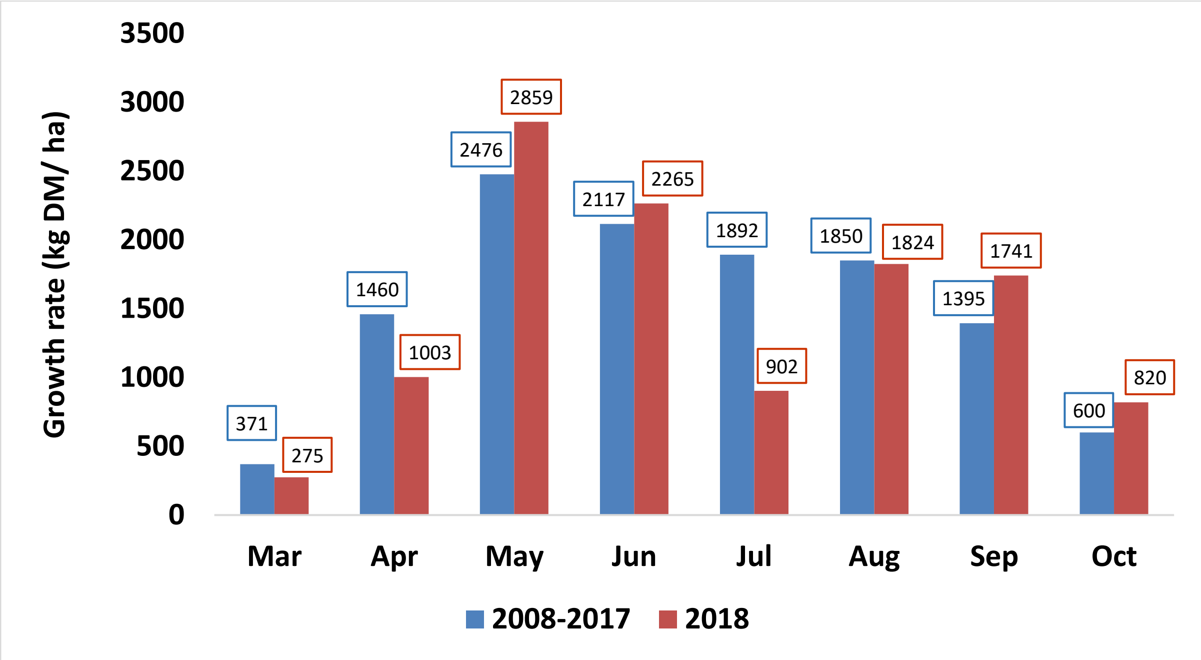


Fig. 7: Comparison of combined average monthly grass production at the Greenmount and Hillsborough sites in 2018 compared with average for the period 2008-2017.

Grass quality

Grass quality over the 2018 season was generally lower, but not significantly lower than the 2008 – 2017 long term averages (Table 4). As might be expected, DM% was slightly raised due to the dry conditions as was acid detergent fibre. Conversely crude protein, water soluble carbohydrate and metabolisable energy were all slightly lower than average but again, not significantly.

Table 1: Grass quality characteristics observed from the GrassCheck plots throughout the 2018 grass growth season as compared with the 2008 – 2017 average.

	2018 Mean	**s.d.***	**2008-2017 Mean**	**s.d.**
DM (%)	18.0	4.45	16.7	1.22
CP (%)	17.7	2.85	19.0	1.80
ADF (%)	28.3	3.83	27.4	1.17
WSC (%)	13.1	3.21	13.9	1.69
ME (MJ/kg/DM)	11.1	1.29	11.6	0.40

**s.d. = Standard deviation*

Dry matter content

Grass DM% increased dramatically mid-season in response to the drought conditions (Fig. 8). The increased DM% between June and August mirrors the decreased growth (Fig. 8) in the same period and effectively represents water stressed grass growing poorly during this time.

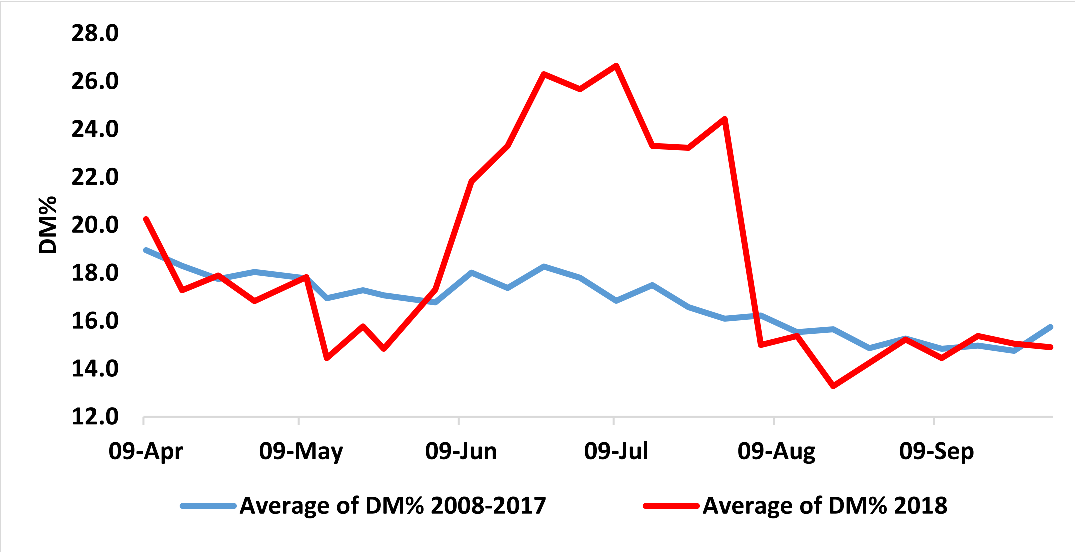


Fig. 8: Comparison of average DM% in 2018 with average for the period 2008-2017

Crude protein content

Grass crude protein content averaged 17.7% during the 2018 season on the GrassCheck plots, lower than the long term average of 19.0% (Table 4). Grass crude protein content was lower than expected during the spring period, mostly likely as a result of cooler temperatures, restricting soil nitrogen mineralisation processes (AHDB, 2017) (Fig. 9). Increases in grass crude protein content were evident from late July until mid-August as grass production began to return to normal levels and as soil moisture content increased from below 20% to above 30% (Fig. 4). The dip in crude protein content at the 30th July (marked with black triangle) corresponds to the very heavy rainfall on the 28th (10 mm) and 29th (35 mm) of July and was possibly due to the resultant lower soil temperatures hindering soil nitrogen mineralisation.

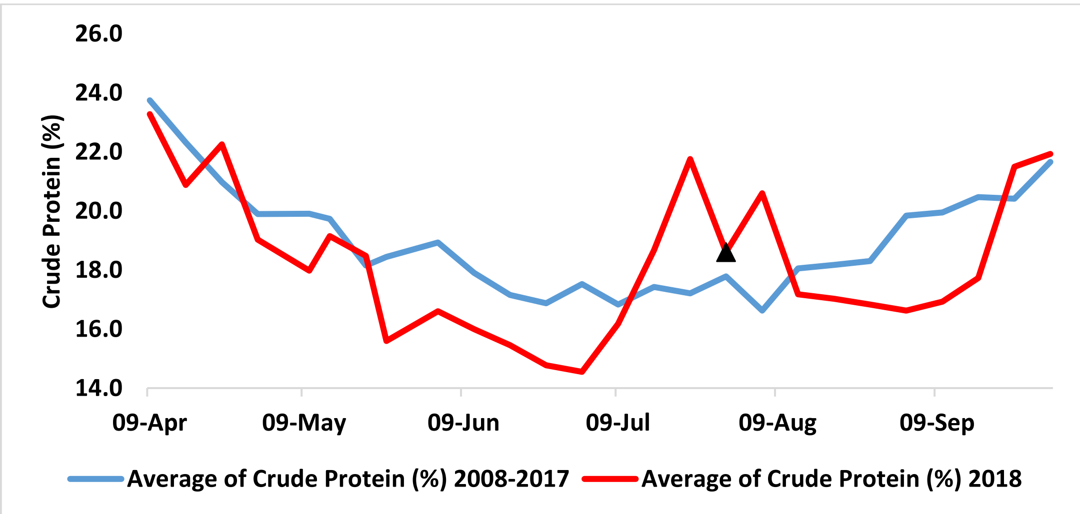


Fig.9: Comparison of average Crude Protein in 2018 with average for the period 2008-2017

Acid detergent fibre content

The acid detergent fibre content ranged from 21.1 to 33.9% during the 2018 season, averaging 28.3%, reflective of perennial ryegrass swards managed predominantly in a vegetative state (Table 4). Some increases in acid detergent fibre content were evident in late May and June, reflecting changes in crop maturity as plants entered the reproductive phase. Plant ADF content however remained high throughout the rest of the season, most likely due to the impact drought stress facilitating a higher stem: leaf ratio. (Fig. 10)

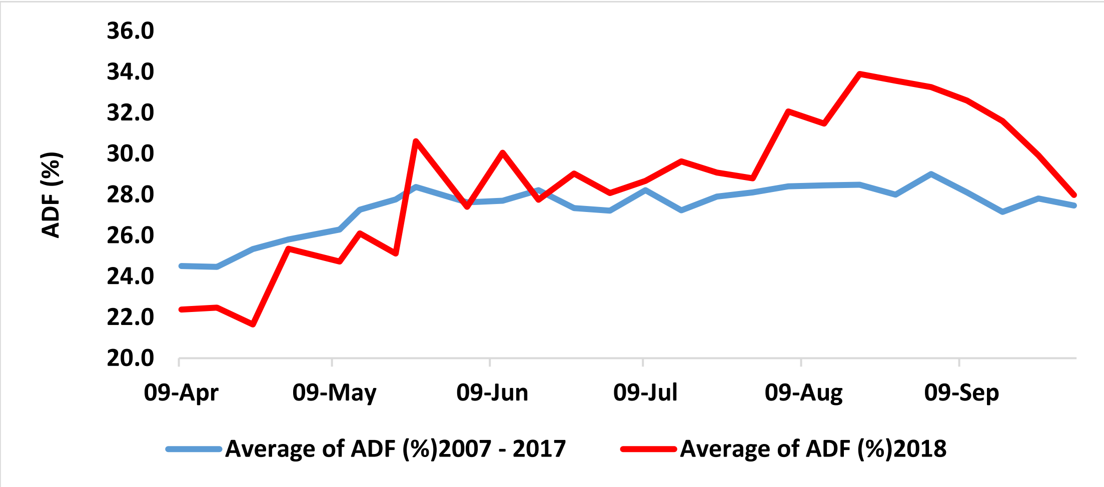


Fig. 10: Comparison of average Acid Detergent Fibre in 2018 with average for the period 2008-2017.

Water soluble carbohydrate (WSC) content

Water soluble carbohydrate concentrations averaged 13.1% during the 2018 season, 0.8% lower than the long term average (Table 4). The effect of the drought can be seen in the steep decline of WSC between the peak on the 2nd July (18.6%) and the lowest point (7.2%) on the 6th August (Fig. 11). Grass cut for silage by mid-May would have had good WSC content but grass grazed in late July and throughout August would have had lower than average WSC. Produced via photosynthesis and required for respiration and growth, the varying WSC of grass plants reflects a balance of the two processes. The WSC levels in 2018 peaked at 18.6% by 2nd July and fell steeply to a low of 7.2% by 6th August most probably as a result of an inability to photosynthesise due to decreasing soil moisture. Normal levels of WSC are achieved again by early September when soil moisture has returned to average values.

