2014 Lake City Research Center Beef Report

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August 6th, 2014

Dear Field Day Participant,

Thank you for participating in this year's field day. To accompany the discussion, we have worked to put together a report detailing work with beef cattle and their forages including performance and economic data. I would like to thank all of my wonderful colleagues that help make Lake City Research Center a leader in grazing, ecology and local food systems. Doug Carmichael, Evan Elder, Ty Houghston, Jerry Lindquist, Kable Thurlow, Kevin Gould, Paul Gross, Matt Raven and Kim Cassida, among others, have helped to catalyze the research and outreach seen here. I too am very thankful for Dr. John Baker, Dr. Janice Swanson and Chuck Reid for all of their guidance.

CENTER GOALS

In 2010, staff associated with Lake City Research Center met with a holistic manager to outline a new direction for the station. Three important goals were outlined. First we would like for the Center to be a national leader in pasture based, lower-cost beef production systems. Secondly, we wish to maintain a high quality of life for all the Center effects: our visitors, employees and other coworkers. Essentially, we envision the Lake City being an education center for others to gain information and concurrently maintain, positive beneficial relationships with all stake holders. Finally, with the pressures being placed on research institutions as faculty, management and staff, we wish to have security in the opportunity to research alternative approaches and not be pushed back into more status quo work that has been often replicated the last 30 years.

CENTER RESOURCES

This year the center is managing 180 Red Angus breeding age females, 65 of which are registered. We currently graze the cowherd on 600 acres of land including 64 acres of low pressure irrigation. We have 80 acres of alfalfa that is used to hay the calf crop through the winter. We maintained 80 heifers and 70 steers through the winter.
We are very fortunate to have the Rood Trust Endowment tied into the research center. In the past, the funds had been primarily administered into small research grants that were run at the farm. However, because of the budgetary challenges of the university, we have become more reliant on external funds and the Rood Trust has been used to help address infrastructure needs capital improvements of the facility. Faculty do still have the opportunity to apply for granting opportunities through the Rood Trust but generally in a matching situation with federal funding.

NEW FEDERAL FUNDING!!!!!!!!

I am pleased to announce we have new federal funding to further conduct our research and outreach with respect to grass finishing. The new $470,000 grant will allow us to investigate the influence of cover-crops on grass finishing along with forage type influence on beef sensory characteristics. We too will investigate the sensory performance of fresh and frozen products. The overall outcome we hope to achieve is to identify grass finishing practices that are profitable and ultimately increases the amount of grass finished beef into the landscape.

GRASSFED EXCHANGE 2015

Michigan is proud to host the Grassfed Exchange National Meeting September 16-18, 2015. The meeting strives to forward the grass finishing livestock industry with exciting pasture walks, world renown speakers and also recognizes industry leaders through a multitude of awards. Accompanied with industry trade booths, the three day conference also attracts producers, distributors and retailers from across the nation. Stay tuned for more information.

LAKE CITY GOES TO LONDON

Just recently, I presented our grass finishing and carbon emission data to the International Savory Conference in London, England. There was a collection of ranchers and farmers, business investors interested in carbon, NGO's, authors and medical doctors from over 20 countries in attendance. I was amazed at those interested in grazing and carbon. I spoke with investors from Goldman Sachs and Virgin Investments (the Richard Branson company) Based on my interactions there, the future is in our soil and this will drive food and health. I believe that further developing food production methods that are profitable, ecologically regenerative and are neighborly and socially just is the future of food in MI. There are those who are ready to invest in this.

NEW ADMINISTRATORS

If you have a chance, please welcome our new administrators to MSUE and AgBioResearch: Dr. George Smith has taken over the role from Dr. John Baker as Associate Director of AgBioResearch. George grew up on a sheep farm in Idaho and has a great combination of applied background and research acumen. Also we have a new trio of MSUE administrators: Margaret Bethel, Ray Hammerschmidt and Patrick Cudney. If you get a chance, please introduce yourself to our new leadership.

In summary, I am thankful for the progress we continue to make at Lake City. We always want to focus on you the stakeholder, the environment in which we all live and will do our best to be responsive to the research and outreach needs of the area.

Sincerely,

Jason Rowntree
Assistant Professor and Lake City Research Center Coordinator

Cow-Calf Production at Lake City AgBioResearch Center

K. Thurlow, MSU Extension, J. Lindquist, MSU Extension, J.E. Rowntree, Department of Animal Science, MSU, D.E. Carmichael, Lake City AgBioResearch Center

Introduction

In the fall of 2010, the Lake City MSU AgBioResearch Center made a change in the type of cattle that were utilized for research. There were several major reasons for making this change. From a standpoint of orienting to the future, as an extension and research team, we felt that the future of beef production should be oriented towards lowering costs and relying more on forages. Thus the move was made to a type of beef cow that was believed to produce offspring that will be more efficient on forage without greatly sacrificing beef quality. As you look at these cattle they may look slightly different, they may not wean calves in the top 10% of the industry, but they are still stout, thick made cattle. Its also important to remember that being a low cost producer does not mean that you are selling a low quality product, we aim to continue to educate producers on the fine point of finishing the beef to a high quality on an all grass (and forbs) based diet.

Cow Herd Data

In the 2012 Beef Report, we stated that we were shooting for a frame score of 3-4 on our mature cowherd, and a mature weight of around 1100 pounds. For 2011, frame score measurements were taken on January 20, 2011, and the average frame score on our cowherd was 4.53, the measurements were taken again in March of 2013, and the average frame score was at 4.7.

Mature weights were taken on the cows in October of each year, and were post weaning. The average cowherd weights are as follows: 1187 pounds for 2011, 1279 pounds for 2012, and 1196 pounds for 2013. The weight range was 810 to 1475 pounds. The lightest cow was born in 2008, so at 3 years of age she weighed 810 pounds, and in 2013 at the age of 5, she weighed 960 pounds.

The cows were also given a Body Condition Score (BCS) at the same time as the weights were taken. Those average BCS scores were: 5.7 for 2012, and 5.5 for 2013. No BCS measurements were taken in the fall of 2012.

There are two cows, 5L Lakota 1736-158, and 5L Sheila 2795-2988, which are serving as foundation females for our herd. Their pedigrees are listed in Figures 1 and 2.

We have also used PCC Jazz Boy 4064W, and 5L Tradesman 1715-6237 as A.I. sires for our herd. We feel that both of these sires fit the program that we are working on. Jazz Boy was born on 7/7/2009, had a birth weight of 60 pounds, and has a 3.5 frame score. He was also the highest selling bull in the 2010 Fall Bull Sale for Pharo Cattle Company. His EPD's are as follows: BW -3.4, WW +39, YW +50, and Milk +12. The 5L Tradesman 1715-6237 bull was born on February 2, 2007, and he has the following EPD's: BW -2.2, WW +50, YW +94, and Milk +16.

Starting with the 2013 Breeding season, the herd was closed, and we are using Sons of both of these bulls; our efforts are focused on homogenizing the herd. The Jazz Boy sired females are being bred to the Tradesman Sons, and the Tradesman sired females are being bred to Jazz Boy sired sons.

Conducting a pregnancy check each year-monitored conception Rates on the cows. There were 14 open cows in the cowherd (n=169) in 2011, there were 169 cows exposed. The cows were all checked on October 15, 2011. There were 42 head that were bred via AI on July 1, 2011; the breeding bulls were turned out on July 1, 2014.

There were 7 open cows in the herd (n=166) in 2012, there were 166 cows exposed. AI conception rate was around 17% in 2012, and breeding bulls were turned out on July 3, 2012, and were taken back out on September 6, 2012. The cows were pregnancy checked on October 17, 2012.

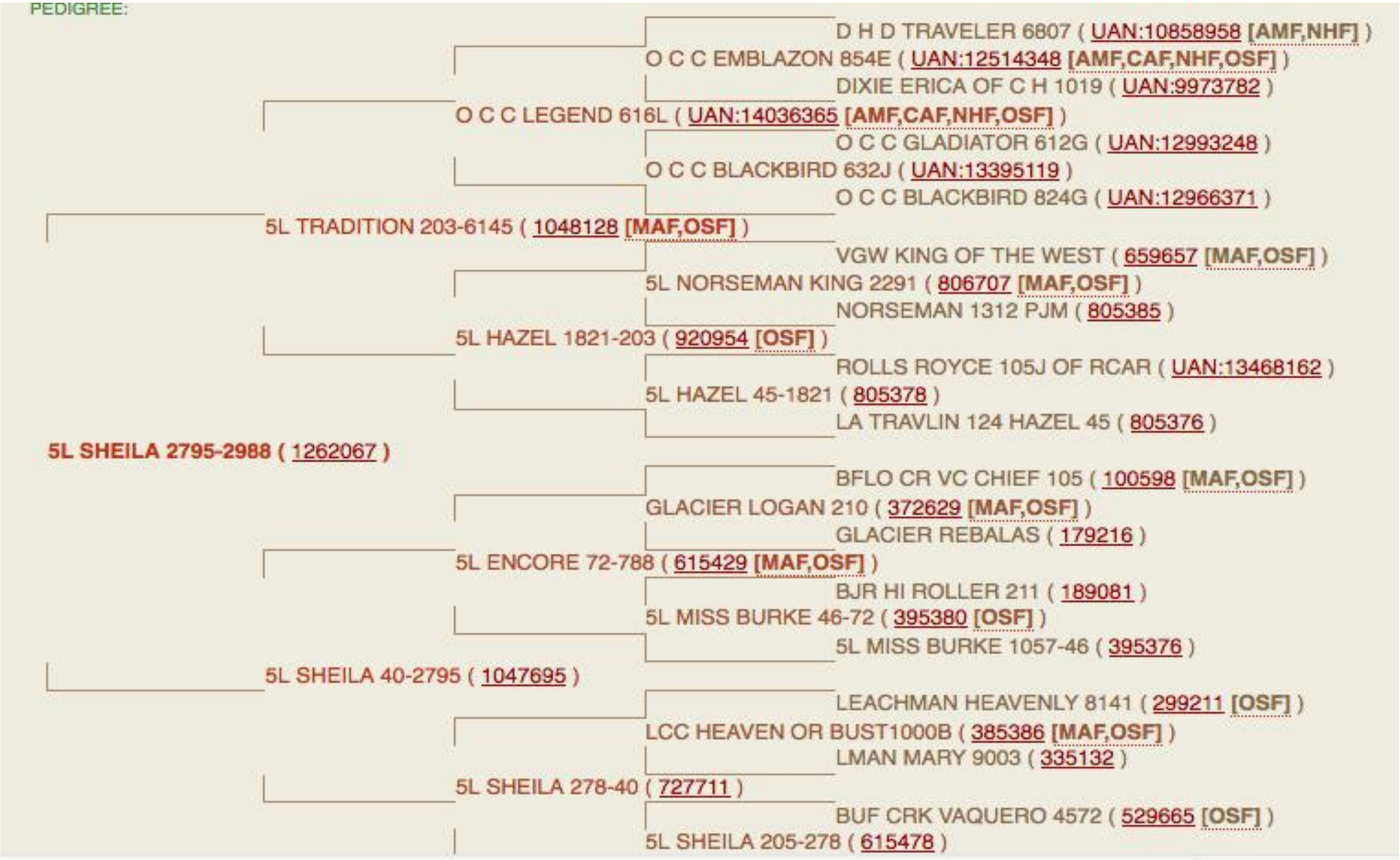
In 2013, there were 22 open cows in the herd (n=127 exposed), 15 of them were mature cows, and 7 were open heifers that were roughly 18 months of age at the time they were pregnancy checked. They were pregnancy checked on October 3, 2013. We have been putting intentional breeding pressure on cows to increase long-term herd fertility. We do believe there is a high correlation between fertility, and the ability to finish on grass.

Calf Data

The average adjusted 205-day weaning weight for the 2011 Heifers (n=62) was 566 pounds. The average adjusted 205-day weight for the bulls (n=3) was 562 pounds. The steers (n= 63) had an average weight of 598 pounds. The average 205 day weight for the 2012 calf crop was as follows, Heifers (n=57) were 552 pounds, steers (n= 35) were at 605 pounds, and the replacement bulls (n=8) averaged 615 pounds. On the 2013 calf crop, the adjusted 205-day weight for the calf crop was 573 pounds. This weight includes heifers, steers, and the replacement bull calves. If you split those groups into the different sexes, they showed averages that are as follows: 1) steers (n=28) averaged 590 pounds, heifers (n= 40) averaged 555 pounds, and the bull calves (n=7) averaged 601 pounds. These number do not represent the entire calf crops from these respective years, as some of them were below 180 day in age and we were not able to calculate their adjusted 205 day weight.

Conclusion

At the Lake City AgBioResearch Center, we are working to provide information that will help to answer questions many in the grass finishing businesses have. We are uniquely positioned, as we are one of only a handful of facilities in the US conducting this type of research. Although the grass-fed beef industry may be small compared to the traditional feedlot beef system, it is well over a multi billion dollar industry today, and is continually growing. We are not in any way saying that the grain fed feedlot system should or will be replaced any time soon; we are only presenting grass finishing as an option for producers as it may have a special fit in Michigan. Further much of the work being conducted at the Center could be applied in any beef operation. We look forward to continually developing the new genetic base. We envision the continual increase of forages needed to make beef production profitable long term and hope our genetic work can help in this progression.



PEDIGREE:

D H D TRAVELER 6807 (UAN:10858958 [AMF,NHF])
O C C EMBLAZON 854E (UAN:12514348 [AMF,CAF,NHF,OSF])
DIXIE ERICA OF C H 1019 (UAN:9973782)
O C C LEGEND 616L (UAN:14036365 [AMF,CAF,NHF,OSF])
O C C GLADIATOR 612G (UAN:12993248)
O C C BLACKBIRD 632J (UAN:13395119)
O C C BLACKBIRD 824G (UAN:12966371)
5L TRADITION 203-6145 (1048128 [MAF,OSF])
VGW KING OF THE WEST (659657 [MAF,OSF])
5L NORSEMAN KING 2291 (806707 [MAF,OSF])
NORSEMAN 1312 PJM (805385)
5L HAZEL 1821-203 (920954 [OSF])
ROLLS ROYCE 105J OF RCAR (UAN:13468162)
5L HAZEL 45-1821 (805378)
LA TRAVLIN 124 HAZEL 45 (805376)
5L SHEILA 2795-2988 (1262067)
BFLO CR VC CHIEF 105 (100598 [MAF,OSF])
GLACIER LOGAN 210 (372629 [MAF,OSF])
GLACIER REBALAS (179216)
5L ENCORE 72-788 (615429 [MAF,OSF])
BJR HI ROLLER 211 (189081)
5L MISS BURKE 46-72 (395380 [OSF])
5L MISS BURKE 1057-46 (395376)
5L SHEILA 40-2795 (1047695)
LEACHMAN HEAVENLY 8141 (299211 [OSF])
LCC HEAVEN OR BUST1000B (385386 [MAF,OSF])
LMAN MARY 9003 (335132)
5L SHEILA 278-40 (727711)
BUF CRK VAQUERO 4572 (529665 [OSF])
5L SHEILA 205-278 (615478)

Figure 1. 5L Sheila 2795-2988

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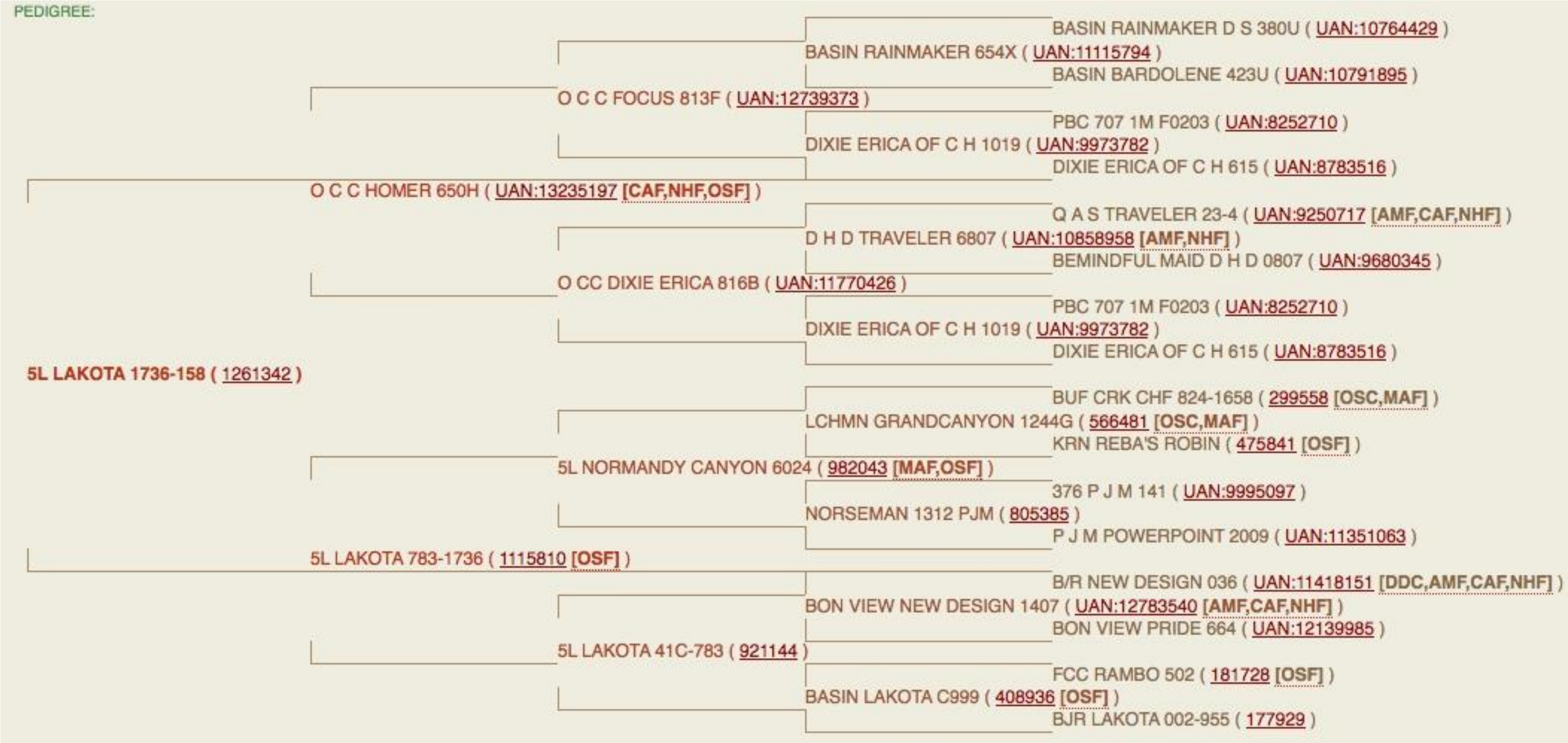


