Summary

Increasing sustainability of livestock production in the Northern Great Plains has significant implications for the agricultural sector in the focus region. Crop and beef cattle commodity prices fluctuated widely from the projects beginning in 2012 to the end in 2015. A weather market stimulated by drought in the corn and soybean producing region of the U.S. resulted in unprecedented high corn and soybean price followed by price lows that in some instances fall below the cost of production. Likewise, drought in Texas, Oklahoma, and to a lesser extent in neighboring states initiated a sharp selloff of cows reducing the nation’s cattle herd that reduced the supply of feeder cattle for growing and finishing. CME fed cattle price rose to $172 and feeder cattle price escalation followed. The price explosion that began in June 2013 was completely liquidated in the 3rd and 4th quarters of 2015. The point of this is that as markets fluctuate widely, integrating crop and beef cattle production systems provides a degree of insulation from wide fluctuations in crop and animal inputs. Research in this project evaluated the integration of crop and beef cattle systems to identify the complementing holistic potential that may exist. Growing nutrients through crop rotation and improved cultural practices reduced the cost of production. Beef cattle grazing sequences of perennial and annual forages for longer periods of time consuming forages of higher nutritive quality complement the cropping system, soil integrity, and beef system net return. Paralleling the actual research was a focus on education for existing producers through farmer-cooperator projects, educational events for high school and undergraduate students, and an international connection with a Turkish short-term research scholar. Public awareness of alternative production methodologies is increasing as evidenced by agronomic programing awareness and attendance at the 2012-2015 Beef Cattle and Forage Field Days held at the Dickinson Research Extension Center. The field days are designed as workshops for a cross section of stakeholders including farmers and ranchers, research personnel, local, state and federal agency representatives who may or may not be actively raising cattle and crops, but have a focused interest in non-traditional production methods. Program topics include project data summary presentations and tours of the integrated diverse cropping and beef cattle systems being studied, and presentations and tours of producer-cooperator projects. Producer-cooperator demonstrations highlight cover crop and residue grazing, and unharvested corn grazing is being utilized to provide a lower-cost free-ranging approach to backgrounding calves after weaning. The field day/workshops are practical sessions focusing on soil health, and the mechanics of upgrading and attaining soil health benchmarks using the pillars of soil health, which include no-till minimum soil disturbance seeding and planting, crop diversity from cool and warm season broadleaf and grass crops, crop rotations that include cover crops, maintaining a living root in the soil, keeping soil surface residue, and livestock grazing whenever possible. Youth education at the high school level has resulted in active participation by southwestern North Dakota Vocational Agriculture students through their annual participation in the Vo-Ag High School Student Field Day. Fifty to sixty enthusiastic students have attended each year to learn about a variety of agricultural topics as well as the connectivity between the microbial world and agriculture, and how the components of water, air, soil, and sun are the foundation of food production. At the undergraduate college student level, Dickinson State University (DSU), Agriculture and Technical Studies undergraduate student, Lauren Pfenning, evaluated soil bulk density (BD) difference between spring wheat control, rotation crops, and native range. When BD values for native range were compared to rotation crops, BD was less except for corn ($P<0.05$) and tended to be less for the pea-barley intercrop ($P>0.05$). Traditional soil testing and fertilizer recommendations from the NDSU Soil Testing Laboratory are used to determine the amount of N-P-K-Cl to apply. Fertilizer recommendations are declining due to the interactive and collective effect of the soil health principles employed, and crop yields which have increased steadily as years of crop yield history accumulate. Seasonal growing season nitrogen mineralization was measured during the growing season from June through October 2014. Field plots within each rotation crop were established and affixed with 8”x24” irrigation pipes that were pushed into the soil. Soil samples were collected at 0-6”, 6-12” and 12-24” inside and outside of the root restriction cylinders. During the period between mid-July and mid-August the average pounds of nitrogen measured per acre was 86 and 66 pounds/acre for the isolated and cropped samples indicating that plant roots scavenged 20 pounds/acre of the 86 pounds/acre of the available mineralized nitrogen. The project was started with farmland that had been farmed conventionally to grow corn and oats that were harvested as silage and hay for cattle feed. The primary objective of the study was to employ the principles of soil health and determine the effect on hard red spring wheat (HRSW) production and economics when grown in a diverse crop rotation (HRSW, double cropped winter triticale-hairy vetch followed by a 7-species cover crop in the same year, corn, field pea-barley, and sunflower) and compare it to HRSW grown continuously (Control). All crops in the study were sowed using no-till seeding and planting equipment. After 5 crop years, the 5-year average HRSW yield was the same for both treatments (Control 40 vs. Rotation 41 bu/ac). But how that occurred is a clearly a demonstration of the soil’s power to *grow nutrients* resulting from crop rotation and animal grazing. Yields for crop years 1-5 were the same year 1, but in year 2, control wheat yield was 24.4% higher than rotation wheat (56 vs. 45 bu/ac). Change that started when the rotation was initiated became more evident year three,

