Nutritional Quality of Perennial Forages from May to August:

Impact of Delaying First Cut on Dairy and Beef Production

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Executive summary

Perennial forage production supports Ontario's livestock industry and the livelihoods of thousands of farmers. Hay and pasture also provides nesting habitat for grassland birds such as the threatened Bobolink and Eastern Meadowlark. Delaying hay harvest until July 15 allows time for most nestling birds to develop sufficiently to leave the nest and prevent mortality during hay harvest. However, the nutritional value of hay decreases substantially by July 15 and beyond. Better understanding of the agricultural production and economic impacts of practices to benefit grassland birds like the Bobolink and Eastern Meadowlark was identified as a research priority in the recovery strategy for these species at risk. Research into the relative nutritional value of late-harvest hay and the resulting economic impact helps address that research priority.

As perennial forage (hay) matures over the season there is a natural overall drop in nutritional quality. Mature forages contain a higher ratio of stems to leaves. Leaves contain high levels of available protein and non-structural carbohydrates, while stems are composed primarily of fibre, providing limited energy. As forage matures, the overall volume of forage increases, but this is mostly stem growth with an increase in fibre and drop in the relative amount of available energy and protein.

This project sampled forage crops across Ontario between May and August in 2014 and 2015, undertook laboratory analysis of the nutritional value of forage samples, and modelled the impact of late-harvest forage on beef and dairy production and economic cost of using late harvest hay. 634 forage samples were collected over 13 weeks at 16 sites throughout Ontario from May 21 to August 14 of 2014 and 2015.

As expected, average nutritional quality for forage samples declined at all sites over the season in 2014 and 2015. Crude protein (CP) decreased by an average of 4.5%, total digestible nutrients (TDN) by 7.7%, neutral detergent fibre digestibility (NDFd48) by 20.1%, while lignin increased by 3.5%, neutral detergent fibre (NDF) by 11.2%, and acid detergent fibre (ADF) by 9.9%.

For modeling purposes, nutrient composition of samples was determined for 2015 samples and averaged weekly for each of four regions: Central, Eastern, Northern and Southern Ontario. The standard 2001 National Research Council dairy and 2016 beef models were used to generate estimates of expected milk yields, bodyweight gains, excretory nitrogen losses and rates of methane production from dairy and beef cattle. The yearly milk production of a dairy cow was predicted to decrease an average of 10.9 kg for each day of delay of the forage harvest. Based on 2017 milk prices, the annual milk loss was valued at $7.87/cow for each day of delay in harvest (range of $4.65-$14.26 in different regions).

The growth of beef steers during a 400-day backgrounding program was predicted to decrease an average of 1.56 kg for every day of delay in forage harvest. Based on 2017 auction prices, the loss in bodyweight gain was valued at -$5.49/head for each day of delay in harvest (range of $4.11-$6.96 / head / day in different regions).

Further analysis converted the reduced beef weight gain into lost revenue per acre of forage for backgrounding steers and feeding beef cows over winter. The lost value from delaying first cut from mid-June to mid-July, for backgrounding steers was estimated at $31 per acre (range of $13-$42 per acre in different regions) and approximately $45 per acre (range of $23-$66 per acre in different regions) for beef cows over winter.

Some agri-environmental cost sharing programs in Ontario, PEI, the US and Europe offer incentives to offset the reduced revenue due to lower quality forages. In Ontario, the Grassland Stewardship Program (2016-18), has offered up to $40/ac/year for delayed haying, among other BMPs. The evidence from this research generally support the values already being used in Ontario assess cost sharing programs.

This analysis contributes to knowledge needed to make recommendations to farmers about practices to benefit grassland birds and how to structure stewardship information and incentives to reward adoption of these practices.

Introduction

Perennial forage production in Ontario, both hay and pasture, is an important agricultural industry estimated in value at $746 million in 2007 (Fisher 2008). In 2016, perennial forages, hay and pasture, were grown on over 20,000 farms and covering 1.2 million hectares of farmland in 2016. Forage production supports livestock agriculture, including beef, dairy, sheep, horse and other sectors (Mussel et al. 2013).

Grassland birds, such as the Bobolink and Eastern Meadowlark, commonly nest in pasture and hay production fields in many parts of Ontario (McCracken et al. 2013). In pre-European colonization conditions, grassland birds were more restricted to natural grasslands, wet meadows and habitats created by Indigenous peoples' landscape management (McCracken et al. 2013). Populations of grassland birds increased in Ontario with the spread of European-style agriculture during the 18th and 19th centuries, especially the vast areas of pasture and hay (McCracken et al. 2013; Smith 2018, 2015). Today many grassland-nesting species are largely dependent for nesting on pasture and hay on working agricultural lands as breeding habitat. During the 20th and early 21st centuries, Ontario agriculture shifted to greater focus on annual crops and hay and pasture acreage has declined significantly (Smith 2018, 2015) as it has across North America in recent decades (Stanton et al. 2018).

Bobolink and Eastern Meadowlark were designated threatened species in 2010 and 2012 respectively under Ontario's Endangered Species Act due to their declining populations and a recovery strategy was developed (McCracken et al. 2013). Further, a roundtable of stakeholders was formed and developed recommendations on how to conserve the bird species while allowing agricultural practices to continue and encourage voluntary stewardship (McCracken and Crews 2013). Better understanding of the economic impact of practices to benefit grassland birds like the Bobolink and Eastern Meadowlark was identified as a research priority in the recovery strategy for these species (McCracken et al. 2013). This current research project into the nutritional value of late harvest hay and the resulting economic impact helps address that research priority. It also builds on previous analysis of the economic impact (Mussel et al. 2013) and other nutritional studies (Diemera and Nocera 2016; Brown and Nocera 2017).

The specific causes of the decline in grassland bird populations are complex (McCracken et al. 2013; Hill et al. 2014; Ethier and Nudds 2015; Ethier et al. 2017) but failure of nesting to result in enough young birds surviving to adulthood and breeding is clearly a major concern. Young birds are dependent on their parents for food for a long period and are especially vulnerable until they fledge, or leave the nest. Hay harvest or grazing before the young birds have fledged can result in bird mortality. Biologists estimate that most young Bobolinks have left the nest in Ontario by July 15 in most years (Pintaric 2018; Brown and Nocera 2017; Diemer and Nocera 2016; Mussel et al. 2013). July 15 is quite late from a forage nutritional quality perspective (Mussel et al. 2013; Diemera and Nocera 2016). In addition, if no harvest took place until July 15, the first cut harvest season would extend well into August.

The science of forage production has long established the decline of nutritional value of forages through the growing season and sought to identify optimal harvest times (Ball et al. 2001; Upfold and Wright 1994). After mid-July has usually been beyond the usual range of dates when forage nutritional analysis has been done. As perennial forages (hay) mature over the season there is an inevitable drop in quality. Mature forages contain a higher ratio of stems to leaves, lower levels of available protein and non-structural carbohydrates, and higher amounts of fibre, providing limited energy.

The species composition of perennial forage crops is variable but generally includes legumes and grasses in differing mixtures tailored to site conditions and livestock species (Ontario Ministry of Agriculture, Food and Rural Affairs [OMAFRA] 2009; Upfold and Wright 1994). Forage grown for dairy production tends to be primarily alfalfa-dominated, while forage for beef, sheep and other livestock species may have more grass species and include other legumes. Bobolink and Eastern Meadowlark are more numerous in grass-dominated hay fields, but do nest in all types of hay (McCracken et al. 2013). As well, alfalfa-dominated hay grown for dairy production is usually harvested much earlier and more often that grass-dominated hay, to meet the higher nutritional needs in dairy production. This combination of factors has led to grassland bird conservation efforts to focus on mixed forage crops grown for beef, sheep and other livestock, rather than forage grown for dairy production (Diemera and Nocera 2016; McCracken et al. 2013).

The trade-offs between conservation of grassland birds and forage nutritional value for livestock is becoming a familiar one. In Europe, many farmland bird species also depend on agricultural grasslands and delaying forage harvest is often recommended there (Broyer et al. 2016; Dicks et al. 2014). Yet the delay of harvest undermines the purpose of agricultural grasslands for production of livestock. Stewardship funding and extension programs seek to address these trade-offs. Educational materials and tools allow farmers to assess those trade-offs and make informed decisions (e.g. Kyle and Reid 2015).

Some agri-environmental cost sharing programs in Ontario, Prince Edward Island, the United States and Europe offer incentives to offset the reduced revenue due to lower quality forages. In Ontario, the Grassland Stewardship Program provided up to C$40/ac/year for delayed haying (Ontario Soil and Crop Improvement Association 2018). PEI recently offered farmers C$25 / acre for delayed haying to benefit grassland birds. In Vermont, the Wildlife Habitat Incentive Program provided reimbursement of up to US$62/ha (C$33 / acre) for delayed hay cutting in 2008–2009 (Perlut et al. 2011). The US Conservation Reserve Program funds setting aside land from production and harvest until after the nesting period. European agri-environmental schemes offer significant incentives for biodiversity conservation including farmland birds (e.g. as much as £260 /ha, or C$183 / acre for the endangered Corn Crake; Perkins et al. 2011).

This study sought to quantify the nutritional quality of Ontario forages over the entire growing season into mid-August and model the nutritional and production effects to improve understanding of the trade-offs between nutritional quality and grassland bird nesting success. Estimates of the reduced quality of forage allows the calculation of the reduced animal weight gain or milk production and thus economic return for lower quality forage. These in turn allow for calculation of reduced value of hay on a per acre basis based on average yields. These estimates will contribute to evidence-based design of educational materials and stewardship programs that assist farmers in adopting practices to benefit grassland birds.

Methods

Outlined below are methods used for the three components of this study:

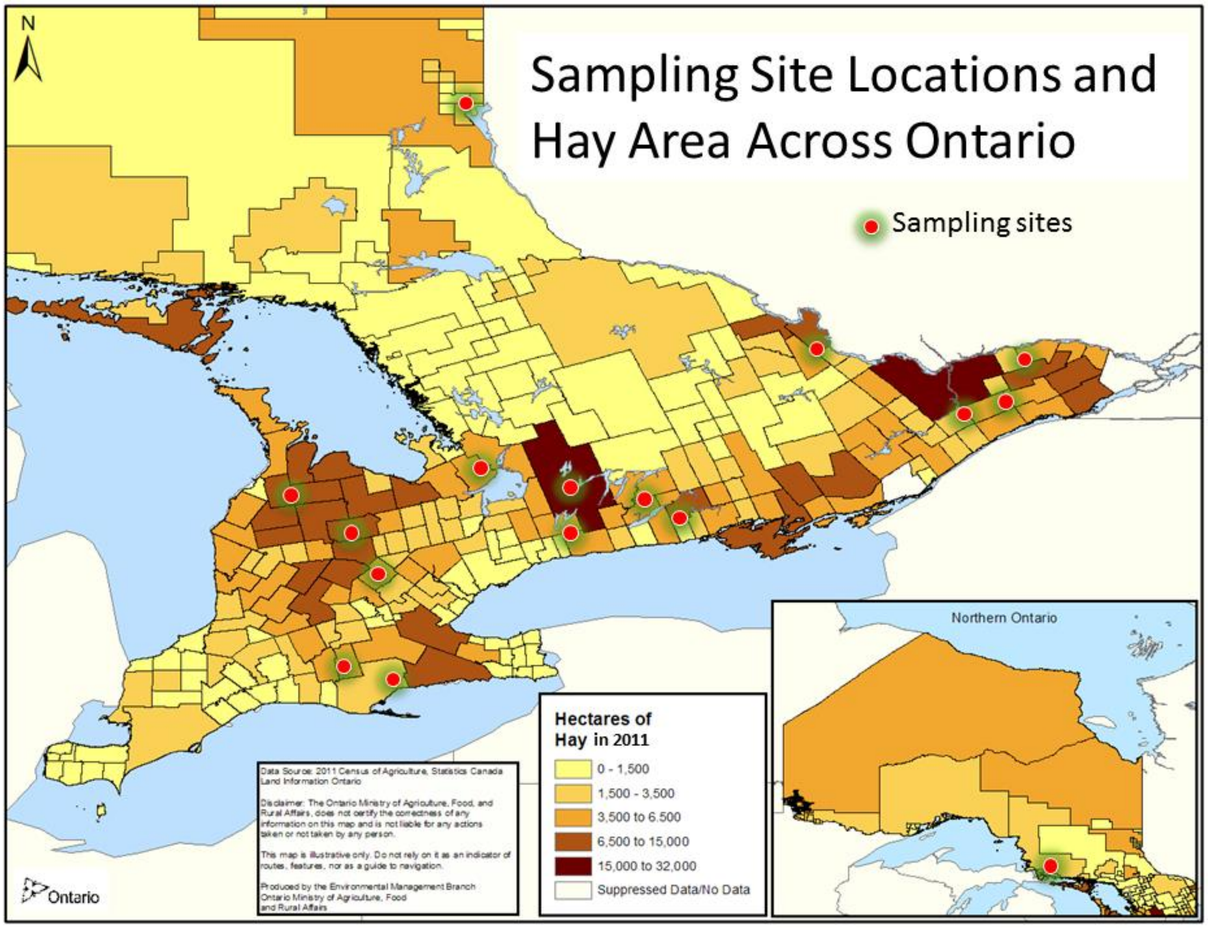
- Field sampling and locations
- Laboratory analysis of forage samples
- Nutritional modeling of the effect of date of forage harvest

METHODS: Field Sampling and Locations

Perennial forage (hay) samples were collected weekly (12-13 weeks, two samples per site, 634 samples) at 16 sites across Ontario from May 21 - August 14 of 2014 and 2015. This extends beyond the usual first-cut hay harvest dates to mid-August to reflect an extended season under hypothetical delayed haying until July 15 with hay harvest operations starting on July 15 and continuing until complete.

Figure 1 shows the geographic locations of the 16 sampling sites as well as the area of hay by township in Ontario. The sampling sites were selected to reflect the differences in growing conditions across the province and predominant areas of forage production. The sites reflect a wide range of values of Crop Heat Units for production from 2400-3100 (Table 1), covering most common growing conditions for forages. The sites include different species mixes (Table 1), Legume (alfalfa-dominated), Grass (grass-dominated) or Mixed (a relatively equal mixture of legumes and grasses). Fields tend to be initially seeded with a larger legume component and gradually change over time toward a more grass–dominated mix. Bobolink and Eastern Meadowlark are generally more abundant in grass-dominated species mixes (and delaying hay field rejuvenation or rotation is a BMP, Kyle and Reid 2015). Where possible, sites with all three types of forage categories were sampled in each geographic region. At two sites (Oro and St. Williams), more detailed plant species identification was done on each sample.

Figure 1. Sampling site locations and hay area across Ontario.



Sampling sites were near the communities of Alfred, Cambray, Chesley, Dundalk, Echo Bay, Elora, Embro, Enniskillen, Keene, Kemptville, New Liskeard, Oro, St. Williams, Warkworth and Winchester. The Chesley and Embro sites were excluded from nutritional modeling due to inconsistent sampling procedures, but are included in the general analysis of lab results. The sampling sites were grouped into four regions and these regions and location data are noted in Table 1.

Table 1. Location and characteristics of sampling sites for forage nutritional study

Region	County, Region, District	Sampling Site Location	Crop Heat Units	Type of Forage
Eastern Ontario	Prescott and Russell	Alfred	2900	Mixed
	Leeds and Grenville	Kemptville	2900	Grass-dominated
	Stormont, Dundas and Glengarry	Winchester	2900	Legume-dominated
	Renfrew	Renfrew	2700	Grass-dominated
Central Ontario	Kawartha Lakes (formerly Victoria)	Cambray	2700	Grass-dominated
	Durham Region	Enniskillen	2900	Legume-dominated
	Peterborough County	Keene	2700	Grass-dominated
	Northumberland County	Warkworth	2900	Mixed
Northern Ontario	Algoma District	Echo Bay	2500	Grass-dominated
	Timiskaming District	New Liskeard	2400	Grass-dominated
	Simcoe County	Oro	2700	Grass-dominated
Southern Ontario	Grey County	Dundalk	2500	Grass-dominated
	Wellington County	Elora	2700	Legume-dominated
	Norfolk County	St. Williams	3100	Grass-dominated
	Oxford County	Embro	2900	Legume-dominated
	Bruce County	Chesley	2700	Grass-dominated

A section of each field was taped off and left unharvested and undisturbed for sampling throughout the duration of the project. Samples were taken from an 18x18 inch section by cutting the forage 3 inches above the ground. Two samples, or replicates, were taken each week for 12-13 weeks. 634 forage samples were collected for analysis, 292 in 2014 and 342 in 2015. Collected samples were bagged and frozen until they were all delivered to the lab for analysis.

This is not how hay would be handled during commercial production. Under realistic conditions it can be expected that 15-30% of the crop may be lost during harvest and storage, with the nutrient-dense leaves being more vulnerable to leaf shattering. As no harvest losses occurred with the sampling method used, total nutrient values of all the sampled forages may be overstated. However, this effect is likely greater in later-cut forages as more mature leaves are more brittle and susceptible to shattering.

METHODS: Lab Analysis

Lab analyses were conducted on each sample (634 samples) and determined the concentration of dry matter (DM), neutral detergent fibre (NDF), acid detergent fibre (ADF), crude protein (CP), soluble protein, undegradable intake protein (UIP), lignin, and other variables such as micronutrients. Neutral Detergent Fibre Digestibility (NDFd48) was also measured to assess truer digestibility in rumen fluid based (for 48 hours, see more below). Replicates were averaged to provide a single mean value of each nutrient measure for each week. Key variables are defined and their significance described below (OMAFRA 2016).

Dry Matter - is the moisture-free material left after drying the sample in a laboratory oven. The reason for obtaining dry matter is that moisture dilutes the concentrations of the nutrients present, and it is standard practice to evaluate the feed and balance rations using a dry matter basis.

Crude Protein (CP) - is calculated based on the nitrogen content of the feedstuff. Protein is made up of approximately 16% nitrogen. In the lab, total nitrogen is measured and multiplied by 6.25 (100/16) to derive a value for 'crude protein'. CP is expressed as a percent of dry matter.

Soluble Crude Protein - is most readily available to animals and can be absorbed across the rumen wall. Soluble protein is expressed as a percentage of the total crude protein.

Undegradable Intake Protein (UIP) – or by-pass protein, is the fraction of protein that is resistant to degradation by rumen microbes. UIP is also is expressed as a percentage of the total crude protein.

Acid Detergent Fibre (ADF) - refers to the cell wall portion of the forage, made up of lignin and cellulose. The value is important as it relates to the ability of an animal to digest the forage. The ADF represents the portion of the hay that doesn't dissolve in an acid detergent solution. It has a strong (negative) relationship with total forage digestibility. ADF is used to define guidelines for hay quality, as ADF increases, forage quality declines. ADF is expressed as a percent of dry matter.

Neutral Detergent Fibre (NDF) - refers to the cell wall fraction that includes ADF and hemicellulose. The NDF value is related to the amount of forage the animal can consume and as NDF increases, the dry matter intake generally decreases. NDF is expressed as a percent of dry matter.

Neutral Detergent Fibre Digestibility (NDFd) – is feed digestibility in rumen fluid based on 48 hours (NDFd48) in an in-vitro digestibility analysis. In other words, it measures how much of the feed material has been digested by the microbes in rumen fluid after 48 hours. This more accurately reflects the digestibility by rumen microbes. NDFd48 is expressed as a percent of NDF.

Total Digestible Nutrients (TDN) - an equation is used to calculate energy or total digestible nutrients (TDN). This is the first limiting parameter for milk production. This measure includes NDF, lignin, fat, starch, mineral and bound protein and is used to estimate energy values. TDN is expressed as a percent of dry matter.