PEDIGREE:

BASIN RAINMAKER D S 380U (UAN:10764429)
BASIN RAINMAKER 654X (UAN:11115794)
BASIN BARDOLENE 423U (UAN:10791895)
O C C FOCUS 813F (UAN:12739373)
PBC 707 1M F0203 (UAN:8252710)
DIXIE ERICA OF C H 1019 (UAN:9973782)
DIXIE ERICA OF C H 615 (UAN:8783516)
O C C HOMER 650H (UAN:13235197 [CAF,NHF,OSF])
Q A S TRAVELER 23-4 (UAN:9250717 [AMF,CAF,NHF])
D H D TRAVELER 6807 (UAN:10858958 [AMF,NHF])
BEMINDFUL MAID D H D 0807 (UAN:9680345)
O CC DIXIE ERICA 816B (UAN:11770426)
PBC 707 1M F0203 (UAN:8252710)
DIXIE ERICA OF C H 1019 (UAN:9973782)
DIXIE ERICA OF C H 615 (UAN:8783516)

5L LAKOTA 1736-158 (1261342)

BUF CRK CHF 824-1658 (299558 [OSC,MAF])
LCHMN GRANDCANYON 1244G (566481 [OSC,MAF])
KRN REBA'S ROBIN (475841 [OSF])
5L NORMANDY CANYON 6024 (982043 [MAF,OSF])
376 P J M 141 (UAN:9995097)
NORSEMAN 1312 PJM (805385)
P J M POWERPOINT 2009 (UAN:11351063)
5L LAKOTA 783-1736 (1115810 [OSF])
B/R NEW DESIGN 036 (UAN:11418151 [DDC,AMF,CAF,NHF])
BON VIEW NEW DESIGN 1407 (UAN:12783540 [AMF,CAF,NHF])
BON VIEW PRIDE 664 (UAN:12139985)
5L LAKOTA 41C-783 (921144)
FCC RAMBO 502 (181728 [OSF])
BASIN LAKOTA C999 (408936 [OSF])
BJR LAKOTA 002-955 (177929)

Figure 2. 5L Lakota 1736-158

Table. Mean LCRC Cowherd Expected Progeny Difference with Current Breed Rankings

Object	CED	BW	WW	YW	Milk	MAT	ME	HPG	CEM	Stay	MA	YG	CW	BF	REA
2011	4	0	30	57	17	32	4	4	10	9	.05	-.03	34	0	.03
2014	4.4	-.94	42	63	17	38	-.6	9	7	11.25	.47	-.07	6.4	0	.18
Rank (%)	50	58	80	82	55	75	7	60	25	30	35	25	80	45	40

Evaluating the Economics of Pasture Based Systems for the Beef Cow Herd

Jerry Lindquist, Michigan State University Extension Grazing and Crop Management Educator, Reed City, MI.

Introduction

The rapidly changing agricultural commodity markets have put economic pressure on the beef cattle industry of the United States. Rising corn and soybean prices put demand on farmland for grain planting, which in turn brought increased farmland demand from other farm sectors such as potato, sugar beet and dairy. Over this period the beef markets were not strong and beef farms across the United States and here in Michigan had a hard time competing for farmland. As a result significant acres of pastureland and hay fields were converted to row crop production. Fortunately beef markets have recovered to historical new highs and profitability has returned to the pasturelands. With this brighter economic picture, remaining beef and livestock farms are contemplating pasture improvements. Additionally a few new individuals are considering venturing into the beef industry and are wondering about the economics of renting or buying land.

Pasture economics are rarely analyzed and thus are not well understood. Pasture land is often leftover, sometimes non-tillable land that is viewed as not having as much economic value. The expensing calculation of pasture land can also be complex as native pasture is a long lived perennial sod and improvements to it in the form of major fence repair, water facilities, etc. are usually not an annual expense, but instead a long term depreciable expense complicating the calculation.

Procedure

This analysis will compare native pasture and improved pasture projected expense budgets for 2014 and correlate the yield to historic pasture yield data conducted by MSU researchers at the MSU research facilities in East Lansing and Lake City.

Analysis

The accompanying budgets (table 1 & 2) project the cost of common expense items for pastures in Michigan based on the year 2014. The assumption for the Native Pasture land in Table 1 is land that has not experienced additions of seed nor commercial fertilizer for at least the past 25 years. It does assume some additional fencing for minimal rotational grazing. The Improved Pasture land in Table 2 has a frost seeding application every three years with annual fertilizer application based on MSU soil test recommendations for average pasture soils in the Missaukee/Osceola County area of Michigan.

Based on these budget projections by the author the cost of Native Pasture land is less than half the cost of Improved Pasture Land - $87 compared to $202 per acre annually. The largest expense of the Native Pasture land is land ownership/rent itself at 57% of the total cost. Not surprisingly the largest expense of the Improved Pasture is the fertilizer cost which is $75/acre and 37% of the total expense.

Table 1

Native Pasture Budget, 2.3 T/acre 2014

Expenses	Quantity	Price per Unit	Total per Acre
Seeding Yr. Costs (50 yr. stand life)		$100/a	$2.00
Fertilizer			
Potash	0 lbs ($455/t 0-0-60)	$0.38	$0.00
Nitrogen	0 lbs ($600/t 46-0-0)	$0.58	$0.00
Lime			0
Fence	Exterior & Interior, 25 yr. life		$10.40
Water System			$ 2.00
Land Charge (taxes & land ownership cost or rent)			$50.00
Equipment Repairs			$ 8.20
Equipment Depreciation			$ 3.75
Utilities			$ 2.00
Misc. (fuel, weed control, energizer, depreciation)			$ 9.00
TOTAL SELECTED CASH EXPENSES			**$87.35**

Table 2

Improved Pasture Budget, 4.0 T/acre 2014

Expenses	Quantity	Price per Unit	Total per Acre
Seeding Yr. Costs (30 yr. stand life)		$180/a	$ 6.00
Frost Seeding Legumes (every three years)		$ 35/a	$11.66
Fertilizer			
Potash	30 lbs ($455/t 0-0-60)	$0.47	$11.40
Nitrogen	110 lbs ($535/t 46-0-0)	$0.58	$63.80
Lime	1 ton every 7 years ($35/t)		$ 5.00
Fence	Exterior & Interior, 25 yr. life		$10.40
Water System (pipe in pasture, tank & fittings) HDPE plastic 2,000 ft. @ $0.70; 20 yr. life			$ 5.00
Land Charge (taxes & land ownership cost or rent)			$50.00
Equipment Repairs			$ 8.20
Equipment Depreciation			$10.00
Utilities			$ 3.00
Misc. (fuel, weed control, energizer, depreciation)			$17.50
TOTAL SELECTED CASH EXPENSES			**$201.96**

If one does strictly a cost comparison there is no doubt the Native Pastureland is less of a financial outlay. But we must ask what increased yield and carrying capacity can be realistically expected from the additional inputs with the Improved Pasture System? We have 16 years of nitrogen fertilizer on grass research at MSU and 12 years of frost seeding pasture research that gives us good indications of what to expect over a wide range of weather conditions. But first let's look at what research says about the efficiency or utilization of the forages in three different feeding systems.

Based on pasture research at the University of Missouri measuring the pasture utilization of different grazing systems and using the cost analysis in Tables 1 & 2 we can draw the following conclusion in Table 3:

Table 3

Cost of Forage Feeding Comparison for the Beef Cow Herd

Feeding System		Cost per Ton of Forage
Feeding dry hay (16% moisture) priced @ $105/ton, assuming an 8% storage loss & 10% feeding loss, 82% utilization	-	$151/ton of DM consumed
Grazing Native Pasture, 2.3 tons DM/acre, 14 day rotations, 40% utilization	-	$ 95/ton of DM consumed
Grazing Improved Pasture, 4.0 tons DM/acre, 4 day rotations, 65% utilization	-	$ 78/ton of DM consumed

So when we factor in utilization, and equate all forages out to the same dry matter level, we see that the Improved Pasture system, even though it costs more than the Native Pasture system will yield a lower cost consumed forage than native, un-improved pasture and the other option of feeding hay. Now let's look at the question, can we really expect to receive 4.0 ton/acre of forage dry matter on average, every year, if we make pasture improvements.

Table 4

Dr. Milo Tesar's Nitrogen on Orchard Grass Trial at Lake City, 1968 - 1977

Nitrogen Applied	Avg. Yield	Range of Yields
0	2.09 tons/acre	0.93 – 2.64 tons/a
50# spring	3.02 tons/acre	1.69 – 4.01 tons/a
50# spring; 50# late June	3.72 tons/acre	2.23 – 5.46 tons/a
100# spring; 100# late June	4.60 tons/acre	3.28 – 6.33 tons/a
Grass/legume mix, no nitrogen added (alfalfa & some clover)	4.27 tons/acre	3.07 – 6.31 tons/a

All yields are 16% moisture hay equivalents. Wide yield ranges are attributed to two drought years and two years with excellent growing conditions over the ten year period.

Table 5

Economic Analysis of Dr. Tesar's 10 Yr. Lake City Trial with 2014 Prices

N Applied	Increase Above Control	Yield Value Above Control Less Cost of Fert. & Spread
0 (control)	-	-
50# spring	0.93 tons	$64/acre
100# split	1.63 tons	$103/acre
200 # split	2.51 tons	$142/acre
Grass/legume	2.18 tons	$205/acre

$110/ton hay value used, $0.58/lb. N; $11/acre spreading fee, Grass/legume assumes clover addition every fourth year with $3.00/lb. red clover.

Table 6

Dr. Richard Leep's Nitrogen on Grass Research at East Lansing over 3 years (2003 – 2005)

N Applied	Yield of Orchard Grass	Yield Value Above Control Less Cost of Fert. & Spread
0	2.38 tons/acre	-
50# May; 50# July	4.64 tons/acre	$169/acre
50# spring; & 50# after next 3 harvests	6.43 tons/acre	$286/acre

Assuming 2014 prices of $110/ton forage value at 16% moisture hay equivalent value, $0.58/lb. of N, $11/acre per application spreading cost.

Table 7

2012 & 2013 Pasture Nitrogen Trial MSU Lake City BioAg Research Station

Trials	Annual Yield	Value	Costs of Treatment	Net Value	Comparison to Control
Control No fertilizer applied	2.50 tons/a of dry matter	$275/a	0/a	$275/a	-
60# N/a Spring applied Urea	3.21	$603/a	$95/a	$508/a	+$37/a
60# N/a Spring applied Urea + Super U	3.17	$597/a	$97/a	$500/a	+$29/a
Frost Seeding	2.76	$519/a	$45/a (1)	$474/a	+$3/a
110# N/a Spring applied Urea	3.69	$694/a	$132/a	$562/a	+$91/a
110# N/a Spring applied Urea & Super U	3.2	$602/a	$136/a	$466/a	-$5/a
60# N/a Spring applied Urea Plus 50# N/a Summer applied Super U	3.23	$608/a	$145/a	$463/a	-$8/a

Trial conducted by Jerry Lindquist, MSU Extension Grazing Educator.

Fertilizer for trial supplied by the Falmouth Cooperative of Falmouth & McBain, MI.
2012 was a drought year. 2013 was very dry in July – September.

(1) Frost seeding of red clover failed in 2012 and had to be repeated in 2013 with white clover

From these budgets and research trials one can make decisions on whether or not to improve pastures based on many factors which may include:

- livestock stocking rates and carrying capacities (do you have extra land or do you have too many grazing animals and need more forage yield)
- capital resources and/or credit for input costs (can cash flow handle the cost of pasture improvement)
- comfort with risk (after investing $50-100/acre in your pastures can you handle the stress of a dry summer)
- is part of the farm mission to reduce carbon footprints, be low input, etc.

- can the animal component that is selling meat, milk, or fiber be profitable based on these costs of forage production?

These and many more questions must be answered when making these important decisions.

Farms are advised to utilize these projections and research trials to guide them in calculating their own budgets to better determine which pasture management system is better for their situation.

Based on current livestock prices and on the research presented in this paper it does appear for most farms that grazing livestock is again profitable. Pasture improvements may be justifiable for farms wishing to increase carrying capacity and/or wishing to extend their grazing season. Following are pasture grazing guidelines to achieve optimum efficiency in a pasture grazing system:

1. **Graze as many days as possible –** a ton of pasture forage will cost you roughly 1/2 the price to grow vs. the cost to make a ton of hay: $78/ton for pasture forage vs. $151/ton for hay when all are adjusted to dry matter and consumption utilization is factored in.
2. **Proper forage rest is critical** – grazing down the top pasture growth reduces the plant's root mass and depth, soil moisture will be located deeper in the soil profile in dry weather so resting the pasture 20 – 30 days in May & June and 30 – 55 days in July – Oct allows the roots to regrow and go deeper to find moisture and nutrients in the soil.
3. **Do not graze shorter than 5 inches** – animals should be removed from paddocks when the theoretical average forage height is still 5-6 inches; this is the height at which research says the remaining leaves and stems will still intercept 95% of the sun's solar energy with only 5% reaching the soil surface (the sun's solar energy warms the soil evaporating soil moisture excessively in mid-summer and decreasing biological activity). Grazing shorter than this height also removes the growing center of the cool season grass plants that store most of their energy in the crown or the stem of the plant. Grazing too low also leads to plant moisture stress and potentially to plant die off which allows weeds opportunities to creep in. Kentucky bluegrass and tall fescue are the grass exceptions to this height rule as they do tolerate and recover better from lower grazing.
4. **Do not graze a stand longer than 3 to 5 days** – it is best to size paddocks small enough that the herd has to be moved every 3 days in the spring, every 4 days in mid-summer and at least every 5 days in late summer. Plants after being eaten will start to re-grow a new leaf in as short as 3 days in the spring when growth is rapid and as early as 5 days in August and September if there is adequate soil moisture. Once grazed this re-growth should be rested for the periods mentioned in item #2 above or plant stunting will result.
5. **Re-graze once forage reaches 10 to 12 inches of height** – an average height of 10 -12 inches will assure that the plant's roots have re-grown to optimum levels in their reach into the soil to obtain moisture and find nutrients. It also assures that the plants have stored an optimum amount of energy in their vascular storage system.
6. **Graze before the average height is over 16 inches tall** – for optimum forage quality, solar efficiency and animal gain/acre try to graze before the height reaches 16". Plants above this height turn reproductive, reduce their ability to take in solar energy as their cell structure changes, lower their feed quality, and shade out shorter plants especially

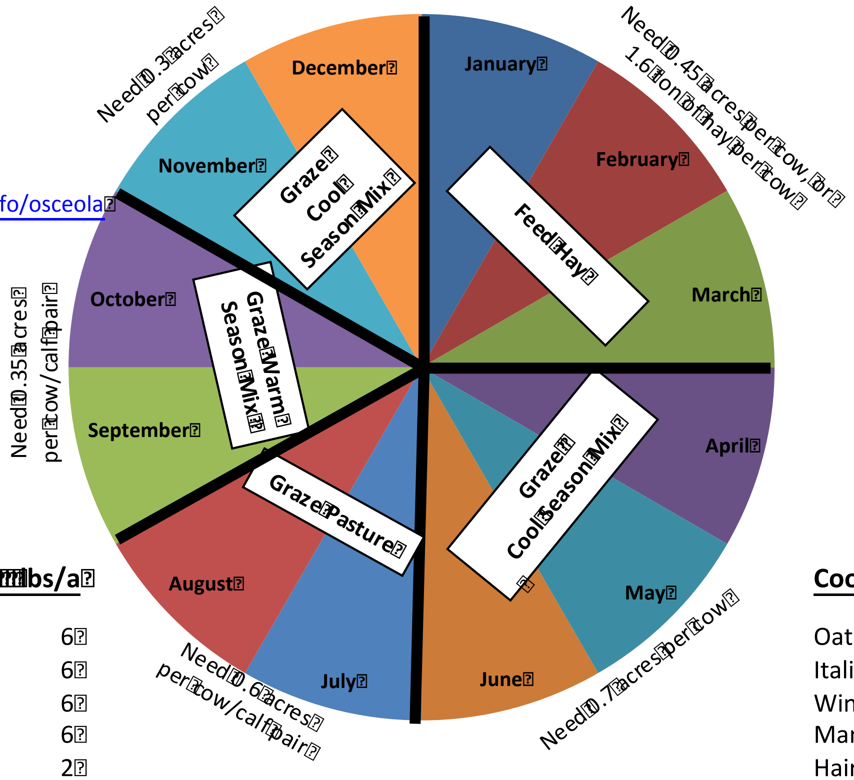
legumes. Pasture growth above this height either needs to be mowed for hay or grazed using high density stocking rates in paddocks with very small area to trample down the remaining stems into the soil surface building soil organic matter.