when the yield margin between the two management practices began to narrow, but remained 20.5% higher for the control (47 vs. 39 bu/ac). Yield reversal became fully realized by year 4, when the rotation wheat yield was 9.1% higher (44 vs. 48 bu/ac), and by the 5th crop year rotation wheat yield was 38.9% higher than the control wheat yield (36 vs. 50 bu/ac). The 5-yr average input cost (CTRL $193 vs. ROT $178/ac) and gross return (CTRL $263 vs. ROT $258/ac) resulted in a net return that was $10 higher for rotation HRSW compared to the control HRSW (CTRL $70 vs. ROT $80/ac). There were no differences in protein (CTRL 13.9 vs. ROT 13.3 %) or test weight (CTRL 61.8 vs. ROT 62.0 lb/bu). Rotation crops were evaluated on their grain, oilseed, and forage production input cost, gross return, and net return. Net return was 80, 50, 62, 90, $147/ac for HRSW, cover crop, corn, pea-barley, and sunflower, respectively (P=0.11). Non-confinement grazing of crops and residues by beef cattle is showing that less intensive, non-confinement, procedures can have a positive effect on profitability. One hundred replacement heifer calves were used in lower-input increasing gain development program to evaluate the effect of frame score, growth, fertility, and economics. Heifer frame score was 3.5 for small frame (SF) and 5.6 for the large frame (LF) heifers. There were 3 increasing gain phases. During phase 1 (209 days – October 13 to May 10), heifers grazed unharvested corn, corn residue as the winter progressed, and supplemental hay. Gain during phase 1 was 0.60 lb/day. For phase 2 (58 days – May 10 to July 6), the heifers grazed spring crested wheatgrass and gained 1.03 (SF) and 1.33 (LF) lb/day. In phase 3 (85 days – July 7 to September 29), were confined to replicated feedlot pens with 10 heifers/pen and a bull in each pen. The heifers were fed a forage-based 80% alfalfa diet plus 20% DDGS supplement (21% CP) diet. Heifer ADG during the phase 3 breeding period was SF-1.87 and LF-2.14. The number of heifers cycling was based on progesterone assay at the end of the winter period May 10 and at the start of the breeding season August 11. Two blood samples were collected separated by 10 days and serum decanted from clotted samples for analysis. A heifer was considered to have reached puberty when serum progesterone level was ≥ 1 ng/mL. Puberty in May was 18 and 40% for SF and LF heifers, respectively, and in August the percent of heifers cycling was 90 and 96% for SF and LF heifers, respectively. Total pregnancy for the 50 day breeding period was 86 and 84% for the SF and LF heifers, respectively, indicating that the increasing gain development program was successful. Partial economic analysis taking into account the value of open market heifers was lowest for SF heifers that cost $263/heifer to develop compared to the LF heifer that cost $316/heifer. Compared to traditional feedlot growing and finishing of yearling steers, 141 steers grown for modest winter growth of approximately 1.0 pound/day that grazed perennial and annual forages (crested wheatgrass, native range pasture, pea-barley intercrop, and unharvested corn) for 182 days before entering the feedlot required the least number of days on feed (66 days) compared to the feedlot control (142 days) and an all perennial treatment (91 days). Reducing feedlot residency from 142 days to 66 days was profitable even during a period when corn was priced over $7/bushel. Control feedlot steers lost $298/steer whereas the perennial/annual forage steers returned $9 profit/steer; a margin difference of $307/steer. Cattle hedging is a common practice in the cattle feeding industry. When agricultural economists at North Dakota State University applied hedging techniques to the biological data collected in this study, realizing that marketing months differ, the feedlot steers (142 days on feed) would have lost an additional $65/steer, whereas the grazing treatment would have gained an additional $22/steer. The net hedging result would have been a combined net loss of -$363/steer for the feedlot steers and a net gain of $31/steer for the steers that grazed perennial and annual forages over a period of 182 days. The data clearly shows that long-term extended grazing has the greatest potential for profitability. A second and ongoing similar study is evaluating the performance and economic difference between small (3.4 frame score) and large frame (5.31 frame score) steers using a similar long-term grazing protocol. Small and large frame steers were sent directly to the feedlot (FLOT) and a comparable randomly assigned group grazed perennial and annual forages (GRAZ - crested wheatgrass, native range pasture, pea-barley intercrop, and unharvested corn). To determine system net return, expenses (e.g. steer placement cost, grazing, farming, and feedlot finishing expenses, transportation and brand expenses) were deducted from the gross carcass value. FLOT steers were in the feedlot for 222 days and the GRAZ steers grazed 219 days before entering the feedlot for final short-term finishing. As in