Lignin - is the indigestible portion of the plant cell. This number will increase with the maturity of the forage. It is a good indicator of any digestibility issues as lignin negatively affects the digestion of the cell wall by acting as a physical barrier to the microbial enzymes. Lignin is expressed as a percent of dry matter.

Forage samples were analyzed at a commercial feed laboratory (A&L Canada Laboratories Ltd., London, Ontario). Analyses were done using wet chemistry methods for the reported parameters. This is the first systematic survey over time (season and year) of forage quality in Ontario that analyzed samples for neutral detergent fibre digestibility (NDFd48), which is a newer forage analysis method that assesses NDF digestibility using an in vitro system that approximates the true digestibility of NDF fibre fraction in the rumen. Samples were analyzed for NDFd using the Daisy II incubator (Ankom Technology, Macedon, New York) using the Van Soest buffers for macro and micro solutions. In vitro true digestibility was determined using Ankom Technology Method 3. After the required in vitro incubation time, NDF was determined using Ankom Method 6, Neutral Detergent Fibre in Feeds – FBT for A2 fibre analyzer.

Statistical analysis of the laboratory nutritional analysis data was undertaken using Microsoft Excel and associated statistical add-ins. Analytical tools include analysis of variance, regression and correlation.

METHODS: Nutritional Modeling

Modeling methods were used to estimate the effects on milk production and weight gain in livestock fed rations including forages harvested at different dates. The standard National Research Council models for livestock production were used for estimates for dairy (National Research Council 2001) and beef production (National Academies of Sciences, Engineering, and Medicine 2016). These models are sets of equations developed by industry experts to predict production outcomes of animals fed varying diets. The equations are based on decades of research and are viewed as an industry and academic standard.

For the nutritional modeling study, sites were grouped into the four regions (Table 1) and the corresponding nutritional data was averaged together to provide a single value for each sampling time period. These regions reflect different climatic, geographic and agricultural production conditions across Ontario known to affect forage growth and quality.

RESULTS: Forage Sampling

All forage samples from both 2014 and 2015 were analyzed for nutritional variables, including those noted above in Methods.

Trends across the season May-August (both 2014 and 2015) in nutritional value are consistent with other studies (Table 2 and Figure 2 below). Generally nutritional quality variables decline over the season in both years. This includes Neutral Detergent Fibre Digestibility (NDFd48), crude protein (CP), Total Digestible Nutrients (TDN), soluble protein, and undegradable intake protein (UIP). Neutral Detergent Fibre Digestibility (NDFd48) is the best indicator of nutritional value (OMAFRA 2016).

Table 2 shows the average percent change over the season May to August in eight key nutritional parameters. Most variables associated with positive nutritional value, Crude Protein (CP), Neutral Detergent Fibre Digestibility (NDFd48) and Total Digestible Nutrients (TDN), all showed overall declines through the season. Soluble Crude Protein and Undegradable Intake Protein (UIP) changed relatively little. Variables indicative of low digestibility increased over the season, Lignin, Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF).

Table 2. Percent change in average nutritional parameters of forage harvested from May to August, averaged for all sites (least squares estimates).

Variable	2014 Average May-Aug change	2015 Average May-Aug change	Overall Average May-Aug change with standard error
Crude Protein (CP)	-4.5%	-5.9%	-5.2% ± 1.3
Soluble Crude Protein	-0.7%	-1.4%	-1.1% ± 2.1
Un-degradable Intake Protein (UIP)	0.4%	0.7%	0.5% ± 1.0
Neutral Detergent Fibre Digestibility (NDFd48)	-13.0%	-27.3%	-20.1% ± 5.4
Total Digestible Nutrients (TDN)	-5.8%	-9.7%	-7.7% ± 1.2
Lignin	+2.2%	+4.8%	+3.5% ± 0.8
Acid Detergent Fibre (ADF)	+7.5%	+12.4%	+9.9% ± 1.6
Neutral Detergent Fibre (NDF)	+9.4%	+13.1%	+11.2% ± 2.1

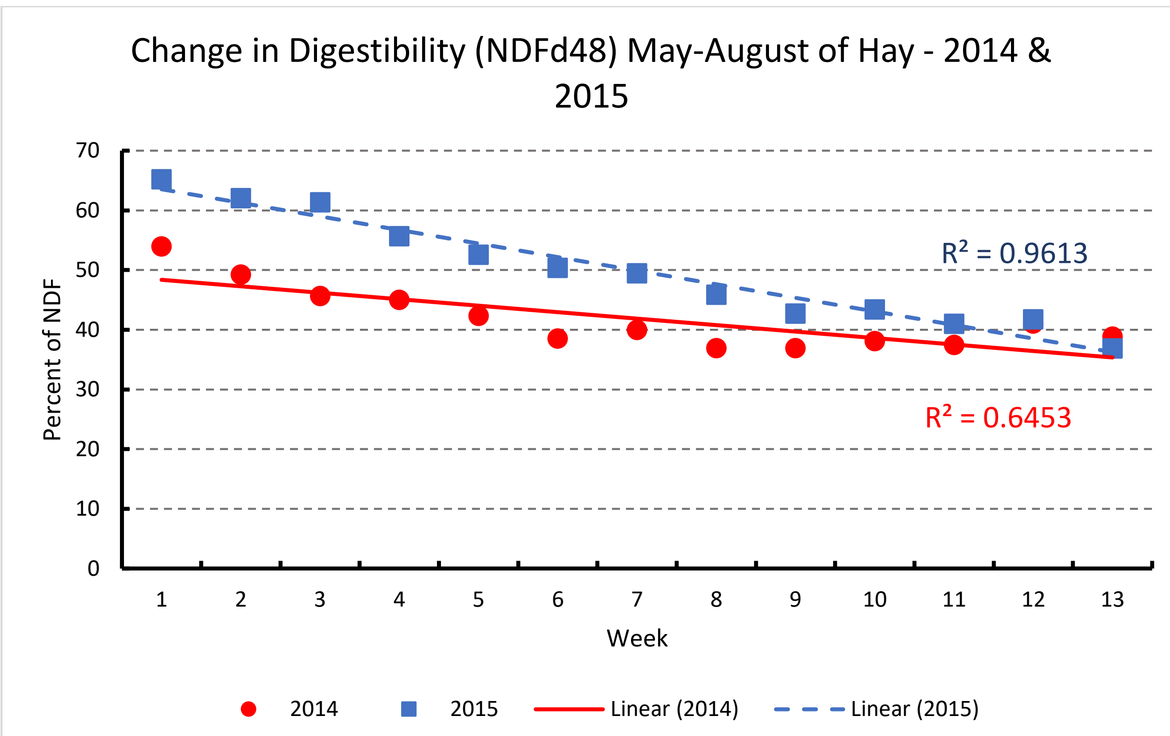
Figure 2 shows the average values of these variables over the season, May to August in both 2014 and 2015, averaged across all sites. These provide the simplest way to illustrate the overall results. Similar to Table 2, variables associated with positive nutritional value, Crude Protein (CP), Un-degradable Intake Protein (UIP), Neutral Detergent Fibre Digestibility (NDFd48) and Total Digestible Nutrients (TDN), all showed declines through the season in each year. Conversely, variables indicative of low digestibility increased over the season, Lignin, Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF), in each year. Regression lines and the variance explained (R^2

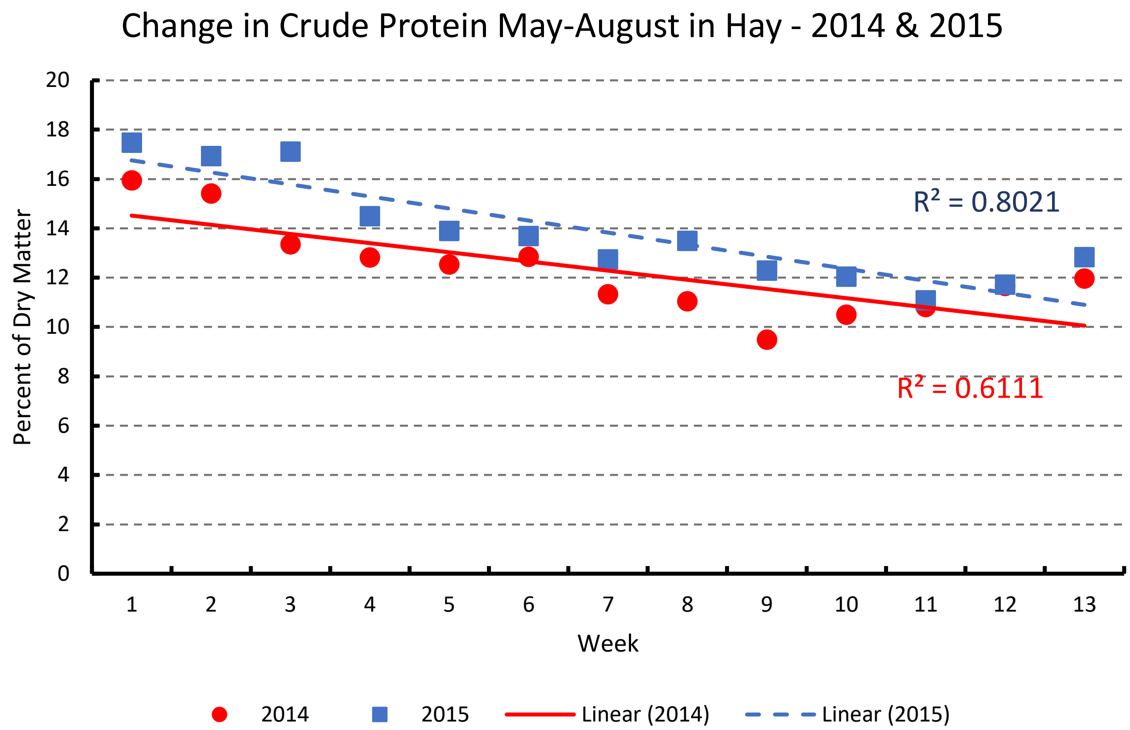
values) are shown in the graphs. Again, these results are typical and reflect well known trends in seasonal forage quality (e.g. Upfold and Wright 1994; Ball et al. 2001; Berdahl et al. 2004).

Each site shows slightly different trends, but generally reflect the provincial average trends. To illustrate the variation between sites, Appendix 1 shows the graphs for each site for one variable (Neutral Detergent Fibre Digestibility, NDFd48).

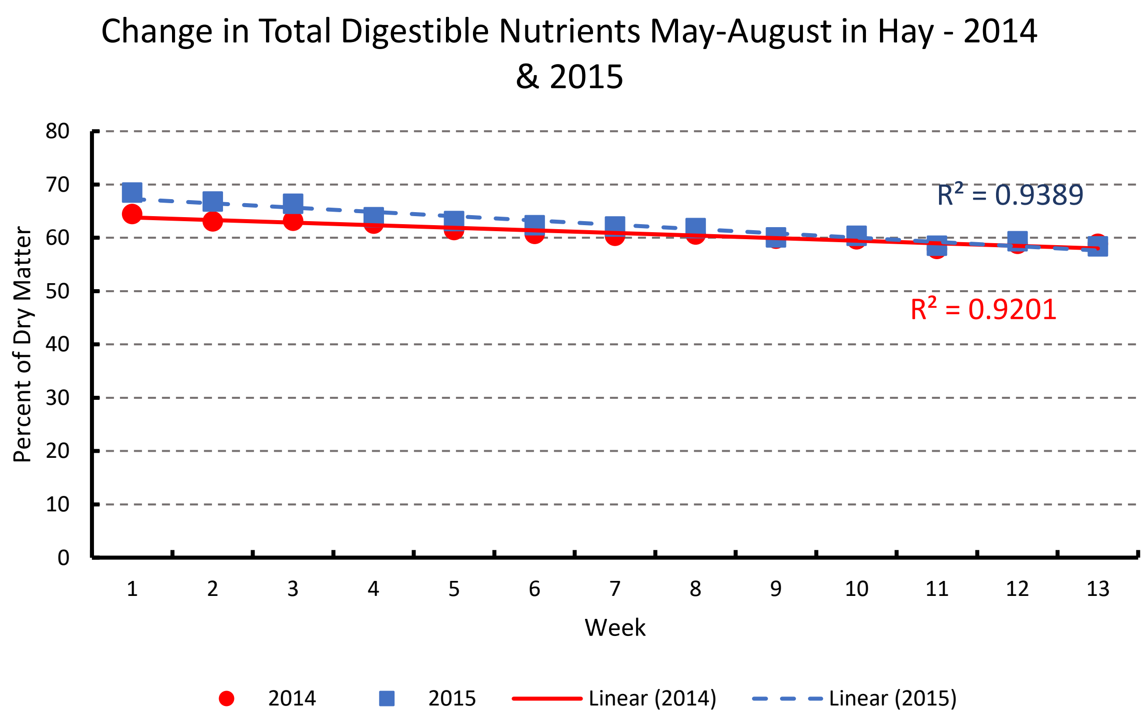
The more detailed site data is used in modeling analyses in the next section of the report on nutrition modeling.

Figure 2. Graphs of average values for all sites of nutritional variables of forage harvested May-August 2014 and 2015 (NDFd48, CP, TDN, NDF, ADF and Lignin)

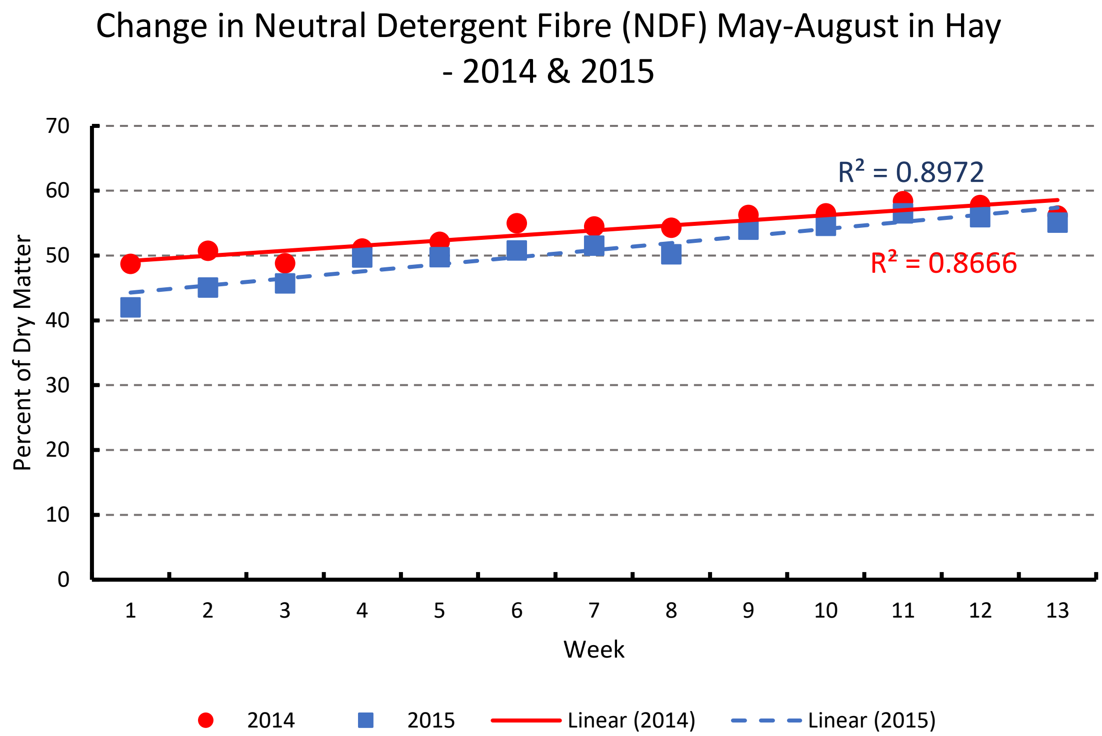


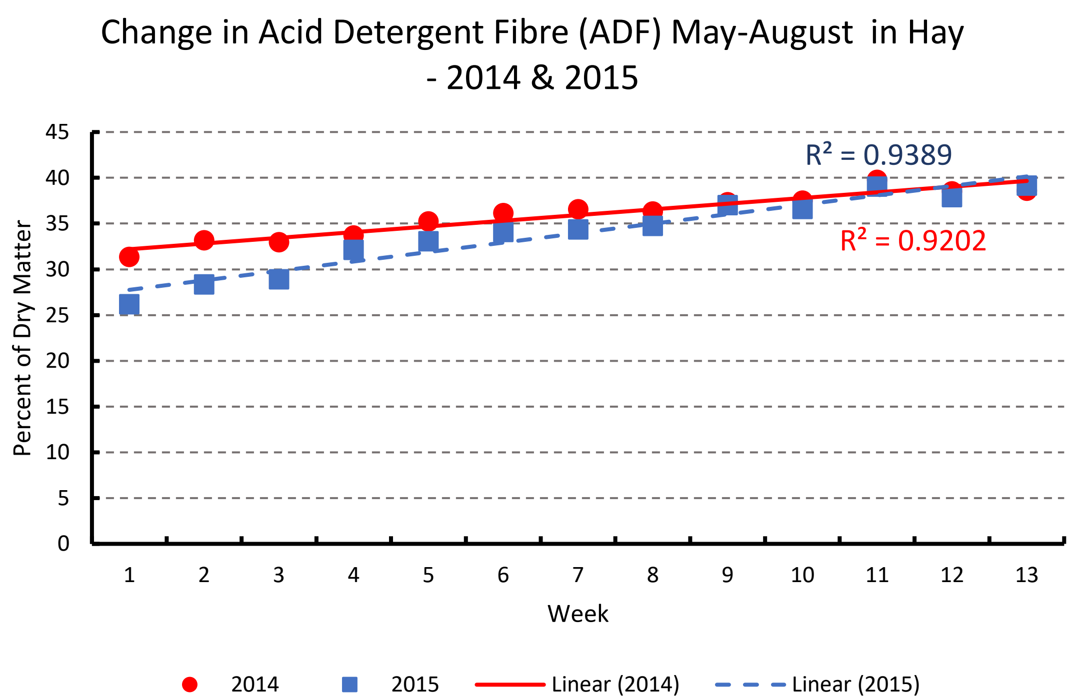


Change in Crude Protein May-August in Hay - 2014 & 2015
Percent of Dry Matter
0
2
4
6
8
10
12
14
16
18
20
1
2
3
4
5
6
7
8
9
10
11
12
13
Week
R^2 = 0.8021
R^2 = 0.6111
2014
2015
Linear (2014)
Linear (2015)



Change in Total Digestible Nutrients May-August in Hay - 2014 & 2015
Percent of Dry Matter
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11
12
13
Week
R^2 = 0.9389
R^2 = 0.9201
2014
2015
Linear (2014)
Linear (2015)


Change in Neutral Detergent Fibre (NDF) May-August in Hay - 2014 & 2015
Percent of Dry Matter
Week
R² = 0.8972
R² = 0.8666
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
11
12
13
2014
2015
Linear (2014)
Linear (2015)


Change in Acid Detergent Fibre (ADF) May-August in Hay - 2014 & 2015
Percent of Dry Matter
Week
R² = 0.9389
R² = 0.9202
0
5
10
15
20
25
30
35
40
45
1
2
3
4
5
6
7
8
9
10
11
12
13
2014
2015
Linear (2014)
Linear (2015)