7. **Graze half leave half** – this crude rule of thumb simply means if the average pasture height is 12 inches tall at turn-in, the animals should be removed from the stand when the average height is 6 inches tall. Many producers realize that they will have less grazing days by pulling the herd out at 6" rather than maybe 3" and are reluctant to pull them when there is still good grass there, but what they never get to experience is that on average they will be able to return to that paddock much quicker because at 6" the forage plants were never set back that much and will re-grow to 12 inches that much quicker.
8. **Soil test and follow the recommendations whenever financially possible** – don't let fertility be your weak link.
9. **Need more grass growth? Make sure it has enough N every spring** – over 16 years of research at MSU shows that for every 1 lb. of nitrogen applied to grass per acre, the forage growth response of 18% moisture hay equivalent was an extra 36 lbs. of forage per acre. For example if you applied in the spring 130 lbs./acre of 46-0-0 which is 60 lbs. of nitrogen/acre on average the research shows the increase hay equivalent yield should be 2,160 lbs. of forage/acre. Invest $43/acre of fertilizer (spreading cost included) and see a yield response of $108/acre. In drought years the return was only 24 lbs. of hay/lb. of N/acre or $72 of extra hay value, but in the years of good rainfall the yield was 54 lbs. of hay/lb. of N/acre or $162 of extra hay equivalent per acre. A fourfold return on your investment!
10. **Let the legumes supply Nitrogen naturally –** having 40% of the pasture forages be a legume like red or white clover, Birdsfoot trefoil, or alfalfa will provide as much yield as putting on 120 lbs. of N/acre. Even if you have to frost seed in new legumes every 2-3 years the annual cost will be 1/4 of the cost of 120 lbs. of N will be (only $20/acre vs. $86/acre). Try to achieve legume diversity by adding legumes that are lacking in the pasture first and then rotate every two to three years with red clover one time, white clover the next and Trefoil the next if necessary. Alfalfa does not frost seed well. Do not increase clovers and alfalfa % much above 40% as livestock bloat is a risk.
11. **Utilize manure better by decreasing pasture size –** the average meat animal recycles from 70 – 90% of the nutrients they consume on pasture back on the pasture in their manure and urine. If the stocking rate is 3 – 5 acres per a cow/calf pair for the grazing season they only remove 3 -5 lbs. of P_2O_5 and 2 lbs. of K_2O per acre per season. But they may not recycle (deposit) these nutrients evenly across the pasture. If we give them large pastures that they can roam and graze for 2 – 3 weeks or longer, they may graze nutrients from the open spaces and then loaf back in the shaded areas depositing a larger portion of the nutrients in the loafing area and around water sources. University of Missouri research found that if we give cattle a pasture to continuously graze all summer that it would take 25 years before manure was deposited on every square yard of that pasture. Not good uniform recycling! But if cattle were rotated every two weeks to new pasture it would take approximately 8 years to randomly cover every square yard with manure. If we can reduce the grazing allotment down to only enough area to graze in 4 days and move them after 4 days, this increased stocking density would provide for complete manure coverage every 4.5 years.

12. **Consider and utilize all nutrient sources -** lime and processed fertilizer sources are the norm but scrape your winter feed areas, bale graze in pastures and hay fields, consider fly ash, compost, poultry litters and others as ways to improve pasture soil fertility.
13. **Find more land to graze –** we may be driving by land every day that has grazing potential. With leasing contracts of 10 – 15 years fence building can be economical on rented land.
14. **Include annual forage multi-specie cover crops into your pasture system** – these plantings can extend your fall and spring grazing periods with high quality feeds while providing crop rotation that may improve soil quality and crop yields. See the diagram on the following page for details.

Beef Cow Herd Annual Feed Supply Utilizing Multi Specie Cover Crop Mixes

For more info go to: http://msue.anr.msu.edu/county/info/osceola under "Grazing"



Note that the cool season mix acreage for Nov-Dec and for April-June will be the same crop.

Acreage requirements per cow do not include feed requirements for replacement heifers.

Warm Season Mix Example lbs/a

Sorghum/Sudan grass hybrid	6
Hybrid millet	6
Forage soybean	6
Italian ryegrass	6
Mammoth red clover	2
Sunflower	1
Radish	1
Turnip	1

All blended in large seed box of grain drill and seeded after risk of spring frost is gone.

Cool Season Mix Example lbs/a

Oats	6
Italian ryegrass	6
Winter triticale	6
Mammoth red clover	2
Hairy vetch	1
Radish	2
Turnip	2

All blended and seeded in grain drill large seed box in July – mid August after a hay, oat or wheat harvest.

Michigan State University Grass Finishing Beef Report

Jason Rowntree, Doug Carmichael, Kim Cassida, Jerry Lindquist, Kable Thurlow Grazing Team, Michigan State University

A set of Red Angus steers weighing between 750-800 pounds were allocated to either an intensive grazing system with low pressure irrigation or a lower-input leader-follow system with the intent to grass finish, May 15, 2013. Within the intensive system, steers (n = 54) were grazed on a cool season pasture sward irrigated one acre-inch of water weekly until mid-August. The leader follow system consisted of steers (n = 25) integrated into the breeding heifer population and moved in synchrony either before or after 180 head of beef cows grazed at a density of 150K/acre moving three times daily. Botanical compositions of the two systems are presented in Table 1.

Table 1. Botanical composition of pastures grazed with different grazing management strategies.

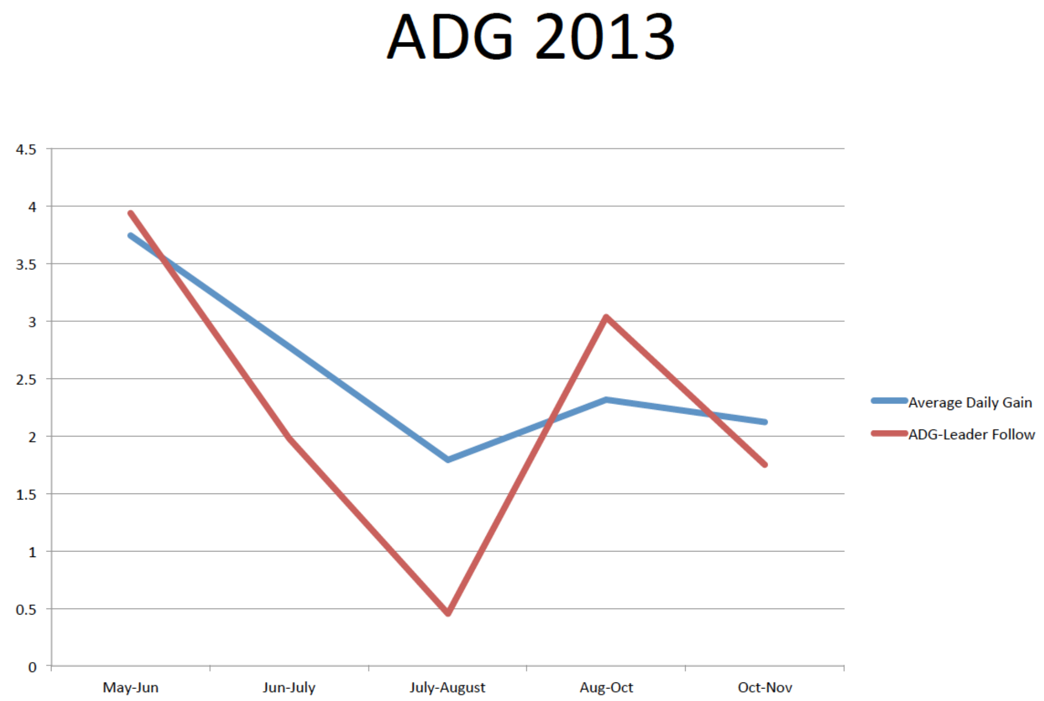
Systems	May 15th	%	August 15th	%
2013 grazing season				
L/F	Kentucky (*Poa pratensis*)	50	Bromegrass (*Bromus inermis*)	51
	Orchard (*Dactylis glomerata*)	17	Orchard (*Dactylis glomerata*)	26
	Red/white clover (*T. pratense*/*repens*)	7	Birdsfoot trefoil (*Lotus corniculatus*)	9
Irrigation	Kentucky (*Poa pratensis*)	54	Orchard (*Dactylis glomerata*)	55
	Orchard (*Dactylis glomerata*)	30	Kentucky (*Poa pratensis*)	14
	Red/white clover (*T. pratense*/*repens*)	3	Red clover (*Trifolium pratense*)	21

Within the two systems, especially later in the grazing season there was roughly double the legumes in the irrigated system when compared to the leader-follow system. Our hypothesis would be that grazing the taller forages in the low-input system led to some shading of legumes that thrive lower in the overall canopy.

Figure 1 shows the overall average daily gain performance for the steers in each of the finishing systems. Importantly, steers gained very aggressively early in the grazing season (turnout day May 15th) such that cattle maintained a 3.5 lb average daily gain for the first 30 days of the grazing season (May 15th to June 15th). Concurrently, it is also important to note that the forage quality during this early stage was over 20%. While there is a premise that crude protein can be too high early in the grazing system because of 'washy grass', we enjoyed very high gains coming out of the winter.

As the summer slump ensued, in July and August, the systems dramatically changed in terms of weight gain. In the irrigated system, gains were managed at close to 2 lbs a day, this was done by supplementing 10 lbs of high quality hay/head daily for a 30 day window. This was done for two reasons. First, we wanted to maintain a high plane of gain for the entire grazing and secondly (perhaps most importantly) we did not want to overgraze lowering residual forage and slowing subsequent growth which would prevent having high quality forage late in the grazing season for finishing cattle. The stocking rate for the irrigated system averaged 1.20 steers per acre. On the other hand the leader-follow system fell to below a 0.5 pound average daily gain. These cattle were stocked at 1 steer/1.5 acres. Not only were these cattle not supplemented forage, but also we determined that there was not enough high quality forage during these months. If we chose to lead with the calves, we did not witness enough immature forage for the steers to enjoy 2 pound average daily gains and if we chose to follow the cows to graze fresh regrowth, the warmer months limited overall forage availability.

Figure 1. Average Daily Gain of Cattle in Two Systems

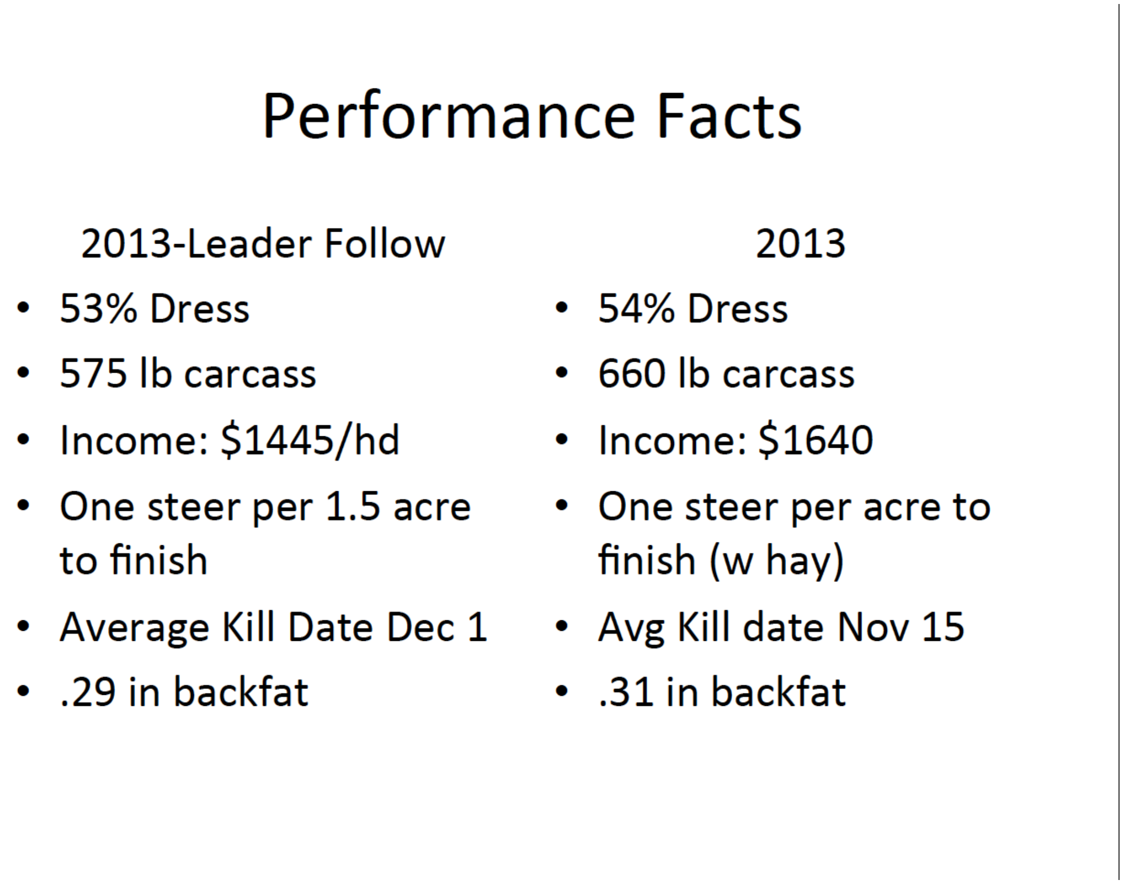


In mid August we pulled the steers out of the irrigated paddocks and leader-follow systems and placed them on predominately alfalfa pasture for the remainder of the finishing system. This was done for two reasons, forage started to become limiting in the irrigated group and we also identified low performance in the leader-follow. Once receiving higher quality forage, the leader-follow group improved to a 3 pound average daily gain, while the steers from the irrigated group maintained over 2 pound of gain daily. Beginning in October with cooler temperatures and less overall energy in the alfalfa, we again supplemented hay for the final finishing period.

Steers were ultrasounded as well to ensure they had adequate last rib backfat at slaughter (over 0.30 in last rib backfat).

Figure 2 shows overall carcass merit and income from the two of cattle from the two systems. Because of overall carcass weight and performance, steers from the

Figure 2. Overall carcass and income of steers from Leader-Follow or Irrigated System



Performance Facts

2013-Leader Follow	2013
53% Dress	54% Dress
575 lb carcass	660 lb carcass
Income: $1445/hd	Income: $1640
One steer per 1.5 acre to finish	One steer per acre to finish (w hay)
Average Kill Date Dec 1	Avg Kill date Nov 15
.29 in backfat	.31 in backfat

irrigated system enjoyed close to $200.00 more income per head and were finished at the desired back fat two weeks earlier with a 85 pound carcass weight advantage. This was our first year to attempt a leader-follow system. The main take home we learned from this system was that it is very challenging to use the cows and steers symbiotically to keep gains high throughout the grazing system.

Overall costs of the irrigated system are outlined in Table 2. Please also note that opportunity costs are built into the budget and your overall on farm costs could vary greatly. Especially on hay cost. We used $200/T hay costs and an estimated calf cost of $945.00/hd. However, the overall budget should be a guide for a grass-finishing beef budget. Please, too, note that irrigation is included in this overall budget.

Table. 2. Grass Finishing Budget for 2014

Production Costs Per Head-GF 2014	($) Cost/year
Calf Costs[1]	945
Labor Costs	-
Hay Period[2]	12
Pasture Period[3]	41
Land Costs	
Pasture Rent (1 steer/ac)	70
Fence, Electric and Water[4]	9
Feed	
Alfalfa Hay[5]	281
Alfalfa Hay[6]	169
Rent Ownership	8
Mineral Cost	11
Irrigation Costs	
$7.50/ac in	51
Health[7]	10
Machinery[8]	20
Misc/Supplies[9]	15
Operating Cost	1641
Interest[10]	82
Death[11]	17
Total Costs 2014	1740
Total Income[12]	1815
Net Income	75

[1] Taking an average 525 lb steer at $1.80, Midwest, calf worth $945
[2] Two hours/wk, 25 wks at $12.50/hr
[3] One half hour/d May 14-November 7, 177 days at $12.50/hr
[4] Fencing pro-rated 25 years; Electric for meter, water and piping/upkeep
[5] Represents 2814 lbs of winter intake (Nov-May) at $200/T
[6] Represents 1692 lbs of summer/fall intake at $200/T
[7] Assumes one deworming winter treatment and any other health trt
[8] Assumes a straight depreciation of 10 yrs on new equipment
[9] Represents additional items identify as important
[10] Interest of 5% on operating
[11] Death Loss at 1%
[12] Average carcass weight 668 lbs at $2.75/lb carcass weight basis

2013-14 Wintering costs for Lake City Research Center

Doug Carmichael and Jason Rowntree

- **2013-14 winters feed intake averaged 29.2 pounds of dry matter for the cow herd.**
- **Winter feed costs are at $2.21 per cow per day.**
- **Winter daily gains for calves averaged 1.54 pounds per day**.