the 1st study, extending the grazing period and delaying feedlot entry until the GRAZ steers were 68% heavier than the FLOT control steers were, when entering the feedlot, reduced expenses. Net return for the FLOT treatment was considerably smaller than the GRAZ treatment and within the individual treatments net return for SF steers was much lower. Net return was $188, 113, $527, and $345/steer for the FLOT-LF, FLOT-SF, GRAZ-LF, and GRAZ-SF, respectively. Carcass quality (% Choice or better) was greater for SF steers; however, there was no difference in muscle tissue shear force tenderness measurement. SF and LF steers where of very high eating quality. There were three primary factors that resulted in the GRAZ steers yielding the highest net return. First, large frame GRAZ steers gain weight at a faster rate under grazing conditions resulting in a lower grazing cost/lb of gain (LF-$0.598 vs. SF-$0.658), secondly, GRAZ steers in general demonstrate large compensating growth in the feedlot after an extended grazing period (1.5 lb/day better ADG) and feed efficiency is significantly improved (7.7 vs. 5.5 lb feed/lb body weight gain), and third, carcass weight of large frame GRAZ steers was is heavier than the SF GRAZ steers (111 lb heavier). Based on data from the two SARE funded delayed feedlot entry studies, a methodology that includes grazing of perennial grass pasture coupled with grazing seeded annual forage (field pea-barley; unharvested corn) has resulted in positive net return each year. Extremely high corn grain price did reduce net return to near breakeven in the first study; however, the $9 net return was convincing compared to the -$298 loss/steer, and hedging, during a period of rising cattle prices, would have only added to the loss. May-June calving cows in the project were utilized to evaluate cow weight change, body condition change, and wintering cost/cow when the winter grazing season was extended by grazing a 7-specie cover crop, crop residues, and stockpiled winter grass (brome and crested wheatgrasses). Control system cows (CS) were fed medium quality bromegrass-alfalfa hay for an average 134 days from mid-November to early-April, integrated system cows (IS) grazed a 7-specie cover crop and crop residues (corn and sunflower) for an average 73 days from mid-November to late -January, and the forage systems cows (FS) grazed stockpiled grass (brome-crested wheatgrass-alfalfa) and corn residue for an average 107 days from mid-November to early-March. All cows were fed 1.0 lb/cow/day of a 32% crude protein range cake supplement The pounds of hay fed to the CS, IS, and FS system cows was 4724, 1824, and 891 lb/cow, respectively. From the start to the end of the wintering period, cows in all of the treatment groups increased body weight. CS and IS cows increased 0.70-0.80 BCS; however, the FS cows started the study with a BCS of 5.4 and maintained body condition ending with a BCS of 5.4. Reproductive performance is the best measure of evaluation for cow wintering nutritional practices. The total percent of cows calving for the CS, IS, and FS systems was 89.3, 95.2, and 89.6%, respectively, indicating that there was no difference in calving percent and that the winter grazing programs are a good fit with May-June calving, replace labor, reduce cost, without sacrificing animal performance. Producer educational schools have been reserved until the last year of the project to allow for accumulation of data upon which to base the educational format and knowledge transfer. The project PI requested a no-cost extension to completed crop, soil, and animal data collection, and outreach programming. Public awareness of this SARE project is increasing and with increasing awareness project PI, Doug Landblom, has been an invited program speaker at a number of soil health workshop programs in western North Dakota and southeastern Montana. Free-lance writers have also published articles on different aspects of the SARE project in the regional bi-monthly publication, Farm and Ranch Guide, and the national magazine, Feed-Lot. Research reports have been published in non-peer reviewed publications in research center annual reports, field day reports, and scientific journal abstracts to include the NDSU Dickinson Research Extension Center annual and field day reports, NDSU North Dakota Beef Report, abstracts in the Western Section, American Society of Animal Science annual meeting proceedings, and the University of Wyoming field day report. Extensive heifer development research conducted as a component of this SARE project has been published in the Asian-Australasian Journal of Animal Science and additional peer-reviewed publications are being prepared for publication. Information obtained from this research suggests that by integrating beef cattle production into a diverse cropping system soil quality improves and both production systems are enhanced. When the inputs of mechanical forage harvesting are replaced with grazing, in which the animal does its own foraging and harvesting, profit margins are improved.