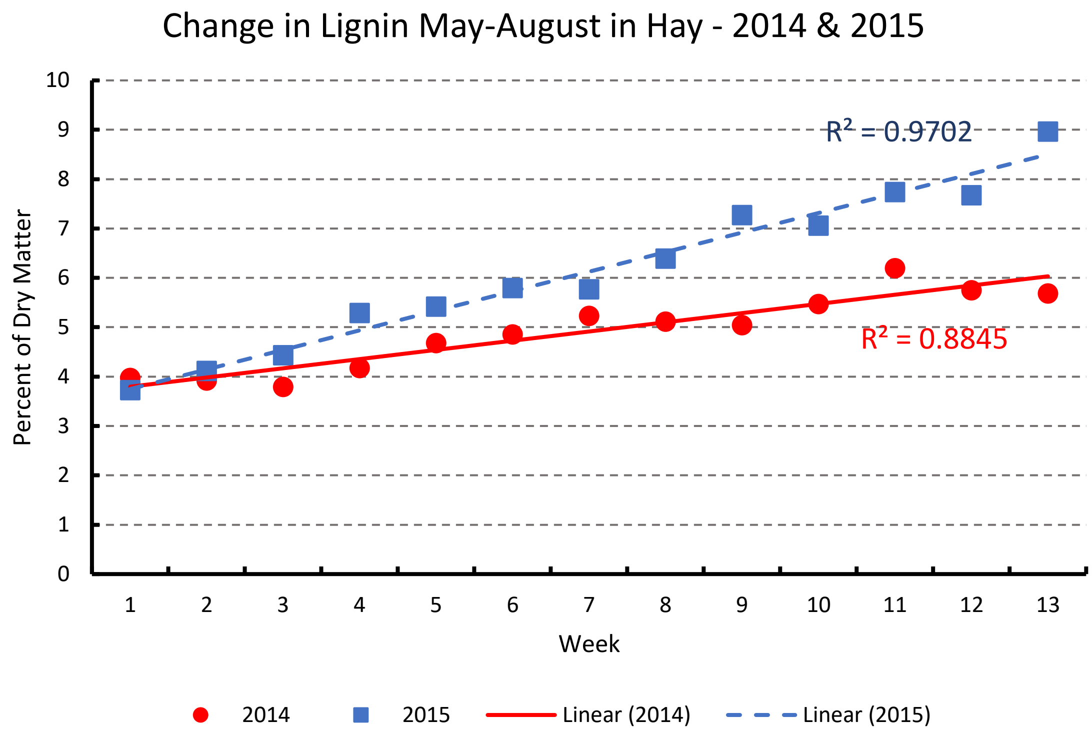

Change in Lignin May-August in Hay - 2014 & 2015
Percent of Dry Matter
10
9
8
7
6
5
4
3
2
1
0
R² = 0.9702
R² = 0.8845
1
2
3
4
5
6
7
8
9
10
11
12
13
Week
2014
2015
Linear (2014)
Linear (2015)

*Table 3. Average forage quality values for each sample site (combined values 2014 and 2015).**

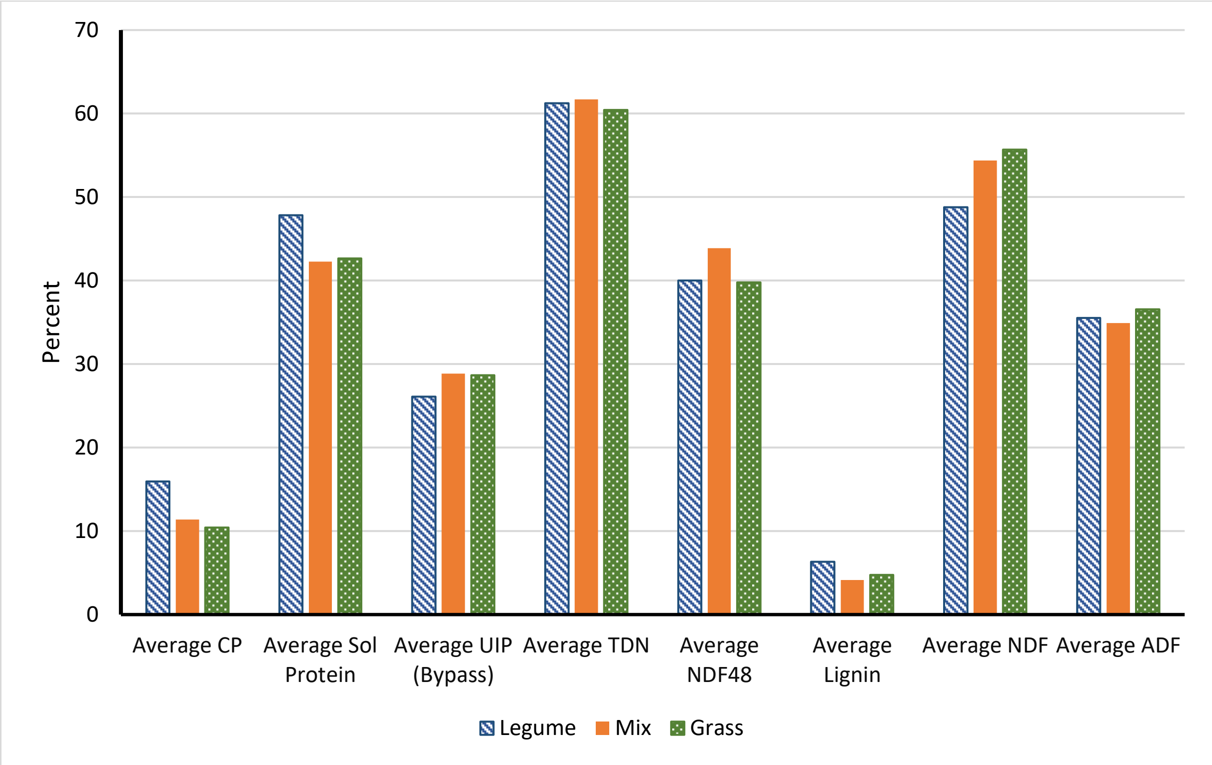
Region	Site	Average CP	Average Soluble Protein	Average UIP (Bypass)	Average TDN	Average NDFd48	Average Lignin	Average NDF	Average ADF
East	Alfred	12.40	43.53	28.23	62.19	51.25	5.42	50.45	34.29
	Kemptville	12.01	33.85	33.07	61.40	50.83	5.09	60.21	35.30
	Renfrew	8.18	52.18	23.91	54.81	34.48	5.57	64.97	43.76
	Winchester	20.20	50.69	24.65	63.04	44.44	6.69	42.34	33.19
Central	Warkworth	14.91	50.24	24.88	60.74	40.90	7.59	46.53	36.15
	Enniskillen	15.71	48.65	25.67	63.79	37.91	6.74	44.26	32.24
	Cambray	12.18	42.74	28.63	59.57	38.56	6.45	56.15	37.65
	Keene	12.08	40.89	29.56	60.97	45.05	5.29	56.04	35.85
North	Echo Bay	10.27	37.94	31.03	62.05	49.41	4.76	53.93	34.47
	New Liskeard	14.45	44.22	27.89	66.54	44.96	6.84	40.49	28.71
	Oro	8.57	38.34	30.83	60.03	48.75	4.79	60.02	37.06
South	Embro	14.90	52.82	23.59	54.82	27.92	10.69	52.84	43.75
	St. Williams	11.87	40.54	29.73	60.24	45.89	5.35	55.94	36.79
	Dundalk	11.07	42.26	28.87	62.79	44.46	4.87	52.09	33.52
	Elora	14.30	41.20	29.40	61.46	44.82	5.84	49.78	35.22
	Chesley	13.53	44.47	27.77	61.87	54.63	3.96	58.26	34.70
Average over all samples		12.91	43.64	28.18	61.60	45.10	5.61	52.32	35.05

** Quantities in table are expressed as percent of dry matter except for soluble protein and undegradable intake protein (UIP) which are expressed as percent of crude protein and Neutral Detergent Fibre Digestibility (NDFd48) which is expressed as percent of NDF.*

Each site differs due to many parameters including soils, climate, geography, and drainage. *Table 3* shows the average values for the forage quality variables for each site, combining all measurements taken in both 2014 and 2015. The values for CP and ADF are comparable to values reported from sites across Ontario in Brown and Nocera (2017). The values of all variables were significantly different among sites (ANOVA, F-test, $p<0.001$).

Many of the nutritional variables showed a statistically significant influence from crop heat units (CP, ADF, NDFd48, TDN, soluble protein, UIP, Lignin) while controlling for seasonal change as a covariate. Forage species mixture type also significantly influenced a number of nutritional variables (CP, NDF, NDFd48, Soluble Protein, UIP, Lignin; see *Figure 3*). Such results are expected. This suggests further data analysis may provide greater insights into factors influencing nutritional value.

Figure 3. Differences in nutritional variables for different forage types



RESULTS: Nutrition Modeling

The nutrition modeling portion of the study uses the lab analysis of forage samples as inputs into standard nutrition models to estimate the effect of decreasing nutritional quality over the season on milk production and weight gain.

Modeling included analyses for:

- Dairy cows
- Beef steers
- Beef cows

Results for each of these are presented below.

Nutrition Modeling Results: Dairy

Most lactating dairy cows in Ontario are fed a total mixed ration (TMR) containing some combination of corn silage, concentrated energy, protein and vitamin/mineral supplements, and forages, usually in the form of an alfalfa silage (haylage). The 2001 NRC dairy equations were used to generate estimates on how feeding forages harvested at each timepoint during the summer would affect milk production.

The following assumptions were made when using the dairy software:

- Mature cows with a body weight of 681 kg

- The average milk yield is 36 kg/day
- The cows are 105 Days in Milk

The following diet (on a DM basis), which is representative of a typical Ontario ration, was used for all calculations, with the quality of all ingredients, other than hay, being constant:

- 3.6% straw
- **25.5% of the sampled hay**
- 38% corn silage, containing 40% grain
- 19.4% high moisture corn
- 13.5% custom concentrate

Estimated milk production (net energy or NE allowable milk, metabolizable protein or MP allowable milk), protein intake (CP crude protein, MPI metabolizable protein intake) and nitrogen excretion (an indicator of protein availability) all decreased over the season, declining with the decreasing quality of forage already noted in previous sections. The extent of the decreases are quantified for averages of all samples in Table 4 and for each region in Appendix 2.

The decline over the summer in estimated milk production (Table 4), as measured by net energy (NE) allowable milk, metabolizable protein (MP) allowable milk, shows the impact of the different maturity of forage samples impact on milk production. Milk production is determined by dietary energy and protein availability. Energy is utilized by microbes located within the cow's rumen. The microbes ferment the varying carbohydrates into volatile fatty acids (VFAs) that are subsequently utilized by the cow as a source of energy and to synthesize the lactose and fatty acids in milk.

Dietary protein is found in two forms: rumen degradable protein (RDP) and undegradable protein (UIP). The rumen microbes utilize the RDP to synthesize their own microbial proteins that flow out of the rumen and can be digested in the cow's small intestine. UIP is unavailable to the rumen microbes, but can be available to the cow, if the protein can be digested by the cow's own enzymes, which is mainly dependent on the protein being unbound from fibre. Neutral detergent (hemicellulose) bound crude protein may be freed by the rumen microbes, but is unavailable once past the rumen, acid detergent (cellulose + lignin) bound protein is completely unavailable and will pass through undigested.

Table 4. Dairy: Trends in estimated milk production, protein intake and nitrogen excretion on a diet including forage harvested May-August 2015

Week	Week of Harvest	Net energy allowable milk (kg/day)	Metabolizable protein allowable milk (kg/day)	CP Intake kg/d	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
1	22-May	36.4	38.0	4.0	2635.0	2862.0	1457.0	1405.0
2	29-May	36.0	37.7	3.9	2617.3	2731.3	1448.6	1282.8
3	04-Jun	36.2	37.2	3.9	2602.0	2773.5	1448.0	1325.5
4	12-Jun	35.9	36.6	3.8	2572.8	2617.0	1439.7	1177.3
5	19-Jun	35.7	36.6	3.8	2576.5	2626.2	1442.7	1183.5
6	26-Jun	35.5	35.8	3.7	2542.8	2592.7	1433.0	1159.8
7	03-Jul	35.5	35.8	3.7	2541.3	2589.3	1433.0	1156.3
8	10-Jul	35.3	35.7	3.7	2538.0	2579.9	1432.9	1147.0
9	17-Jul	35.1	34.7	3.6	2495.8	2535.1	1420.8	1114.3
10	23-Jul	35.0	35.1	3.6	2514.3	2550.2	1426.9	1123.3
11	30-Jul	35.2	34.0	3.6	2476.3	2513.7	1423.4	1090.3
12	07-Aug	35.0	36.2	3.7	2562.7	2614.5	1440.5	1174.0
13	14-Aug	34.9	35.3	3.6	2519.5	2552.3	1426.8	1125.5
Average		35.5	36.0	3.7	2551.0	2616.2	1435.6	1180.6
Correlation with date		-0.9657	-0.8265	-0.8280	-0.8238	-0.8116	-0.7962	-0.8071
R^2		93.25%	68.32%	68.55%	67.86%	65.86%	63.40%	65.14%

The amount and availability of protein is important as it determines how much protein is available to support lactation. Net energy and metabolizable protein are both critical to supporting milk production and a decrease in either will cause a loss in milk production. When reading NE and MP allowable milk, the lower number of the two will represent the actual level of milk that a cow would be expected to give on the diet containing the sampled forage.

Both crude protein and metabolizable protein intake (MPI) decline May-August (Table 4). MPI is shown to demonstrate the effect of the maturing sampled forages on protein intakes and retention. MPI indicate the level of crude protein in the diet and how available the protein is to the animal.

Urinary nitrogen is another indicator of protein intakes and balance. Excess protein is converted to urea. Normally most of this is excreted in the urine while some is sent to the rumen to be "recycled" by the rumen microbes. During times of lower protein availability, less urea will be formed, and a greater proportion will undergo "recycling" in an effort to maintain normal homeostatic function. Fecal nitrogen indicates CP levels in the diet and how digestible the protein was to both the microbial and animal enzymes. Declines in nitrogen excretion over the season, averaged for all sites, are shown in Table 4. Detailed tables and graphs for each region are shown in Appendix 2.

The above results were to be expected. As forages mature there is an overall drop in quality. Mature forages contain a greater ratio of stems to leaves. The leaves are the drivers of forage value as they contain high levels of available protein and non-structural carbohydrates, which provide energy. Stems on the other hand are composed of primarily fibre in the form of NDF and ADF, which provide limited energy and much of the protein they contain is fibre-bound, making it poorly available. Therefore, as forage is left to mature there is an overall increase in the amount of forage, but this is almost exclusively driven by stem growth causing an increase in the amount of NDF and ADF in the forage and a dilution of available energy and protein.

Nutrition Modeling Results: Beef Steers

An analysis for beef steers was also undertaken. Feed information was input into the feed library of the Beef Cattle Nutrient Requirements Model 2016. The following assumptions were made for all calculations:

- The diet was being fed to Angus steers on a backgrounding program
- Initial body weight of 226 kg (500lb) and finishing at 408 kg (900lb)
- Steers were raised at an ambient temperature of 20° Celsius
- The steers were fed a 100%-forage diet, consisting of the sampled forage
- The steers would be fed *ad libitum,* therefore the inputted dry matter intake (DMI) was matched to the predicted DMI

Measures of beef steer weight gain and nitrogen excretion decrease over the season with decreasing forage quality (Table 5). Metabolizable energy (ME) allowable gain, metabolizable protein (MP) allowable gain, urinary and fecal nitrogen and median methane emissions per kg of DMI. ME and MP allowable gain follow the same principles as NE and MP allowable milk, but in the case of backgrounding beef steers the energy and protein are being utilized to support the structural growth of muscle tissue in beef steers. The average results for all sites pooled are presented in Table 5. Results for each site are shown in Appendix 3.

Table 5. Beef Steers: Trends in estimated weight gain and nitrogen excretion on a diet of forages harvested May-August 2015

Week	Week of Harvest	Average ME allowable gain (kg/day)	Average MP allowable gain (kg/day)	Average Urinary N (g/day)	Average Fecal N (g/day)	Average Manure N (g/day)	Average Methane (g/kg DM)	Average Expected DMI (kg/day)
1	22-May	0.940	0.790	133.6	61.32	194.9	14.66	7.36
2	29-May	0.940	0.848	111.0	61.28	172.3	13.94	7.36
3	04-Jun	0.943	0.810	114.3	59.08	173.4	14.13	7.36
4	12-Jun	0.870	0.797	94.9	57.97	152.9	13.33	7.40
5	19-Jun	0.860	0.800	83.7	56.67	140.3	13.03	7.40
6	26-Jun	0.808	0.768	84.4	56.67	141.0	12.86	7.42
7	03-Jul	0.785	0.745	79.4	55.46	134.9	12.63	7.41
8	10-Jul	0.763	0.720	78.8	55.34	134.2	12.55	7.43
9	17-Jul	0.693	0.688	71.3	54.62	125.9	12.09	7.42
10	23-Jul	0.647	0.660	61.9	53.03	114.9	11.64	7.42
11	30-Jul	0.570	0.613	70.0	55.02	125.0	11.63	7.40
12	07-Aug	0.597	0.643	61.5	53.98	115.5	11.42	7.41
13	14-Aug	0.517	0.547	92.9	57.13	150.0	11.99	7.39
Average		0.762	0.726	85.3	56.54	141.8	12.69	7.40
Correlation with date		-0.9837	-0.9448	-0.7946	-0.8075	-0.7988	-0.9535	0.6475
R^2		96.8%	89.3%	63.1%	65.2%	63.8%	90.9%	41.9%

Once again, urinary and fecal nitrogen indicate both the amount of protein in the diet and its availability and decline May-August (Table 5). Note that the overall urinary and fecal nitrogen numbers are much lower than those found in dairy cows, which is to be expected as the beef steers are only consuming about 30% of the DM of the dairy cows and the growing steers will more efficiently utilize the protein they consume. Predicted methane emissions are included as an indicator of rumen microbial activity.

Like the dairy cows, the primary production parameter, being daily body weight gain, tends to decrease as the rations include forage from lower quality later harvests. These results are also due to the increase in the proportion of stems in the mature forage, causing an increase in fibre and decrease in the concentration of energy and protein. Since the steers physically cannot eat more to compensate for the decrease in nutrient concentration, the result is lost production.

Nutrition Modeling Results: Wintering Beef Cows

Another analysis was undertaken for feeding wintering beef cows on the sampled forage. Using the same groupings, feed information was input into the feed library of the Beef

Cattle Nutrient Requirements Model 2016. The following assumptions were made for all calculations:

- The diet is being fed to 3-year old Angus cows being over-wintered
- The cows have a mature weight of 532 kg (1170lb)
- The cows are 200 days pregnant and will give birth to a 40 kg calf in April; therefore the cows are all dry (non-lactating)
- The average outdoor temperature is -5 C, with average lows of -10 C and wind speeds of 15 km/h. The cows are assumed to be sheltered.
- The cows are fed harvested forage from October to April (180 days)
- The cows are being fed enough of the sampled forage to exceed energy requirements by 0.5 Mcal/day

This model scenario differs from the others in that DMI is allowed to increase to exceed the daily energy requirements noted above. The DMI is also required to slightly exceed energy requirements, which represents the primary cost of keeping a mature beef cow over the winter. With a drop in feed quality, the cows will need to eat more to meet their nutrient requirements. This is reflected in the increase in DMI using forage harvested later in the period May-August (Table 6). Linked to the increased DMI for late season forage, both metabolizable energy (ME) and metabolizable protein (MP) also increase with the later season forage. Days to gain one body condition score are included to demonstrate that the cows are being fed just enough to slightly exceed requirements, as a cow fed to her maximum intake could gain one body condition score (BCS) every 30 days. Urinary and fecal nitrogen and methane emissions all demonstrate the same concepts as explained in the previous sections.