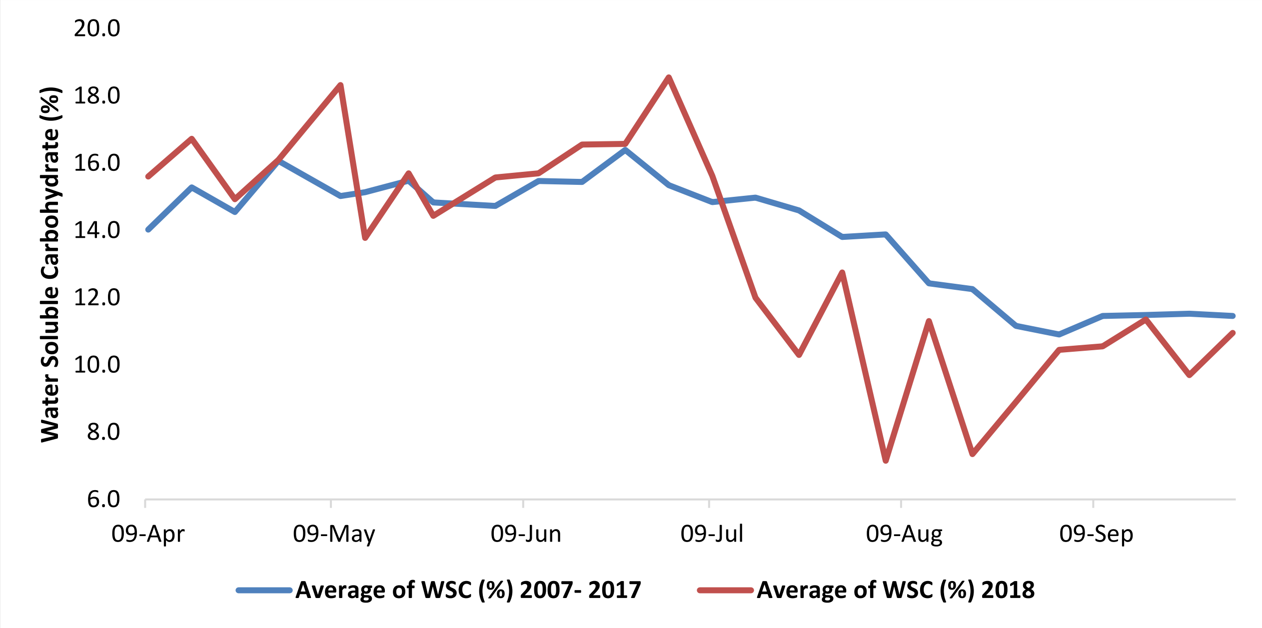


Fig. 11: Comparison of average Water Soluble Carbohydrate in 2018 with average for the period 2008-2017.

Metabolisable energy content

During 2018 grass ME ranged from 10.4 to 12.6 MJ/ kg DM, with an average of 11.1 MJ/ kg DM indicating the lower than average digestibility of the sward from late May until almost the end of the season. These values coincide with higher plant ADF and DM% values. The dry summer conditions reduced the ability of the grass to photosynthesise and therefore the resulting metabolisable energy production was also reduced (Fig. 12).

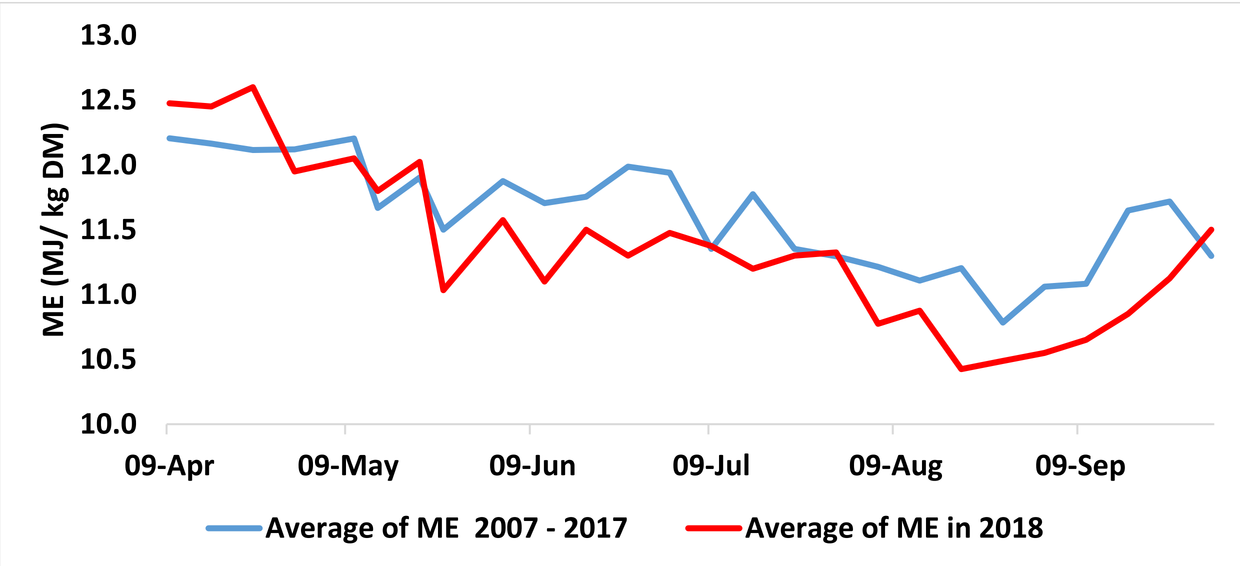


Fig. 12 Comparison of average Metabolisable Energy in 2018 with average for the period 2008-2017.

Grass growth forecasts

Grass production at Hillsborough and Greenmount in 2018 was closely matched with that of the dairy farms (Fig. 13a). Where the AFBI and CAFRE sites showed a greater peak in production in late May they also demonstrated a greater drop in production by mid-July. The dairy farm growth curve is an average of 20 farms and therefore considering the individual influences of location, aspect, soil moisture etc. it could be reasonably argued that the GrassCheck data broadly reflects the commercial dairy farm data.

The accuracy of the predictions throughout the growing season can be seen in the graph where the dotted lines (predictions) closely resemble the position of the solid line (actual growth) throughout April and with varying degrees of deviation from this such as in mid-May, mid-July and early September. The 14 day predictions were less accurate than the 7 day predictions as a result of unexpected weather changes affecting grass growth. The 7 day and 14 day predictions are compared with actual growth rates recorded at the Hillsborough and CAFRE plot sites (presented as an average of these) (Fig. 13b). For both the 7 and 14 day forecasts it can be seen that the actual grass growth recorded did follow the trend of these predictions closely. The low growth during the summer drought in mid-July was well predicted by the model, matching the actual 17 kg DM/ha/day recorded although again the predictions placed this low one week later than it actually occurred. Grass growth recovery following the drought period was recorded in August, and had been well predicted by both the 7 and 14 day model forecasts. As the predictions are made based on local weather forecasts there will always be scope for a degree of variance from the actual meteorological conditions as they occur.

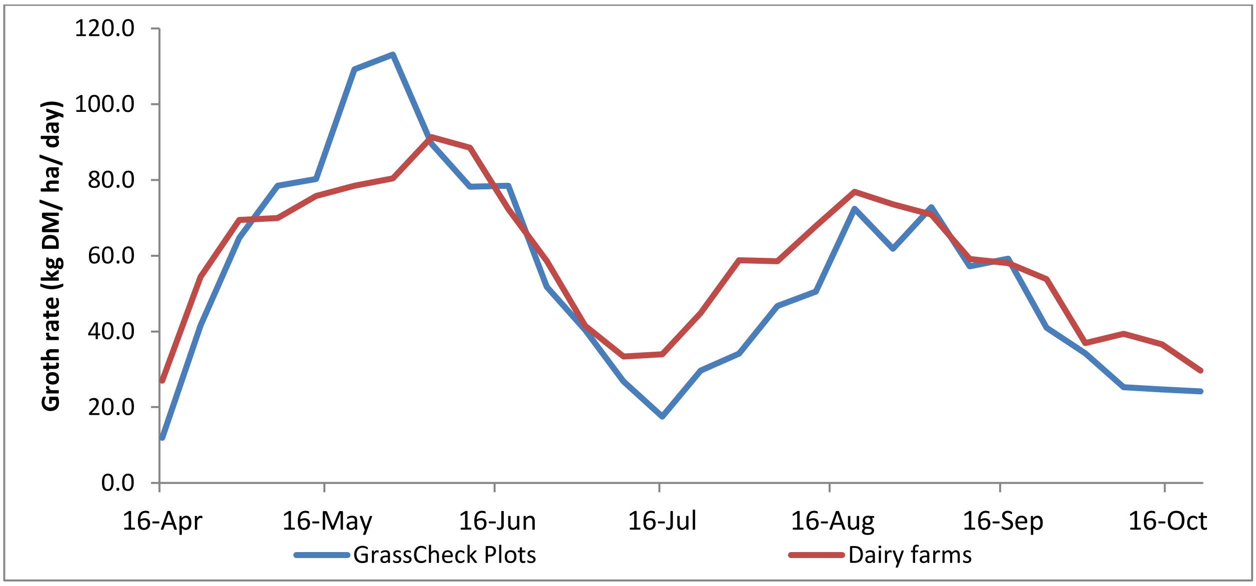


Fig. 13a Relationship between actual grass growth rates observed during the 2018 growing season between the GrassCheck plots and the participating dairy farms.

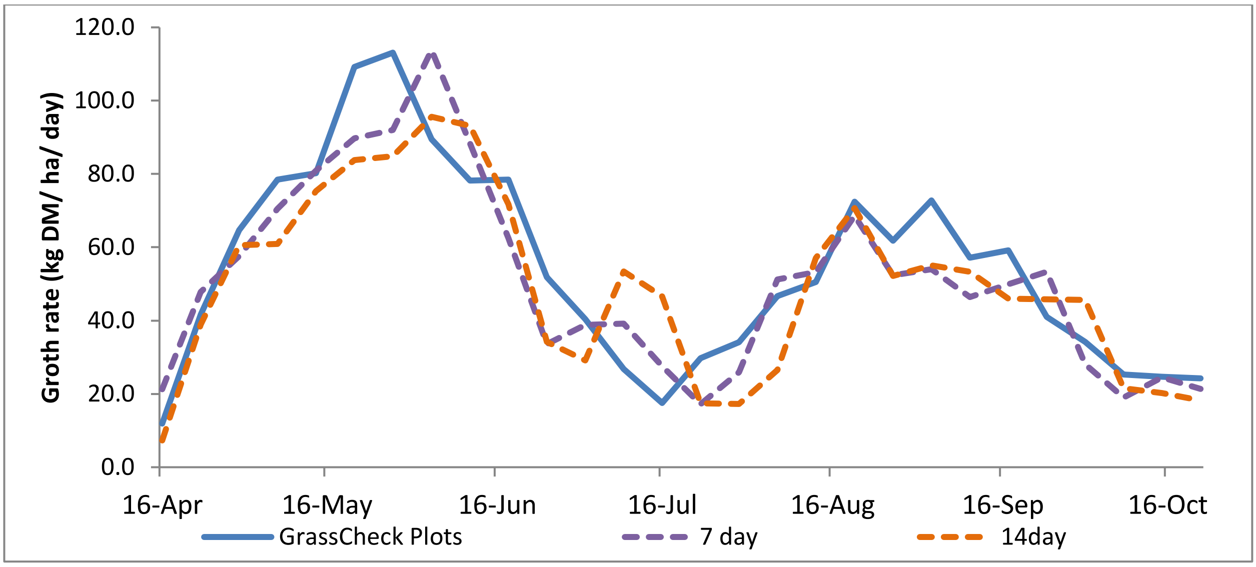


Fig. 13b Relationship between actual grass growth rates observed during the 2018 growing season on the GrassCheck plots and the published forecast grass growth rates based on a seven day and 14 day forecast period.