Introduction

In response to an increasing need for comparative research and demonstration of holistic practices, SARE project LNC11-335 was designed to evaluate managed grazing within an integrated crop and livestock system to determine the change in soil and crop production when crop production was centered on a diverse crop rotation, and to further determine the effect of integration on beef production. An important aspect of the study was to determine the effect of integrated systems on farm profitability and educational venues for high school and college students, a post-doctorate short-term research scholar, producer-cooperator farm demonstration projects, field days, workshops, YouTube videos, regional seminars, and professional meetings. In the sections that follow, the project objectives and performance targets defined and the approach, results and discussion, and economic analysis, publications and outreach, and farmer adoption are presented. Finally, areas needing additional study are presented in the last section.

Objectives

1. Compare three cow-calf production systems (Conventional, Integrated, and Yearling) tailored for the semi-arid region of the Northern Great Plains from birth to final harvest to determine the effect of system on production and profitability using whole-systems econometric analyses and ranch profitability analyses.

2. Evaluate the effect of systems integration on the biological responses of animals, crops, weeds, soil, and water conservation.

3. Establish student alternative production system programs to include: High school and college student awareness programs, undergraduate summer internships and research projects.

4. Conduct integrated crop-livestock grazing management workshops for producers, Extension educators and other government agency personnel.

Materials and Methods

The integrated agronomic and livestock components of this study defined in the project objectives were addressed with the following research projects:

1. Effect of spring wheat yields when grown continuously or as a component within a diverse crop rotation

Prior to the initiation of the project the cropping study area had been previously seeded to spring wheat (HRSW) and the cropping systems (continuous spring wheat (Control-**C**), spring wheat grown in rotation (R)) were established the following crop season. The triple replicated C and R fields are shown in Table 1. Briefly, the continuous spring wheat was compared to a 5-yr rotation that consisted of HRSW, cover crop (dual crop winter triticale-hairy vetch harvested for hay in June and immediately reseeded to a 7-species cover crop mix grazed by cows in the fall early winter), forage corn, field pea-forage barley, and sunflower. The cereal grains, cover crops, pea-barley intercrop were seeded using a JD 1590 no-till drill, 7.5 in row spacing, and seed depth of 1 in. Plant population was 1,250,000 plants/ac. The row crops were planted using a JD 7000 no-till planter, 30 inch row spacing, and seed depth of 2 in. Plant population for the row crops was 19,000 plants/acre. Since this was not an organic study, weeds were controlled using a pre-plant burndown and post-emergence control. For the cover crops and pea-barley, a pre-plant burndown was the only chemical applied. The small grain pre-plant burndown consisted of a tank mix that included Gly Star Plus (32 oz/ac), AMS (17lb/100 gal) and HelFire (1qt/100 gal). The post-emergence tank mix consisted of Sierra (1.0 oz/ac), Wide Match (12.8 oz/ac), and Transactive HC (1 qt/ac). The tank mixes were applied at a rate of 10 gal mix/ac at a ground speed of 12 mph. During the study period, grain, oilseed, and forage production were documented. Production was valued and economic analysis for each crop each year of the study was determined using the procedure as defined by the ND Farm and Ranch Business Management Program.

2. Consequence of perennial and annual forage grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass measurements, meat evaluation, and system net return

The procedures used in this investigation have been approved by the North Dakota State University Institutional Animal Care and Use Committee. After weaning in November of each year (2011 and 2012), medium to large frame steers (5-7 frame score; n = 141) were wintered for modest gain of < 1.0 lb/day grazing corn aftermath plus medium quality hay. In early May of each year, the steers were randomly assigned to one of three treatments based on frame score and weight. The treatment groups were as follows: 1) Feedlot Direct (**FLT**), 2) Perennial grass pasture (crested wheatgrass (CWG) > native range (NAT) (**PST**), 3) Perennial grass pasture followed by annual forage (crested wheatgrass > native range > field pea-barley (PBLY) > unharvested corn (CN)) (**ANN**).   The FLT steers were shipped directly to the University of Wyoming, Sustainable Agriculture Research Extension Center, Lingle, WY, and fed to final harvest weight. Steers assigned to the PST and ANN forage grazing treatments were also fed to final harvest at the University of Wyoming feedlot after the long-term extended grazing period was completed. During the grazing season, PST steers were moved from spring crested wheatgrass to native range pastures in early