Table 6. Wintering Beef Cows: Trends in dry matter intake, energy, protein and nitrogen excretion on a diet of forage harvested May-August 2015

Week	Harvest Week	DMI (kg/d)	Metabolizable Energy ME provided (Mcal/d)	Metabolizable Protein MP provided (g/d)	Days to gains 1 BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
1	22-May	6.80	16.38	480.20	294.00	139.90	55.53	191.27	14.88
2	29-May	6.79	16.36	494.68	302.75	118.78	55.52	166.51	14.17
3	04-Jun	6.80	16.37	485.38	299.00	121.94	53.54	170.48	14.35
4	12-Jun	7.06	16.52	498.63	302.67	105.83	54.41	152.45	13.53
5	19-Jun	7.09	16.54	502.05	303.75	95.83	53.55	142.27	13.22
6	26-Jun	7.30	16.68	506.40	299.25	97.47	54.96	144.77	13.03
7	03-Jul	7.41	16.74	508.25	300.00	92.72	54.61	140.52	12.79

Week	Harvest Week	DMI (kg/d)	Metabolizable Energy ME provided (Mcal/d)	Metabolizable Protein MP provided (g/d)	Days to gains 1 BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
8	10-Jul	7.49	16.80	505.63	296.50	93.48	55.18	141.27	12.71
9	17-Jul	7.80	16.99	515.85	296.75	87.75	56.77	137.31	12.22
10	23-Jul	7.99	17.11	521.90	298.67	79.24	56.73	129.20	11.75
11	30-Jul	8.36	17.36	530.78	295.50	90.67	61.84	144.95	11.71
12	07-Aug	8.21	17.26	530.13	295.67	80.45	59.63	133.10	11.50
13	14-Aug	8.61	17.53	524.17	294.67	114.67	66.31	172.05	12.04
Average		7.52	16.82	508.90	298.73	99.44	56.68	148.98	12.85
Correlation with date		0.9783	0.9748	0.9548	-0.4917	-0.6814	0.7624	-0.5463	-0.9592
R^2		95.7%	95.0%	91.2%	24.2%	46.4%	58.1%	29.8%	92.0%

Increases in forage maturity resulted in a need for higher feed intakes to meet the cow's nutritional requirements. A result of note is that unlike with dairy cows and beef steers, urinary and fecal nitrogen did not always decrease as forage maturity increased, this is likely because intakes were not held constant in this model, unlike the previous two analyses, and therefore the cows were often consuming more total protein even though the feeds they were consuming contained lower protein concentrations.

RESULTS: Production Loss

Based on the documented decreases in nutritional value of forages, animal production values, milk output, and weight gain all showed linear declines over the season. To determine the opportunity cost of lost production due to delaying harvest by an additional day, a linear model predicting production loss per day of delayed harvest was developed for each region. The models were then adjusted to an annual scale to make the data more relevant and simple to interpret. Models predicting the lost revenue per animal per unit time were made by multiplying the production models with market prices.

Dairy and Beef

Predicted milk yields from diets containing the sampled forages declined in a linear manner over the course of the forage-harvesting season. The economic value of lost milk production due to time of harvest was estimated based on March 2017 sale prices of milk components of $10.71/kg fat, $7.45/kg protein and $1.52/kg other solids, assuming 3.8% fat, 3.1% protein and 5.5% other solids in the predicted milk yields (Dairy Farmers of Ontario website, March 2017). For each day of delayed harvest, annual revenue from milk sales was predicted to decline $7.87/cow provincially, or $4.65/cow, $5.16/cow,

$14.26/cow and $7.41/cow for Central, Eastern, Northern, and Southern Ontario, respectively (Table 7). For an average 80-cow dairy farm in Ontario, the revenue loss is expected to be $630 for each additional day of delay, which is equivalent to $19,000 for 30 days of delay and $38,000 for 60 days of delay. 30 days would represent a delay from mid-June, generally an optimal time for harvest nutritionally, to mid-July, optimal for the fledging of nestling birds. First cut in forage for dairy is often in mid to late May, closer to a 60 day difference between mid-May and mid-July.

The economic value of lost bodyweight gain in beef cattle was estimated based on an average April 2017 auction price of $3.52/kg live weight and a backgrounding duration of 400 d. For each day of extending the harvest, reduced weight gain was equivalent to $5.49/head provincially, or $6.96/head, $6.36/head, $4.53/head and $4.11/head for Central, Eastern, Northern, and Southern Ontario, respectively (Table 7). For an average 175-head feedlot in Ontario, the revenue loss is expected to be $961 for each additional day of delay, which is equivalent to $28,830 for 30 days of delay. First cut timing for hay for beef is variable, but is often mid-June to early-July.

Table 7. Average change in annual dairy and beef cattle performance per day of delayed harvest across Ontario and in each region.

	Ontario: Change per day of extended harvest	South	Central	East	North
Milk production (kg/yr/cow)	-10.9	-10.27	-6.44	-7.15	-19.75
Milk production ($/yr/cow)	-$7.87	-$7.41	-$4.65	-$5.16	-$14.26
Bodyweight gain (g/d/head)	-1.56	-1.16	-1.97	-1.79	-1.29
Bodyweight gain ($/400 d/head)	-$5.49	-$4.11	-$6.96	-$6.36	-$4.53

RESULTS: Impact on Cost of Production

Another method to analyze the cost of delaying forage harvest is to compare production costs, in this case feed costs, using forage harvested on different dates. To accomplish this, the outputs must be the entire time period, so the cost of inputs may be fairly compared. By estimating the cost of the different forages and using the predicted feed intakes, the production cost of raising an animal through its respective phase can be estimated.

For beef cows and steers the following assumptions were used for yield calculations and costs:

- A blend of 75% timothy and 25% red clover was being fed
    - This assumption was used purely to provide estimations of yield. This is reasonable for the sampled forages. All predictions for DM required per animal were calculated from the sampled forages.
- Cuts would be spaced 35 days apart, but could be pushed to 30 days if needed.
- Critical fall harvest period for clover was used to determine when another cut was no longer feasible. August 31st was used as the last day to cut for Central, Eastern and Southern Ontario, whereas August 20th was used for Northern Ontario.
- For simplicity, cuts 2 and 3 were considered of equal quality to the first cut. Few comparable estimates are available. This assumption would lead to some over estimation of cost per acre.[1]
- Per acre costs were estimated using the 2017 edition of Ontario Ministry of Agriculture, Food, and Rural Affairs' (OMAFRA) Publication 60: Field Crop Budget for Alfalfa-Timothy Hay and the 2016 Farmland Value and Rental Value Survey (Deaton 2017)
    - Variable costs such as fuel, labour and custom work were adjusted based on the number of cuts undertaken
    - Rent costs were $75, $115, $83[2] and $140/acre for Central, Eastern, Northern and Southern Ontario, respectively.

To determine the cost of delayed harvest, the production cost per acre of hay was first estimated. Then estimated yields (from 2016 edition of Field Crop Budgets, OMAFRA Publication 60) and estimated production costs per acre were used to calculate the feed cost per kg of DM, using the following formulae.

$$Feed\ Cost = \frac{Cost/Acre}{kg\ DM/Acre}$$

Next, the amount of DM required per animal during their phase of production was calculated assuming they were fed solely on the sampled forage.

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[1] A major limitation of the cost/acre estimates is that the 2nd and 3rd cuts were considered the same quality as the first cut. We felt it important to include the impact of delayed harvest on the overall forage DM yield per acre as this would have significant impacts on feed costs. In reality the second and third cuts would be of different quality than the first, especially when the first cut is delayed to mid-July. However, estimating the nutritional value of a blend of the sampled first cut and hypothetical later cuts would require other assumptions. Assuming all the cuts were of the same quality likely had limited effects when the first cut was taken before mid-June as the stage of plant development would be similar in all three cuts. The assumption has no impact when the first cut was in August as it was assumed only one cut could be taken. The assumption likely leads to some undervaluing of the forage when first cut was taken late-June to late-July. In these situations, it was estimated that about 70% of the total yield would be from the first cut, leaving about 30% of the total yield from a second cut assumed of greater quality. So there may be some overestimating of cost differences between a first cut in mid-June and mid-July.

[2] The value for northern Ontario may be somewhat high, being likely influenced primarily based on cropland rental rate rather than hay land rental.

$$DM\ req.\ per\ Animal = DMI\ \left(\frac{kg}{d}\right) \times Days\ on\ Feed$$

Using the cost of the sampled forage ($/kg of DM) and the DM requirements, the cost of feeding one steer or cow through their respective production phase was determined.

$$Cost\ per\ Animal = \frac{Feed\ Cost}{kg\ DM} \times \frac{DM\ req.}{Animal}$$

Finally, following equation was used to determine what the cost per acre of delayed harvest:

$$Cost/Animal_{mid-June} = Cost/Animal_{mid-July}$$

$$Cost/Animal_{mid-June} = DM\ req_{mid-July} \times \frac{Subsidized\ Cost/Acre_{mid-July}}{kg\ DM/Acre_{mid-July}}$$

$$Subsidized\ Cost/acre_{mid-July} = \frac{Cost/Animal_{mid-June}}{DM\ req./Animal_{mid-July}} \times kg\ DM/Acre_{mid-July}$$

$$Loss\ of\ Delayed\ Harvest = Original\ Cost\ per\ Acre - Subsidized\ Cost\ per\ Acre$$

$Cost/Animal_{mid\text{-}June}$, DM $requirement_{mid\text{-}July}$ and kg of $DM/Acre_{mid\text{-}July}$ were all taken from Table 8 and Table 9. Subsidized $Cost/Acre_{mid\text{-}July}$ was the calculated cost of production, of a first cut taken in mid-July that would need to be met to match the cost per animal of a 1^{st} cut taken in mid-June.

Backgrounding Steers

For backgrounding steers, a target rate of an Average Daily Gain (ADG) of 0.6kg/d was selected for the models as it was predicted that forages sampled in both mid-June and mid-July could both meet this target, with the only variable being the amount of intake required to meet the target. This allowed for the cost of delayed harvest to be estimated on a per acre basis as it is assumed that other costs associated with raising a steer (housing, labour, etc.) would remain constant as the predicted time to finishing weight was the same for steers fed the mid-June and the mid-July first cuts.

Table 8 shows the average estimates for all regions combined. Estimates for each region are in Appendix 5. Per Acre Cost – Backgrounding Steers. Average dry matter intake (DMI) increases May-August to meet the average daily gain (ADG) target as forage quality decreases. As dry matter intake increases, average cost per steer increases.

Table 8. Estimate of average production impact per acre for Backgrounding Steers on forage (kg) harvested May-August

Week	Harvest Week	Average DMI (kg/d)	Average ADG (kg/d)	Average Days to Finish	Average DM Required (kg)	Average 1st Cut weight (kg)	Average 2nd Cut weight (kg)	Average 3rd Cut weight (kg)	Average Total yield (kg)	Average Cost/ acre	Average Cost/ kg	Average Cost/ steer
1	22-May	6.55	0.600	300	1965	1250	650	450	2350	399.5	0.1700	334.01
2	29-May	6.37	0.600	300	1910.3	1550	650	450	2650	427.7	0.1614	308.44
3	04-Jun	6.49	0.600	300	1947.8	1750	650	450	2850	427.7	0.1501	292.58
4	**12-Jun**	6.58	0.600	300	1974.0	1950	650	450	3050	434.5	0.1424	281.19
5	19-Jun	6.56	0.600	300	1968.8	2075	650	281	3006	427.7	0.1425	279.93
6	26-Jun	6.71	0.600	300	2013.8	2150	650	0	2800	406.4	0.1452	292.29
7	03-Jul	6.81	0.600	300	2043.8	2200	650	0	2850	406.4	0.1426	291.19
8	**10-Jul**	6.91	0.600	300	2073.8	2200	650	0	2850	406.4	0.1426	295.54
9	17-Jul	6.96	0.583	310.2	2164.6	2200	612.5	0	2812	406.4	0.1445	311.43
10	23-Jul	7.20	0.565	321	2314.5	2200	450	0	2650	388.8	0.1466	339.36
11	30-Jul	7.20	0.553	331	2389.2	2200	333.3	0	2533	378.9	0.1492	354.32
12	07-Aug	7.21	0.563	323	2332.7	2200	0	0	2200	332.0	0.1509	350.55
13	14-Aug	7.40	0.517	354	2617.8	2200	0	0	2200	342.7	0.1558	404.54
	Average	6.84	0.584	309.98	2125.7	2048.9	521.1	145	2715	401.2	0.1481	314.42
	Cor-relation with Date	0.968	-0.822	0.815	0.914	0.820	-0.793	-0.861	-0.452	-0.804	-0.324	0.656
	R^2	93.8%	67.5%	66.4%	83.6%	67.3%	62.9%	74.2%	20.4%	64.6%	10.5%	43.1%

On a per acre basis, the offset needed to replace the value lost from delaying 1st cut from mid June to mid July, when backgrounding steers was found to be approximately $31 provincially, or $42, $36, $13 and $32 per acre for Central, Eastern, Northern and Southern Ontario respectively (based on data in Appendix 5).

Wintering Beef Cows

For wintering beef cows, the reported feed intakes are the same as those used in the previous section on beef cows (see page 20).

Table 9 presents the estimates of costs for wintering beef cows using hay harvested at different stages in the season. Intake of dry matter would increase over the season as nutritional quality decreases. Average cost per cow increases due to the increased intake required to provide nutrition.

Table 9. Estimate of average production impact per acre for wintering beef cows on a diet of forage harvested May - August

Week	Harvest Week	Average DMI (kg/d)	Average 180 d DM Req.	Average 1st Cut weight (kg)	Average 2nd Cut weight (kg)	Average 3rd Cut weight (kg)	Average Total DM yield (kg)	Average Cost/ acre	Average Cost/kg DM	Average Cost/cow
1	22-May	6.80	1224.0	1250	650	450	2350	399.5	0.1700	208.05
2	29-May	6.79	1222.4	1550	650	450	2650	427.7	0.1614	197.50
3	04-Jun	6.80	1224.0	1750	650	450	2850	427.7	0.1501	183.70
4	**12-Jun**	7.06	1270.9	1950	650	450	3050	434.5	0.1424	181.00
5	19-Jun	7.09	1276.6	2075	650	281.2	3006.2	427.7	0.1425	181.47
6	26-Jun	7.30	1314.3	2150	650	0	2800	406.4	0.1452	190.68
7	03-Jul	7.41	1333.1	2200	650	0	2850	406.4	0.1426	189.63
8	10-Jul	7.49	1348.6	2200	650	0	2850	406.4	0.1426	192.21
9	**17-Jul**	7.80	1403.5	2200	612.5	0	2812.5	406.4	0.1445	202.30
10	23-Jul	7.99	1437.5	2200	433.3	0	2633.3	378.9	0.1439	206.36
11	30-Jul	8.36	1503.8	2200	375	0	2575	388.8	0.1506	226.25
12	07-Aug	8.21	1477.7	2200	0	0	2200	332.0	0.1509	222.80
13	14-Aug	8.61	1550.6	2200	0	0	2200	342.7	0.1558	240.90
	Average	7.52	1354.2	2048.9	521.1	145	2715	401.2	0.1481	200.36
	Correlation with Date	0.9783	0.9783	0.8203	-0.7886	-0.8612	-0.4449	-0.7972	-0.3256	0.7026
	R^2	95.7%	95.7%	67.3%	62.2%	74.2%	19.8%	63.5%	10.6%	49.4%

On a per acre basis, the value lost from delaying 1st cut from mid-June to mid-July, when feeding cows over winter, was found to be approximately $45 provincially, or $66, $45, $23 and $46 per acre for Central, Eastern, Northern and Southern Ontario respectively (details in Appendix 6 on page 48).

Table 10. Estimated cost per acre of reduced production value due to use of hay harvested mid-July compared to mid-June.

	Provincial	South	Central	East	North
Backgrounding steers	$31/ acre	$32 / acre	$42/ acre	$36/ acre	$13/ acre
Wintering beef cows	$45 / acre	$46/ acre	$66/ acre	$45/ acre	$23/ acre

Conclusion / Discussion

The nutritional quality of perennial forages (hay) inevitably declines over the growing season. The production and economics of farms are necessarily affected. Delayed hay harvest is often recommended by biologists to benefit the survival of grassland birds, like Bobolink and Eastern Meadowlark. This study quantified the nutritional quality of forages across the production season to more accurately assess the impact of delayed hay harvest on livestock production. This provides scientific evidence on which to inform program design and educational materials for on-farm decision-making. It also contributes to a priority research topic identified in the recovery strategy for these species-at-risk (McCracken et al. 2013).

Sampling and analysis on hay over the whole season, May to August, provides new data on nutritional value, as most studies do not include sampling into late July and August. Data from 634 samples in two different years and 16 locations across Ontario provides a strong data base in terms of livestock nutrition. Combined with nutritional modeling, this data provides a stronger basis for scientific estimates of production and economic effects of the use of late harvest hay. Research coupling forage analysis, nutritional modeling and bird nesting studies would also be useful.

Timing of Bobolink fledging generally begins in mid-June and often peaks in late June or early July (Pintaric 2018; Brown and Nocera 2017; Diemera and Nocera 2016; Mussel et al. 2013), although there can be significant annual and geographic variation. Delay of harvest until July 15 is thought to allow fledging of most nestlings (Kyle and Reid 2015). Delay until July 1 may allow 80-90% of young to fledge (Mussel et al. 2013). Linking data on bird fledging and survival with data on nutritional value would allow more explicit analysis of trade-offs and optimization between bird conservation and livestock production values (also see Brown and Nocera 2017).

The design of stewardship programs should be based on scientific evidence. Considerable research has gone into evidence on bird survival and reproduction. The estimates of reduced production values in this study support the cost sharing approaches taken in Ontario under the Grassland Stewardship Program for delayed haying (OSCIA 2018). Regional differences in seasonal change of nutritional quality are revealed in this study and in Brown and Nocera (2017). Understanding the extent and magnitude of these differences may be useful in the design of future agri-environmental programs.

The results of this study will support on-farm decision-making by farmers and landowners, providing science-based estimates of the economic and production impacts of adopting BMPs commonly recommended to benefit grassland birds. For example, a farmer considering the suggested BMPs for delayed haying in “Farming with Grassland Birds: A guide to making your hay and pasture bird friendly” (Kyle and Reid 2015), would be better able to assess the impact those practices would have on production. Combined with data on bird survival, this makes it easier to assess the economic impact of cutting later on one or more fields to benefit bird nesting.

Inter-disciplinary research on grassland bird BMPs would better integrate the assessment of their ecological efficacy with production, economics, and on-farm practicality. European researchers have done more interdisciplinary work including both conservation and agricultural researchers to assess different aspects of projects (e.g. Tallowin and Jefferson 1999). Inter-disciplinary approaches should be considered for future projects in Canada.

Acknowledgements

Joel Bagg and Jack Kyle initiated this project to assess the nutritional quality of forages over the entire summer period to build a data base on nutritional value beyond existing knowledge. Matthew Wells undertook data analysis and nutrition and economic modeling under the supervision of Dr. John Cant, professor of Animal and Poultry Sciences, University of Guelph. Many thanks to the farmer cooperators who allowed their land and forage crops to be used for sampling. Thanks to the many volunteers and summer students that undertook the collection of forage samples. Thanks to Jon McCracken (Bird Studies Canada) and Ron Reid (Couchiching Conservancy) for their reviews of the draft report. The project steering committee included, at different times, Jack Kyle, Joel Bagg, Peter Roberts, Tom Wright, Gabe Ferguson, Laura Van Vliet, Christine O'Reilly, Christine Schmalz, Maria Ramirez and Paul Smith. Funding for portions of this study was provided from the Best Management Practices Verification and Development Program of OMAFRA and the Species at Risk Partnerships on Agricultural Lands (SARPAL) program of Environment and Climate Change Canada. The views expressed herein are solely those of the authors.