Introduction

At Lake City Research Center the winter was long and a lot of snow for 2013-14. The feed intake was pretty consistent, but with hay prices at an all-time high our costs have been more than expected. In 2013-14 we purchased the majority of our feed with an average feed cost of $113 per ton. With feed costs being the major costs in any operation, our wintering costs are at the forefront of cow calf costs. Our strategy for 2014-15 winters will be to graze longer if the weather permits. If we have moisture enough to graze into November and possibly December we will extend our season and weaning. One of the decisions made for 2014 is that we will plan to wean when we come off of pasture to reduce our feed costs and improve gains on the calves. The longer we can utilize our cows and calves on pasture the more economical we should be at Lake City. Our flesh score for the cowherd as of the fall of 2013 was 5.5 with a weight of 1196 pounds at a frame score of 4.7.

Results

In the fall of 2013 we began feeding hay on the 18th of October of 2013 due to dry conditions at Lake City throughout the summer. It was so dry we fed the cows and heifers in the beginning of September for 11 days. This gave the pastures a chance to rejuvenate into the fall with the moisture that we received late in the summer or early fall. In the fall of 2013 we were carrying 96 cows to calve in the spring of 2014 with 56 bred heifers.

Our feed costs per cow in the last two years have gone up considerably based on the price of hay. In the fall months of 2013 we averaged dry matter intake of 27.74 pounds of hay. We limit feed the hay based on need and body condition score. Body condition scores are officially taken in the fall of every year and we use a general assessment of the cows the rest of the year to determine grazing and hay needs. Our costs in the fall averaged in the range of $1.50 to $1.90 per day depending on the type and quality of the hay.

Mid-Winter costs (Jan-March) reflect a higher cost in hay for this period and a higher consumption in dry matter also. Our costs for this period were in the range of $1.80-$2.07, again depending on the type and quality of the hay. In January we had an intake of 29.93 of dry matter. In February the condition of the cows was in decline and we upped the dry matter to 36 pounds per day. Part of the increase in February's intake was because of the colder weather and feeding some marginal hay that was used for bedding as well as feed. In March the dry matter was decrease as the cows BCS improved. Dry matter intake for March was 26.24 reflecting an overall better condition on the cows. In the last trimester of pregnancy as the cows get closer to calving we try and feed better quality hay as to not short the calf during gestation. The calves that are well taken care of in the last trimester will be better performing when they hit the ground.

Spring hay costs this last year have been excessive, reflecting the increased cost of hay and the colder spring than normal. Our hay cost was in the range of $3.35-3.54 per day per animal. In April and May dry matter intake was from 26 to 32 pounds. With our calving starting in April, our feed intake will vary greatly in this time period. This past spring we fed until the 18th of May, the latest we have ever feed hay in the spring at Lake City Research Center.

Winter Calf Management

At Lake City we are still working at perfecting the grass fed wintering of steers with hay. We come to realize that the NDF value of our hay plays a large part of getting the gains we need to finish. In the fall of 2013 we weaned off steers at 457# actual. Our weights were down slightly from previous years due to the dry weather and weaning early. We were able to pasture the weaned animals until November 1st.

On the first of November the steers were started on dry hay and high moisture balage. During the first three months of adjustment to the new feed the steers gained 1.45 pounds per day and ended up weighting 591.90 pounds on January 2nd.

	Weight	Lbs/Day
February	631.21	1.23
March	699.82	1.95
April	742.35	1.61
May 14	760.17	0.25

In May our average starting weight onto pasture was at 760.17 pounds per animal.

The hay fed this last year was a combination of first cutting dry hay, second and three cutting alfalfa baleage. Our gains on the majority of the year are in direct correlation to the NDF and the palatability of the hay. Some of the second cutting hay was too coarse and reduced intake. With our hay not as ideal as expected, we adapted with what was available on the market. In May we ran out of second and third cutting alfalfa resulting in a drastic cut in performance.

On performance of varying types of hay, there was a significant difference on the gains and costs. The third cutting that cost $228 per ton had better gains on *cost per pound* than the $180 per ton gains. These gains were in the month of February, which was colder but still resulted in an increase in dry matter intake. The higher quality hay had a NDF of 36.5, crude protein of 21.5, and energy of .73. The second cutting that we fed the previous month had an NDF of 45.1 and a crude protein of 20.1, energy of .71. With the majority difference in quality being in the NDF, the other major points of energy and protein being similar.

Summary

At Lake City we will continue to try and graze as long as possible. The cost savings per acre of grazing to feeding hay for us is a lot less than it costs to feed hay to the cow herd. The advantages of grazing to hay is significant enough to focus most of our energies on grazing vs. haying. Hay costs this year will be up higher than last year at Lake City.

Grass fed calve costs are continuing to rise with the cost of hay and land. At Lake City we plan to graze the calves on the cows longer to gain on the average daily gain that a calf will get on his mom vs. hay. When we do feed hay, high quality with low NDF has been getting us the best gains per pound of feed and at the lowest cost.

High Energy Forages for Grass-Finishing Beef

Kim Cassida, Jason Rowntree, Matt Raven, Janice Harte, Jeannine Schweihofer, and Sarah Wells

In late 2013, we were excited to receive a USDA grant for just under a half-million dollars. This three-year grant will be conducted at LCRC with the objective of evaluating use of high-energy forages to grass-finish beef. The work has four objectives: 1) evaluate finishing potential of high-energy pastures for beef cattle, 2) determine consumer acceptability of beef from the four pasture treatments versus commercial corn-fed beef, 3) determine consumer acceptability of fresh versus frozen grass- and corn-fed beef, and 4) determine factors limiting acceptance of frozen beef in the meat supply chain.

This first phase of the research is being conducted by Jason Rowntree and Kim Cassida. It will build from the previous work at Lake City Research Center by Dr. Rowntree, which showed that cattle with the right genetics can be successfully finished to choice quality grade on irrigated pastures. The control pastures to be used in upcoming trial are the same ones used in the previous work so that we can maintain a standard of comparison. Control pastures contain primarily bluegrass, smooth brome, orchardgrass, white, red, and alsike clovers, and a small amount of alfalfa. The irrigation research showed that low pasture growth rates and low energy content of this mixture limited cattle growth during fall, which coincides with the final phase of finishing. In the last six to eight weeks before market, we are trying to get cattle to put on that last little bit of fat that is so important for a high quality grade.   In fall, most perennial forage species are reducing growth rates and preparing for winter, and it is very difficult to get the necessary energy for fat deposition out of such a pasture.

Forage brassicas, such as this turnip hybrid, have become popular forages. They contain very high levels of non-structural carbohydrates that can support rapid animal weight gain, but do they taint the flavor of the beef?

Market-driven limitations for the expansion of grass-fed beef include consumer fears about off flavors in grass-fed meat and the supply chain preference for fresh product. It is obvious that Michigan has limitations in being able to provide a constant supply of local pasture-finished beef throughout the year, and it would be less costly to supply grass-fed beef to local markets if they would accept frozen beef. Therefore, the second phase of

the research will include investigating consumer and food industry preferences in both fresh and frozen forms for beef from our four pastures and purchased corn-fed beef from a supermarket. The second phase of the research will be conducted by Matt Raven, Janice Harte, Jeannine Schweihofer, and Sarah Wells.
We took two approaches to increasing the energy potential of the finishing pastures. The first approach is to establish a perennial mix of forages selected for increased sugar concentration. We are using a mix of perennial and Italian ryegrass selected for high sugar content, in combination with a small proportion of alfalfa and white clover for nitrogen fixation (SucraSeed 'Cash Cow' mix). The second approach is to use annual forages that are replanted each year. The right annual forages for this task will grow quickly, tolerate cool temperatures, and even increase sugar content during cool fall weather. Components of the annual forage mixtures were selected for specific purposes. The simple mix contains a fast-growing brassica ('Winfred' hybrid turnip, 5 lb/acre) to supply non-structural carbohydrate and oats (‘Forage Plus’ oats, 50 lb/acre) to provide effective fiber. The complex mix contains Winfred turnip (3 lb/acre) and Forage Plus oat (20 lb/acre), plus ‘Barsica’ rape (3 lb/acre), ‘Jumbo’ annual ryegrass (5 lb/acre) and ‘Arvika’ spring field pea (10 lb/acre). The additional species provide biodiversity, nitrogen fixation, and an broader range of time to maturity.

Pastures are being managed with minimum inputs. Existing sod was killed using an application of Roundup Weathermax in May, and forages were planted into residue two weeks later using a no-till drill. Nitrogen was applied to newly planted treatments at a rate of 50 lb/acre approximately one month after planting. Irrigation water has been applied if needed to provide about 1 inch of water to pastures each week. The control pastures have been rotationally grazed through the end of July, at which time they will be stockpiled for fall grazing. Each two-acre pasture will be strip grazed by two steers beginning in September each year, or earlier if forage growth permits. Dry hay will be offered to insure that cattle have enough effective fiber for good rumen function. Cattle will be sent to the abattoir in stages through October and November when backfat reaches 1 cm thickness. Carcass traits will be measured at harvest. The meat evaluations will conclude during 2016 and will include consumer taste panels comparing our grass-finished frozen beef to commercial feedlot frozen beef.

We have already learned some useful things from this trial. In an ideal world, we know that we should have sprayed Roundup in fall of 2013 and allowed plant residue and sod to break down over the winter. Unfortunately, we could not do this because we did not know we were getting the grant until December. Playing catch-up with the late, wet, cold spring, we did not get the sod killed until May, by which time there was a vigorous stand of spring grass. Drilling into this heavy sod residue two weeks later in June was less than ideal. The large-seeded annuals managed to establish adequately, but the small-seeded perennial ryegrass struggled. Some ryegrass did emerge, but it soon disappeared, probably eaten by a healthy population of insects supported by the plant residue. We replanted the perennial ryegrass in late July and it remains to be seen if the second planting into a partially decayed sod will be more successful. At any rate, we will not be able to graze the ryegrass this year, so the first year of the trial will proceed with only three grazing treatments. This experience should emphasize the importance of planning pasture renovation operations at least a year ahead of time to be sure all steps can be completed on time. Trying to rush things rarely produces good results!

Grass and Legumes for Forage, Pastures and Cover Crops

Paul Gross-AABI Educator, Lindsey Gardner-Summer Intern

Crop	Planting Date	Seeding rate per acre (lb)	*Type	Remarks
Red Clover	With oats or barley or alone in spring.	8-12 alone of 2-4 lb. with timothy	CSP (acts as biennial)	Two cuts for hay use. Excellent grazing and forage value.
Sweet Clover	With oats or barley in spring.	12-15 alone	Annual or Biennial	Used primarily as green manure crop.
Alsike Clover	With oats or barley in spring.	3-5 in grass mixture	CSP	Used in lowland pasture mixtures.
Mammoth Clover	Feb- Mid. April.	8-12 alone	Is a perennial but acts as biennial.	Broadcast seeded in winter wheat for green manure pasture.
Alfalfa	With oats or barley in Apr.-May. Clear seeded in Apr. –mid Aug.	12-16 alone or with grass	CSP	Seeding alone with herbicides. Does well on well drained mucks with bromegrass. Excellent forage and grazing value.
Birdsfoot Trefoil	Apr- May. Can be seeded with oats or barley in spring or alone by Aug. 1.	10 alone or with grass	CSP	Must remove small grain early as silage, hay, or pasture.
Crownvetch	Clear seed Apr.-June 1.	8-12 alone	CSP	Scarify seed. No companion crop.
Ladino Clover	With oats or barley in spring or Aug. 1-15 alone.	1-2 alone or with grass	CSP	Use ¼ lb. per acre in alfalfa/brome mixtures.
Oats and Peas	April.	2-3 bu. mix in equal amounts.	SA	For silage or baleage. Excellent grazing value and very good forage value.
Sorghum	May 1-25 in S. Mich. June 1-15 in M. Mich.	6-10 in 20 to 40 inch rows	SA	Plant in rows similar to corn. Cut once for silage.
Sudangrass	May 1- June 15 in S. Mich. June 1-15 in N. Mich.	20-30 broadcast	SA	Summer pasture or hay. Excellent forage and grazing value.
Sorghum Sudangrass Hybrid	May 1-June 15 in S. Mich. June 1-15 in N. Mich.	30 broadcast	SA	Green chop or pasture. Very good grazing value and excellent forage value.
Millet, common, pearl, foxtail, Japanese	May 1- June 20.	20-30 broadcast	SA	Use for, hay, or silage. Very good grazing and forage value.
Smooth Bromegrass	Spring-Aug. 15 or Nov. 1-20 alone on muck soil.	3-5 in legume grass mixture or	Perennial or Annual	Normally seeded with alfalfa or on mucks dry enough for corn.

		12-15 alone		
Orchardgrass	Spring-Aug. 15 or Nov. 1-20 alone on muck soil.	12-15 alone or maximum of 2 in legume grass mixture	CSP	Normally seeded with alfalfa or on mucks drier than for canary grass. Use late maturing varieties.
Timothy	Spring or Aug 1-15.	2 in legume grass mixture or 8 alone.	Perennial	Normally seeded with alfalfa, red clover, birdsfoot trefoil
Reed Canary Grass	Spring-Sept. 15 or Nov. 1-20.	6 alone	CSP	On wet soils: especially on very wet muck soils.
Kentucky Bluegrass	Early spring or Aug. 15-Sept 15 or Nov. 1-20.	15-25 or 5-10 for pasture	CSP	August planting preferred.
Fescue-tall (endophyte free)	Spring-Sept. 15 or Nov. 1-20.	15 alone	CSP	Pasture .or mixed stands
Italian Ryegrass	Early Spring	15-20	CSP	Very good forage value but is lower in total yield. Single Season Crop.
Fescue Red	Spring-Sept. 15 or Nov. 1-20.	15-30 alone	CSP	Will tolerate shaded conditions. Use for spring cover crop or turf.
Redtop	Spring-Sept. 15 or Nov. 1-20.	2-3 in grass mixture	CSP	Normally not used. Adapted to moist soils in grass mixtures.
Cereal Rye	By Oct. 1.	60-90	SA	Works well in soils where fertility is low and winter temperatures are extreme.
Annual Rye	Sept. 1-Nov. 1	84-112	WA	Excellent grazing value.
Wheat	August	90	WA	Excellent grazing value.
Oats	Soon as possible in spring. By May 15 in S. Mich., by June 1 in N. Mich. or Aug 1-Sept 10	64-80	WA	Excellent grazing value and very good forage value. Summer seeding for fall oatlage or grazing
Perennial Ryegrass	April-Mid May	30 Alone	CSP	Is a bunch grass that is high in forage value but has a lower total yield.
Barley (Winter)	Sept. 10-30	96-120	WA	Very good forage and grazing value.

Adapted from Seeding Practices for Michigan Crops E-2107 and Midwest Cover Crops Field Guide ID-433

***TYPE**

CSP - Cool Season Perennial
SA – Summer Annual
WA – Winter Annual

Improving Alfalfa Forage Performance, or "Why Not Just Use Vernal?"

Kim Cassida, Joe Paling, and Christian Kapp

I am pleased to report that the forage variety test program is growing! Support for this endeavor has come from increased industry entries, Project GREEEN, MDARD, and the Rood Trust. In addition to the conventional alfalfa test, we have added tests for Roundup Ready alfalfa in East Lansing, Lake City, and Chatham, and the first yield data is being collected this year. We have expanded the grass variety test to begin a new test every year instead of every four years, with new tests planted this year at all three locations. We are also conducting an annual grass test this year in East Lansing. With all this activity, we expect to have lots of new data to show you in the near future.

So what about that Vernal? Since arriving at MSU, I have repeatedly heard the comment that the old standby Vernal alfalfa outlasts and outperforms modern varieties. I have heard this often enough that I began to wonder what is behind it. Obviously producers would not think this without some reason. Now, bear in mind that Vernal was released in 1953 and is used as the check variety in public alfalfa tests because it has been around forever. Long ago it really was the variety to beat. Today it is very unusual for Vernal to rank anywhere except at the bottom of a public test conducted in any state, but we keep using it as a check because it allows us to compare relative yields across all years and environments in the time span since its release. Vernal is a fall dormancy 2 alfalfa with excellent winter survival. It has a very weak package of pest resistance traits compared to most modern varieties. Of the eight pests currently rated for resistance by the National Alfalfa and Forage Alliance, Vernal is resistant to only two: bacterial wilt and fusarium wilt. It is susceptible to phytopthera root rot, anthracnose, verticillium wilt, aphanomyces race 1, and stem nematode, all of which occur in Michigan. Its low fall dormancy number helps boost winter survival, but also indicates that it is slow to break dormancy in the spring, slow to regrow after harvest, and quick to go dormant in the fall. This combination of traits explains why it does not yield as well as modern varieties in tests under intensive cutting management with harvest in the bud stage.