Future Work

The GrassCheck 18 project provided further insight into the temporal and spatial variability of grass production and growing conditions in NI. Advice to farmers through weekly GrassCheck bulletins and press releases will be more accurate, predictive and robust through maintenance of extant data sources and further development of sward and meteorological data collection sources. Therefore the most relevant type of future work is the extension of the network of farms contributing their own data and thorough analysis of these data.

WP2: On-farm grass growth and quality monitoring

Materials and Methods

During January 2017 and 2018, 12 and 8 monitor dairy farms respectively were recruited into the project. These farms were located across N.I. and spanned a range of management systems, calving pattern, herd size, milk yield and concentrate input (Fig. 14). Of those farms recruited, 45% were not conducting regular grass yield or quality measurements. In addition, 23 beef and 5 sheep farmers were recruited as part of complementary projects prior to spring 2018. All 48 farms were requested to take measurements or samples, for grass yield and quality respectively, on a regular (weekly for growth, fortnightly for quality) basis. Farms were also required to supply key grassland management information.

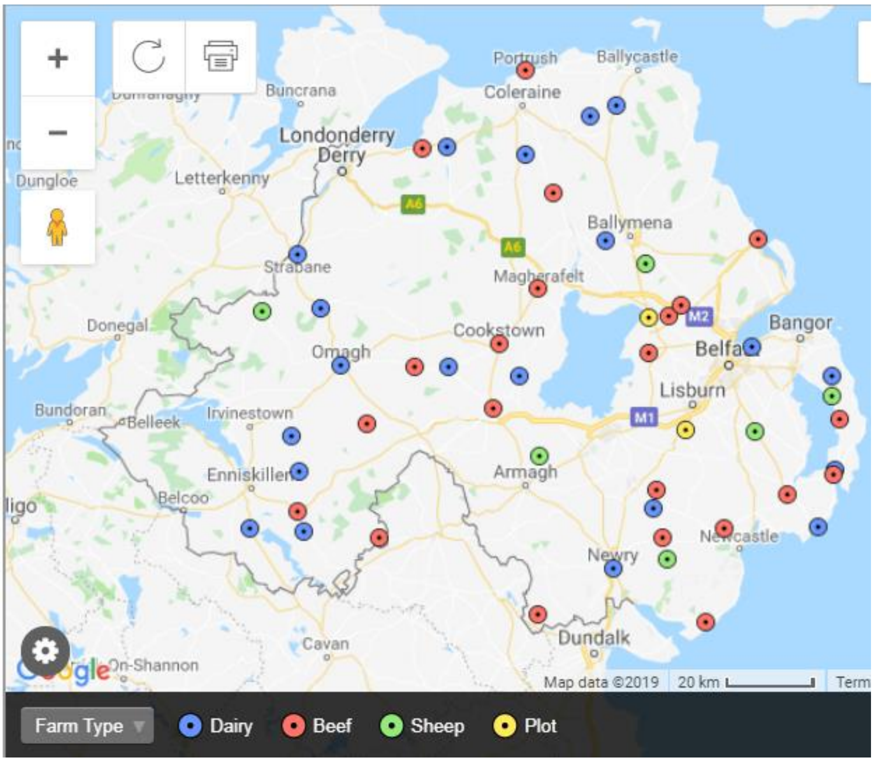


Figure 14: Location of dairy, beef and sheep farms contributing data to the grasscheck project.

Grass yield measurements

Grass yield measurements were obtained from each active grazing paddock from each farm once per week. An active paddock was defined as any paddock currently in the dairy cow grazing rotation which was not being managed for silage, grazed by another class of livestock or removed for reseeding. These measurement were obtained using a rising plate meter on 17 dairy farms (with equation y = 248x + 608, where y is grass DM yield per hectare and x is compressed sward height in centimetres) and a cut and weigh technique on the remaining 3 dairy farms. Paddocks were walked in a 'W' shaped pattern, and a minimum of 30 platemeter drops per paddock recorded. Farms were asked to include any areas of sward variation (patches of visibly lower/higher growth) within the 'W' pattern to ensure a representative picture of grazing sward growth was obtained. Measurements were typically recorded between Friday and Sunday of each week. Results for weekly yield assessment were entered into a grassland management software programme (AgriNet, www.agrinet.ie) under individual farm profiles before midnight each Sunday. All weekly farm grass yield data was obtained by AFBI researchers through an AgriNet advisor account with oversight of all participating farms. Data was compiled on a weekly basis and summary statistics and calculation of weekly, monthly and daily average data performed, with farm data grouped according to county by farm location or on an individual farm basis. A copy of the instructions provided to farmers is available in Appendix A.

Grass quality sampling

Participating farms were assigned to one of two grass sampling groups (balanced for location and system), and requested to take fortnightly grass samples for quality analysis beginning on March 5th 2018 (group A) or March 12th 2018 (group B). Grass samples were taken from the next field due to be grazed on each farm on a Wednesday morning (after 10 am) or early afternoon. Samples of a ‘large handful’ of grass were cut to the post-grazing residual target height of 5 cm (1500 kg DM/ha) using scissors or clippers from a minimum of 5 different areas of the paddock, selected at random by the farmer. Excess water was gently shaken off before placing cut samples directly into a single clean bucket. After all samples had been cut, the grass was gently mixed by hand to evenly distribute the samples within the bucket. A 500g sub-sample was then weighed from the bucket and placed in the provided sample bag, the majority of air expelled and the bag sealed. Bagged samples were stored in the fridge if there was to be a delay to posting. Samples were posted to AFBI Hillsborough in pre-paid envelope along with the following details: Farmer name and group A/B, Dairy (G1) or Beef (G2) or Sheep (G3), sampling date and weather conditions at sampling. Envelopes were posted every Wednesday before the last post collection time. Samples received at AFBI Hillsborough were analysed using NIRS as described above for the cut-plot samples. Data was compiled on a weekly basis and summary statistics and calculation of weekly, monthly and daily average data performed, with farm data grouped according to county by farm location or on an individual farm basis. A copy of the instructions provided to farmers is available in Appendix A.

Weather data

Each farm was fitted with an automatic weather station (Davis Vantage Pro2, Davis Instruments, USA). Data summaries were collected every 30 minutes from the weather station across a range of variables including: rainfall, soil moisture, soil temperature, air temperature, solar radiation and wind speed. Data was collated weekly from each weather station and summary statistics and calculation of weekly, monthly and daily average data performed, with farm data grouped according to county by farm location or on an individual farm basis. Statistical analysis of the variation between data points was performed using GenStat (v16, VSN International, UK) where appropriate.

Grass management data

On-farm grass management data was retrieved at the end of the grazing season from AgriNet. Variables collected included: paddock grazing dates, pre and post grazing covers, nutrient application, soil test results and reseeding events. All data were compiled into excel and summary statistics and calculation of weekly, monthly and daily average data performed, with farm data grouped according to county by farm location or on an individual farm basis. Statistical analysis of the variation between data points was performed using GenStat (v16, VSN International, UK) where appropriate. A copy of the instructions provided to farmers is available in Appendix A.

Results and discussion

Grass yield and meteorological data were analysed across the 2018 growing season for 18 dairy farms. The data presented are from farms with the following codes:

Antrim (3): GC4; GC5; GC46

L' Derry (3): GC11; GC12; GC41

Down (6): GC1; GC2; GC3; GC44; GC47; GC48

Fermanagh (2): GC10; GC43

Tyrone (4): GC6; GC7; GC8; GC42

Further detailed data or incomplete data from other farms were not presented in this report, but were included in the summary information presented in figures 16 and 36.

Growth across farms

Recorded grass growth on the participating dairy farms and beef and sheep farms generally followed the same patterns as that on the GrassCheck cut-plot sites and the 7 day and 14 day grass growth predictions produced throughout the 2018 season (Figs. 15). Notable differences between measurements from cut-plots and commercial farm systems, and the predicted growth figures were seen in the magnitude of some growth rate peaks and troughs. GrassCheck plots peaked higher than the average of the dairy farm plots, although some dairy farms had greater production than GrassCheck plots in specific weeks (see fig. 15). Beef and sheep farms recorded slightly lower spring peak growth rates (28th May - 4th June 2018) than either the dairy farm or cut-plot measurements (78.8, 95.6 and 113.1 kg DM/ha/day respectively), but sustained growth better than the cut-plots and similar to that of dairy farms during the heatwave of July-August (lows of 27.6 kg DM/ha/day for dairy farms, 34.0 for beef and sheep farms and 17.5 on the cut-plots, 16th July 2018).

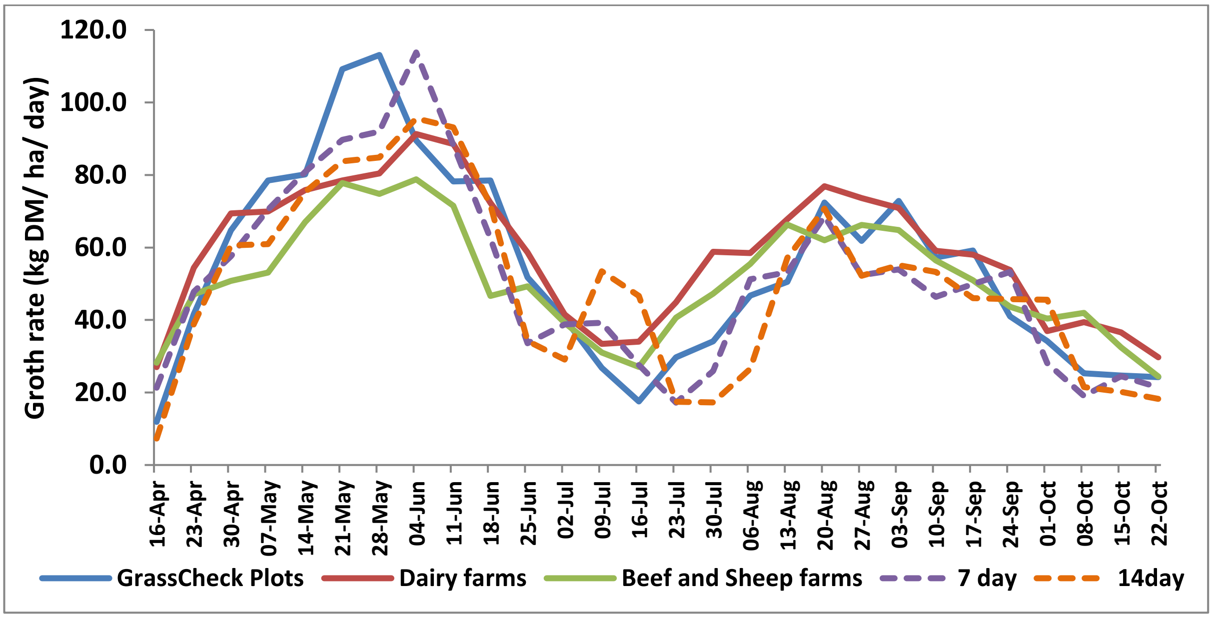


Fig. 15 Grass growth rates for GrassCheck plots compared with dairy farms, beef and sheep farms and the 7 day and 14 day predictions.