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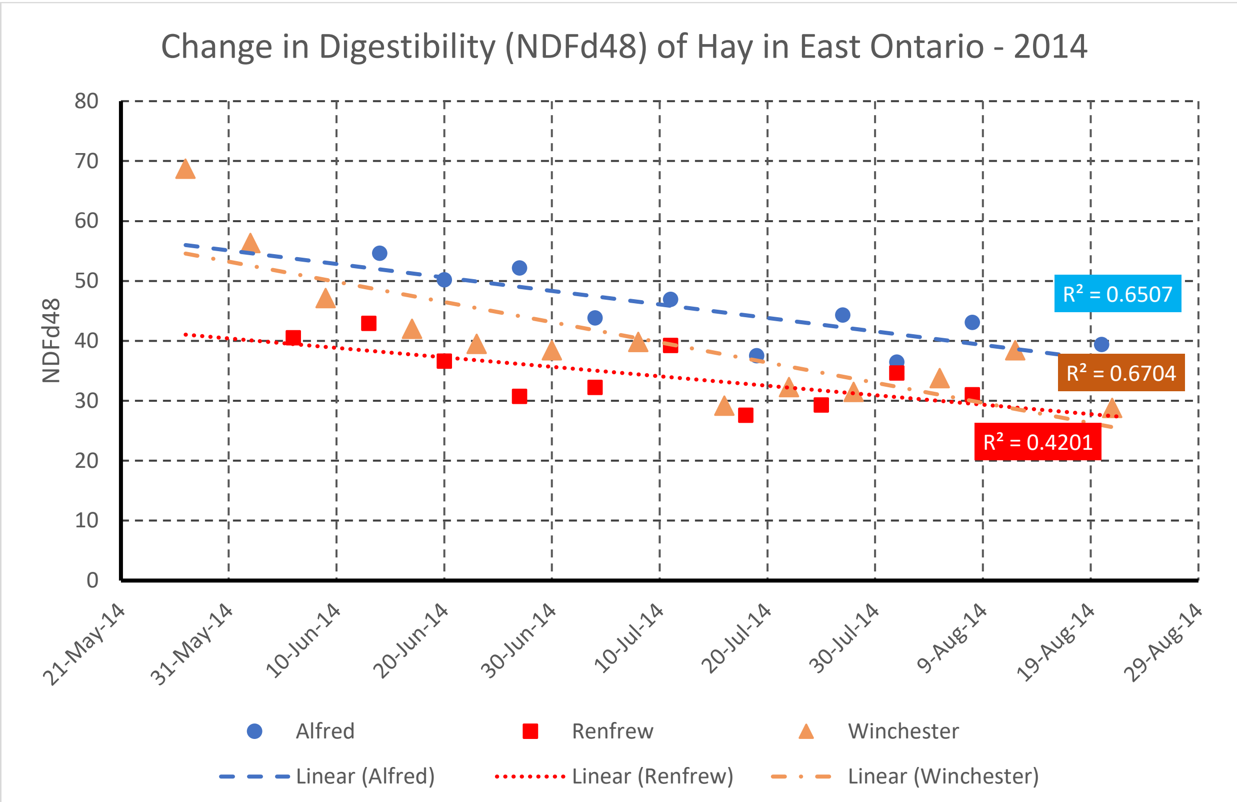
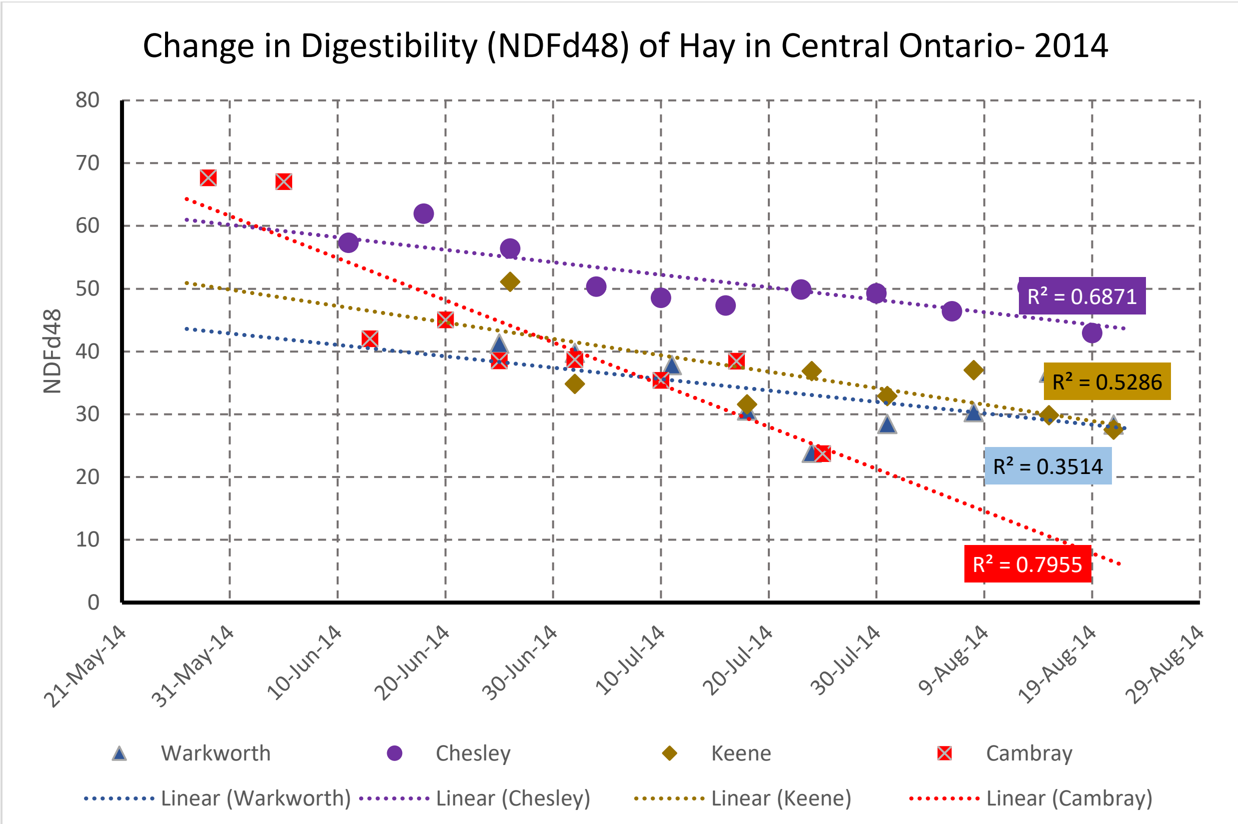
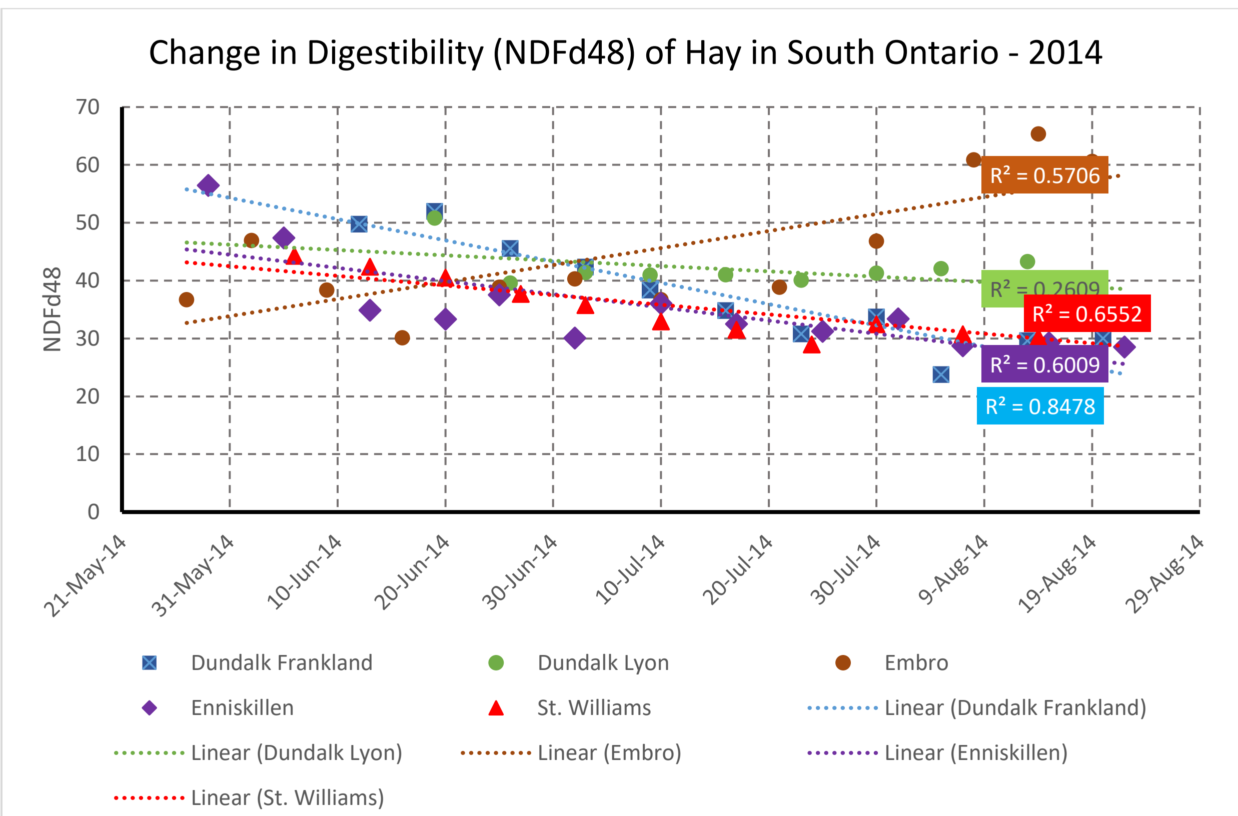
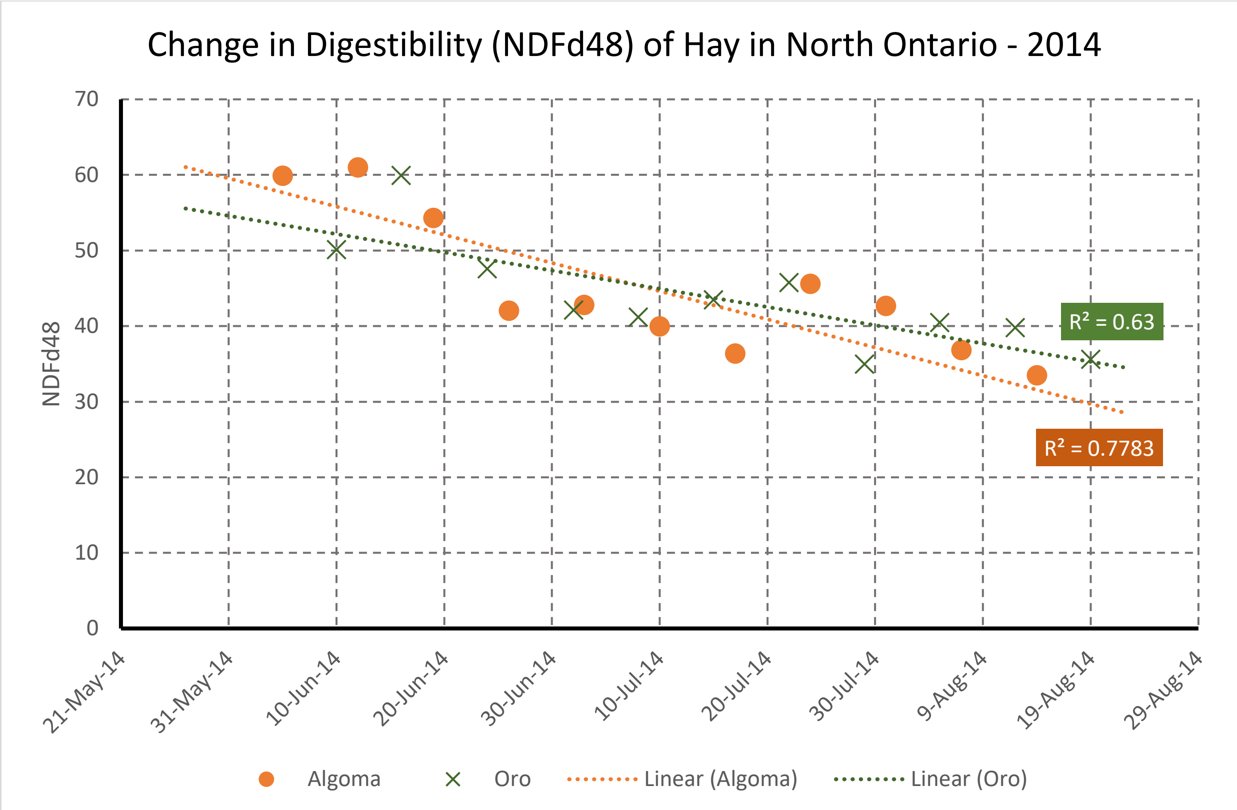
Appendix 1. Site Level Forage Lab Analysis Graphs

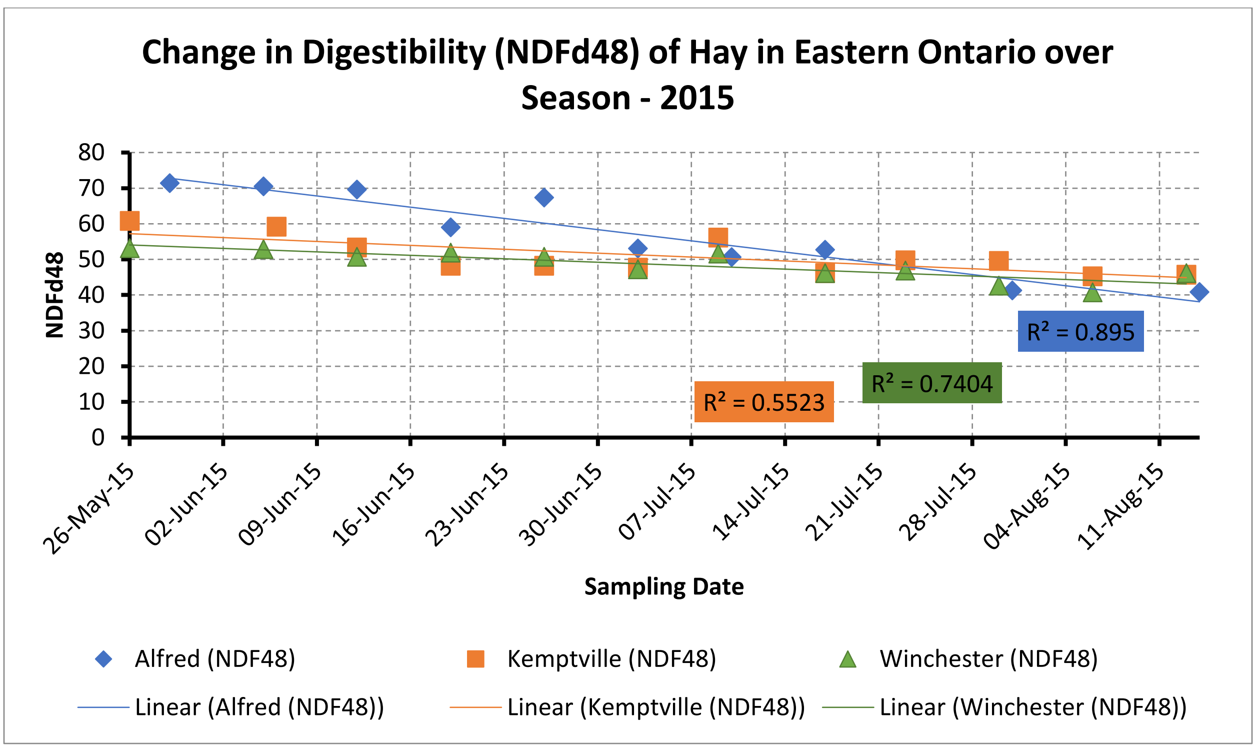
Graphs shown below illustrate the change in digestibility, NDFd48, of Hay over the season May to August during both 2014 and 2015 at each sampling site in the four regions (see Table 1).

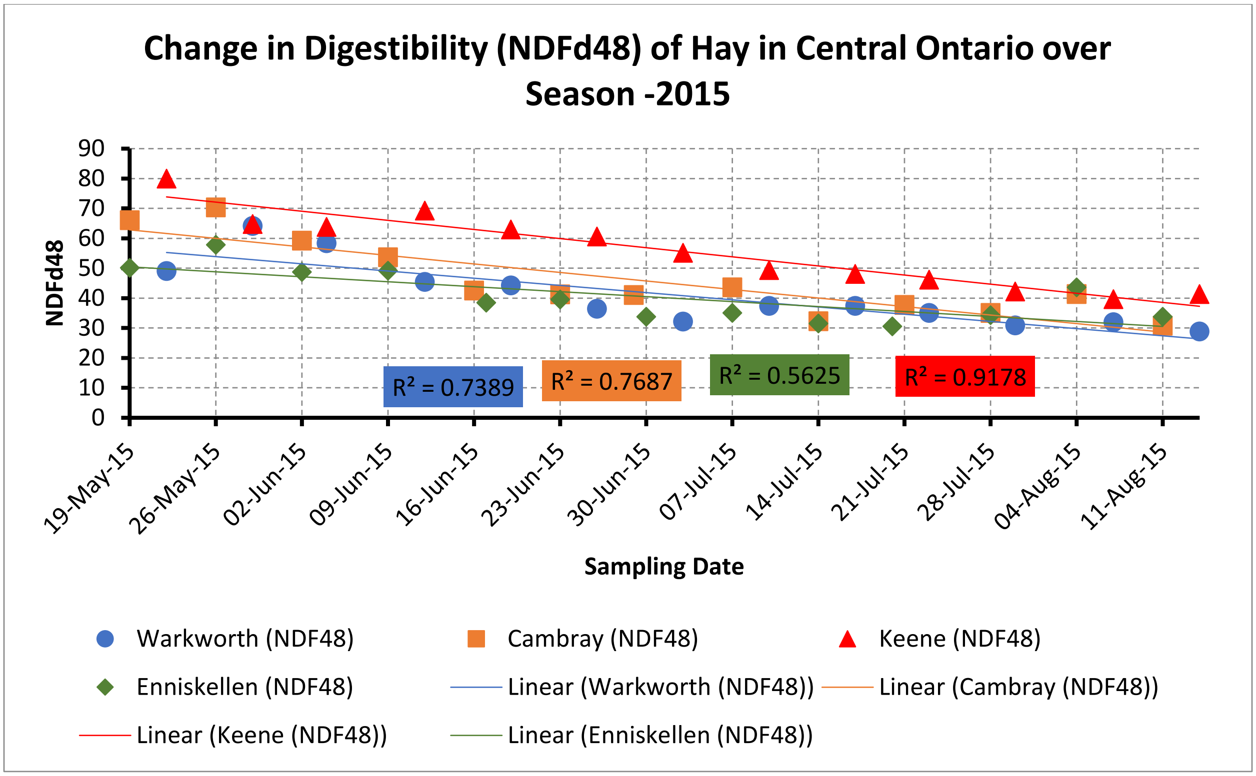


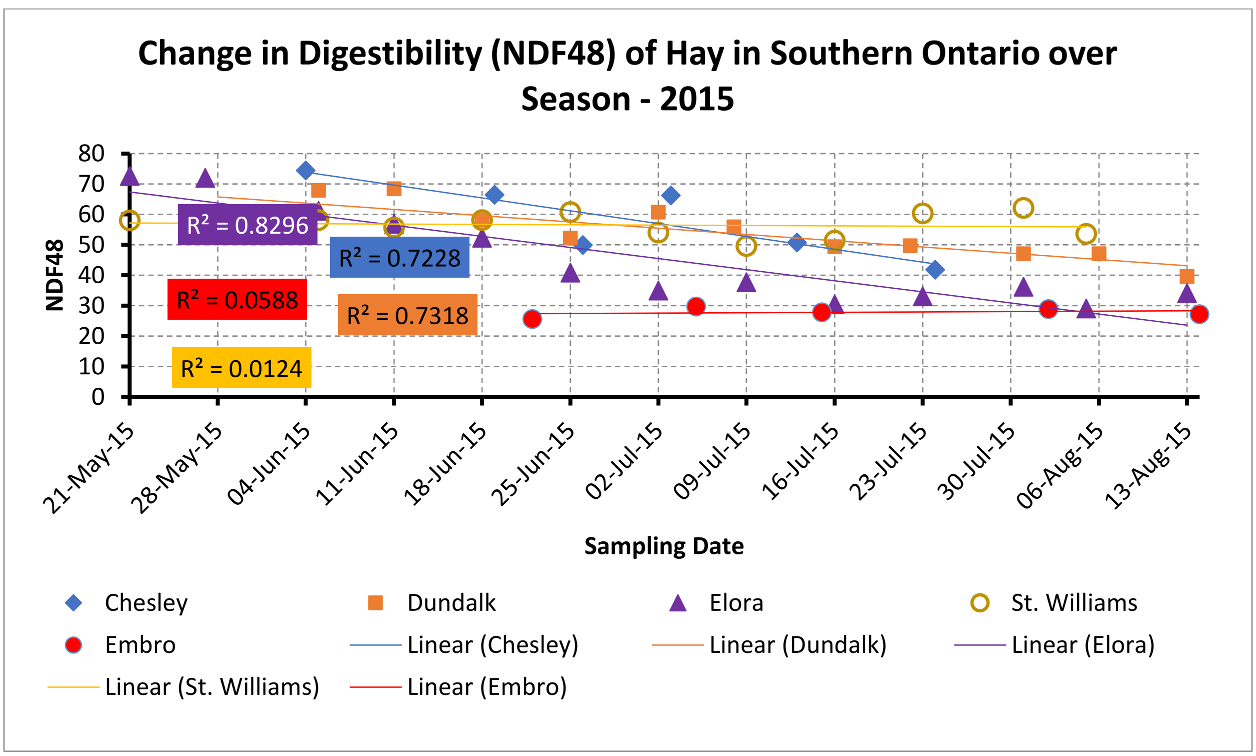

Change in Digestibility (NDFd48) of Hay in Central Ontario- 2014
NDFd48
80
70
60
50
40
30
20
10
0
21-May-14
31-May-14
10-Jun-14
20-Jun-14
30-Jun-14
10-Jul-14
20-Jul-14
30-Jul-14
9-Aug-14
19-Aug-14
29-Aug-14
R² = 0.6871
R² = 0.5286
R² = 0.3514
R² = 0.7955
Warkworth
Chesley
Keene
Cambray
Linear (Warkworth)
Linear (Chesley)
Linear (Keene)
Linear (Cambray)