Our test data in Michigan do not support the idea that Vernal is a superior alfalfa variety. The two figures below show the results of 16 years of variety testing in Michigan, averaged over three full production years (seeding year is not included). Figure 1 indicates the mean of all entries in each test and Figure 2 indicates the best entry in each test, all expressed as a percentage of the corresponding Vernal yield. The dark horizontal line at 100% is the Vernal reference line. Values greater than 100% yielded more than Vernal and values less than 100% yielded less than Vernal. Vernal never won a single test during this period in Michigan (Fig. 2), although it did yield better than the average in 2 out of 14 tests in Lake City and 1 out of 6 tests in Chatham (Fig. 1). In all other cases, it ranked near the bottom. It is noteworthy that the relative advantage of new varieties over Vernal has tended to increase over time at East Lansing and Lake City, with the exception of the 2010 test which was probably unduly impacted by the 2012 drought. This shows that, as expected, new varieties improve over time. The relative advantage of new varieties over Vernal tends to decrease as the tests move farther north, but it is difficult to tell if this is simply because we get fewer entries in the northern tests and therefore don't have as much data to evaluate the best varieties.

Figure 1. Mean 3-year DMY relative to Vernal in Michigan alfalfa

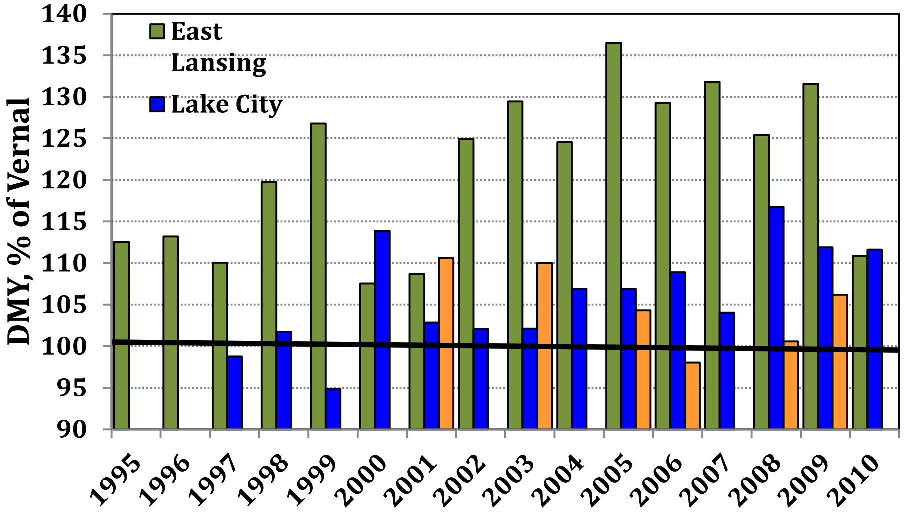
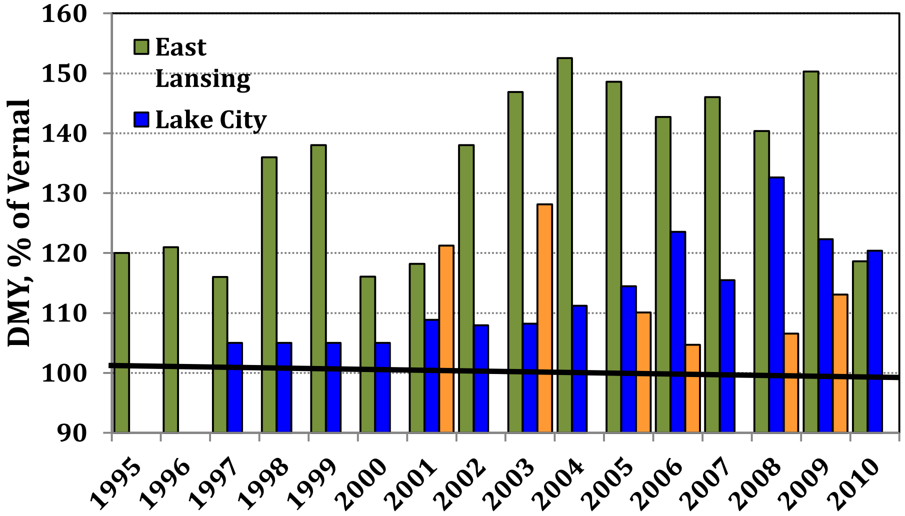


Figure 2. Best 3-year DMY relative to Vernal in Michigan alfalfa tests.



My second and possibly more important point regarding Vernal is the question of whether new seed is really Vernal at all. *What?!?* This was brought home to us when we tried to obtain some Certified Vernal seed for use in the variety tests in 2012.

We were not able to locate a single commercial source of Certified Vernal seed.

Why is this so important? The key is to understand how seed is produced by the alfalfa plant. Alfalfa is cross-pollinated by bees and this means that each seed has potential to be different from the parent plant. Certified seed is carefully produced from fields of known parentage using methods designed to prevent drift of plant characteristics away from the original variety traits. As a public variety, Vernal seed can legally be produced by anyone, but after 61 years on the market and potentially up to 61 seed selection cycles in a multitude of different environments, it is quite likely that the genetics of uncertified seed have shifted. Furthermore, different sources of Vernal seed have almost certainly shifted in different directions. Unfortunately, this makes buying uncertified Vernal seed rather like gambling. Are you getting a descendant of Vernal that is similar to the original, better, ... or worse? If you are lucky and get one well-adapted to your growing conditions and harvest system, then you are probably one of the people asking me why I don't recommend growing more Vernal. If not, then you won't be so happy.

When planting alfalfa, consider that seeding 16 lb/acre of a Certified top-yielding conventional variety costing approximately $4.80/lb only incurs an extra $23/acre for purchase of seed compared to planting uncertified Vernal at $3.40/lb of seed. Based on the Michigan test data, over three production years, that extra $23 in seed cost is worth up to 1.8 tons of extra alfalfa hay in Lake City and Chatham, and a whopping 6.4 tons of extra alfalfa hay in East Lansing. At a hay value of $200/ton, that returns $15 to $56 for each extra dollar invested in seed. Of course, your numbers will differ from this example, but it should serve as an illustration that being too focused on cheap seed may be a case of "penny wise, pound foolish."

Many producers have commented that the advantage of Vernal is persistence, and then they ask why modern alfalfa varieties don't persist like they used to. This is because modern alfalfa varieties are designed for a three year productive stand life. The potential for fast regrowth means less energy is put into roots and long-term survival, and intensive cutting schedules eventually deplete the plant. As a result, these varieties simply do not live as long. Most alfalfa breeders are not focusing on long term persistence traits because research indicates alfalfa production falls below the economic threshold of an intensive cutting schedule after the third production year. At that point, it is more economical for most farmers to rotate out of alfalfa and use the nitrogen credits towards another crop.

Because Vernal holds back some production potential to protect its survival resources, it is quite possible that Vernal stands might last longer than three years, especially if there is not much pest pressure and a conservative harvest schedule is used. The question then becomes, is that still a profitable yield? If you have paid careful attention to your costs of production, in some cases using a lower-yielding but longer-lived variety like Vernal may indeed be satisfactory if you can keep the stand producing at a profitable level for more than three years and do not need the land for a more valuable rotation. However, in most production situations where alfalfa is desirable, spending the money for a better variety and rotating stands more frequently will give better return on your land investment.

For more information:
The 2013 Michigan Forage Variety Test Report is online at
http://fis.msue.msu.edu/extension/MSU_Variety_Test_Reports/2013-Forage-Variety-Test-REPORT.pdf.

Carcass Ultrasound Scanning for Breeding Cattle Selection

Kevin Gould, MSU Extension Beef Educator

Why do we use ultrasound?

Ultrasound technology allows for the capture and standardization of carcass information on live cattle without the need for harvest. Research has indicated that cattle breeders can scan yearling bulls and heifers for carcass traits and have this information included for National Cattle Evaluation ultrasound Expected Progeny Difference (EPD) values. Ultrasound EPDs are equivalent to carcass EPDs and may someday completely replace carcass EPDs. Certified ultrasound technicians collect the images and send them to certified independent labs where the images are interpreted for:

- rump fat
- 12-13th rib fat thickness
- ribeye area
- percent intramuscular fat (marbling)

The measurements are sent to the appropriate breed associations for database storage and preparation of the performance records to be sent back to the breeder. This tool is currently being used at Lake City for selection and breeding decisions in the Red Angus cow herd.

At what age do we scan cattle?

Yearling heifers and bulls

Scans: Yearling heifers and bulls are scanned when they are in a breed specific age range and adjusted to 365 days of age for bulls and 390 day of age for heifers. All cattle within a contemporary group are to be scanned on the same day or over no more than three consecutive days.

Weights: Body weight is a factor when calculating the carcass EPD values. Yearling heifer and bull weights are recorded within seven (7) days of the scan date.

Scanning for Harvest Timing;

Ultrasound can also be used to predict or schedule market readiness. This is done by scanning for 12th rib fat thickness and scheduling cattle for marketing. This creates a much more uniform product that hits specific marketing requirements. This tool is currently being used at Lake City for harvest timing for the grass finished cattle.

Assessing and Improving Forage Utilization and Management

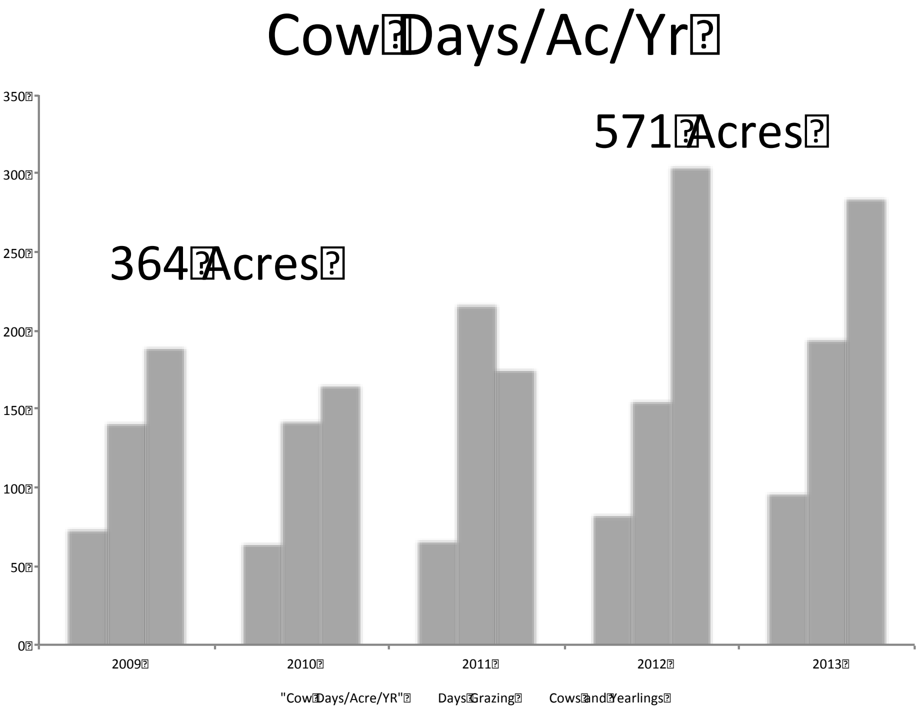
T. Hughston,, J. Rowntree, D. Carmichael

Introduction

In 2010, Lake City Research Center altered fifty years of management in order to more aptly take advantage of the bountiful forage growing potential of N. MI. Primary changes that took place on the farm was implementing an intensive rotational grazing scheme. Further, we elected to fence our hay ground and graze this more often. While the farm does put up some hay, we have elected to graze more pasture and purchase a majority of our winter feed.

Performance Updates

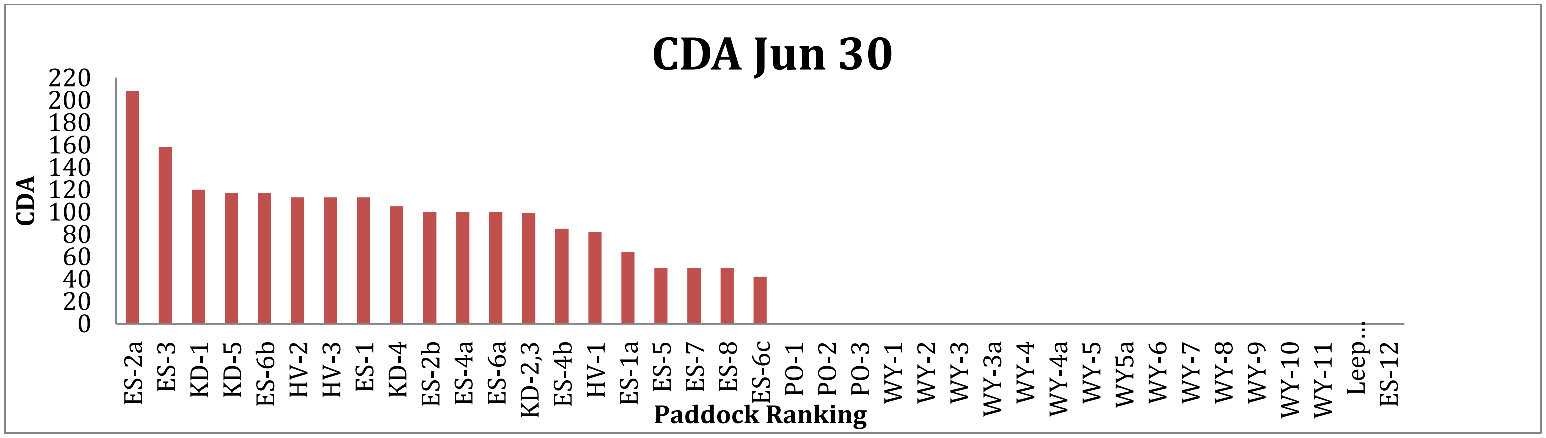
Figure 1 demonstrates the changes in our management along with the improvements in utilization.

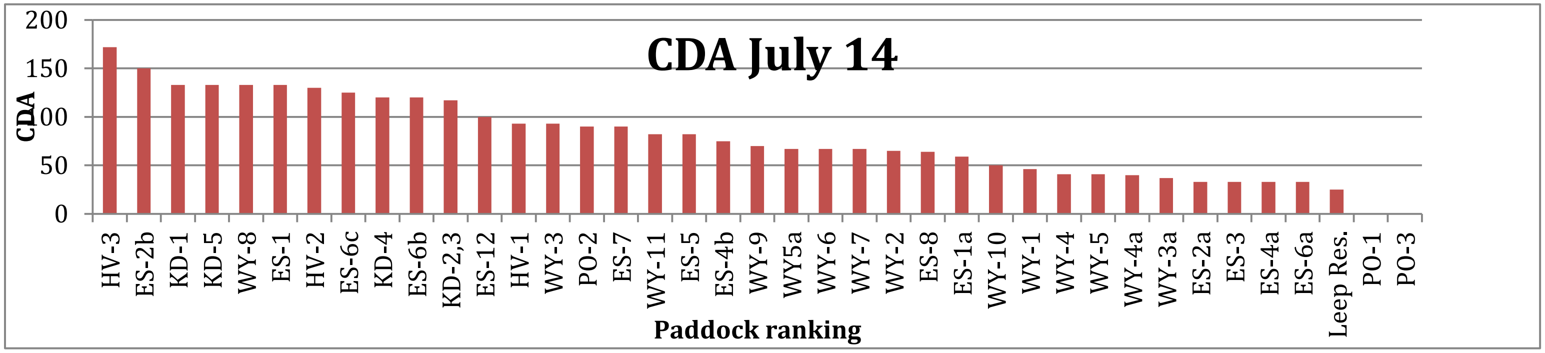


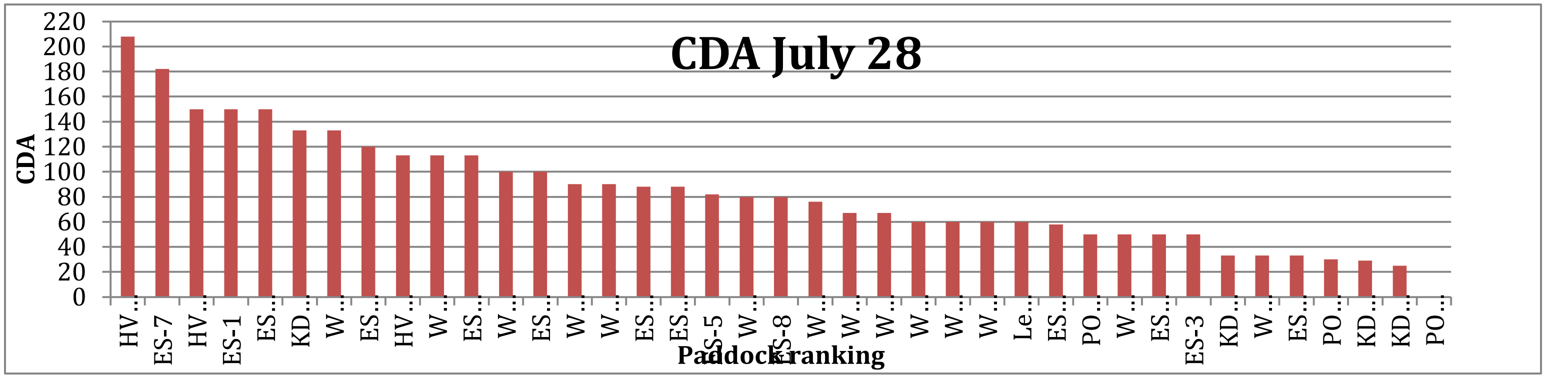
The green bar represents the overall cows and yearlings that we maintained on the farm. Therefore, in 2009 we maintained 190 incremental units of cows and stockers. In 2013, we maintained 285 incremental units.   This was accomplished in a two fold way. First we extended the acreage we were grazing and not just using for hay harvest. The adding of the 200 acres also allowed us to increase the overall land. However management also made a huge difference. The blue bar represents the overall utilization of forage in a term we use at the farm, “cow days per acre” (CDA). This term represents a 30 pound forage intake increment. Therefore in 2009, we were essentially harvesting around 75 CDA across the entire farm. In 2013, we harvested 100 CDA or a 25% improvement. This is due to management and maintaining forage inventories and moving cattle on a daily basis. It is true, we can inherit a minimum of 25% of a new farm just by rotationally grazing. Also, the red bar in the figure represents the days spent grazing. In 2013, we grazed for approximately 185 days or just slightly over six months. As you are aware, this region has had unseasonably dry weather for the last two years. So our overall goal is to graze a minimum of 210 days, which was accomplished in 2011 under lighter carrying capacities and more ideal precipitation. In 2014, we are continuing to manage somewhere in the 300 animal unit area on the 571 grazeable acres. We hope to continue to gain higher utilization and graze through December this year.