June and, for the ANN treatment, the steers were moved from crested wheatgrass to native range mid-June, and from native range to PBLY the 3rd week of August each year, for an average grazing period of 27 days. After PBLY grazing was completed the steers were moved to standing unharvested corn for an average 52 days. Forage crude protein change was determined with bi-monthly sampling from 3 locations in the PST and ANN treatments. The design was to graze each forage type until forage crude protein content declined to a range between 9-10.0% CP or the pasture or field was sufficiently grazed. Grazing season cost/steer for the perennial (CWG and NAT) pastures was determined using a constant cost/pound of body weight of $0.0009 multiplied times the start weigh and end weight to arrive at a daily grazing cost. Then, using one-half the total number of days grazed, the first half and second half grazing charges were summed to arrive at the total grazing charge/steer. For the ANN treatment, the grazing cost was based on the sum of the custom grazing charge for the CWG and NAT pastures plus the actual farming input costs for crop establishment and $30/acre cash rent for western North Dakota. The length of time on feed was determined using ultrasound measurements for ribeye muscle area (longissimus dorsi), external fat depth and percent intramuscular fat. At the packing plant and after a 48 hour chill, strip loin steaks were taken from each carcass half between the 12th and 13th ribs and frozen for shear force and sensory panel evaluation at the NDSU Meats Laboratory.

Warner-Bratzler shear force

Steaks were thawed for 24 h at 4°C, weighed, and then cooked on clamshell-style grills, (model GRP99B, Salton Inc., Lake Forest, IL) at 177°C until steaks reached an internal temperature of 70°C. Temperatures were monitored internally in the geometric center of each steak with a copper, constantan, Neoflon PFA insulated wire and temperatures were recorded using an Omega handheld digital thermometer model HH801B (Omega Engineering Inc, Stamford, CT). A minimum of six 1.27-cm diameter cores were obtained from each steak parallel to the muscle fibers (AMSA, 1995). Each core was sheared once using a 250 mm/min crosshead speed. The mean of the 6 cores was used in the statistical analysis.

Sensory analysis

Prior to this study, the sensory analysis protocol was approved by the North Dakota State University Institutional Review Board. An experience quality attribute panel evaluated the samples. Panelists had been previously screened and trained to rate tenderness, juiciness, and flavor attributes of cooked meat samples (AMSA, 1995). Thawing and cooking procedures were the same as those used for shear force measurement. Steaks were selected randomly for each daily taste panel, with six samples served each day representing each different treatment. Each day a warm-up sample was evaluated by the panel as the first sample to ensure proper ratings of treatment samples. After cooking, steaks were allowed to set at room temperature for five minutes to equilibrate. Steaks were cut into 1.27 × 2.54 cm pieces, and all external fat and connective tissue was removed. Samples were placed in a covered container and served to each panelist. Panelists were given two cups, the first was filled with distilled water and the other was empty for sample expectoration. Each panelist was also given unsalted saltine crackers, toothpicks, and a ballot (AMSA, 1995). The same sample was given to each panelist at the same time. Panelists were first asked to take a bite of cracker and a sip of water to cleanse their palate before starting and between each sample. Tenderness, juiciness, and flavor intensity were on a rated scale of one to eight, with one being extremely tough, dry, and flavorless, and eight being extremely tender, juicy, and flavorful. The animal data was analyzed using MIXED procedures of SAS with treatment and year as fixed effects and performance and carcass measurements as dependent variables. Pen (pasture) served as the experimental unit and treatment, year, and the treatment x year interactions were determined. Hot carcass weight was used as a covariate to adjust carcass values. Sensory panel and shear force data were analyzed across panelist or pen and then pen means were analyzed using the GLM procedure of SAS with pen (pasture) serving as the experimental unit. MIXED and GLM least-square means were separated using the predicted difference option of SAS and differences were considered significant at $P \leq 0.05$.

3. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics

Over a 2 year period, 192 yearling steers (96 steers/year) originating from two beef cattle herds maintained at the Dickinson Research Extension Center (DREC) were divided into two frame score groups identified as small frame (SF: average 3.64) and large frame (LF: average 5.44). After weaning each fall (2012 and 2013), the steers were managed as a single group and backgrounded grazing unharvested corn that was supplemented with mixed hay (alfalfa-bromegrass-crested wheatgrass) and 2 lbs/steer/day of a 32% CP supplement until the end of April each year. During the backgrounding period, the steers grew at a modest ADG of 1.10 lb/day. The first week of May each year, the steers were randomly assigned to either feedlot (FLOT) or grazing (GRAZ) treatments. Within these two main treatments, two feedlot groups (LF: n=24 and SF n=24) and two grazing groups (LF: n=24 and SF n=24) were established. The FLOT steers were shipped to the University of Wyoming, Sustainable Agriculture Research Extension Center (SAREC), Lingle, Wyoming. The 2-year average number of days on feed (DOF) for the LF and SF feedlot control steers was 222 days. The GRAZ steers grazed native range from the first week of May to mid-August, a period of 109 days before being moved to graze annual forage fields of field pea-barley intercrop (30 days) followed by grazing unharvested corn (75 days). The total grazing period was 219 days. At the end of corn grazing, the GRAZ steers were shipped to the SAREC, Lingle, Wyoming for a delayed feedlot entry finishing period of 70 days. When each of the systems treatment groups were finished, the groups were delivered by commercial truck to the Cargill Meat Solutions packing plant, Ft. Morgan, Colorado. Due to the system's differences, the FLOT control groups were slaughtered in mid-December each year and the delayed feedlot entry GRAZ treatment steers were slaughtered mid-February to the first week of March.