Change in Digestibility (NDFd48) of Hay in South Ontario - 2014
NDFd48
70
60
50
40
30
20
10
0
21-May-14
31-May-14
10-Jun-14
20-Jun-14
30-Jun-14
10-Jul-14
20-Jul-14
30-Jul-14
9-Aug-14
19-Aug-14
29-Aug-14
R² = 0.5706
R² = 0.2609
R² = 0.6552
R² = 0.6009
R² = 0.8478
Dundalk Frankland
Dundalk Lyon
Embro
Enniskillen
St. Williams
Linear (Dundalk Frankland)
Linear (Dundalk Lyon)
Linear (Embro)
Linear (Enniskillen)
Linear (St. Williams)


Change in Digestibility (NDFd48) of Hay in North Ontario - 2014
NDFd48
70
60
50
40
30
20
10
0
21-May-14
31-May-14
10-Jun-14
20-Jun-14
30-Jun-14
10-Jul-14
20-Jul-14
30-Jul-14
9-Aug-14
19-Aug-14
29-Aug-14
R² = 0.63
R² = 0.7783
Algoma
Oro
Linear (Algoma)
Linear (Oro)


Change in Digestibility (NDFd48) of Hay in Eastern Ontario over Season - 2015
NDFd48
80
70
60
50
40
30
20
10
0
26-May-15
02-Jun-15
09-Jun-15
16-Jun-15
23-Jun-15
30-Jun-15
07-Jul-15
14-Jul-15
21-Jul-15
28-Jul-15
04-Aug-15
11-Aug-15
Sampling Date
R² = 0.895
R² = 0.7404
R² = 0.5523
Alfred (NDF48)
Kemptville (NDF48)
Winchester (NDF48)
Linear (Alfred (NDF48))
Linear (Kemptville (NDF48))
Linear (Winchester (NDF48))


Change in Digestibility (NDFd48) of Hay in Central Ontario over Season -2015
NDFd48
90
80
70
60
50
40
30
20
10
0
R² = 0.7389
R² = 0.7687
R² = 0.5625
R² = 0.9178
19-May-15
26-May-15
02-Jun-15
09-Jun-15
16-Jun-15
23-Jun-15
30-Jun-15
07-Jul-15
14-Jul-15
21-Jul-15
28-Jul-15
04-Aug-15
11-Aug-15
Sampling Date
Warkworth (NDF48)
Cambray (NDF48)
Keene (NDF48)
Enniskellen (NDF48)
Linear (Warkworth (NDF48))
Linear (Cambray (NDF48))
Linear (Keene (NDF48))
Linear (Enniskellen (NDF48))

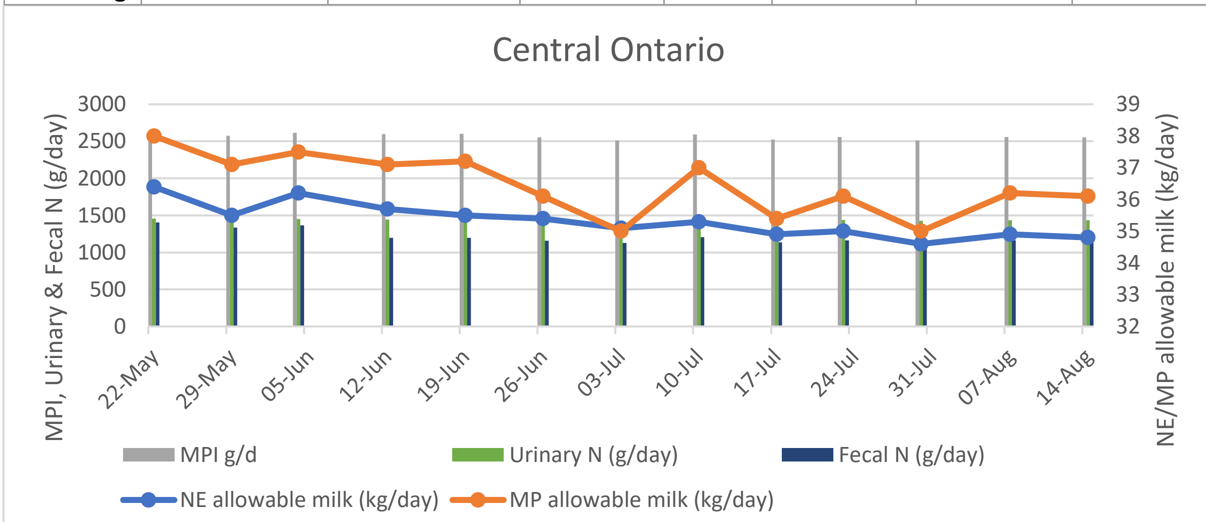

Change in Digestibility (NDF48) of Hay in Southern Ontario over Season - 2015
NDF48
80
70
60
50
40
30
20
10
0
R² = 0.8296
R² = 0.7228
R² = 0.0588
R² = 0.7318
R² = 0.0124
21-May-15
28-May-15
04-Jun-15
11-Jun-15
18-Jun-15
25-Jun-15
02-Jul-15
09-Jul-15
16-Jul-15
23-Jul-15
30-Jul-15
06-Aug-15
13-Aug-15
Sampling Date
Chesley
Dundalk
Elora
St. Williams
Embro
Linear (Chesley)
Linear (Dundalk)
Linear (Elora)
Linear (St. Williams)
Linear (Embro)

Appendix 2. Regional Nutritional Analysis Results: Dairy

Data shown here reflects the dairy nutritional modeling results for each region, pooled for the sites within that region (as grouped in Table 1). This provides additional detail for the section Nutrition Modeling Results: Dairy on page 16.

Central Ontario

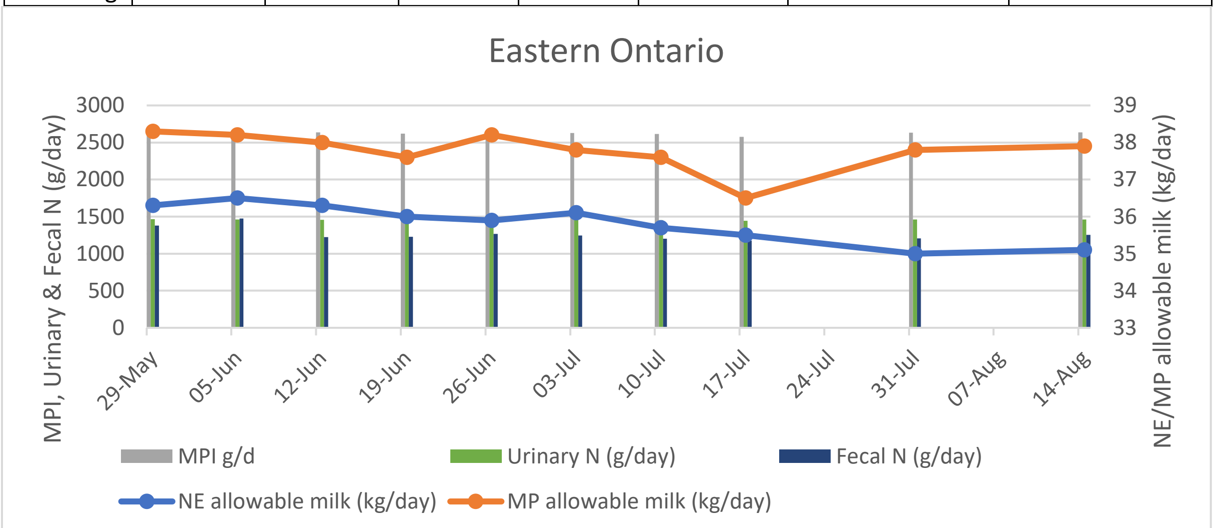
Harvest Week	NE allowable milk (kg/day)	MP allowable milk (kg/day)	CP Intake kg/d	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
22-May	36.4	38	4.04	2635	2862	1457	1405
29-May	35.5	37.1	3.91	2576	2759.9	1425.9	1334
04-Jun	36.2	37.5	3.98	2613	2817.5	1450.5	1367
12-Jun	35.7	37.1	3.79	2595	2639.9	1444.9	1195
19-Jun	35.5	37.2	3.8	2602	2646.8	1448.8	1198
26-Jun	35.4	36.1	3.71	2552	2590.9	1432.9	1158
03-Jul	35.1	35	3.64	2510	2555	1425	1130
10-Jul	35.3	37	3.8	2593	2653	1446	1207
17-Jul	34.9	35.4	3.66	2523	2562.6	1425.6	1137
23-Jul	35	36.1	3.72	2557	2600.9	1437.9	1163
30-Jul	34.6	35	3.64	2510	2555	1425	1130
07-Aug	34.9	36.2	3.72	2559	2597.8	1436.8	1161
14-Aug	34.8	36.1	3.71	2554	2590.9	1434.9	1156



Eastern Ontario

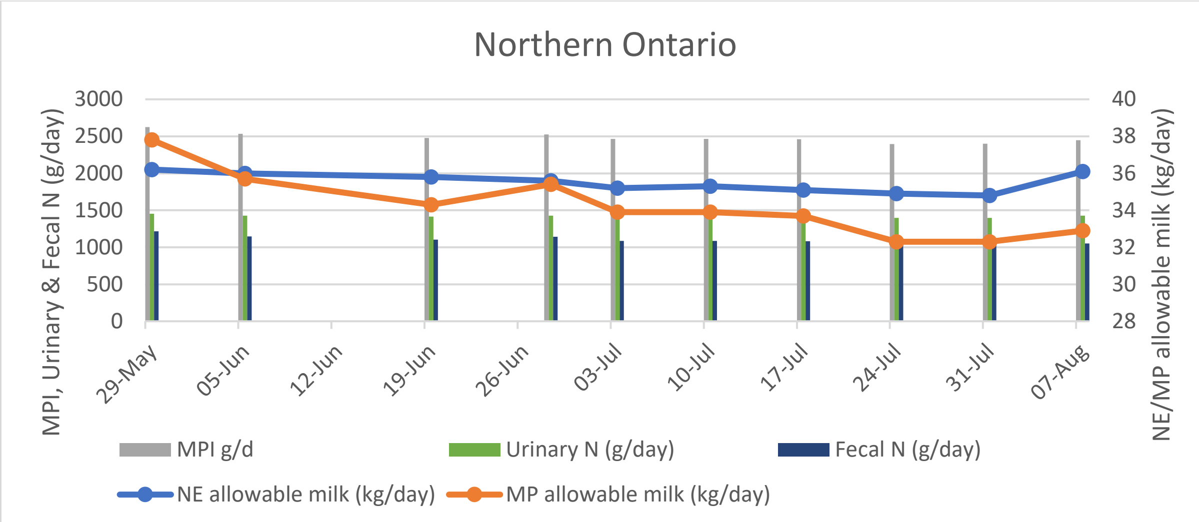
Harvest Week	NE allowable milk (kg/day)	MP allowable milk (kg/day)	CP Intake (kg/day)	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
29-May	36.3	38.3	4.03	2651	2842.7	1463.7	1379
05-Jun	36.5	38.2	4.12	2645	2935.8	1460.8	1475
12-Jun	36.3	38	3.86	2635	2682	1457	1225
19-Jun	36	37.6	3.85	2620	2684.4	1454.4	1230
26-Jun	35.9	38.2	3.91	2644	2725.8	1459.8	1266
03-Jul	36.1	37.8	3.87	2627	2698.2	1455.2	1243

Harvest Week	NE allowable milk (kg/day)	MP allowable milk (kg/day)	CP Intake (kg/day)	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
10-Jul	35.7	37.6	3.82	2617	2654.4	1451.4	1203
17-Jul	35.5	36.5	3.75	2575	2618.5	1443.5	1175
31-Jul	35	37.8	3.84	2632	2668.2	1460.2	1208
14-Aug	35.1	37.9	3.89	2637	2715.1	1462.1	1253



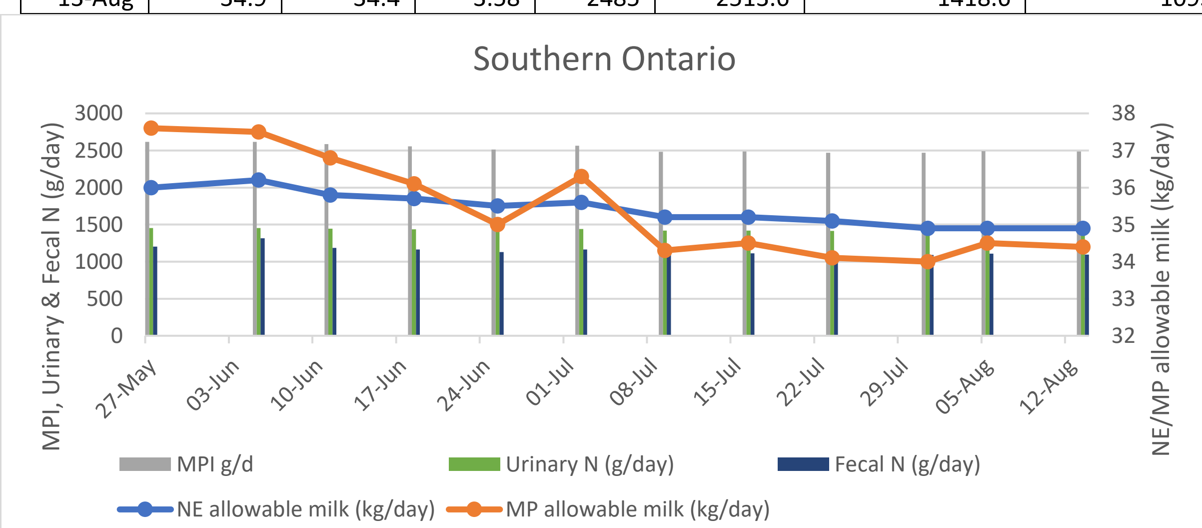
Northern Ontario

Harvest Week	NE allowable milk (kg/day)	MP allowable milk (kg/day)	CP Intake (kg/day)	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
29-May	36.2	37.8	3.84	2625	2668.2	1453.2	1215
05-Jun	36	35.7	3.68	2535	2573.3	1428.3	1145
19-Jun	35.8	34.3	3.58	2477	2516.7	1413.7	1103
28-Jun	35.6	35.4	3.67	2527	2572.6	1429.6	1143
03-Jul	35.2	33.9	3.55	2465	2499.1	1414.1	1085
10-Jul	35.3	33.9	3.55	2464	2499.1	1413.1	1086
17-Jul	35.1	33.7	3.54	2459	2495.3	1414.3	1081
24-Jul	34.9	32.3	3.43	2397	2428.7	1395.7	1033
31-Jul	34.8	32.3	3.43	2398	2428.7	1396.7	1032
07-Aug	36.1	32.9	3.5	2448	2480.1	1428.1	1052



Southern Ontario

Harvest Week	NE allowable milk (kg/day)	MP allowable milk (kg/day)	CP Intake (kg/day)	MPI g/d	Manure N (g/day)	Urinary N (g/day)	Fecal N (g/day)
27-May	36	37.6	3.82	2617	2654.4	1451.4	1203
05-Jun	36.2	37.5	3.93	2615	2767.5	1452.5	1315
11-Jun	35.8	36.8	3.77	2584	2629.2	1443.2	1186
18-Jun	35.7	36.1	3.72	2557	2600.9	1437.9	1163
25-Jun	35.5	35	3.64	2510	2555	1425	1130
02-Jul	35.6	36.3	3.73	2564	2604.7	1438.7	1166
09-Jul	35.2	34.3	3.58	2483	2516.7	1419.7	1097
16-Jul	35.2	34.5	3.6	2488	2530.5	1418.5	1112
23-Jul	35.1	34.1	3.56	2470	2502.9	1412.9	1090
31-Jul	34.9	34	3.56	2471	2506	1417	1089
05-Aug	34.9	34.5	3.6	2492	2530.5	1422.5	1108
13-Aug	34.9	34.4	3.58	2485	2513.6	1418.6	1095

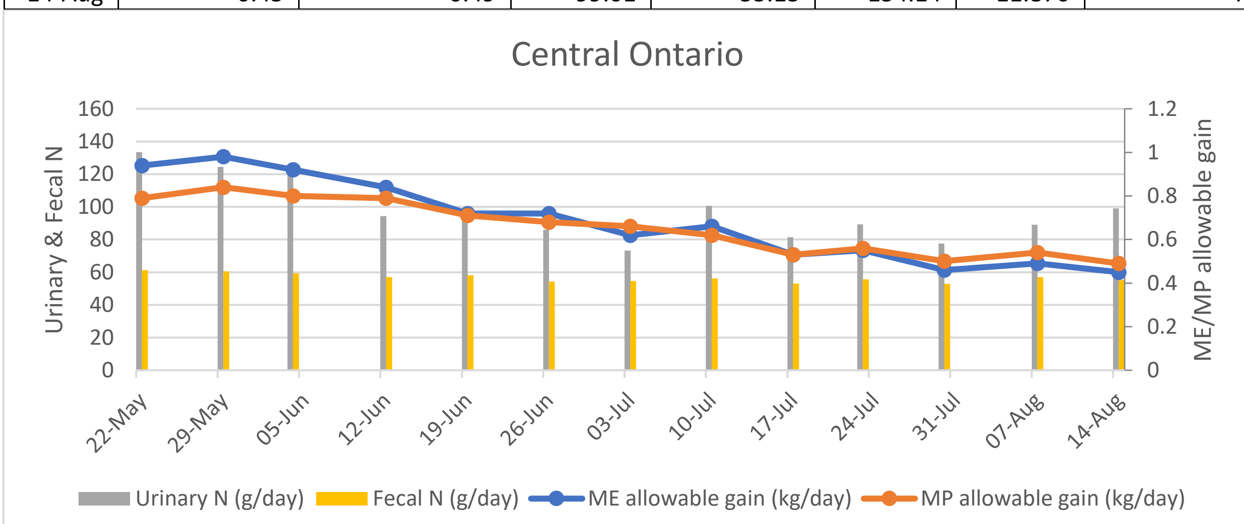


Appendix 3. Regional Nutritional Analysis Results: Beef Steers

Data shown here reflects the nutritional modeling results beef steers for each region, pooled for the sites within that region (as grouped in Table 1). This provides additional detail for the section “Nutrition Modeling Results: Beef Steers“ on page 19.