A very strong correlation (91%) existed overall between weekly grass production on dairy farms and that on beef and sheep farms (Fig. 16). The general trend of the correlation shows dairy farms had higher weekly grass growth rates, particularly when growth was >30 kg DM/ha, than was measured on beef and sheep farms in the same week. This suggests management differences between dairy and beef/sheep grazing platforms may influence the growth and kg DM/ha production of grazing paddocks.

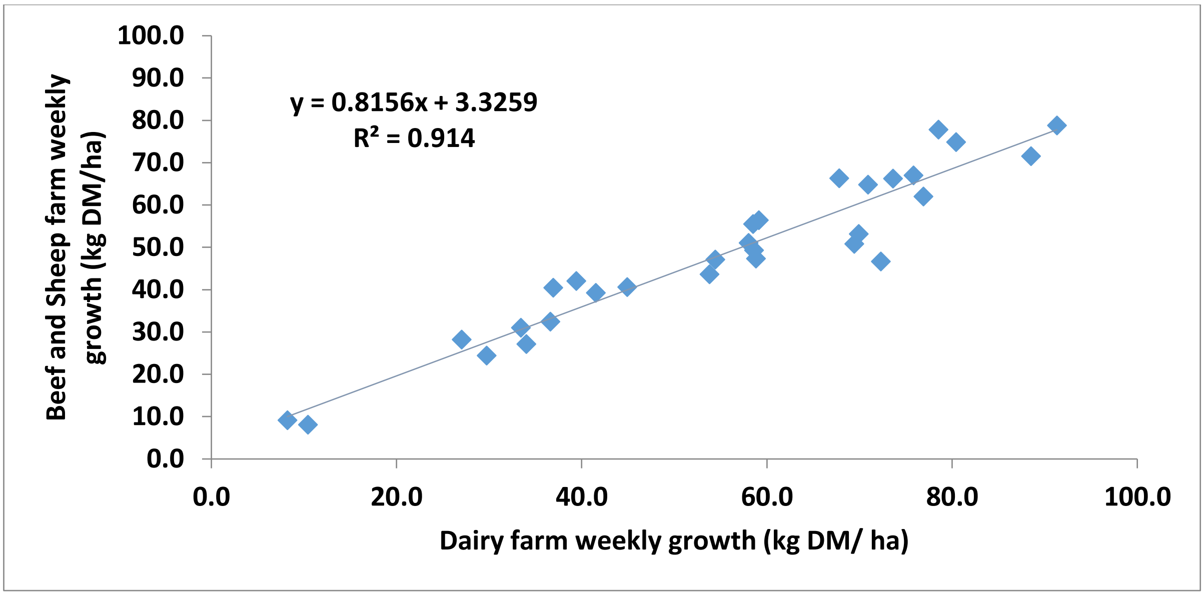


Fig. 16 Correlation during 2018 between weekly grass growth rates on Dairy farms and Beef and Sheep farms

Significant differences were observed in grass production between months (Fig. 17) and in total between counties (Table 5) in 2018. County Down farms produced notably less grass than the average (10.5 t DM/ha vs 11.9 t DM/ha) and farms in Counties Fermanagh and Tyrone produced the highest overall grass yields (12.3-12.8 t DM/ha respectively).

Table 5 Average annual yields for dairy farms per county.

County	Total growth (kg DM/ha)
Tyrone	12,816
Fermanagh	12,264
L' Derry	12,183
Antrim	11,922
Down	10,536
Average	11,944

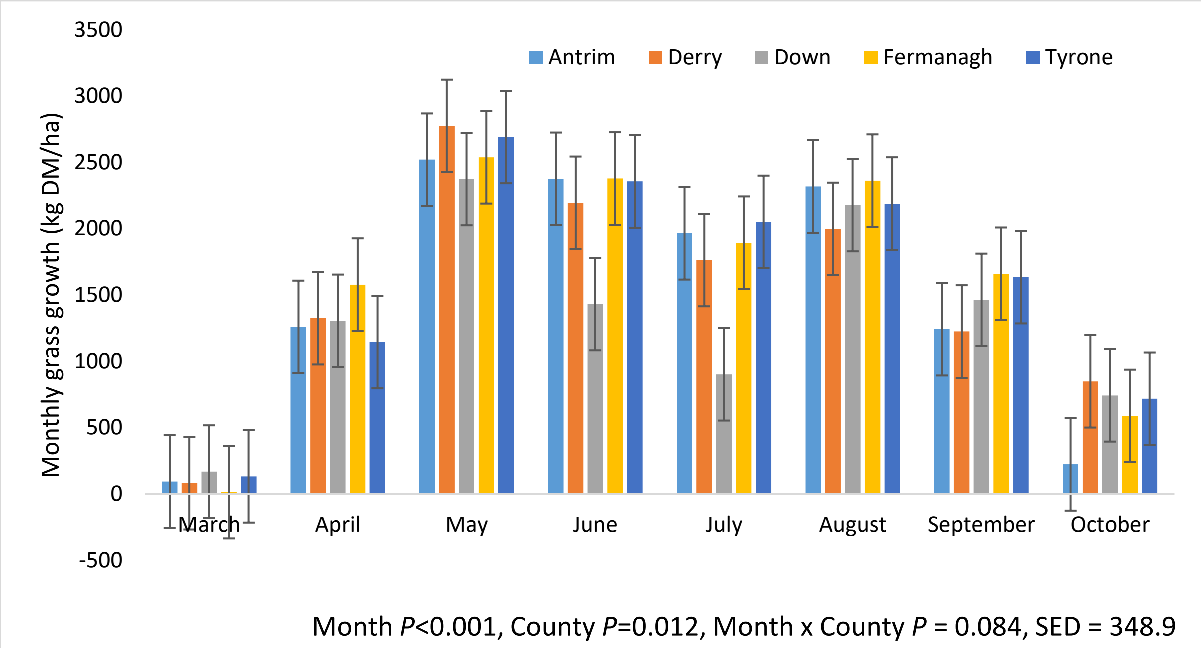


Fig. 17 Monthly grass DM yield by county from April - October.

A typical seasonal grass growth pattern was seen using weekly data from the 2018 season (Fig. 18). A sharp increase in growth rate occurred in late April and early May, peaking in late May and early June. Differences between the farms' production rates were most noticeable in early July where productivity in County Down was markedly lower. This period coincided with drought conditions and broadly reflected the overall growth pattern seen at Hillsborough and Greenmount in 2018 also (Fig. A + B). Growth rates returned to what would be expected based on the long-term average growth rates recorded by the GrassCheck projects over the last decade by mid-August, following a return to average meteorological conditions.

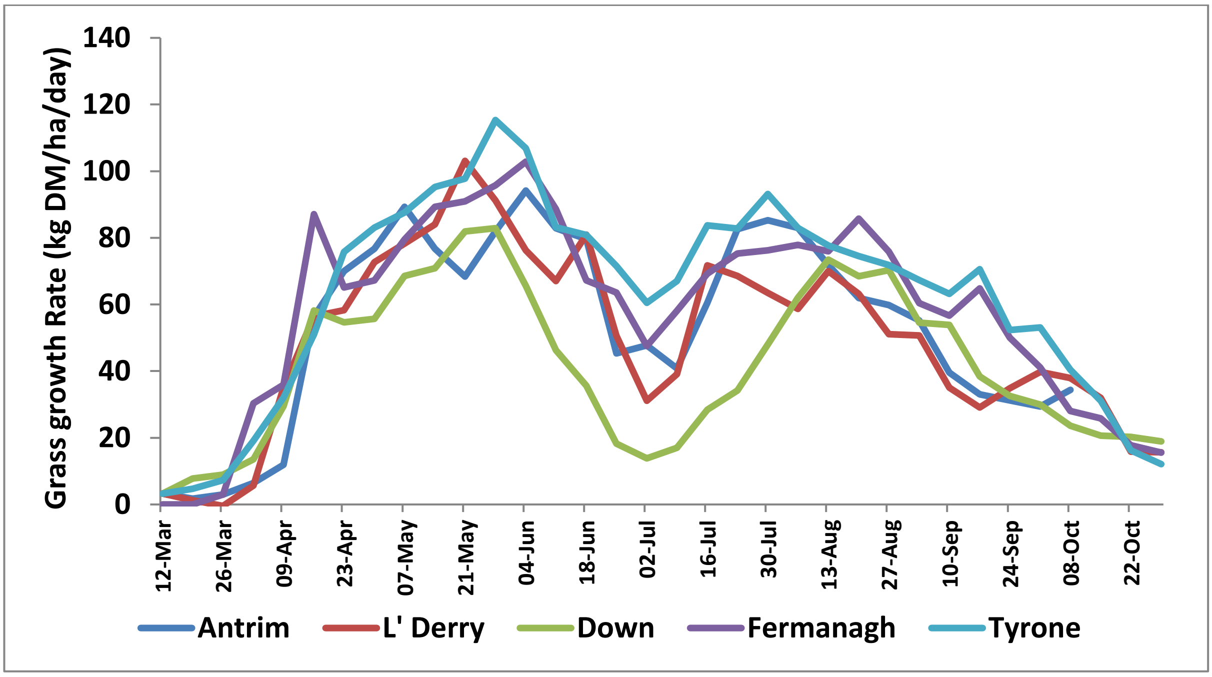


Fig. 18 Weekly grass DM yield by county from 12th March- 29th October.

The high variability in grass production seen between individual farms across NI is illustrated in Fig. 19. The large range in weekly grass DM yields measured across farms in NI may be linked to meteorological factors, such as the highly variable rainfall figures detected between individual farms and across different NI counties in summer 2018, or may be influenced by grassland management decisions specific to individual farms.

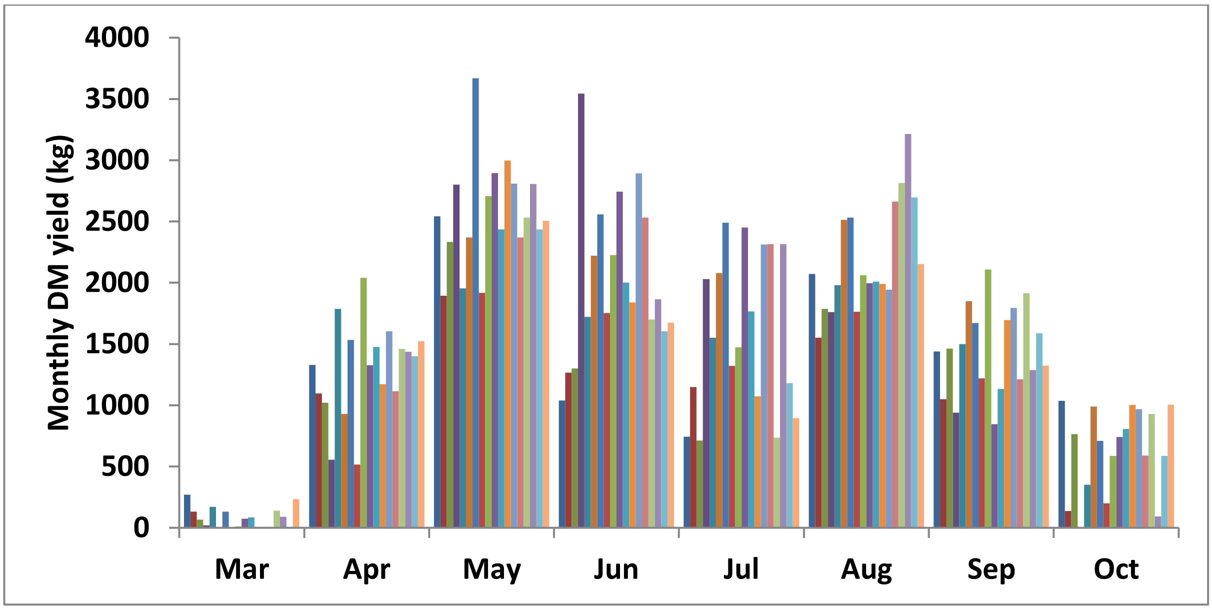


Fig. 19 Monthly grass DM yield individual farm from March- October.