All expenses and returns associated with this alternative growing and finishing systems study were recorded. Native range grazing costs were assessed using the custom grazing rate determination shown in Table 1 and farming expenses for the annual forages in the GRAZ system are shown in Table 2. Steer frame score grazing performance, cost/steer, and cost/lb of gain are shown in Table 3. Feedlot finishing performance, feed intake and efficiency, and finishing economics for the LF and SF treatment groups are shown in Table 4. Carcass traits, tenderness measurements, and total carcass value are shown in table 5. The effect of steer frame score and extended grazing on system net return is shown in Table 6.

4. Effect of heifer frame score on growth, fertility, and economics

This grazing and drylot forage-based heifer development and breeding study was conducted at the North Dakota State University, Dickinson Research Extension Center (DREC) (47°11′40″N 102°50′23″W) located 35 km north of Dickinson, ND, USA, in accordance with guidelines approved by the North Dakota State University Institutional Animal Care and Use Committee (Approval Number A12007).

One hundred beef heifer calves originating from two separate frame size cow herds at the DREC were weaned mid-October 2010 and weaning weight and hip height measurements were recorded. Using heifer age and hip height measurement, frame score values were determined for each heifer according to the BIF procedure for 5 to 21 month old heifers (BIF, 2010). Based on computed heifer frame score values, the heifers were assigned to either the SF (Range: 2.4 to 4.2; mean: 3.50±0.697) or LF (Range: 4.6 to 6.5; mean: 5.56±0.569) treatment groups. Genetic composition of the SF heifers was obtained through mating of conventional LF crossbred cows (Angus×Red Angus× Gelbvieh or Angus×Red Angus×Simmental) with Lowline sires resulting in SF heifers that were one-half Lowline.

Pre-trial increasing gain management

Phase 1 (P1), the baseline for an increasing energy regimen started on October 13, 2013, when 7.5 month old SF and LF heifers began grazing 14.7 ha of standing unharvested corn together as a common group (Table 1). Corn was planted using a John Deere 6-row planter set at 0.762 m row spacing for a plant population of 7,692 plants per ha. Corn forage dry matter (DM) yield was 4.91mt/ha and the crude protein (CP) content at the start of grazing was 9.72% and neutral detergent fiber (NDF) content was 51.1% (Detail: Forage and Supplement Analysis Section). As the heifers grazed standing corn with unrestricted access, forage quality declined with the advancing winter season (December 4, 2010; 7.75% CP and 70.2% NDF). Beginning December 4, the corn residue was supplemented with a medium-quality mixed hay (smooth bromegrass, *Bromus inermis*; CWG, *Agropryon desertorum*; alfalfa, *Medicago sativa*) (Table 1) until May 10, 2011; a period of 209 d. Hay was delivered to the heifers in large round bales (1.67×1.52 m) and fed in cone-type round bale feeders (Weldy Enterprises, 911 E. Waterford St., Wakaruse, IN 46573, USA). Since the SF and LF heifers were managed as a common group, heifer dry matter intake (DMI) for corn and hay was estimated based on the average DMI for all heifers (corn forage 5.79 kg/d, hay 5.21 kg/d) and then adjusted to account for SF and LF heifer intake difference. The adjustment for estimated DMI was calculated according to the following formula: $2y = (1.0+0.799)x$, where y is average DMI for corn or hay and x is DMI for the LF heifer. Thus, the SF heifer DMI is solved by subtraction. The estimated corn forage and hay DMI for SF heifers were 5.14 and 4.63 kg/d, and LF heifers were 6.44 and 5.79 kg/d, respectively. At the end of the P1 wintering period, heifer BW, ultrasound Longissimus dorsi muscle area (LMA), LMA/unit of BW (cm^2), 12th rib fat thickness and percent intramuscular fat (IMF) were recorded, and blood was drawn for progesterone assay. This pre-trial wintering procedure restricted average daily gain (ADG) for the SF and LF heifers creating a basis for increased growth rate during phase 2 (P2) and phase 3 (P3).

Phase 2 began on May 10, 2011, when the heifers began grazing a common CWG pasture, and continued until July 6, 2011 (58 d). The stocking density while grazing CWG was based on 0.40469 ha per animal unit month (AUM), or SF = 0.253 and LF = 0.294 ha per heifer per month, which was based on an estimated heifer mid-weight between May 10 and July 6 of 284 and 330 kg for the SF and LF heifers, respectively. During the CWG grazing period, the SF and LF heifers were predicted to utilize 0.49 and 0.57 ha per heifer, respectively.