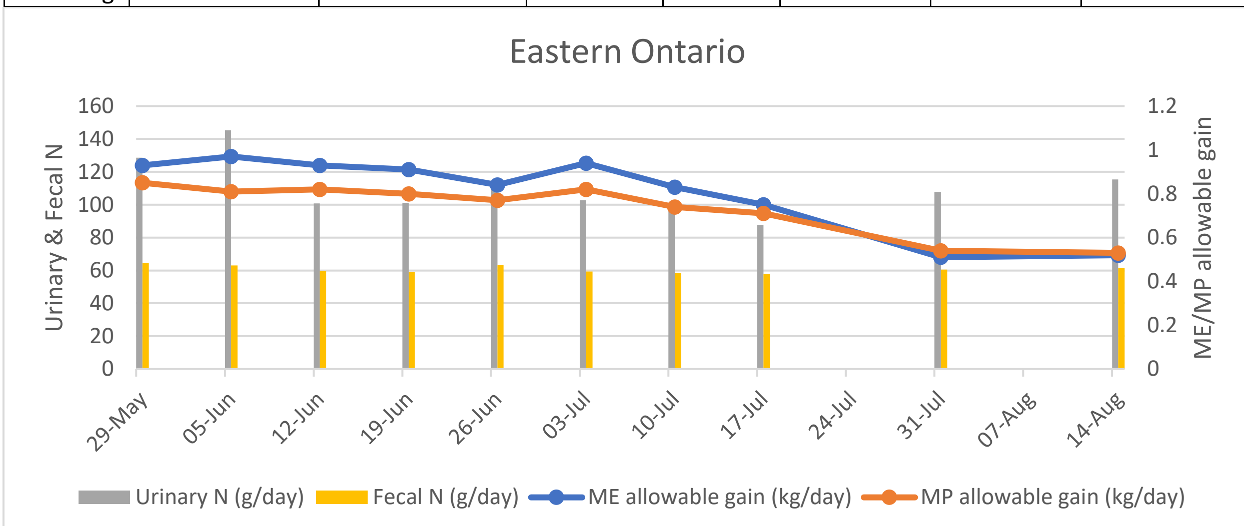
Central Ontario

Harvest Week	ME allowable gain (kg/day)	MP allowable gain (kg/day)	Urinary N (g/day)	Fecal N (g/day)	Manure N (g/day)	Methane (g/kg DM)	Expected DMI (kg/day)
22-May	0.94	0.79	133.57	61.32	194.89	14.664	7.36
29-May	0.98	0.84	124.56	60.48	185.04	14.528	7.34
04-Jun	0.92	0.8	124.29	59.41	183.7	14.432	7.38
12-Jun	0.84	0.79	94.37	56.93	151.3	13.251	7.41
19-Jun	0.72	0.71	98.36	58.08	156.44	13.021	7.43
26-Jun	0.72	0.68	86.02	54.29	140.31	12.736	7.43
03-Jul	0.62	0.66	73.19	54.61	127.8	11.903	7.43
10-Jul	0.66	0.62	100.66	56.29	156.95	12.962	7.43
17-Jul	0.53	0.53	81.51	53.04	134.55	11.858	7.4
23-Jul	0.55	0.56	89.27	55.61	144.88	12.113	7.4
30-Jul	0.46	0.5	77.55	52.88	130.43	11.548	7.36
07-Aug	0.49	0.54	89.05	56.99	146.04	11.82	7.38
14-Aug	0.45	0.49	99.01	55.13	154.14	11.876	7.36



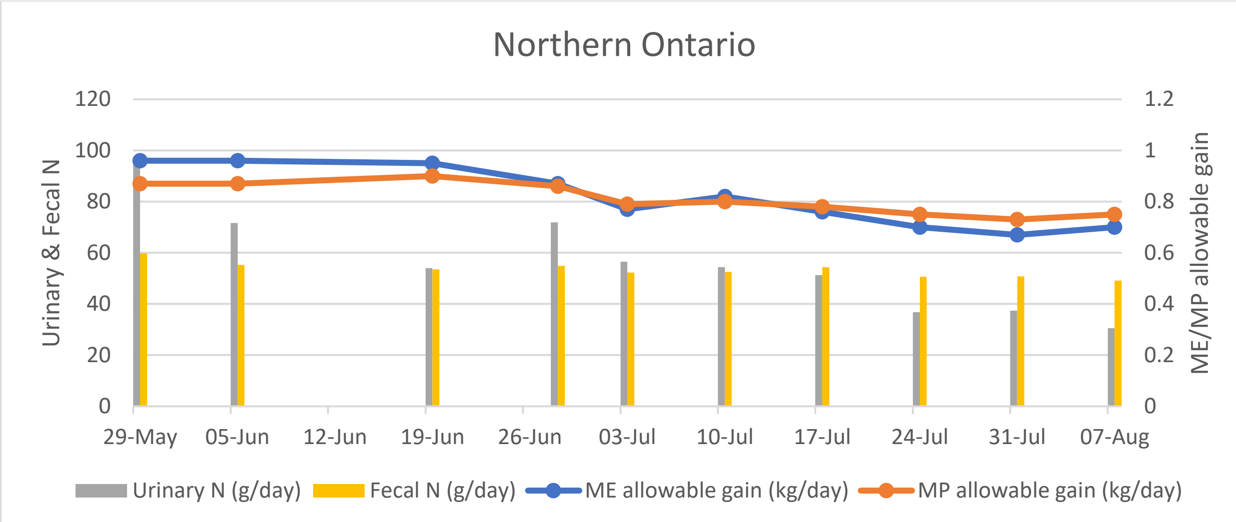
Eastern Ontario

Harvest Week	ME allowable gain (kg/day)	MP allowable gain (kg/day)	Urinary N (g/day)	Fecal N (g/day)	Manure N (g/day)	Methane (g/kg DM)	Expected DMI (kg/day)
29-May	0.93	0.85	128.66	64.56	193.22	14.552	7.37
05-Jun	0.97	0.81	145.25	63	208.25	15.373	7.34
12-Jun	0.93	0.82	100.8	59.52	160.32	13.767	7.37
19-Jun	0.91	0.8	101.11	58.93	160.04	13.794	7.38
26-Jun	0.84	0.77	110.39	63.13	173.52	13.56	7.41
03-Jul	0.94	0.82	102.72	59.39	162.11	13.919	7.37
10-Jul	0.83	0.74	99.49	58.26	157.75	13.468	7.42
17-Jul	0.75	0.71	87.7	57.9	145.6	12.765	7.43
31-Jul	0.51	0.54	107.78	60.57	168.35	12.565	7.39
14-Aug	0.52	0.53	115.43	61.54	176.97	12.675	7.39



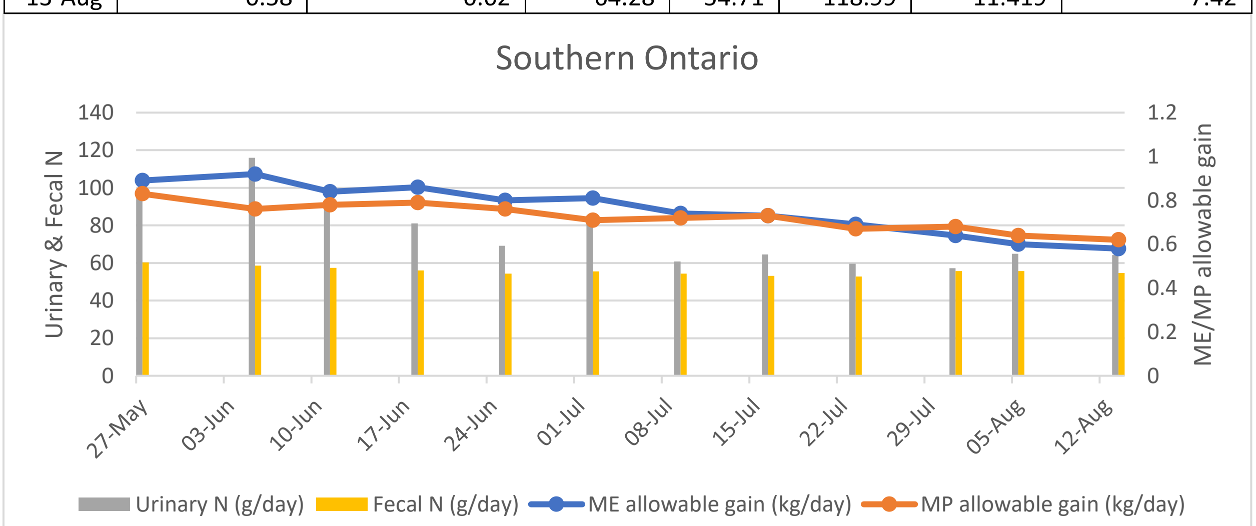
Northern Ontario

Harvest Week	ME allowable gain (kg/day)	MP allowable gain (kg/day)	Urinary N (g/day)	Fecal N (g/day)	Manure N (g/day)	Methane (g/kg DM)	Expected DMI (kg/day)
29-May	0.96	0.87	96.1	59.78	155.88	13.51	7.35
05-Jun	0.96	0.87	71.66	55.32	126.98	12.704	7.35
19-Jun	0.95	0.9	54.05	53.59	107.64	12.451	7.36
28-Jun	0.87	0.86	71.9	54.92	126.82	12.865	7.4
03-Jul	0.77	0.79	56.47	52.27	108.74	11.995	7.43
10-Jul	0.82	0.8	54.38	52.53	106.91	11.989	7.42
17-Jul	0.76	0.78	51.33	54.38	105.71	11.733	7.43
24-Jul	0.7	0.75	36.76	50.62	87.38	11.166	7.43
31-Jul	0.67	0.73	37.45	50.84	88.29	11.135	7.43
07-Aug	0.7	0.75	30.53	49.18	79.71	11.023	7.43



Southern Ontario

Harvest Week	ME allowable gain (kg/day)	MP allowable gain (kg/day)	Urinary N (g/day)	Fecal N (g/day)	Manure N (g/day)	Methane (g/kg DM)	Expected DMI (kg/day)
27-May	0.89	0.83	94.84	60.29	155.13	13.157	7.39
05-Jun	0.92	0.76	115.98	58.58	174.56	14.012	7.38
11-Jun	0.84	0.78	89.54	57.45	146.99	12.981	7.41
18-Jun	0.86	0.79	81.14	56.08	137.22	12.845	7.41
25-Jun	0.8	0.76	69.14	54.32	123.46	12.267	7.43
02-Jul	0.81	0.71	85.3	55.58	140.88	12.712	7.42
09-Jul	0.74	0.72	60.78	54.26	115.04	11.792	7.43
16-Jul	0.73	0.73	64.51	53.15	117.66	12.02	7.43
23-Jul	0.69	0.67	59.58	52.86	112.44	11.636	7.43
31-Jul	0.64	0.68	57.18	55.77	112.95	11.291	7.43
05-Aug	0.6	0.64	64.93	55.78	120.71	11.407	7.42
13-Aug	0.58	0.62	64.28	54.71	118.99	11.419	7.42

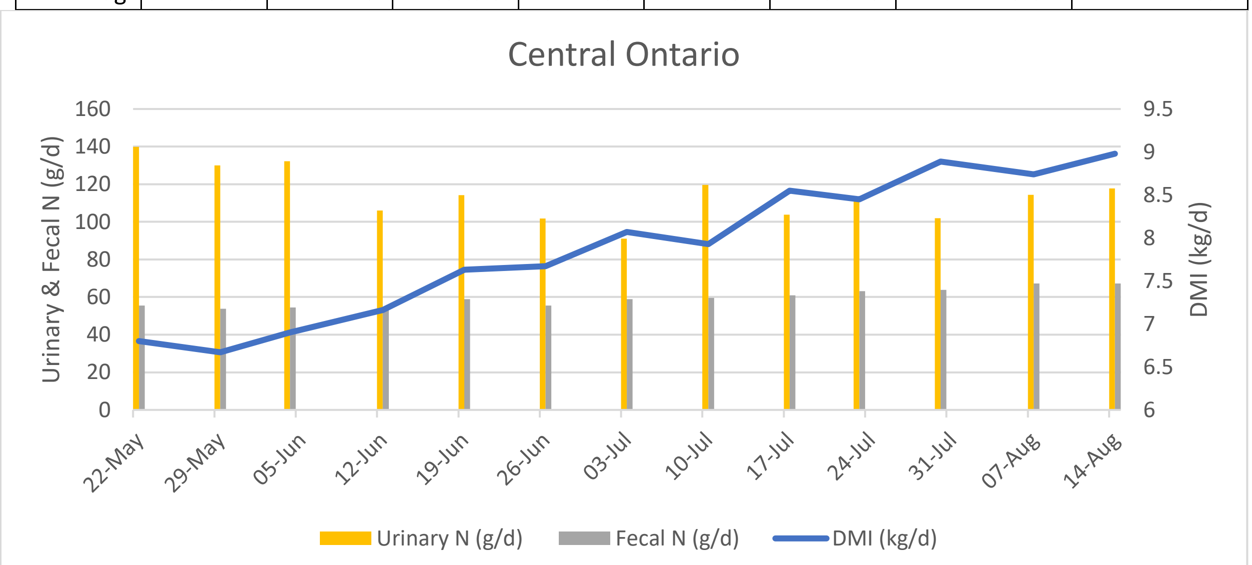


Appendix 4. Regional Nutritional Analysis Results: Wintering Beef Cows

Data shown here reflects the nutritional modeling results for wintering beef cows for each region, pooled for the sites within that region (as grouped in Table 1). This provides additional detail for the section "Nutrition Modeling Results: Wintering Beef Cows" on page 20.

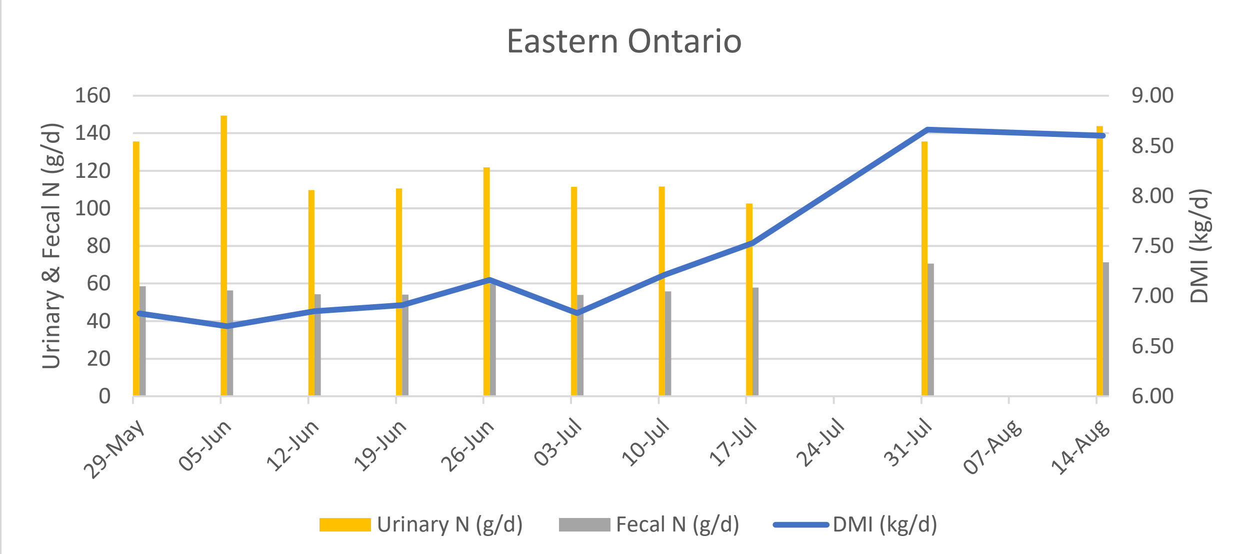
Central Ontario

Harvest Week	DMI (kg/d)	ME provided (Mcal/d)	MP provided (g/d)	Days to gains 1 BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
22-May	6.8	16.38	480.2	294	139.9	55.53	191.27	14.88
29-May	6.67	16.3	483.4	299	130.07	53.82	178.47	14.757
04-Jun	6.9	16.43	487	297	132.27	54.53	180.08	14.633
12-Jun	7.16	16.57	502.4	308	106.1	54.19	152.37	13.428
19-Jun	7.63	16.87	512	305	114.26	58.92	164.71	13.151
26-Jun	7.67	16.91	506.9	295	101.85	55.46	149.41	12.865
03-Jul	8.07	17.16	528.3	300	91	58.84	142.48	12
10-Jul	7.93	17.08	504	293	119.58	59.52	170.21	13.071
17-Jul	8.55	17.5	515.7	288	103.86	61.01	156.66	11.914
23-Jul	8.45	17.43	520.9	292	112.02	63.15	166.58	12.178
30-Jul	8.89	17.72	528.2	292	101.97	63.75	157.58	11.574
07-Aug	8.74	17.63	530.8	289	114.43	67.25	172.65	11.863
14-Aug	8.98	17.79	528.5	291	117.82	67.16	175.82	11.896