Grass Quality

Significant differences were found for average annual values of DM%, CP, ADF and ME between counties (Table 6). County Down which had the lowest production (Table 5) also exhibited the highest DM%. This is likely due to the lower rainfall and soil moisture levels evident here during the summer months. Fermanagh exhibited the lowest CP and ME values and the highest corresponding ADF values.

Table 6 Average grass quality values per county in 2018

	Antrim	L' Derry	Down	Fermanagh	Tyrone	SED	P value
DM (%)	16.8^{a}	18.0^{b}	20.3^{c}	17.0^{b}	17.2^{b}	0.53	<0.001
CP (%)	19.7^{b}	20.7^{b}	19.4^{b}	17.6^{a}	19.8^{b}	0.75	<0.001
ADF (%)	28.6^{a}	27.4^{a}	28.1^{a}	30.1^{b}	28.7^{ab}	0.70	0.003
WSC (%)	11.6	12.5	12.9	12.3	11.9	0.77	NS
ME (MJ/kg DM)	11.2^{a}	11.6^{b}	11.5^{b}	11.1^{a}	11.4^{ab}	0.10	<0.001

The average values for grass quality measurements taken across all 18 dairy farms are presented for ME, DM%, CP and WSC in Figs. 20, 21, 22 and 23 respectively, and are presented on a dry matter basis. The averages of the farm data (red lines) are compared in each case over the season with the data averages from the GrassCheck plots (blue lines). A similar pattern is observed between the two sources of data with a number of anomalies such as divergence of ME peaks (late July early August), timing of peak DM% (earlier on plots than the on-farm average), and a drop in WSC on farms in samples measured throughout June which was not mirrored by samples taken from the GrassCheck plots at Greenmount and Hillsborough. It is possible that the cloudier conditions reported towards the end of May or start of June by many of the 18 farms resulted in comparatively reduced photosynthesis and therefore lower average WSC levels compared with the two GrassCheck sites.

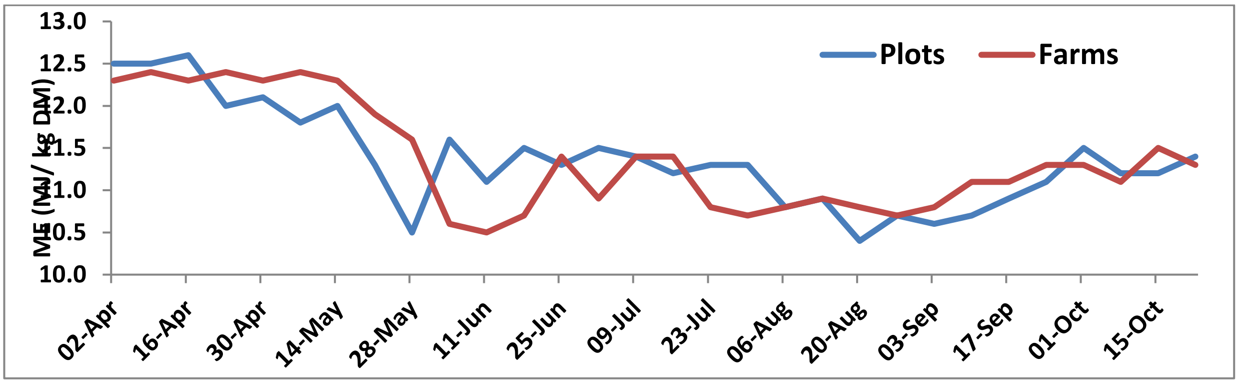


Fig. 20: Comparison of 2018 ME data between GrassCheck plots and dairy farms

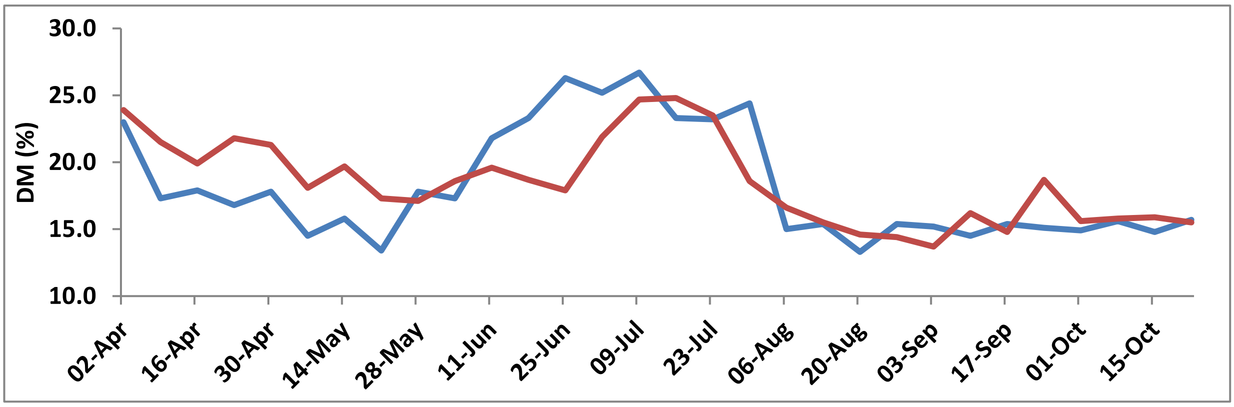


Fig. 21: Comparison of 2018 DM% data between GrassCheck plots and dairy farms

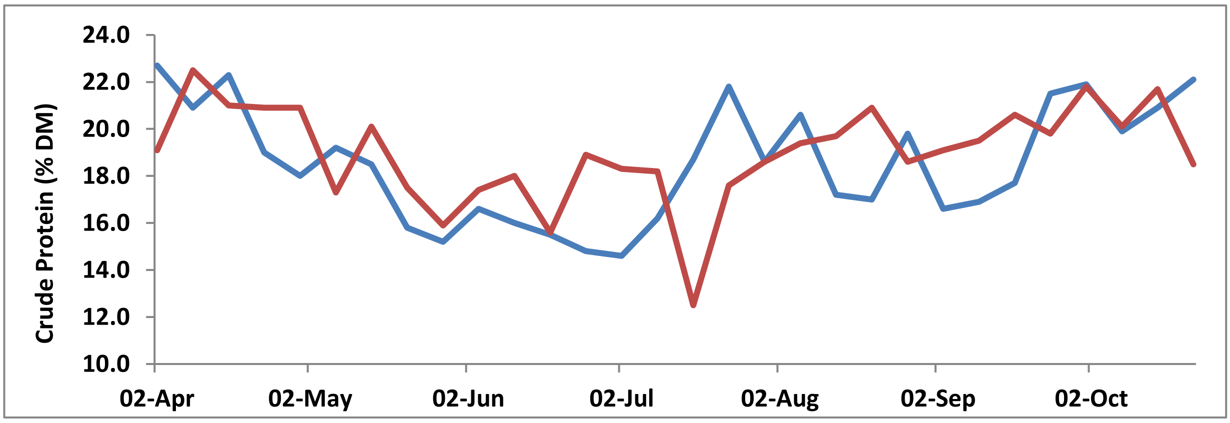


Fig. 22: Comparison of 2018 CP data between GrassCheck plots and dairy farms

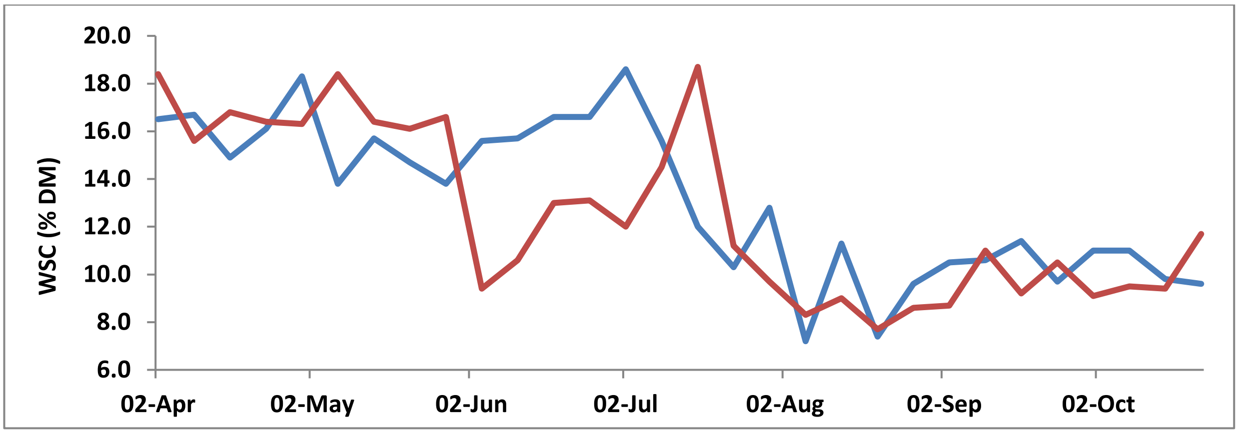


Fig. 23: Comparison of 2018 WSC data between GrassCheck plots and dairy farms

The relationship between ADF and ME is demonstrated in Fig. 24. As ADF increases from below 20% to above 30% the ME value of the grass decreases proportionately from a high of 13.4 MJ/kg DM to a low of 9.9 MJ/kg DM. Average ME values per county ranged from 11.1 MJ/kg DM to 11.6 MJ/kg DM and their corresponding ADF values ranged from 30.1% to 27.4% (Table 6). Higher ADF is associated with increased "steminess" and a more lignified and fibrous grass sample, therefore with a reduced ME value.

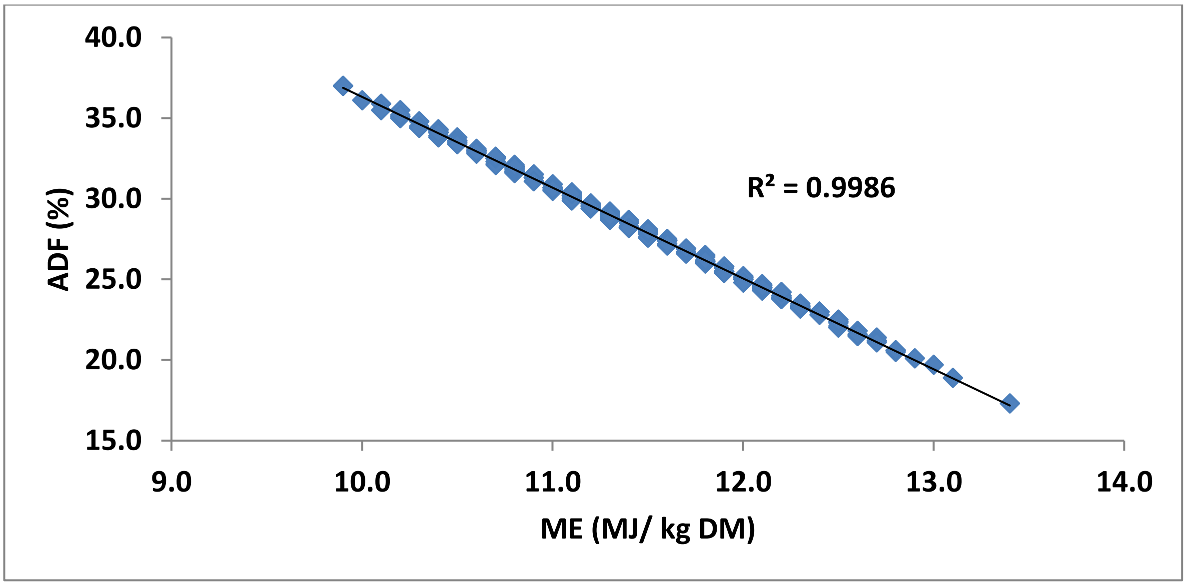


Fig. 24 Correlation between ME and ADF for grass samples taken across 18 farms throughout 2018 growing season. (n=237)

Meteorological data.