Experimental design

When the heifers were removed from the CWG pasture on July 6, 2011, they were weighed and assigned to drylot pens (19.5 m×31.7 m) for the replicated P3 growing and breeding study. Heifers within each frame score treatment group (SF, n = 50; LF, n = 50) were allotted according to weight within 5 weight block pens with 10 heifers per pen. Thus, there were 5 pen weight blocks of SF heifers and 5 pen weight blocks of LF heifers. Drylot pen group served as the experimental unit for the study that started on July 6, 2011 and ended on September 29, 2011.

Diets

Without feeding grain to increase energy during the P3 growing-breeding period, a total mixed ration (TMR) consisting of 80% alfalfa and a 20% co-product supplement was fed (Table 1). Attainment of approximately 57% of mature BW at the start of the breeding season was an essential benchmark in this non-traditional forage-based heifer development investigation (Freetly et al., 2011). Therefore, heifer growth rate between CWG and the start of the breeding season in drylot was crucial and feeding alfalfa alone would not provide sufficient dietary energy to meet the 57% of mature BW goal, because alfalfa as the sole ingredient would only supply sufficient energy to support ADG of approximately 0.30 kg/d; or one-third of the projected 0.85 to 0.95 kg/d needed to meet the target goal at the start of the breeding season. The resulting TMR (80% alfalfa+20% co-product supplement) was fed *ad libitum* in fence line concrete bunks and provided 2.51 Mcal of metabolizable energy (ME)/kg of diet (Table 1). On a daily basis, the diet was estimated to provide 23.7 and 28.5 Mcal ME/d for the SF and LF heifers, respectively. Prior to TMR mixing, the alfalfa hay had been previously chopped by a local commercial hay grinding company using a 7.62 cm screen. The TMR ration was delivered to the bunks daily using a Gehl feedlot mixing wagon (Model 8400, Farmers Implement, LLC, Allenton, WI, USA) equipped with Digi-Star EZ 2000 electronic scale (Digi-Star, LLC, Fort Atkinson, WI, USA).

Forage and supplement analysis

Prior to diet formulation, 40% of the alfalfa bales fed in the study were core sampled using a 1.27 cm electric drill and a stainless steel Penn State Forage Sampler (2.9 cm× 45.7 cm, Nasco Agricultural Sciences, Fort Atkinson, WI, USA) and analyzed by a commercial laboratory for CP, NDF, acid detergent fiber (ADF), calcium (Ca^{++}), phosphorus (P), total digestible nutrients (TDN) (96.35 -(ADF% × 1.15), *in vitro* dry matter disappearance (IVDMD), and *in vitro* organic matter disappearance (IVOMD), (Table 1; AgSource Soil and Forage Laboratory, Bonduel, WI, USA).

The co-product supplement (Table 1) that was mixed with alfalfa for the TMR diet fed in drylot was prepared commercially as a 0.635 cm pellet and supplement nutrient analysis and energy density were provided by the company (Cenex Harvest States Nutrition, Sioux Falls, South Dakota, USA).

Pre-grazing corn forage yield and nutrient analysis and corn residue nutrient analysis were determined from 5 equi-distant sampling sites along a diagonal field transect. At each sampling site, 5.03 m of corn was removed with a machete, bundled, weighed, and shredded with a forage shredder (Snapper LEAF Shredder-Chipper Model LS5000, Briggs & Stratton, Attn: Snapper Power Products, PO Box 702, Milwaukee, WI 53201-0702, USA). The wet shredded forage from each sampling site was weighed before placement in a forage drying oven for 72 hours at 135°C. After drying, the samples were weighed and the percent DM and DM yield per ha were determined. The dried samples were mixed and subsampled for nutrient analysis.

The CWG pasture was sampled at the start, mid-point, and at the end of the 58 d grazing period using a 0.25 m frame. Forage biomass was clipped to ground level and stored in pre-weighed paper bags. Forage bags were weighed and dried as previously described and composited for nutrient analysis. Grazed forages (corn, corn residue, and CWG) and feedlot TMR were analyzed for CP, NDF, ADF, IVDMD, IVOMD, Ca, and P at the North Dakota State University Nutrition Laboratory (Table 1). Samples were analyzed in duplicate according to the Association of Official Analytical Chemists, AOAC (2010) for DM by drying at 135°C (AOAC method 930.15), CP (AOAC method, 2001.11), and Ca and P (AOAC methods 968.08 and 965.17). Laboratory analysis for NDF and ADF were based on the procedure of Goering and Van Soest (1970), IVDMD and IVOMD analysis was based on the procedure of Tilley and Terry (1963).