Grazing Wedges

One way we are hoping to gain great utilization of our forage resource is through more accurate and updated forage inventories. The estimated dry matter per acre are then put into mathematical equations that give us updated forage mass on our different pastures. These can be seen in the next series of figures. Each pasture is given an estimated CDA which allows us to see ongoing level of stockpile the forage is gaining. We use 80 CDA as a beginning point to graze. Having the up to date forage inventories now gives us an accurate path on which pastures we should head next to versus just rotating in a predictable rotation. By grazing the forage at the peak combination of quality and quantity we will more aptly direct which production group grazes where and know our overall pasture utilization from year to year.


CDA Jun 30
CDA
220
200
180
160
140
120
100
80
60
40
20
0
ES-2a
ES-3
KD-1
KD-5
ES-6b
HV-2
HV-3
ES-1
KD-4
ES-2b
ES-4a
ES-6a
KD-2,3
ES-4b
HV-1
ES-1a
ES-5
ES-7
ES-8
ES-6c
PO-1
PO-2
PO-3
WY-1
WY-2
WY-3
WY-3a
WY-4
WY-4a
WY-5
WY5a
WY-6
WY-7
WY-8
WY-9
WY-10
WY-11
Leep…
ES-12
Paddock Ranking


CDA July 14
CDA
200
150
100
50
0
HV-3
ES-2b
KD-1
KD-5
WY-8
ES-1
HV-2
ES-6c
KD-4
ES-6b
KD-2,3
ES-12
HV-1
WY-3
PO-2
ES-7
WY-11
ES-5
ES-4b
WY-9
WY5a
WY-6
WY-7
WY-2
ES-8
ES-1a
WY-10
WY-1
WY-4
WY-5
WY-4a
WY-3a
ES-2a
ES-3
ES-4a
ES-6a
Leep Res.
PO-1
PO-3
Paddock ranking


CDA July 28
CDA
220
200
180
160
140
120
100
80
60
40
20
0
HV…
ES-7
HV…
ES-1
ES…
KD…
W…
ES…
HV…
W…
ES…
W…
ES…
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ES-5
W…
ES-8
W…
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W…
W…
W…
Le…
ES…
PO…
W…
ES…
ES-3
KD…
W…
ES…
PO…
KD…
KD…
PO…
Paddock ranking

CARBON FLUX ASSESSEMENT IN COW-CALF GRAZING SYSTEMS

M. Chiavegeta, W. Powers, D. Carmichael, J. Rowntree

Introduction

GHG fluxes from grasslands ecosystems are intimately linked to grazing management. In grasslands, CO_2 is exchanged with the soil and vegetation, N_2O is emitted by soils and CH_4 is emitted by animals and exchanged with the soil. When CO_2 exchange with vegetation is included on net GHG exchange calculation, these ecosystems are usually considered GHG sinks (Soussana et al, 2007; Allard et al., 2007). Similarly, the inclusion of SOC change in net GHG exchange accounting might result in grasslands with GHG sink potentials (Liebig et al., 2010).

Grasslands management choices to reduce GHG budget may involve important trade-offs. Allard et al. (2007) and Soussana et al. (2007) studied net GHG exchange from grasslands including CO_2 exchange with the vegetation, and observed net CO_2 equivalent sink activity, but with different trade-offs. Allard et al. (2007) observed that enteric CH_4 emissions expressed as CO_2 equivalent strongly affected GHG budget in intensive and extensive managed grasslands (average 70% offset of total CO_2 sink activity). Soussana et al., (2007) observed that addition of enteric CH_4 and N_2O emissions from pasture soils to CO_2 sink activity of grasslands resulted in relatively small offset of total CO_2 sink activity (19% average). The small trade-off observed by Soussana et al. (2007) was not enough to affect the CO_2 equivalent sink potential of the sites studied.

Management of grasslands modifies SOC storage (Conant et al., 2001; Schuman et al., 2002), potentially increasing C sequestration (Follet et al., 2001). Grasslands management primarily affects SOC storage by modifying C inputs to the soil, including root turnover and C allocation between roots and shoots (Ogle et al., 2004). Liebig et al. (2010) suggested that the factors contributing to net GHG exchange decreased in relative impact in the order of SOC change, soil-atmosphere N_2O flux, enteric CH_4 emissions, CO_2 emissions associated with N fertilizer production and application, and soil-atmosphere CH_4 flux. Similarly, Roberston et al. (2000) observed that SOC change and N_2O flux control net GHG exchange in agroecosystems.

In this study we assessed the net GHG exchange (in terms of Ceq flux) of 2 grazing systems differing in stocking rate and density. We hypothesized that low stocking rate, high stocking density systems have lower C flux resulting from less animals per area, and higher accumulation of SOC because of longer rest periods.

Material and Methods

Pasture management and GHG collection

Cow-calf pairs were managed with 2 rotational grazing management practices differing in stocking rates and density; an intensive system with high stocking rate and low stocking density, and an extensive system with low stocking rate and high stocking density. The system with low stocking rate and high stocking density (SysA) consisted of 120 cow-calf pairs rotating on a total of 120 ha, divided into 0.7 ha paddocks. Cow-calf pairs were moved to a new paddock 3 times daily (at approximately 0600 h, 1200 h and 1800 h). The equivalent stocking rate was 1 cow ha^{-1} and the stocking density was approximately 100,000 kg LW ha^{-1}. The rest period varied from 60 to 90 d during the course of the growing season depending on plant growth. Cow-calf pairs grazed each paddocks 2 to 3 times per year. The system with high stocking rate and low stocking density (SysB) consisted of 4 cow-calf pairs rotating on 1.6 ha pasture, divided into 0.08 ha paddocks. Cow-calf pairs were moved to a new paddock once daily (at approximately 0800 h). The equivalent stocking rate was 2.5 cows ha^{-1} and the stocking density was 28,000 kg LW ha^{-1}. The rest period varied from 18 to 30 d during the course of the growing season depending on plant growth. Cow-calf pairs grazed each paddocks 4 to 5 times per year. The pasture sites in SysB were irrigated as needed, whereas there was no irrigation applied to SysA pasture sites. The only fertilization application was on SysB pasture sites that received urea fertilization (23 kg of actual urea) on June 3rd of 2011 (approximately 30 d before the start of gas sampling, see dates below). In addition to these 2 systems, grazing-exclusion pasture sites (GE) were monitored in order to account for GHG emissions from non-grazed pastures. The use of a non-grazed pasture site was important to confirm that any differences found between SysA and SysB were attributed to the grazing management practices implemented. The soil type across treatments pasture sites was predominantly sandy loam.

SysA and SysB areas were sampled during 3 years (2011 to 2013). Sampling for all treatments was repeated in 2 periods; at the beginning of the grazing season (period 1 – P1) and at the end of the grazing season (period 2 – P2). The first year was considered a preliminary year, for the purpose of adjusting the methodology for GHG from soils collection. For that reason, GE pasture sites were not sampled, dates of periods monitored were closer together in time as compared to 2012 and 2013, soil bulk density (BD) was not monitored, soil was sampled to 10 cm depth, and enteric CH_4 emissions were not monitored. For details on dates of each period and methodologies used on GHG emissions from soils and enteric CH_4 emissions refer to Chapter 2, section 2.2 and Chapter 3, section 3.2. Soil texture and pH in each treatment are described in Table 2.1, Chapter 2.

Soil sample collection occurred in paddocks most recently occupied by cows. Soil samples were collected from 0.08 ha paddocks (3 pseudoreplicates per treatment). Soil sampling occurred approximately 20 days post-grazing. The sampling dates were: August 1st, and August 28th, 2011; June 3rd and September 15th, 2012; June 30th and September 28th, 2013.

Soil bulk density determination

Soil BD samples were collected with a 7.6 cm diameter and 7.5 cm height brass ring, avoiding disturbance of soil structure. Samples were weighed, dried at 105°C to constant weight, and re-weighed. Bulk density was calculated by dividing the dry weight by the soil core volume (Blake and Hartge, 1986). Soil BD was not assessed during 2011. Soil BD was monitored in different depths to allow SOC stock calculation (described below). However the distinction of BD at the 0 to 5 cm and 5 to 10 cm depths was not possible because of the ring height (7.5 cm). For that reason, BD in the top soil was assessed from 0 to 7.5 cm and it was used to calculate SOC stock at 0 to 5 cm and 5 to 10 cm depths. SOC stock at 10 to 20 cm was calculated with BD of 10 to 17.5 cm depth, and SOC stock at 20 to 30 cm was calculated with 20 to 27.5 cm BD.

4.2.3. Soil organic matter and C and N stocks determination

During 2012 and 2013, the soil pool was assessed at different depths: 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, and 20 to 30 cm. SOC and TSN stocks were not monitored during 2011. A 0 to 30 cm depth is often used to report C stocks in soils (Schipper and Sparling, 2011). Previous studies suggest that changes in soil C and N can extend throughout the soil profile rather than just in the topsoil (Schipper et al., 2007; Franzluebbers and Stuedemann, 2009). Therefore, sampling occurred at different depths to illustrate changes along the profile and address the concern that changes in the surface soil may not represent storage in deeper horizons (Blanco-Canqui and Lal, 2008). For each replicate (0.08 ha paddock) 10 soil samples were randomly collected at each depth and composited per paddock. Soil samples were dried at 65°C separated in 2 sub samples. One sub sample was sent to the Michigan State University Soil and Plant Nutrient Laboratory for SOM determination. SOM was determined by wet digestion and colorimetry (Schulte and Hopkins, 1996). The second sub sample was ground manually with a pestle and mortar and sent to Michigan State University Great Lakes Bioenergy Research Center Laboratory for analysis of C and N.

Soil OC and total soil N (TSN) from soil samples were determined by an Elemental Combustion System (ECS 4010 CHNSO Analyzer, Costech, Valencia, CA). The ECS uses combustion and gas chromatography with thermal conductivity detector and helium as carrier gas to determine N_2 and CO_2. We tested for the presence of inorganic C in the soils of the study area and concluded that no inorganic forms were present, thus total C represents SOC. Carbon: nitrogen ratio was calculated for 0 to 30 cm depths.

Soil OC and TSN stocks were calculated based on soil layers of fixed depth (Equation 4.1). However, given that we observed high variability on BD between years and among treatments, we corrected SOC and TSN values for a fixed mass of soil, as suggested by Ellert et al. (2002; Equation 4.2 to 4.4 use SOC as example of calculations). This approach includes the selection of a reference soil mass (M_{ref}), which is the lowest soil mass to the prescribed depth from all sampling sites. The M_{ref} is then used to determine the soil mass to be subtracted from the deepest core segment (excess mass of soil: M_{ex}) so that mass of soil is equivalent to all sampling sites

Equation 4.1. Soil organic carbon and nitrogen stock calculated based on soil layers of fixed volume.

$$SOC_{FD} = \Sigma\, C_i \times BD_i \times L_i \times 0.1$$

where SOC_{FD} is SOC stock to fixed depth (Mg ha^{-1}), C_i is organic carbon concentration in depth i (mg C g^{-1} dry soil), BD_i is the bulk density of soil in depth i (g m^{-3}), and L_i is the length of the depth i (cm).

Equation 4.2. Determination of soil mass in each depth.

$$M_{soil} = \Sigma\ BD_i \times L_i \times 100$$

where M_{soil} is mass of soil to a fixed depth (Mg ha^{-1}), BD_i is bulk density of soil in depth i (g/m^3), and L_i is the length of the depth i (cm).

Equation 4.3. Determination of mass of excess soil in each depth.

$$M_{ex} = M_{soil} - M_{ref}$$

where M_{ex} is mass of excess soil (Mg ha^{-1}), M_{soil} is the mass of soil to a fixed depth (Mg ha^{-1}), and M_{ref} is the lowest soil mass selected from all sampling sites and depths (Mg ha^{-1}).

Equation 4.4. Determination of SOC stock to fixed mass of soil.

$$SOC_{FM} = SOC_{FD} - M_{ex} \times C_{dl}/1000$$

where SOC_{FM} is the SOC stock for a fixed mass of M_{ref}, M_{ex} is mass of excess soil (Mg ha^{-1}), and C_{dl} is organic carbon concentration in the deepest depth (mg C g^{-1} dry soil).

4.2.4. C flux calculations

In this study, fluxes from the ecosystem to the atmosphere are considered a contribution to the atmosphere budget. Therefore, positive GHG emissions indicate emissions to the atmosphere and negative GHG emissions indicate sink activity. According to Chapin et al. (2002) and adapted later by Soussana et al., (2007) the net GHG exchange (NGHGE) of a managed grassland ecosystem is calculated as:

$$NGHGE = NEE + F_{CH4} + F_{N2O}$$

where NEE is the net ecosystem exchange of CO_2 that includes emissions from soil and plant respiration, F_{CH4} is the CH_4 flux from soil and F_{N2O} is N_2O flux from the soil. We adapted the calculation to obtain the net GHG exchange in terms of C equivalent (Ceq_{flux}). The Ceq_{flux} for each site was calculated by adding CH_4 and N_2O emissions to CO_2 emissions using the global warming potential of each of these gases at the 100-year time horizon (IPCC, 2007; GWP_{N_2O} = 298 and $GWP_{CH4 =}$ 25), as follows

$$Ceq_{flux} = F_{CO2} + F_{CH4soil} + F_{N2O} + F_{CH4cows}$$

where F_{CO2} is the C equivalent flux of CO_2 from the soil, $F_{CH4soil}$ is the C equivalent flux of CH_4 from the soil, $F_{CH4cows}$ is the C equivalent flux of enteric CH_4 from the cows, and F_{N2O} is the C equivalent flux of N_2O from the soil. In contrast to Soussana et al. (2007) our F_{CO2} does not include CO_2 lost by plant and animal respiration. The largest part of organic C ingested during grazing is highly digestible and is respired shortly after intake (Soussana et al., 2007). Additional C loss (5% of digestible C) occurs through enteric CH_4 emissions, which was accounted for by the term $F_{CH4cows}$. We did not account for enteric CH_4 from the calves. The non-digestible C (from 25 to 40% of the intake depending on herbage digestibility) is returned to the pasture mainly as feces (Soussana et al., 2007). We did not differentiate between manure-derived emissions and soil-derived emissions. Soil emissions sampling was post-grazing and hence we assume that any emissions from feces or urine decomposition is accounted for in the soil term.

Soussana et al. (2007) and Chapin et al. (2002) included the C lost from the system through plant biomass export. Because our calculations are limited to the grazing season we assumed no C loss via herbage cutting and removal from the sampled sites. C loss from herbage decomposition on top of the soil is assumed to be included in CO_2 and CH_4 emissions from the soil, SOM and SOC content. There was no addition of C into our systems by organic fertilization and hence it is not included on the calculations. We did not account for C leaching from pasture soils.

In order to allow summation of GHG fluxes from soil and cows and determination of Ceq_{flux}, $F_{CH4cows}$ (originally in g CH_4 cow day^{-1}) was converted to an area basis (g CH_4 ha d^{-1}), using stocking rates of each system: SysA = 1 cow ha^{-1}, and SysB = 2.5 cows ha^{-1}. We monitored only the grazing season and the Ceq_{flux} is shown as daily average flux, because extrapolation to annual flux would be inaccurate.

SOC stock change was not included in the Ceq_{flux} determination because SOC content was monitored for a period of 2 years, which is not considered long enough to detect accurate SOC changes (Schuman et al., 2002). However, we consider SOC stock in our discussion of Ceq_{flux} because the main objective of this study was to show the importance of looking at different pools when assessing GHG emissions from grazing systems. SOC stock is an important pool to consider in any C flux accounting.

4.2.5. Statistical analysis

SOC and TSN stocks data were analyzed as a completely randomized design. Statistical analyses were performed using SAS Software (Version 9.2; SAS Institute, 1987). Paddocks were considered experimental units and were treated as the random term, and the compressed term year × period was considered a repeated measure. We associated the effects of year and period to the variability of the data, and hence means are shown pooled my year and period. The main reason for showing pooled means was that the length of this study was not long enough to allow assessment of SOC change in time, and showing means by year could lead to inaccurate conclusions. All tests were performed with 95% confidence ($\alpha = 0.05$). Soil and animal GHG emissions data were analyzed as described in Chapter 2, Section 2.3.3 and Chapter 3, Section 3.2.3, respectively.