Several meterological parameters were recorded by the on-farm weather stations (Davis Instruments, USA) including air pressure (mb), wind speed (mph), rainfall (mm), solar radiation (MJ/m^2) and air temperature (°C). Extra sensors added to these units allowed the additional recording of soil moisture (cb) and soil temperature (°C). Measurements with the strongest relationship to grass production were temperature (air or soil), soil moisture and solar radiation (as photosynthetically active radiation - PAR). Average air temperatures varied greatly between months but not between counties within the same month (Fig. 25).

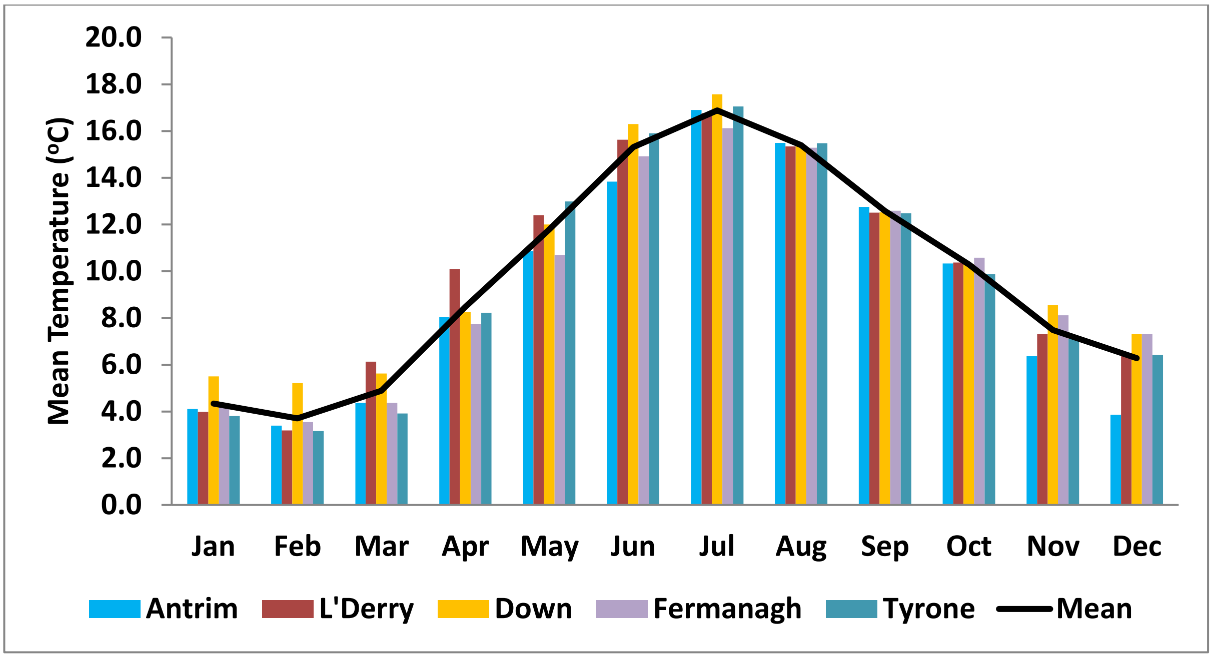


Fig. 25 Mean monthly temperatures (°C) per county recorded on farms throughout NI

Solar radiation measurements recorded on farm were converted to PAR data (as described in equation 2 above) and peaked around the time of theoretical expected maximum (20th/21st June) where daylight hours are at their maximum (summer solstice). There were large differences in PAR between months (Fig. 26). Although the graph would indicate that more PAR was received on farms in County Down than those in County Antrim, likely owing to differences in hours of cloud cover between counties.

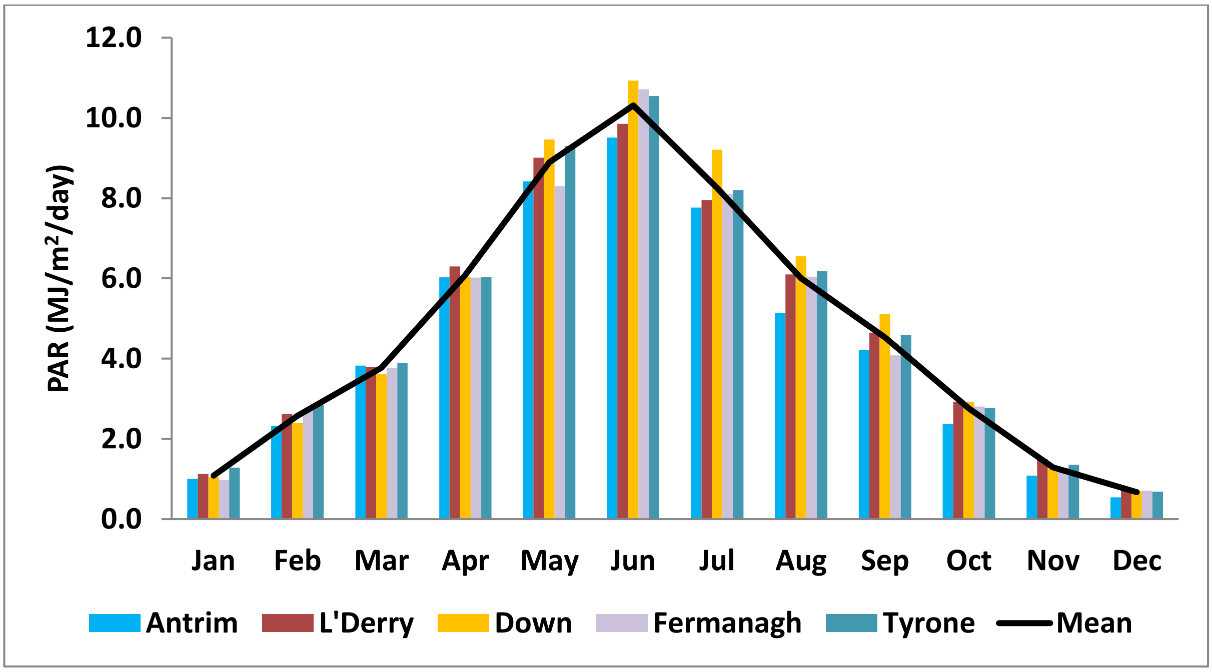


Fig. 26 Mean monthly PAR values (MJ/m2/day) per county recorded on farms throughout NI

Soil moisture content was measured on farms in centibars (cb) using a tensiometer (Davis Instruments, USA). The importance of soil moisture is illustrated by the correlations between soil moisture in the drier periods of the growing season recorded at Hillsborough and Greenmount and their corresponding grass growth rates (Fig 27 and 28). Fewer data points were used in the Greenmount graph as the minimum dry value occurred earlier in July. This low was measured at 24.1% with a corresponding grass production rate of 41.7 kg DM/ha/day. At Hillsborough the dry period lasted longer and soil moisture fell to a minimum of 17.4% corresponding to a grass production rate of 10kg DM/ha/day.

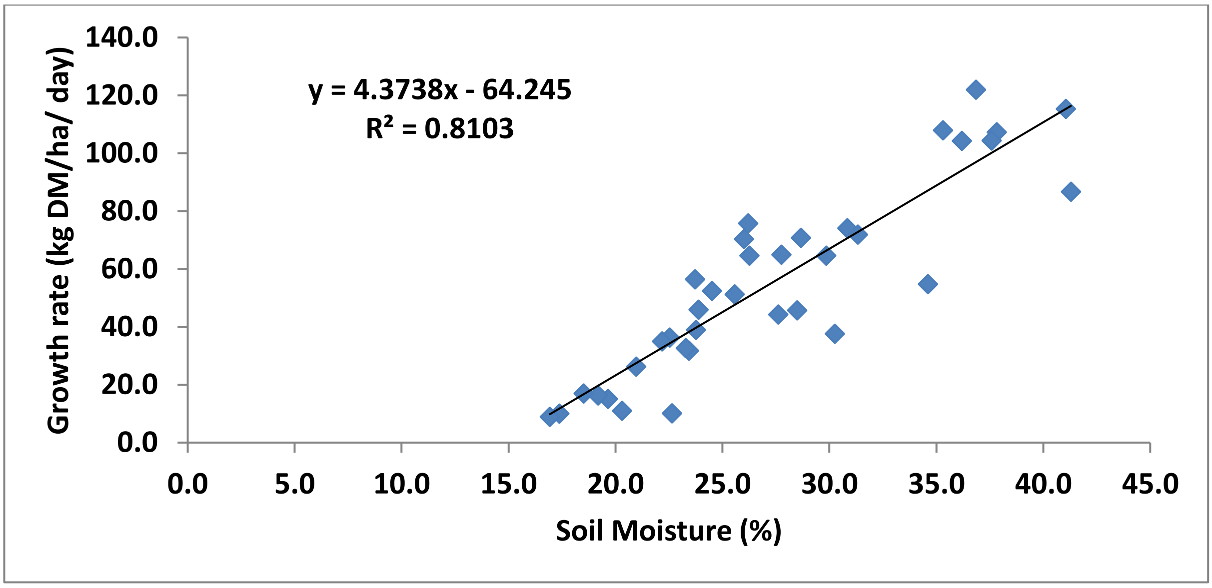


Fig. 27 Correlation between grass growth rate at Hillsborough (14th May-10th September) and average soil moisture from preceding three weeks.

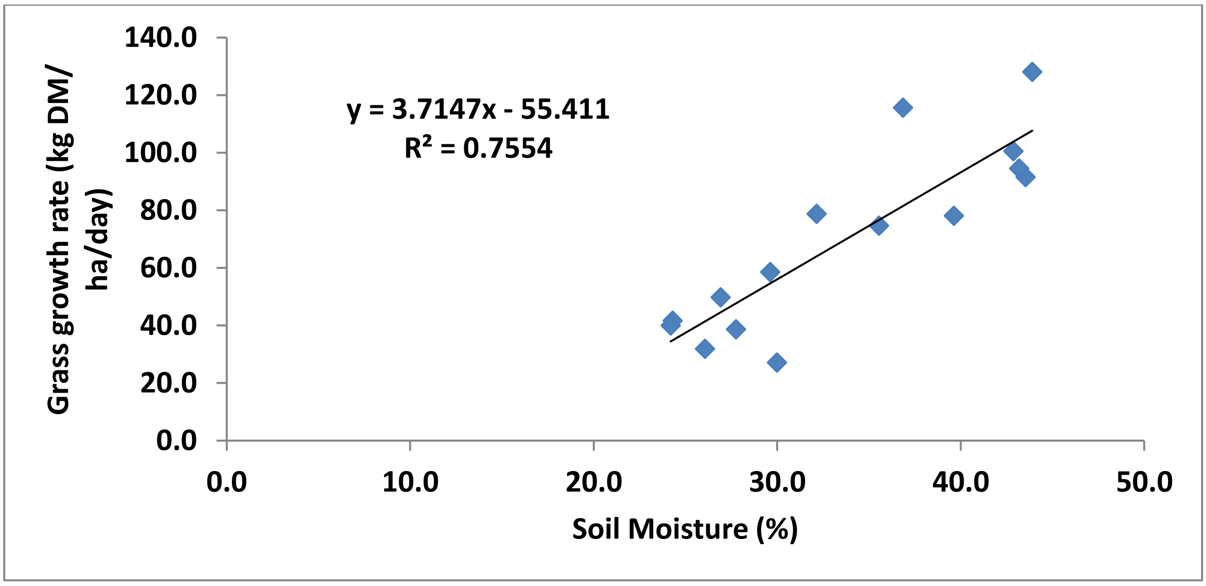


Fig. 28 Correlation between grass growth rate at Greenmount (4th May-2nd July) and average soil moisture from preceding three weeks.