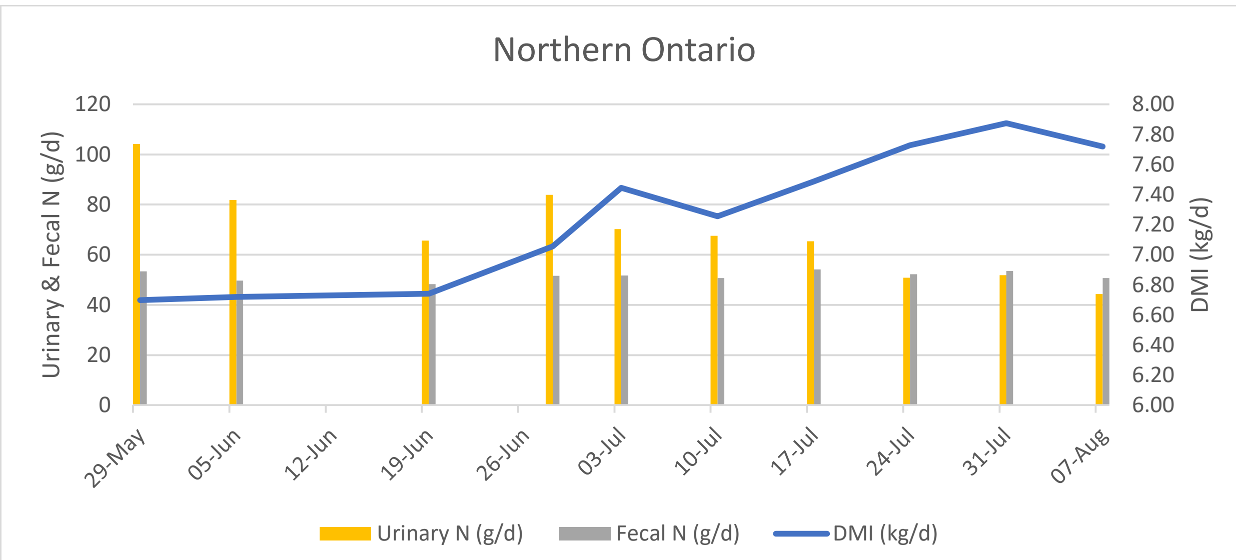
Eastern Ontario

Harvest Week	DMI (kg/d)	ME provided (Mcal/d)	MP provided (g/d)	Days to gains 1 BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
29-May	6.83	16.38	496.8	304	135.65	58.59	184.55	14.781
05-Jun	6.70	16.31	478.7	300	149.44	56.31	201.95	15.6
12-Jun	6.85	16.41	492.2	295	109.82	54.33	156.42	13.988
19-Jun	6.91	16.43	489.5	300	110.56	54.19	157.81	14.01
26-Jun	7.16	16.58	496.5	303	121.77	59.94	172.78	13.77
03-Jul	6.83	16.4	491	296	111.48	54.02	158.2	14.13
10-Jul	7.21	16.63	492.9	293	111.56	55.77	159.14	13.645
17-Jul	7.53	16.82	504.7	295	102.53	57.94	152.49	12.918
31-Jul	8.66	17.56	525.8	293	135.62	70.68	196.23	12.614
14-Aug	8.60	17.52	517.8	295	143.87	71.27	204.57	12.73



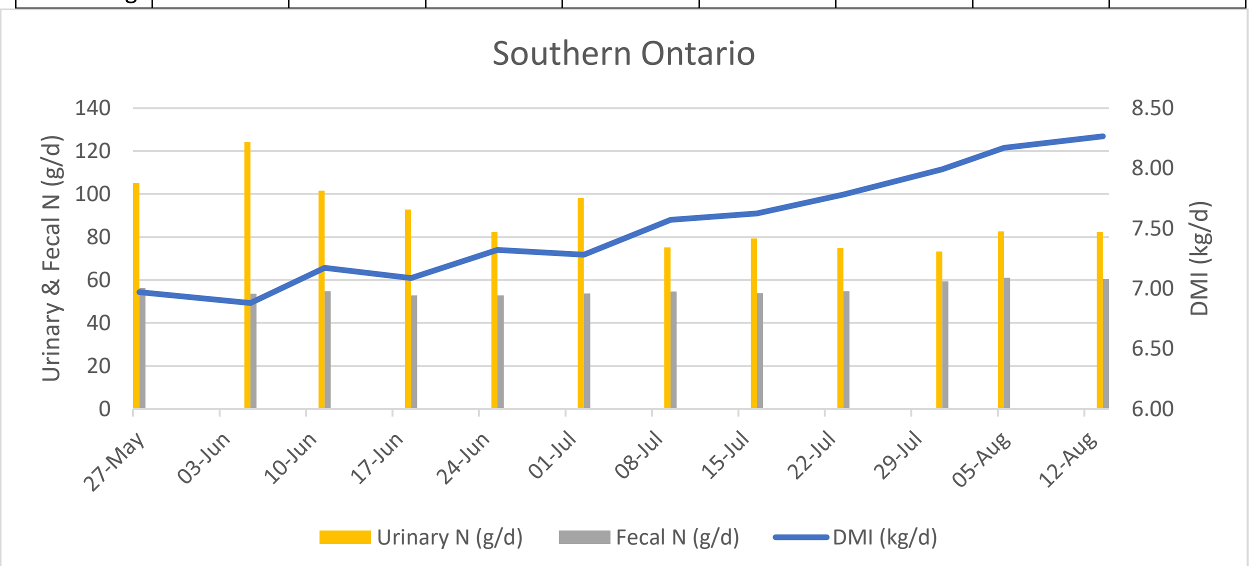
Northern Ontario

Harvest Week	DMI (kg/d)	ME provided (Mcal/d)	MP provided (g/d)	Days to gains 1 BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
29-May	6.70	16.3	496.1	307	104.23	53.39	149.78	13.745
05-Jun	6.72	16.32	498.9	303	81.89	49.67	124.78	12.928
19-Jun	6.74	16.32	508.8	307	65.7	48.26	108.24	12.671
28-Jun	7.06	16.52	516.4	301	83.87	51.62	128.65	13.046
03-Jul	7.44	16.75	524.1	305	70.28	51.77	116.01	12.141
10-Jul	7.26	16.65	514.1	298	67.59	50.77	112.35	12.158
17-Jul	7.49	16.78	525.6	302	65.36	54.19	113.5	11.884
24-Jul	7.73	16.94	533.7	300	50.86	52.2	97.82	11.293
31-Jul	7.88	17.04	539.4	296	51.82	53.49	99.92	11.249
07-Aug	7.72	16.93	533.2	302	44.33	50.69	90.28	11.145



Southern Ontario

Harvest Week	DMI (kg/d)	ME provided (Mcal/d)	MP provided (g/d)	Days to gains one BCS	Urinary N (g/d)	Fecal N (g/d)	Manure N (g/day)	Methane (g/kg DM)
27-May	6.97	16.47	502.4	301	105.16	56.28	153.25	13.379
05-Jun	6.88	16.43	476.9	296	124.14	53.63	175.09	14.227
11-Jun	7.17	16.58	501.3	305	101.56	54.72	148.56	13.165
18-Jun	7.09	16.54	497.9	303	92.78	52.84	138.33	13.036
25-Jun	7.32	16.69	505.8	298	82.38	52.82	128.24	12.438
02-Jul	7.28	16.66	489.6	299	98.1	53.79	145.38	12.885
09-Jul	7.57	16.83	511.5	302	75.2	54.66	123.38	11.948
16-Jul	7.62	16.87	517.4	302	79.26	53.94	126.6	12.158
23-Jul	7.78	16.97	511.1	304	74.83	54.83	123.19	11.766
31-Jul	7.99	17.11	529.7	301	73.26	59.44	126.08	11.407
05-Aug	8.17	17.23	526.4	296	82.59	60.95	136.38	11.506
13-Aug	8.26	17.29	526.2	298	82.32	60.49	135.77	11.505



Appendix 5. Per Acre Cost – Backgrounding Steers

Data shown here reflects the cost modeling results for backgrounding steers for each region, pooled for the sites within that region (as grouped in Table 1). This provides additional detail for the section "Backgrounding Steers" on page 25.

Central Ontario

Harvest Week	DMI (kg/d)	ADG (kg/d)	Days to Finish	DM Req (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total yield (kg)	Cost/ acre	Cost/kg	Cost/steer
22-May	6.55	0.6	300	1965	1250	650	450	2350	399.45	0.169979	$334.01
29-May	6.4	0.6	300	1920	1550	650	450	2650	399.45	0.150736	$289.41
04-Jun	6.55	0.6	300	1965	1750	650	450	2850	399.45	0.140158	$275.41
12-Jun	**6.62**	**0.6**	**300**	**1986**	**1950**	**650**	**450**	**3050**	**399.45**	**0.130967**	**$260.10**
19-Jun	6.95	0.6	300	2085	2075	650	375	3100	399.45	0.128855	$268.66
26-Jun	7.05	0.6	300	2115	2150	650	0	2800	378.18	0.135064	$285.66
03-Jul	7.3	0.6	300	2190	2200	650	0	2850	378.18	0.132695	$290.60
10-Jul	**7.35**	**0.6**	**300**	**2205**	**2200**	**650**	**0**	**2850**	**378.18**	**0.132695**	**$292.59**
17-Jul	7.4	0.53	341	2523.4	2200	650	0	2850	378.18	0.132695	$334.84
23-Jul	7.4	0.55	329	2434.6	2200	650	0	2850	378.18	0.132695	$323.06
30-Jul	7.36	0.46	393	2892.48	2200	500	0	2700	378.18	0.140067	$405.14
07-Aug	7.38	0.49	369	2723.22	2200	0	0	2200	307.72	0.139873	$380.90
14-Aug	7.38	0.45	402	2966.76	2200	0	0	2200	307.72	0.139873	$414.97

To match the cost/steer from hay harvested on June 12th, the cost/acre on July 10th would need to be reduced to $336.18, representing approximately $42/acre to offset delayed harvest.

Eastern Ontario

Harvest Week	DMI (kg/d)	ADG (kg/d)	Days to Finish	DM Req (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total yield (kg)	Cost/ acre	Cost/kg	Cost/ steer
29-May	6.37	0.6	300	1911	1550	650	450	2650	439.45	0.1658302	$ 316.90
05-Jun	6.47	0.6	300	1941	1750	650	450	2850	439.45	0.154193	$ 299.29
12-Jun	**6.47**	**0.6**	**300**	**1941**	**1950**	**650**	**450**	**3050**	**439.45**	**0.144082**	**$ 279.66**
19-Jun	6.55	0.6	300	1965	2075	650	375	3100	439.45	0.1417581	$ 278.55
26-Jun	6.7	0.6	300	2010	2150	650	0	2800	418.2	0.1493571	$ 300.21
03-Jul	6.45	0.6	300	1935	2200	650	0	2850	418.2	0.1467368	$ 283.94
10-Jul	6.8	0.6	300	2040	2200	650	**0**	2850	418.2	0.1467368	$ 299.34
17-Jul	**6.95**	**0.6**	**300**	**2085**	**2200**	**650**	**0**	**2850**	**418.2**	**0.1467368**	**$ 305.95**
31-Jul	7.39	0.51	355	2623.45	2200	500	0	2700	418.2	0.1548889	$ 406.34
14-Aug	7.39	0.52	348	2571.72	2200	0	0	2200	347.7	0.1580455	$ 406.45

To match the cost/steer from hay harvested on June 12th, the cost/acre on July 17th would need to be reduced to $382.07, representing approximately $36/acre to offset delayed harvest.

Northern Ontario

Harvest Week	DMI (kg/d)	ADG (kg/d)	Days to Finish	DM Req (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total yield (kg)	Cost/ acre	Cost/kg	Cost/steer
29-May	6.25	0.6	300	1875	1550	650	450	2650	407.45	0.1537547	$ 288.29
05-Jun	6.25	0.6	300	1875	1750	650	450	2850	407.45	0.1429649	$ 268.06
19-Jun	**6.15**	0.6	**300**	**1845**	**2075**	**650**	**0**	**2725**	**407.45**	**0.1495229**	**$ 275.87**
28-Jun	6.35	0.6	300	1905	2150	650	0	2800	386.2	0.1379286	$ 262.75
03-Jul	6.6	0.6	300	1980	2200	650	0	2850	386.2	0.1355088	$ 268.31
10-Jul	6.6	0.6	300	1980	2200	650	0	2850	386.2	0.1355088	$ 268.31
17-Jul	**6.65**	**0.6**	**300**	**1995**	**2200**	**500**	**0**	**2700**	**386.2**	**0.143037**	**$ 285.36**
24-Jul	6.9	0.6	300	2070	2200	0	0	2200	315.45	0.1433864	$ 296.81
31-Jul	7.05	0.6	300	2115	2200	0	0	2200	315.45	0.1433864	$ 303.26
07-Aug	6.85	0.6	300	2055	2200	0	0	2200	315.45	0.1433864	$ 294.66

To match the cost/steer from hay harvested on June 19th, the cost/acre on July 17th would need to be reduced to $373.36, representing approximately $13/acre to offset delayed harvest.

Southern Ontario

Harvest Week	DMI (kg/d)	ADG (kg/d)	Days to Finish	DM Req (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total yield (kg)	Cost/ acre	Cost/kg	Cost/ steer
27-May	6.45	0.6	300	1935	1550	650	450	2650	464.45	0.1752642	$339.14
05-Jun	6.7	0.6	300	2010	1750	650	450	2850	464.45	0.1629649	$327.56
11-Jun	6.65	0.6	300	1995	1950	650	450	3050	464.45	0.1522787	$303.80
18-Jun	**6.6**	**0.6**	**300**	**1980**	**2075**	**650**	**375**	**3100**	**464.45**	**0.1498226**	**$296.65**
25-Jun	6.75	0.6	300	2025	2150	650	0	2800	443.2	0.1582857	$320.53
02-Jul	6.9	0.6	300	2070	2200	650	0	2850	443.2	0.1555088	$321.90
09-Jul	6.9	0.6	300	2070	2200	650	0	2850	443.2	0.1555088	$321.90
16-Jul	**6.85**	**0.6**	**300**	**2055**	**2200**	**650**	**0**	**2850**	**443.2**	**0.1555088**	**$319.57**
23-Jul	7.1	0.6	300	2130	2200	650	0	2850	443.2	0.1555088	$331.23
31-Jul	7.2	0.6	300	2160	2200	500	0	2700	443.2	0.1641481	$354.56
05-Aug	7.4	0.6	300	2220	2200	0	0	2200	372.7	0.1694091	$376.09
13-Aug	7.42	0.58	312	2315	2200	0	0	2200	372.7	0.1694091	$ 392.19

To match the cost/steer from hay harvested on June 18th, the cost/acre on July 16th would need to be reduced to $411.41, representing approximately $32/acre to offset delayed harvest.

Appendix 6. Per Acre Cost – Wintering Beef Cows

Data shown here reflects the cost modeling results for wintering beef cows for each region, pooled for the sites within that region (as grouped in Table 1). This provides additional detail for the section "Wintering Beef Cows" on page 26.

Central Ontario

Harvest Week	DMI (kg/d)	180 d DM Req. (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total DM yield (kg)	Cost/ acre	Cost/kg DM	Cost/cow
22-May	6.8	1224	1250	650	450	2350	399.45	0.169979	$ 208.05
29-May	6.67	1200.6	1550	650	450	2650	399.45	0.150736	$ 180.97
04-Jun	6.9	1242	1750	650	450	2850	399.45	0.140158	$ 174.08
12-Jun	**7.16**	**1288.8**	**1950**	**650**	**450**	**3050**	**399.45**	**0.130967**	**$ 168.79**
19-Jun	7.63	1373.4	2075	650	375	3100	399.45	0.128855	$ 176.97
26-Jun	7.67	1380.6	2150	650	0	2800	378.18	0.135064	$ 186.47
03-Jul	8.07	1452.6	2200	650	0	2850	378.18	0.132695	$ 192.75
10-Jul	7.93	1427.4	**2200**	**650**	**0**	2850	378.18	0.132695	$ 189.41
17-Jul	**8.55**	**1539**	**2200**	**650**	**0**	**2850**	**378.18**	**0.132695**	**$ 204.22**
23-Jul	8.45	1521	2200	650	0	2850	378.18	0.132695	$ 201.83
30-Jul	8.89	1600.2	2200	500	0	2700	378.18	0.140067	$ 224.13
07-Aug	8.74	1573.2	2200	0	0	2200	307.72	0.139873	$ 220.05
14-Aug	8.98	1616.4	2200	0	0	2200	307.72	0.139873	$ 226.09

To match the cost/cow from hay harvested on June 12th, the cost/acre on July 17th would need to be reduced to $312.57, representing approximately $66/acre to offset delayed harvest.

Eastern Ontario

Harvest Week	DMI (kg/d)	180 d DM Req. (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total DM yield (kg)	Cost/ acre	Cost/kg	Cost/cow
29-May	6.83	1228.5	1550	650	450	2650	439.45	0.16583	$ 203.72
05-Jun	6.70	1206	1750	650	450	2850	439.45	0.154193	$ 185.96
12-Jun	**6.85**	**1233**	**1950**	**650**	**450**	**3050**	**439.45**	**0.144082**	**$ 177.65**
19-Jun	6.91	1243.8	2075	650	375	3100	439.45	0.141758	$ 176.32
26-Jun	7.16	1288.98	2150	650	0	2800	418.2	0.149357	$ 192.52
03-Jul	6.83	1229.4	2200	650	0	2850	418.2	0.146737	$ 180.40
10-Jul	7.21	1298.43	2200	650	**0**	2850	418.2	0.146737	$ 190.53
17-Jul	**7.53**	**1355.13**	**2200**	**650**	**0**	**2850**	**418.2**	**0.146737**	**$ 198.85**
31-Jul	8.66	1559.25	2200	500	0	2700	418.2	0.154889	$ 241.51
14-Aug	8.60	1547.91	2200	0	0	2200	347.7	0.158045	$ 244.64

To match the cost/cow from hay harvested on June 12th, the cost/acre on July 17th would need to be reduced to $373.62, representing approximately $45/acre to offset delayed harvest.

Northern Ontario

Harvest Week	DMI (kg/d)	180 d DM Req. (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total DM yield (kg)	Cost/ acre	Cost/kg	Cost/cow
29-May	6.70	1205.82	1550	650	450	2650	407.45	0.153755	$ 185.40
05-Jun	6.72	1209.6	1750	650	450	2850	407.45	0.142965	$ 172.93
19-Jun	**6.74**	**1213.38**	**2075**	**650**	**0**	**2725**	**407.45**	**0.149523**	**$ 181.43**
28-Jun	7.06	1270.08	2150	650	0	2800	386.2	0.137929	$ 175.18
03-Jul	7.44	1340.01	2200	650	0	2850	386.2	0.135509	$ 181.58
10-Jul	7.26	1305.99	2200	650	0	2850	386.2	0.135509	$ 176.97
17-Jul	**7.49**	**1347.57**	**2200**	**500**	**0**	**2700**	**386.2**	**0.143037**	**$ 192.75**
24-Jul	7.73	1391.04	2200	0	0	2200	315.45	0.143386	$ 199.46
31-Jul	7.88	1417.5	2200	0	0	2200	315.45	0.143386	$ 203.25
07-Aug	7.72	1389.6	2200	0	0	2200	315.45	0.143386	$ 199.25

To match the cost/cow from hay harvested on June 19th, the cost/acre on July 17th would need to be reduced to $363.51, representing approximately $23/acre to offset delayed harvest.

Southern Ontario

Harvest Week	DMI (kg/d)	180 d DM Req. (kg)	1st Cut weight (kg)	2nd Cut weight (kg)	3rd Cut weight (kg)	Total DM yield (kg)	Cost/ acre	Cost/kg	Cost/cow
27-May	6.97	1254.6	1550	650	450	2650	464.45	0.175264	$ 219.89
05-Jun	6.88	1238.4	1750	650	450	2850	464.45	0.162965	$ 201.82
11-Jun	7.17	1290.87	1950	650	450	3050	464.45	0.152279	$ 196.57
18-Jun	**7.09**	**1275.75**	**2075**	**650**	**375**	**3100**	**464.45**	**0.149823**	**$ 191.14**
25-Jun	7.32	1317.6	2150	650	0	2800	443.2	0.158286	$ 208.56
02-Jul	7.28	1310.4	2200	650	0	2850	443.2	0.155509	$ 203.78
09-Jul	7.57	1362.69	2200	650	0	2850	443.2	0.155509	$ 211.91
16-Jul	**7.62**	**1372.14**	**2200**	**650**	**0**	**2850**	**443.2**	**0.155509**	**$ 213.38**
23-Jul	7.78	1400.49	2200	650	0	2850	443.2	0.155509	$ 217.79
31-Jul	7.99	1438.29	2200	500	0	2700	443.2	0.164148	$ 236.09
05-Aug	8.17	1470.42	2200	0	0	2200	372.7	0.169409	$ 249.10
13-Aug	8.26	1487.43	2200	0	0	2200	372.7	0.169409	$ 251.98

To match the cost/cow from hay harvested on June 18th, the cost/acre on July 16th would need to be reduced to $397.04, representing approximately $46/acre to offset delayed harvest.