Ceq_{flux} data were analyzed as a completely randomized design. Paddocks were considered experimental units and were treated as the random term, and the compressed term year × period was considered a repeated measure. When the main effect of year was significant differences were discussed separately by year. When the main effects of treatment or period were significant the interaction treatment × period was evaluated and pre-planned comparisons within treatment and period were performed. All tests were performed with 95% confidence ($\alpha = 0.05$).

Results and Discussion

Soil characteristics

Soil sampling was performed in different pasture sites during each year and period sampled, depending on animal management. The sampling sites in GE were maintained constant for all sampling occasions. A summary of particle size fractions in each pasture size is described in Table 2.1, Chapter 2.

Soil BD values were different from 2012 to 2013 ($P < 0.01$), but did not change from P1 to P2 ($P = 0.19$). Therefore means are poled by period. Soil BD increased with soil depth but no treatment effects were observed (Table 4.1). The accumulation of litter over time is a result of rotational grazing, with adequate rest periods for regrowth. The presence of organic litter dissipates the animal trampling impact, resulting in less compaction and lower soil BD of the soil (Sanjari et al., 2008). The accumulation of litter protected grazed soils from compaction, resulting in no BD differences between grazing systems and GE. Savadogo et al. (2007) and Franzluebbers and Stuedemann (2009) reported BD values similar to this study.

Soil BD has been found to increase because of grazing in soils with large quantities of fine soil particles (clay + silt) that are more sensitive to animal traffic and compaction (Vanhaveren, 1983; Abdelmagid et al., 1987). Our pasture sites were predominantly comprised of sand particles, and mostly sandy loam.

4.3.2. SOC and TSN stock and SOM content

We observed year and period effects on SOC stocks ($P < 0.01$ and $P = 0.05$, respectively), which are likely associated to spatial and temporal variability. Soil C stocks display high spatial variability, especially in grasslands. Cannell et al. (1999) found a coefficient of variation of 50% when evaluating spatial variability of C stocks in grasslands as compared to 15% in arable lands. Previous research have associated the variability to sampling at different depths (Bird et al., 2002), climate (Conant et al., 2001), texture (mainly clay content; Parton et al., 1987), and lack of evaluation of C distribution within the grazing system (Schumann et al., 1999). The ability to detect change in SOC stocks depends on the time since the original sampling, spatial homogeneity of the soil and intensity of sampling (Schipper et al., 2010). In this study, sampled paddocks (pseudoreplicates) were different at each year and period (see Section 4.2.), which did not allow spatial homogeneity between soil samples. In addition, Conant et al. (2001) suggested that periods of 5 to 10 years for a field scale study would be adequate to detect changes in SOC stock. Therefore, the change observed from 2012 to 2013 cannot be associated to SOC stock change (i.e. accumulation or loss). However, because the studied grazing systems were implemented at the study site for 5 years prior to 2012, the relative change between treatments may be considered.

Table 4.2 illustrates SOC stock means by treatment pooled by year and period. On average, SOC stock was higher for SysB pasture sites, and the difference between GE and SysA was not significant (63, 42 and 47.4 Mg C ha^{-1} for SysB, GE and SysA respectively, $P < 0.01$). In SOM, N and C are predominantly covalently bonded (Schipper et al., 2010) and thus the pattern of TSN accumulation in pasture sites was highly correlated to SOC accumulation (Table 4.2). SysB pasture sites had higher TSN stocks compared to GE and SysA (4.85, 3.44 and 3.95 Mg N ha^{-1}, for SysB, GE and SysA respectively, $P < 0.01$). A similar relationship between C and N reported by Pineiro et al. (2009).

The effects of grazing management on C cycling and distribution has been evaluated before, however, literature does not yet suggest a clear relationship between grazing management and C sequestration. Some studies have reported no effect of grazing on SOC stock (e.g. Milchunas and Laurenroth, 1993), others reported increases (Weinhold et al., 2001) or a decrease (Derner et al., 1997). Differences in findings between SOC stocks and grazing management has been associated with factors that affect C cycling and sequestration potential on grasslands, such as: climate, inherent soil properties, landscape position, plant community composition, and grazing management practices (Reeder and Schuman, 2002). The management applied to the land affects soil's ability to retain organic C. Practices that increase plant productivity and C inputs to the soil, and decrease soil exposure to sunlight and erosion allow greater C accumulation (Parton et al., 1987).

Reeder and Schuman (2002) studied the impact of heavy or light grazing on SOC stocks, compared to non-grazed areas. In their evaluation of the 0 to 30 cm layer, they observed significantly higher SOC stock in grazed pastures (67 Mg C ha^{-1}) compared to non-grazed pastures (58 Mg C ha^{-1}). The range of SOC stock observed was from 55 Mg C ha^{-1} to 100 Mg C ha^{-1}. We observed wider range of SOC stock values among all treatments (from 25 to 113 Mg C ha^{-1}; data not shown). The greater variability observed in this study might be associated to the sampling in different pasture sites at each year and period. Sanjari et al. (2008) observed lower SOC stock values for rotational grazing, continuous grazing and non-grazed pasture sites in 5 years of monitoring (on average 25 Mg C ha^{-1}). However, increased SOC content in rotational grazing pasture sites compared to continuous grazing or non-grazed pasture sites was observed by Sanjari et al. (2008) and associated to greater grass growth and rest periods. Southorn (2002) attributed the greater SOC accumulation in rotational grazing systems to the larger proportion of plant material being incorporated into the soil. In addition, adequate rest periods is a key driver in the recovery of grazed species and increase in aboveground organic material, followed by its subsequent incorporation into the soil, resulting in increased SOC (Gillen et al., 1991).

In this study, SysA pasture sites were given longer rest periods (60 to 90 d) than SysB pasture sites (18 to 30 d). Nevertheless, the increased SOC stock of SysB pasture sites suggested that grazing management of SysB is increasing SOC stocks at a faster rate than SysA or GE ($P < 0.01$; Table 4.2). Naeth et al. (1991) suggested that grazing, such as that in SysB, reduces litter mass accumulation because animal traffic enhances physical breakdown and incorporation of litter into the soil. It is likely that more frequent grazing in SysB reduced litter accumulation, and enhanced physical breakdown increasing litter decomposition and incorporation into the soil. Frequent grazing also could have stimulated forage and roots development, increased soil water content and microbial development, enhancing the rate of decomposition of litter and transfer of C into deeper layers of the soil (Sharif et al., 1994). Root decay, although not measured in this study, was identified as another reason for increased SOC under rotational grazing systems. Intensive defoliation under a single grazing event results in cessation of plant respiration, leading to death of roots within a few hours after grazing, in order to equalize biomass (Sanjari et al., 2008). In SysB defoliation was intensive and more frequent than in SysA.

In SysA, forage offered to cow-calf pairs was mature and in reproductive stage, which resulted in selective grazing by cows for higher quality plants (see discussion on Chapter 3, Section 3.3.3). Forage that was not ingested was trampled down, resulting in greater litter accumulation on soil surface (Table 3.1, Chapter 3). The significantly lower SOC stock in SysA and GE compared to SysB might be the result of immobilization of C in excessive aboveground plant litter, due to longer rest periods (SysA) or non-grazing (GE).

Soil organic C constitutes approximately 60% of SOM (Bardgett et al., 2009). Consequently, the differences in SOM content between treatments were similar to the differences observed for SOC stocks. SysB had higher SOM content to 30 cm than SysA or GE that did not differ (4.07%, 3.33% and 3.22%, for SysB, SysA and GE, respectively, $P < 0.01$). SOM decreased throughout the soil profile in all treatments (Figure 4.1).

In SysA pasture sites, animal trampling was more intense at each grazing occasion (due to higher stocking density), but it was less frequent (longer rest periods). The higher stocking density might have contributed to the formation of litter on soil surface, but without frequent animal trampling, it is likely that litter decomposition happened at a slow rate. Because of higher stocking density, cow-calf pairs grazed each paddock of SysA for a short period of time (8 to 12 h). The short time of grazing was likely not prolonged enough to accelerate litter decomposition and incorporation into the soil. Reeder and Schuman (2002) suggests that a build-up of litter on the soil surface affects soil temperature and soil water content, which will, in turn, affect plant residue and SOM decomposition rates.

When observing the SOC distribution along the soil profile, SysB contained higher SOC content in the 20 to 30 cm layers compared with SysA ($P = 0.02$) and GE ($P = 0.03$; Figure 4.2). It was interesting to find that SysB pasture sites had accumulated C mainly in deeper layers. We expected that, because of the long rest period and lack of irrigation on SysA, deep-rooted plant species would develop and significantly contribute to SOC accumulation in deeper layers, as it was observed before (Fisher et al., 1994). However, botanical composition did not support that hypothesis (Table 3.2, Chapter 3). Legumes were found to be present on both SysA and SysB pasture sites, and the same grasses species were found on both systems (although on different proportions).

The surface depth (0 to 10 cm) generally contains the highest levels of labile C, indicative of rapid turnover. This labile C is important mainly to ecosystem function and microbial development. It represents the C participating in C cycling within the ecosystem and is not representative of sequestered C. Carbon sequestered in deeper layers, indicates favorable conditions for root penetration and high levels of microbial activity. Deeply sequestered C enhances ecosystem hydrology and nutrient recycling. Additionally sequestration of C on deeper layers provide long-term benefits, because C is less susceptible to loss from surface-soil disturbances (Franzluebbers and Stuedemann, 2009). Our data supports earlier findings that change in soil C can extend throughout the soil profile (Schipper et al., 2010; Schipper et al., 2007). Schipper et al. (2010) observed that despite the apparent long residence time of soil C in deep horizons, SOC moves through 1 m-deep horizons more rapidly than previously thought. The frequent trampling effect caused by the cow-calf pairs in SysB resulted in disruption of surface soil crust and soil aggregates, increasing SOM decomposition and SOC incorporation in deeper depths (Liu et al., 2004; Neff et al., 2005). Intensive grazing has been associated to high rate of SOM decomposition (Sanjari et al., 2008).

TSN concentration was also highly stratified with depth and followed SOC accumulation (Figure 4.3). Conant et al. (2005) and Franzluebbers and Stuedemann (2009) find that changes in SOC stock were closely related to changes in TSN stock. There are potential benefits as a result of coupling between soil C and N changes. For example, the sequestration or loss of 1 Mg C is associated with approximately 100 kg of N gained or lost (Schipper et al., 2010). There was no treatment effect on C:N ratio (Table 4.2). The relatively high C:N ratio observed in this study suggest that C and N immobilization is the dominant processes over mineralization (Du Preez and Snyman, 1993).

Total C equivalent flux

Means are shown separately by year and period for F_{CO2}, $F_{CH4soil}$, F_{N2O}, $F_{CH4cows}$ and Ceq_{flux} (year effect $P < 0.01$; Table 4.3). Daily means are presented in order to allow discussion on the overall Ceq_{flux} between grazing systems and non-grazed pasture sites (Table 4.4).

Grazing systems versus non-grazed pasture sites - Generally, grazing systems had higher Ceq_{flux} than GE pasture sites, except during P2 of 2012, when the difference between SysA and GE was not significant (Table 4.3). The increased Ceq_{flux} from grazing systems was expected because $F_{CH4cows}$ was considered zero for GE. However, the difference between grazing systems and GE was substantially small.

The initial hypothesis was that Ceq_{flux} would be increased in grazing systems not only due to enteric CH_4, but also because of manure decomposition in pasture soils. However, during 2012 the difference between grazing systems and GE was approximately 3 kg C ha d^{-1}, which approximates $F_{CH4cows}$. This suggests that during 2012, grazing did not increase GHG flux from the soil. The Ceq_{flux} pooled by treatment during 2012 (average 10.3 kg C ha d^{-1}) was greater when compared to 2011 (9.6 kg C ha d^{-1}) and 2013 (19.8 kg C ha d^{-1}). The year of 2012 was relatively dry, with precipitation concentrated in a few days during the grazing season (Table 2.1, Chapter 2). The low soil moisture content could have decreased GHG flux from the soil in all pasture sites. The year of 2011 does not include $F_{CH4cows}$.

During 2013, the difference in Ceq_{flux} between grazing systems and GE was greater (approximately 8 kg C ha d^{-1} during P1, and 11 kg C ha d^{-1} during P2) than the contribution of

$F_{CH4cows}$ (on average 3.3 kg C ha d^{-1}). Generally, during 2013 GE pasture soils had decreased F_{CO2}, $F_{CH4soil}$, and F_{N2O} compared to grazing systems. GE pasture sites were the only ones with observed N_2O and CH_4 sink activities, during the 2013 grazing season. The higher levels of moisture in the soil (compared to 2012) likely increased microbial activity, resulting in increased GHG exchange from pasture soils. During P2 of 2013, SysB had greater Ceq_{flux} than SysA and GE. It was the only occasion when the difference between grazing systems was observed.

<u>SysA versus SysB</u>

During 2011, $F_{CH4cows}$ was not monitored and Ceq_{flux} represents the addition of F_{CO2}, $F_{CH4soil}$ and F_{N2O} (Table 4.3). F_{N2O} and $F_{CH4soil}$ were not different between treatments in neither period. During P2, SysB had greater F_{CO2} than SysA (7.64 and 6.07 kg C ha^{-1} d^{-1}, respectively), which resulted in greater Ceq_{flux} from SysB pasture sites than SysA during P2. Pooled by treatment, Ceq_{flux} decreased considerably from P1 to P2 (11.2 and 8.2 kg C ha^{-1} $d^{-}1$, for P1 and P2, respectively; $P < 0.01$). Because there were no consistent differences in F_{N2O} and $F_{CH4soil}$ from P1 to P2, the decrease in Ceq_{flux} is due only to the decrease in F_{CO2}. These results suggest that, when $F_{CH4cows}$ is not taken into account, F_{CO2} seems to be the driver of Ceq_{flux} in grazed pastures.

During 2012, $F_{CH4cows}$ is included in Ceq_{flux}. The differences between systems observed in F_{CO2}, $F_{CH4soil,}$ F_{N2O}, or $F_{CH4cows}$ were not significant, and consequently the difference between systems in Ceq_{flux} was likewise not significant (Table 4.3). Despite the greater stocking rate of SysB (2.5 cows ha^{-1}) compared to SysA (1 cow ha^{-1}), $F_{CH4cows}$ were not significantly different between grazing systems during P2. We expected greater $F_{CH4cows}$ from SysB because of the greater number of cows per hectare. However, the results suggest that SysA cows had relatively high enteric CH_4 emissions, during 2012 (Table 4.3)

During 2013, SysB had higher Ceq_{flux} when compared to SysA during P2 (22.49 versus 13.40 kg C ha^{-1} d^{-1}, respectively; $P < 0.01$). The increased Ceq_{flux} from SysB was a result of greater $F_{CH4cows}$ compared to SysA during P2 (6.22 versus 1.61 kg C ha^{-1} d^{-1}, respectively; $P = 0.02$), because SysB did not have increased GHG emissions from soils compared to SysA (Table 4.3). During P1, again SysB had greater $F_{CH4cows}$ compared to SysA (3.26 versus 1.93 kg C ha^{-1} d^{-1}, respectively $P = 0.03$). However, Ceq_{flux} was not different between grazing systems (24.11 and 23.35 for SysA and SysB, respectively, $P = 0.13$). The decreased $F_{CH4cows}$ in SysA, was offset by the numerical increased F_{N2O}, which increased Ceq_{flux} of SysA. These results suggest that the contribution of enteric CH_4 to Ceq_{flux} may be not always be the driver of higher GHG emissions. Robertson et al. (2000) showed that half of the total net CO_2 equivalent emissions from arable sites was contributed by N_2O production. Our results indicate that under specific circumstances this concept might apply to grasslands. Results from Soussana et al. (2007) indicate that despite the large error in enteric CH_4 measuring, the CH_4 emission rate would not lead to a large change in the net GHG exchange of the studied grasslands.

Daily Ceq_{flux} pooled by year and period

In order to allow the comparison between treatments across years and periods, we pooled daily means (Table 4.4). It is important to keep in mind that we sampled only during the grazing season. By not monitoring Ceq_{flux} during the winter, early spring or late fall, the pooled daily means cannot be extrapolated to annual means.

Daily Ceq_{flux} from grazing systems was higher than non-grazed pasture sites by approximately 5.8 kg C ha^{-1} d^{-1} ($P < 0.01$). The largest contributor for the greater Ceq_{flux} from grazing systems compared to GE was $F_{CH4cows}$. However, pooled across years grazing systems also had higher F_{N2O} and $F_{CH4soil}$ than GE. Between grazing systems the difference in Ceq_{flux} ($P = 0.60$) was not significant. The only flux that was different between grazing system was $F_{CH4cows;}$ SysB had greater $F_{CH4cows}$ than SysA (4.91 versus 2.09 kg C ha^{-1} d^{-1}, respectively; $P < 0.01$). The increased $F_{CH4cows}$ from SysB was a consequence of higher stocking rate, because daily enteric CH_4 emissions were not difference between systems across years (Table 3.5, Chapter 3). The contribution of $F_{CH4cows}$ in SysB was not large enough to increase Ceq_{flux}.