Rainfall is a major factor affecting crop growth but more accurately, the moisture retained in the soil determines how much water is actually available to plants. Measurements of soil moisture and can therefore more accurately reflect what can be utilised by grass.

Soil moisture content as measured on farm is represented graphically (Fig. 29). Soil is considered saturated at 0cb, very wet at 10cb and close to ideal at 20cb. Readings over 60cb suggest plant growth is restricted by lack of moisture. Average soil moisture was lowest in County Down in June and July and highest in County Antrim outside of May, June and July, reflected by the highest and lowest average tensiometer readings in cb, respectively. The farm data for Fermanagh was incomplete and therefore excluded from the graph. The three driest points on the graph (County Down in June and July and County L' Derry in July) also correspond to the lowest rates of summer grass production recorded (Figs. 3 and 4).

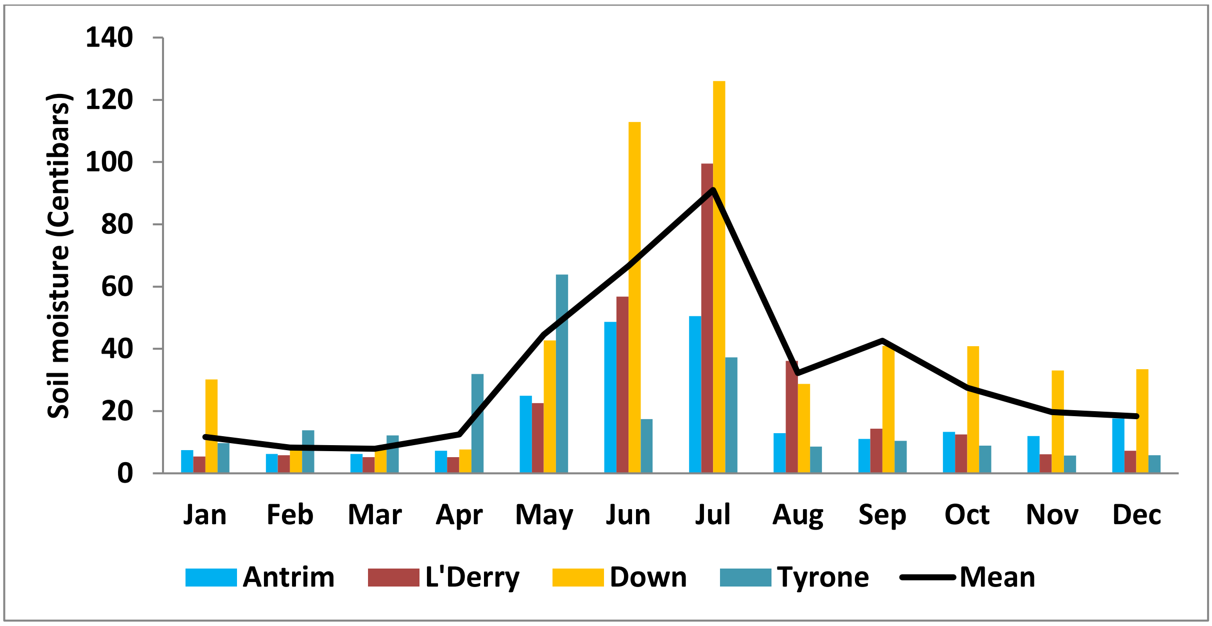


Fig. 29 Mean monthly soil moisture values (cb) per county recorded on farms throughout NI

Grazing utilisation on individual Dairy farms

Average annual grass growth on dairy farms in 2018 was 11.74 t DM/ha and ranged from 8.28 t DM/ha to 15.29 t DM/ha (Fig. 30) across individual farms. Total grass utilisation per farm ranged from 70% to 100%, averaging at 86% (Fig. 31). Additionally, 3 of the 4 farms with the lowest total annual growth (1, 2 and 3) are located in county Down and likely suffered reduced growth rates during the summer drought period where County Down was most severely impacted in terms of grass growth reduction. Farm 9 had the third highest grass production at 13.22t DM/ha and the highest (100%) grazing utilisation, however 9 operates a 'zero-grazing' system so the data recorded here represents machine harvesting of grass instead of grazing events and explains the unusually high efficiency value. Farm 2 had the lowest grass production (8.28 t DM/ha) and a below average grass utilisation at grazing of 76%. That being said, the target grazing efficiency for Dairy farm systems is recommended to be >70 % (AHDB, 2011) so all GrassCheck farms demonstrated a good level of grazing efficiency overall throughout the 2018 season. Farm 6 had the highest number of grazings per paddock at 9.8, and above average total grass growth but below average pre grazing covers.

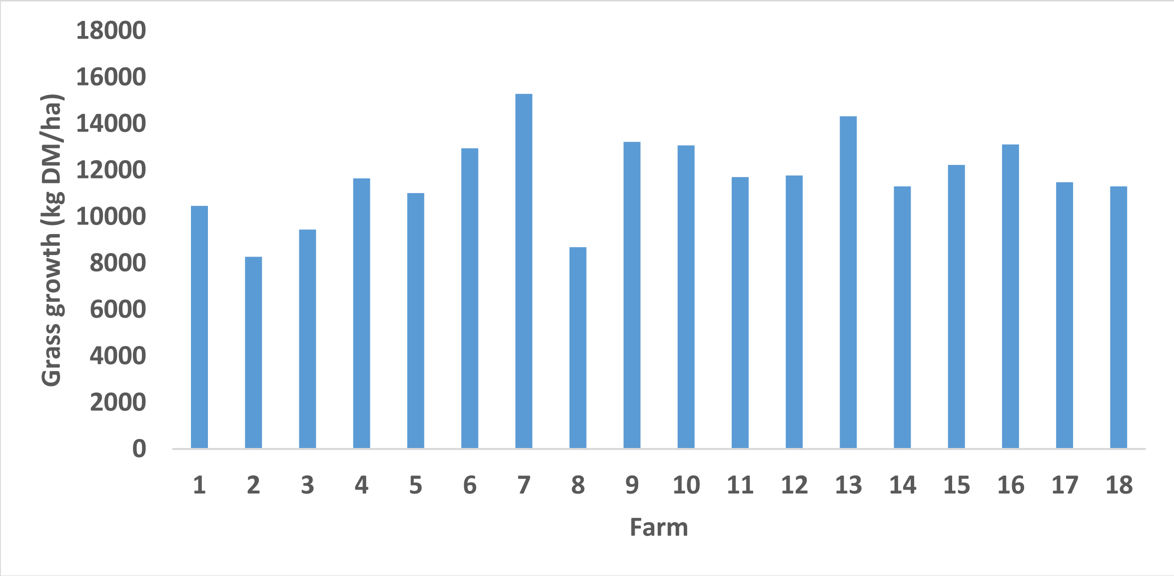


Fig. 30 Average annual growth on dairy farms in 2018.

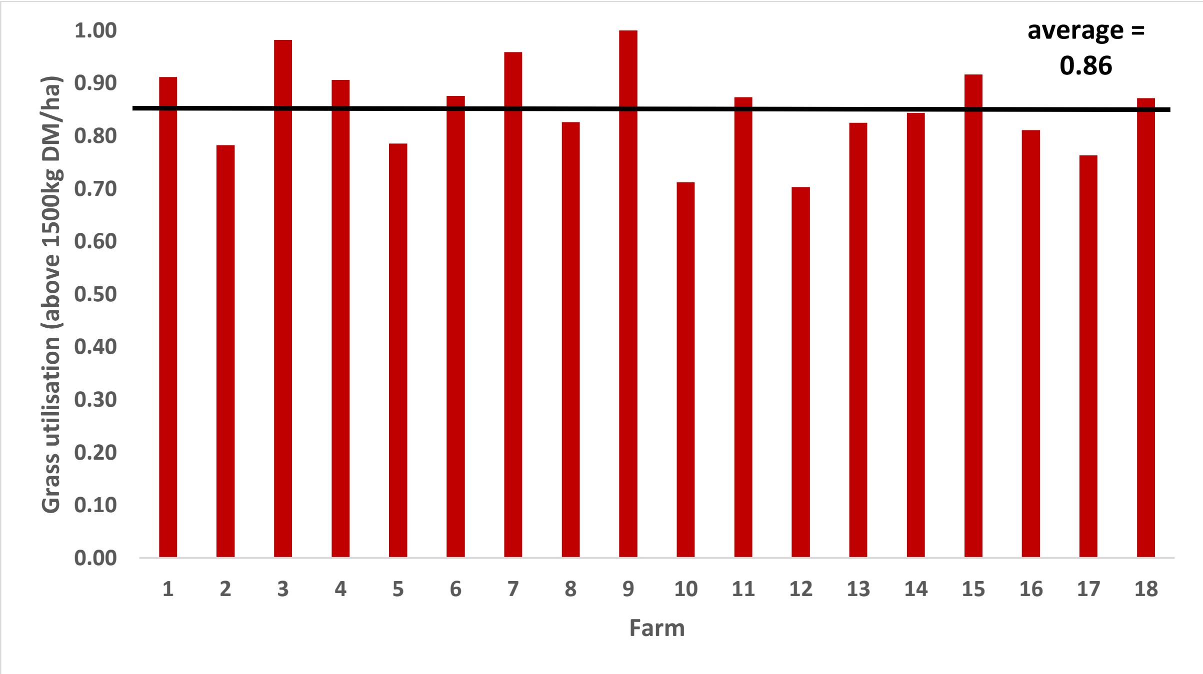


Fig. 31 Grazing utilisation (above 1500kg DM/ ha) on dairy farms in 2018.