Typical N_2O emissions from grasslands soils converted into C equivalent range between 0.3 and 3 kg C ha^{-1} d^{-1} (Machefert et al., 2002). Freibauer et al. (2004) observed N_2O fluxes of 0.7 kg C ha^{-1} d^{-1} from grasslands. On the other hand, Soussana et al. (2007) studied grasslands GHG flux throughout the year and found N_2O emissions varying from -0.08 to 2.4 kg C ha^{-1} d^{-1}. In the present study, we observed F_{N2O} from 0.06 to 1.35 kg C ha^{-1} d^{-1}.

Regarding $F_{CH4soil}$, we observed sink activity ($F_{CH4soil}$ range was from -0.16 to 0.14 kg C ha^{-1} d^{-1}, whilst Soussana et al. (2007) when monitoring CH_4 fluxes throughout the year obtained higher emissions (0.2 to 1.3 kg C ha^{-1} d^{-1}). They associated the lower sink activity observed to the presence of grazers, suggesting that grazing reduces the on-site sink activity for CH_4. In fact, the negative mean of $F_{CH4soil}$ in the present study was from GE pasture sites (Table 4.3). Deposition of excreta by animals is expected to produce CH_4 emissions at a very low level (as compared to application of organic fertilizers; Jarvis et al., 2001), but may increase N_2O emissions (Smith et al., 2001).

In the present study, very low $F_{CH4soil}$ was observed and when differences between treatments were observed they were due to F_{CO2}, F_{N2O} or $F_{CH4cows}$ (Table 4.3). Liebig et al. (2010) suggested that factors contributing to net GHG exchange in grasslands were decreased in relative impact order of SOC change, soil-atmosphere N_2O flux, enteric CH_4 emissions and soil-atmosphere CH_4 flux.

We did not include SOC change in Ceq_{flux} determination, and the differences in N_2O fluxes were not significant between grazing treatments, which resulted Ceq_{flux} differences that were not significant between grazing systems. Liebig et al. (2010) including SOC change in the GHG exchange determination, observed negative net GHG from heavily and moderately grazed grasslands. Allard et al. (2007) and Soussana et al. (2007) also observed negative GHG exchange from grasslands, because CO_2 exchange with the vegetation was included on the determination of net GHG exchange. The annual mean Ceq_{flux} from SysB was lower than the annual mean Ceq_{flux} from SysA (Table 4.4), although means were not statistically different. However, if SOC change was included on Ceq_{flux} these results and conclusions could change. SOC stock results suggested that potentially SysB is accumulating higher SOC than SysA (Table 4.2), but long-term monitoring of SOC stock in the study is needed to allow incorporation of SOC change in Ceq_{flux} determination.

Generally, the higher stocking rate in SysB increased $F_{CH4cows}$, but did not affect $F_{CH4soil}$ and F_{N2O}. We believe that the lower stocking density in SysB and irrigation allowed shorter rest periods, frequent herbage defoliation, faster return of nutrients to soils from excreta deposition, increased plant growth and roots development. These factors, in addition to greater TSN content in SysB, might have contributed to microbial development and faster nutrient cycling, decreasing GHG emissions from soils. It was demonstrated in Section 4.3.2 that SysB is potentially increasing SOC stocks at a faster rate than SysA or GE. Similarly, SOM content was higher in SysB compared to SysA and GE, which suggests faster litter decomposition. SOC accumulation on deeper layers (20 to 30 cm) was greater in SysB, which also suggests potential of C sequestration. In addition, SysB gives the producer more flexibility in terms of animal production. Because of shorter rest periods and frequent defoliation forage quality remained high and constant throughout the grazing season (Table 3.3, Chapter 3). The maintenance of forage quality permits the production of different types of animals, such as finishing steers for instance, which permits the producers to aggregate value to their final product according to market changes.

In SysA there was a decrease in forage quality from P1 to P2 (Table 3.3, Chapter 3) but $F_{CH4cows}$ was not increased, which was associated to selective grazing. We observed the development of legumes in both systems, indicating that the grazing management is not depleting the development of specific plant species, and selective grazing is allowed in both systems. SysA does not need irrigation and longer rest periods results in litter accumulation on the top soil, with slow decomposition rate. It is possible that the SOM slower decomposition rate of SOM in SysA could provide greater resilience to SysA compared to SysB.

It is important to remember that we monitored GHG exchange during the grazing season only. We did not account for emissions in other periods other than post-grazing, and hence annual emissions may not be accurate. Similarly, we are assuming that the grazing seasons of both systems were of the same duration. If one system allowed prolonged or shortened grazing season, Ceq_{flux} would change.

4.4. Conclusion

Grazing systems had greater Ceq_{flux} than non-grazed pasture sites. The largest contributor to increased Ceq_{flux} from grazing systems was enteric CH_4 emissions. However, on an annual basis, grazing systems also had increased N_2O and CH_4 emissions from pasture soils, compared to non-grazed pasture sites. Non-grazed pasture sites were the only sites with CH_4 sink activity. The effect of greater enteric CH_4 contribution from SysB, due to higher stocking rate than SysA, was offset by GHG exchange from the soil. Hence, our results indicate no clear difference in C equivalent flux between the grazing systems studied, when SOC change is not incorporated. SysB potentially increased total SOC stock, the addition of SOC to deeper into the soil horizon and SOM content to 30 cm. SysA, with longer rest periods, allowed litter accumulation on the top soil, resulting in slower SOM decomposition rate, which can result in greater resilience in the long-term.

Grazing management should be adaptive and farm decisions are inherent to grazing management. Both SysA and SysB have opportunities to improve ecosystems services at the farm level, including animal production and food provisioning. Long-term research is needed to confirm SOC stock and SOM decomposition rates of these systems. The incorporation of C sequestration into the determination of Ceq_{flux} could change results and possibly differentiate the grazing systems studied.

Table 4.1. Soil bulk density in pasture soils grazed under two management strategies and non-grazed.

Soil depth, cm	Systems[1]		
	GE	SysA	SysB
2012 grazing season		$g\ cm^{-3}$	
0 to 5	1.27	1.20	1.25
5 to 10	1.27	1.20	1.25
10 to 20	1.57	1.25	1.35
20 to 30	1.43	1.47	1.44
SEM		0.05	
Source of Variation			
Treatment	0.11		
Depth	<0.01		
Treatment x Depth	0.11		
2013 grazing season			
0 to 5	1.46	1.57	1.39
5 to 10	1.46	1.57	1.39
10 to 20	1.65	1.58	1.62
20 to 30	1.65	1.59	1.57
SEM		0.04	
Source of variation			
Treatment	0.14		
Depth	<0.01		
Treatment x Depth	0.36		

[1] GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

Table 4.2. Soil organic carbon and total soil nitrogen stocks in pasture soils grazed under two management strategies and non-grazed.

Systems[1]	Stocks		
	SOC[2]	TSN[3]	C:N
	Mg ha^{-1}		
GE	42.0^{a}	3.44^{a}	21.0
SysA	47.4^{a}	3.95^{a}	18.7
SysB	63.0^{b}	4.85^{b}	19.4
SEM	3.8	0.2	
Source of Variation			
Treatment	<0.01	<0.01	0.06

[1] GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

[2] SOC: soil organic carbon.

[3] TSN: total soil nitrogen

Means differences within columns indicated by letters ($P < 0.05$).

Table 4.3. GHG exchange from pasture soils and animal and total C equivalent flux from pasture sites managed under two different management strategies and non-grazed pasture sites.

	Soil emissions						Animal Emissions		Total emissions	
Systems[1]	F_{CO2}[2]		F_{N2O}[3]		$F_{CH4soil}$[4]		$F_{CH4cows}$[5]		Ceq_{flux}[6]	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
2011 grazing system					kg C ha^{-1} d^{-1}					
GE	-	-	-	-	-	-	-	-		
SysA	10.54	6.07^{a}*	1.16	0.80	-0.18	-0.07	-	-	11.35	6.77^{a}*
SysB	9.74	7.64^{b}*	1.19	1.59	-0.21	0.06*	-	-	10.69	9.57^{b}
SEM	0.41		0.32		0.04				0.64	
Source of Variation										
Treatment	0.28		0.07		0.25				0.03	
Period	<0.01		0.96		0.02				<0.01	
Treatment × Period	<0.01		0.08		0.04				<0.01	
2012 grazing season										
GE	8.24	9.13	0.11	0.05	0.01^{a}	0.003	0	0	8.38^{a}	9.18^{a}
SysA	8.04	8.31	0.44	0.08	0.14^{b}	0.08	3.28	2.26	12.06^{b}	10.75^{ab}
SysB	7.11	9.26*	0.31	0.19	0.08^{a}	0.07	4.89	3.43	12.17^{b}	12.73^{b}
SEM	0.50		0.11		0.04		0.63		0.57	
Source of Variation										
Treatment	0.43		0.19		<0.01		0.12		<0.01	
Period	0.15		0.09		0.38		0.03		0.97	
Treatment × Period	0.07		0.33		0.51		0.68		0.06	

Table 4.3. (cont'd)

Systems[1]	Soil emissions						Animal Emissions		Total emissions	
	F_{CO2}[2]		F_{N2O}[3]		$F_{CH4soil}$[4]		$F_{CH4cows}$[5]		Ceq_{flux}[6]	
	P1	P2	P1	P2	P1	P2	P1	P2	P1	P2
2013 grazing season					kg C ha^{-1} d^{-1}					
GE	19.96	8.57^{a}*	0.96^{a}	-0.88	0.20	-0.17			20.77^{a}	7.71^{a}*
SysA	19.72	10.75^{ab}*	4.75^{b}	0.35*	0.23	0.33^{b}	1.93^{a}	1.61^{a}	26.13^{ab}	13.40^{b}*
SysB	21.49	14.97^{b}*	3.23^{b}	0.82	0.26	0.35^{b}	3.26^{b}	6.22^{b}	28.13^{b}	22.49^{c}
SEM	1.36		0.70		0.18		0.84		1.96	
Source of Variation										
Treatment	<0.01		<0.01		<0.01		0.02		<0.01	
Period	<0.01		<0.01		0.78		0.11		<0.01	
Treatment × Period	0.04		0.03		0.02		0.05		<0.01	

[1] GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

[2] F_{CO2}: C equivalent flux of CO_2 from the soil.

[3] F_{N2O}: C equivalent flux of N_2O from the soil.

[4] $F_{CH4soil}$: C equivalent flux of CH_4 from the soil.

[5] $F_{CH4cows}$: C equivalent flux of enteric CH_4 from the cows.

[6] Ceq_{flux}: net GHG exchange in terms of C equivalent.

Means differences within columns indicated by letters ($P < 0.05$). Means differences within rows indicated by symbols ($P < 0.05$).

Table 4.4. Daily GHG emissions from soil and animal managed under two different grazing strategies and non-grazed pasture sites.

Systems[1]	Soil emissions			Animal Emissions	Total emissions
	F_{CO2}[2]	F_{N2O}[3]	$F_{CH4soil}$[4]	$F_{CH4cows}$[5]	Ceq_{flux}[6]
			kg C ha^{-1} d^{-1}		
GE	9.87^{a}	0.25^{a}	-0.09^{a}	0	8.88^{a}
SysA	10.03^{a}	1.56^{b}	0.13^{b}	2.09^{a}	13.96^{b}
SysB	11.47^{b}	1.17^{b}	0.10^{b}	4.91^{b}	15.34^{b}
SEM	0.66	0.32	0.08	1.09	0.74
Source of Variation					
Treatment	0.17	<0.01	<0.01	0.02	<0.01

[1] GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

[2] F_{CO2}: C equivalent flux of CO_2 from the soil.

[3] F_{N2O}: C equivalent flux of N_2O from the soil.

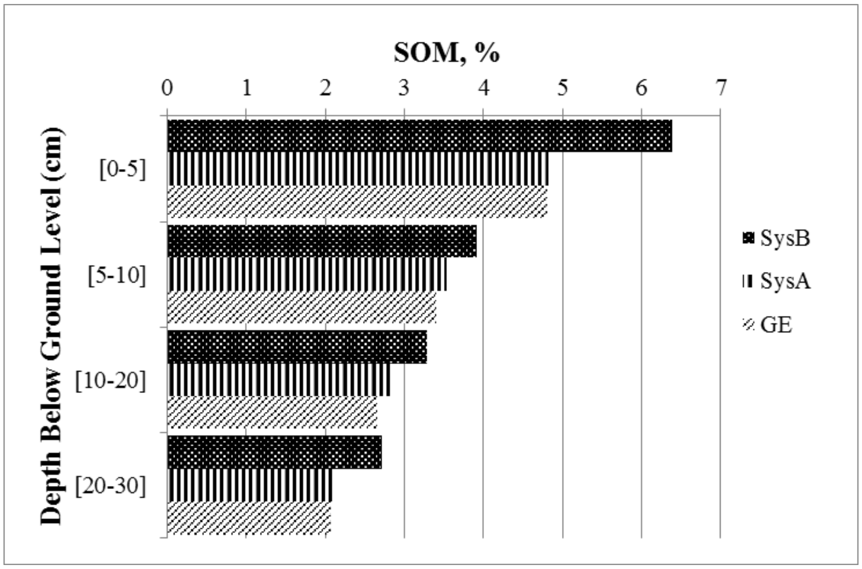
[4] $F_{CH4soil}$: C equivalent flux of CH_4 from the soil.

[5] $F_{CH4cows}$: C equivalent flux of enteric CH_4 from the cows.

[6] Ceq_{flux}: net GHG exchange in terms of C equivalent.

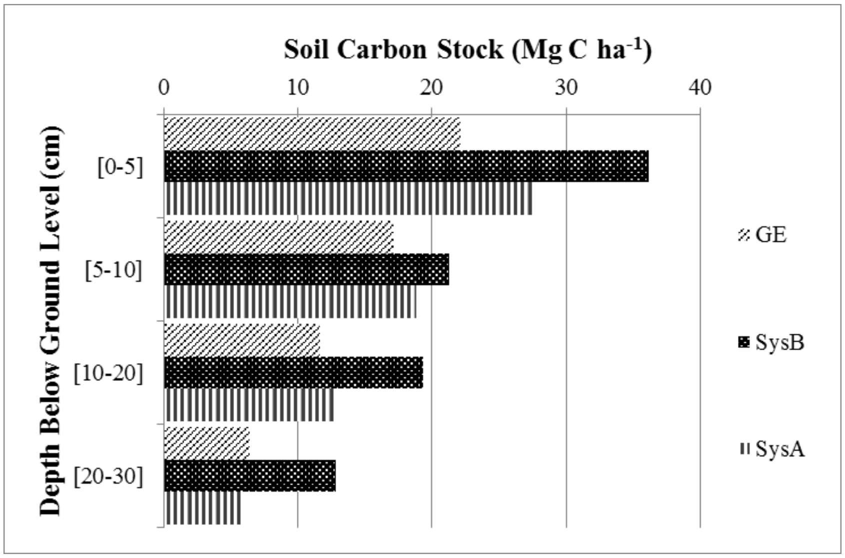
Means differences within columns indicated by letters ($P < 0.05$).

Figure 4.1. Soil organic matter in pasture soils grazed with two different grazing management strategies and non-grazed pastures sites.



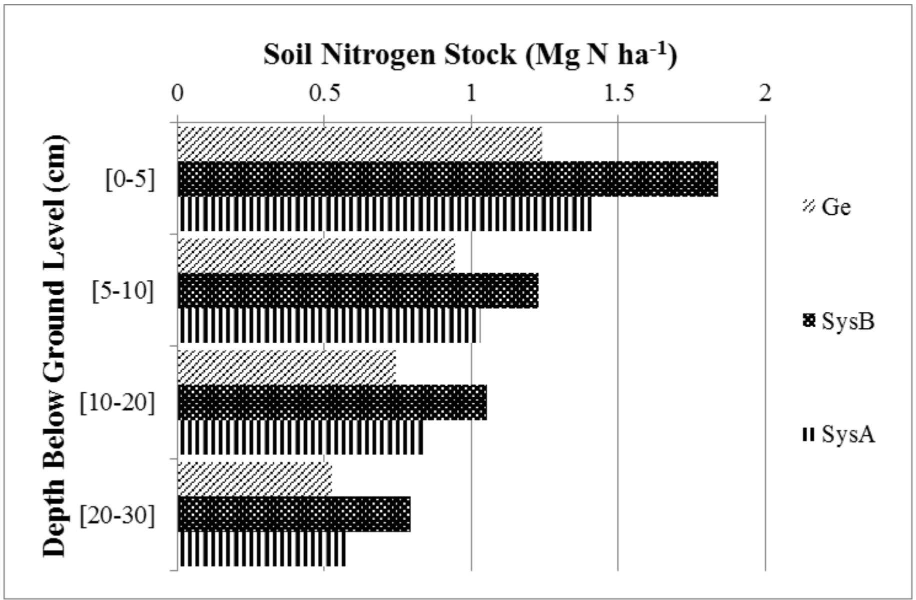
GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

Figure 4.2. Soil carbon stock in pasture soils grazed with two different grazing management strategies and non-grazed pastures sites.



GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

Figure 4.3. Total soil nitrogen stock along the soil profile in pasture soils grazed with two different grazing management strategies and non-grazed pastures sites.



GE: grazing exclusion; SysA: 1 cow ha^{-1} stocking rate and 100,000 kg LW ha^{-1} stocking density; SysB: 2.5 cows ha^{-1} stocking rate and 28,000 kg LW ha^{-1} stocking density.

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