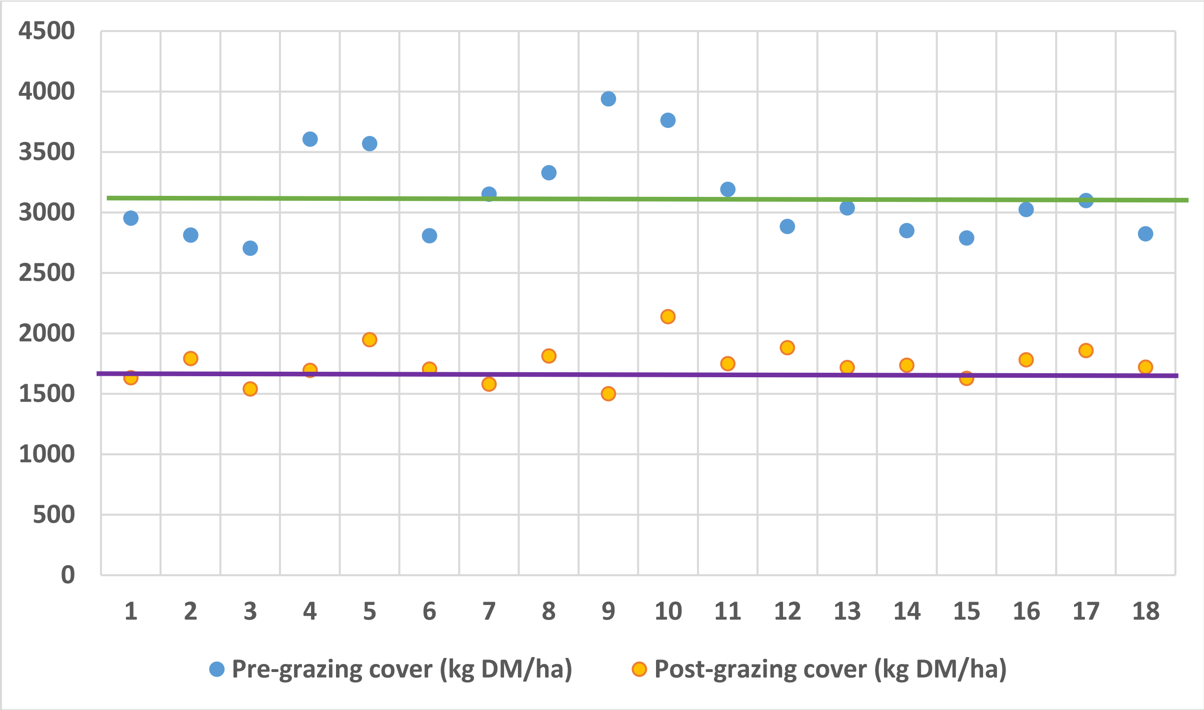


Fig. 32 Average pre and post grazing cover on dairy farms in 2018. Lines represent average pre-grazing (3074kg DM/ha; green line) and post-grazing (1674kg DM/ha; purple line)

Conclusions

- The GrassCheck 18 project, provided robust grass growth and quality data to farmers throughout the 2018 grazing season through managed plots at CAFRE, Greenmount and AFBI, Hillsborough.
- Over 30 GrassCheck bulletins were published on the AFBI and AgriSearch websites and in the farming press providing current grass growth and quality information, management notes and forecast grass growth rates.
- The drought conditions significantly reduced summer grass production, and grazing potential in 2018.
- Grass production in NI as total grass yield in 2018 was 0.6 t DM/ha less than the long-term average, and grass ME content was 0.5 MJ/kg DM lower than the long-term average.
- Soil moisture levels were found to be highly correlated (81%) with grass production during the period of drought.
- The published GrassCheck cut-plot data largely reflected the grass growth patterns seen on commercial dairy farms across NI in 2018.
- Grass growth on NI farms was restricted in summer 2018 due to drought conditions experienced in June and July.
- Drought conditions and therefore reduced soil moisture content affected farms in County Down most, and those in counties Tyrone and Fermanagh least.
- A wide range of soil moisture values were recorded between farms and over the months of the grass growing season (March-October) and these measurements correlated with the rates of grass growth seen.
- The wide range of total annual grass yields recorded on GrassCheck dairy farms across NI is influenced by a multitude of factors including meteorological conditions, soil conditions, and farm-specific management decisions affecting nitrogen availability and soil nutrient status.

Acknowledgements

The authors gratefully acknowledge the hard work and dedication of staff at the AFBI Dairy Unit and Hillsborough Feed Information System, and the CAFRE Greenmount Beef Unit and Advisory teams. Special thanks to Alistair Thompson, Javier Marin and Stephen Clyde for plot management and data collection and Elizabeth Earle and Jason Rankin for weekly publications.

References

AHDB (2017). Nutrient Management Guide. *Fertiliser Manual (RB209) Guidance*, (May). Retrieved from https://ahdb.org.uk/projects/RB209.aspx

AHDB (2011) GRASS+ SECTION 5 - MANAGING YOUR GRAZING. Retrieved from https://dairy.ahdb.org.uk/resources-library/technical-information/grass-management/grassplus-section-5-managing-your-grazing/#.XOLcoW5KiM8

BARRETT, P., LAIDLAW, A. & MAYNE, C. 2004. An evaluation of selected perennial ryegrass growth models for development and integration into a pasture management decision support system. The Journal of Agricultural Science, 142, 327-334.

BARRETT, P., LAIDLAW, A. & MAYNE, C. 2005. GrazeGro: a European herbage growth model to predict pasture production in perennial ryegrass swards for decision support. European Journal of Agronomy, 23, 37-56.

DAERA 2016. Delivering our future, valuing our soils: a sustainable agricultural land managemnet strategy for Northern Ireland. Belfast.

DEFRA 2000. Fertiliser Recommendations for Agricultural and Horticultural Crops (RB209) The Stationery Office, London.

MAYNE, C., ROOK, A., PEYRAUD, J., CONE, J., MARTINSSON, K., GONZALEZ, A., LÚSCHER, A., JEANGROS, B., KESSLER, W. & HUGUENIN, O. Improving the sustainability of milk production systems in Europe through increasing reliance on grazed pasture. Land use systems in grassland dominated regions. Proceedings of the 20th General Meeting of the European Grassland Federation, Luzern, Switzerland, 21-24 June 2004., 2004. vdf Hochschulverlag AG an der ETH Zurich, 584-586.

MET OFFICE, 2019. Regional Datasets. Crown copyright 2019.

WRB, I. 2014. World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources [Reports No. 106].

Appendix 1: Meteorological conditions during 2018 compared with 10 year and 30 year averages. Data from the Met Office.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WN*	SPR	SUM	AUT	ANN
Rain (mm)																	
2018																	
	171	74	86	81	58	49	81	102	57	70	146	110	361	225	232	273	1084
10 yr. Avg. 2008-2017																	
	128	88	84	61	77	84	105	112	93	117	129	122	338	221	302	339	1200
max.	186	171	132	110	124	179	138	201	162	211	220	220	507	286	399	467	1323
min.	55	38	26	25	19	46	70	56	10	45	66	69	208	158	214	224	1047
s.d.	44	38	29	23	32	38	24	45	47	47	51	46	97	40	64	61	95
30 yr. Avg. 1988-2017																	
	118	92	88	76	74	80	89	97	87	120	116	119	328	237	266	323	1157
max.	186	194	147	125	139	179	138	201	178	211	220	220	507	332	399	467	1411
min.	32	32	26	25	11	33	41	14	10	41	50	65	208	158	126	203	899
s.d.	41	41	32	29	35	34	30	41	40	49	43	42	80	45	65	70	116
Temperature (ºC)																	
2018																	
	3.9	2.9	3.9	7.9	11.8	14.9	15.8	14.4	11.5	9.2	7.2	6.4	3.9	7.9	15.0	9.3	9.2
10 yr. Avg. 2008-2017																	
mean	4.2	4.6	5.9	8.0	10.7	13.1	14.6	14.2	12.5	9.9	6.3	4.3	4.4	8.19	14.0	9.6	9.1
max.	5.5	6.2	8.1	10.6	12.3	14.9	17.0	15.1	13.6	10.8	8.7	6.9	5.6	9.17	15.0	10.8	9.6
min.	1.7	2.0	2.8	6.3	9.1	11.8	13.3	13.3	11.5	7.9	4.2	-0.7	2.0	6.3	13.0	8.4	8.0
s.d.	1.1	1.2	1.3	1.3	1.0	0.9	1.0	0.7	0.6	1.0	1.3	2.1	1.2	0.85	0.6	0.7	0.4
30 yr. Avg. 1988-2017																	
mean	4.5	4.7	6.1	7.8	10.5	13.0	14.7	14.4	12.5	9.7	6.6	4.7	4.6	8.13	14.0	9.6	9.1
max.	6.4	7.5	8.1	10.6	12.3	14.9	17.0	17.1	14.2	11.7	8.8	7.2	6.2	9.17	15.5	10.8	9.8
min.	1.7	2.0	2.8	5.7	8.0	10.9	13.1	12.8	10.9	6.8	4.2	-0.7	2.0	6.3	13.0	7.8	8.0
s.d.	1.0	1.1	1.1	1.1	0.9	0.9	1.0	0.9	0.8	1.2	1.2	1.5	0.9	0.67	0.6	0.8	0.4

Wn* Winter data (Dec, Jan, Feb) from December of preceding year.

Appendix 2:

Participating farmers received the following instructions for measurement of grass yield and quality:

1. **Grass Yield**

Grass measurement

- Measurements will start on the week beginning 5 March 2018
- Walk the grazing platform using the platemeter once per week, between Friday and Sunday
- Walking paddocks in the same order will facilitate the recording
- Move across each paddock in a W shape, recording a minimum of 30 'drops'
- Include all different patches of growth to get a representative sample of sward
- Measurements must be updated every Sunday before midnight into Agrinet

Grass sample

- Group A will collect the first sample on the week beginning 5 March 2017
- Group B will collect the first sample on the week beginning 12 March 2017
- After that grass samples will keep being collected fortnightly (see Grass Sampling protocol sheet for more info)

Weather station

- Check the weather station every two weeks (you could do it the week you get your grass sample as a routine)
- Keep the grass around the weather station trimmed (avoid damaging the soil moisture and temperature probes)
- Remove leaves, stones or insects from inside the rain collector gauge
- Remove the filter inside the rain collector gauge and check is not blocked
- Check the funnel hole under the filter is draining properly

Data recording:

Online recording by using AgriNet Grass software (www.agrinet.ie). AgriNet Support available at: Helpline 00353 4692 45118, Email support@agrinet.ie, Website: support.agrinet.ie

Weekly records:

- New paddocks grazed, go to Grass Covers tab (see icon):
    - Date grazed
    - Estimated pre and post covers

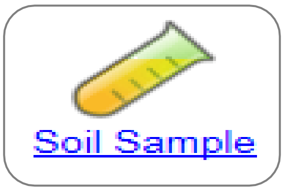
- Enter weekly changes, go to Grass Wedge tab (see icon):
    - Target grass intake
    - Stock numbers
    - Concentrate and silage fed
    - Rotation length
    - Paddocks taken out for silage

- Monthly records:
    - Fertiliser applications (see icon):
    - Receiving paddocks
    - Application date
    - Fertiliser type including lime
    - Amount applied

- Milk deliveries (see icon):
    - Daily herd milk sales
    - Milk quality

- Once a year:
    - Reseeding events:
    - Reseeding date
    - Varieties used
    - New users: most recent results for each paddock including varieties where possible

- Soil samples:
    - Date sampled
    - pH, P and K concentrations
    - New users: most recent results for each paddock



2. Grass sampling protocol for quality measurements.

Where

- Sample from the next paddock to be grazed

When

- Sample Wednesday morning/early afternoon
- Aim to sample immediately before posting
- Avoid sampling before 10am
- Samples to be sent at the latest by last post on Wednesday

Sampling procedure

- Using clipper/scissors cut a large handful of grass to the residual target
- Place cut grass into a bucket
- Take a minimum of a further 5 cuts randomly across paddock and place in the bucket
- Mix gently
- Take a 500g subsample from the bucket
- Gently shake off any external water
- Place grass in the sample bag and gently squeeze the bag to remove the air
- Seal bag and place in the pre-paid envelope
- Place sample in the fridge if possible delay before posting
- Fill in sample questionnaire:
    - Farmer name and group A/B
    - Dairy (G1) or Beef (G2)
    - Sampling date
    - Weather conditions
- Place sample in post Wednesday PM for NIRS analysis at AFBI Hillsborough.