Data collection and assay

The amount of TMR ration delivered to each pen was recorded daily and orts were removed, weighed, and deducted from each pen's feed record bi-monthly. As fed feed weight was recorded for each pen and pen DMI was calculated based on percent moisture content of the alfalfa hay and co-product supplement ingredients.

Heifer BW (2-day mean; no feed or water restriction) was recorded at weaning and then at each forage phase change, drylot entry, start of the breeding season on August 11, 2011, and at the end of the drylot breeding period. Mature cow BW was used to calculate the heifer percent of mature BW at the start of the breeding season on August 11, 2011 and was based on historical mature cow BW taken from the DREC cow herd database (Herd Number-38) for each frame score group (CHAPS, 2000; Individual producer CHAPS, 2000 herd values are confidential and not open to public access). The estimated mature cow BW used for calculation of heifer percent mature BW was 554 kg for the SF heifers and 667 kg for the LF heifers.

The number of heifers cycling at the end of the wintering period and at the start of the 50 d breeding season on August 11, 2011 was based on the circulating progesterone assay derived from serum recovered from two blood draws collected 10 d apart. Circulating concentrations of progesterone were analyzed in all serum samples using the methodology described by Engel et al. (2008). Intra and interassay coefficient of variation for progesterone assays were 2.47% and 5.9%, respectively. A progesterone concentration greater than 1 ng/mL in either sample was interpreted to indicate presence of a functional corpus luteum and attainment of puberty.

Heifers in the study were bred naturally using fertility tested yearling bulls. The yearling bulls were placed with the heifers on August 11, 2011, for May to June 2012 calving, and remained with the heifers until the end of a 50 d breeding period that ended on September 29, 2011. Breeding cycle pregnancy rate (First Cycle, 21 d; Second Cycle, 42 d; Third Cycle, 63 d), overall pregnancy rate, and the percent of non-pregnant heifers were determined using transrectal ultrasound cranial width measurements (eye socket to eye socket external edge) taken 30 d after the end of a 50 d breeding season.

Non-invasive real-time ultrasound was used to estimate changes in economically important live animal carcass traits that relate to muscling and meat quality, which are important criterion for replacement heifer selection included LMA, LMA/unit of BW (cm^2), 12th rib fat thickness, and percent IMF, and were obtained using an Aloka 500 real-time ultrasound machine equipped with a 17 cm probe, gel standoff, PXC200 frame grabber, and UISC-USB-2820 Capture Technology (The National CUP Lab & Technology Center, Ames, IA, USA).

Economics

Replacement heifer production economics were computed upon completion of the study and were based on the direct expenses associated with each of the increasing energy phases. Actual crop production costs were used for the unharvested corn that was grazed and the mixed hay and alfalfa were priced at local opportunity cost. Corn production cost was $376.16/ha, or $53.23/heifer. The mixed hay that was fed was priced at $55.15/mt, or $70.65/heifer. The average total P1 corn forage and hay feed cost per heifer was $123.88. However, feed intake differences recorded during the feedlot P3 revealed that the SF heifers consumed 20.1% less DM feed than the LF heifers ($p = 0.001$). For the economic analysis after the animal performance and reproduction data collections were completed, we assumed that the difference in feed consumption would have been similar during the pre-trial grazing phases and; therefore, was used to adjust the proportion of the total feed cost assigned to the SF and LF heifer groups in P1 and P2. Thus, for P1, the proportion of the feed cost credited to the LF heifers was determined according to the following formula: $2y = (1.0+0.799)x$, where y is the feed cost for the average heifer, and x is the feed cost for the LF heifer. Feed cost for the LF heifer was computed to be $137.72/heifer, and by subtraction ($247.76 –$137.72) the SF heifer portion of the total feed cost was determined to be $110.04.

Stocking density for heifers grazing CWG has been previously described and was based on an estimated mid-weight heifer BW projection for the grazing period between May 10, 2011 and July 6, 2011 (58 d). Grazing charge for CWG was priced at $37.07/ha (USDA, NASS, 2011) and the heifers grazed for 1.93 AUM. The SF and LF heifers were calculated to have grazed 0.489 and 0.578 ha, respectively, resulting in a pasture charge of $18.12 for the SF heifers and $21.42 for the LF heifers.

Alfalfa hay was priced into the analysis at $66.18/mt and the pelleted 20% co-product supplement was manufactured commercially (Harvest States Nutrition, Dickinson, ND, USA) and was priced into the analysis at $420.24/mt. Phase 3 feed cost totaled $135.18 and $157.12, respectively, for the SF and LF heifers. The combined cost for the three increasing gain phases totaled $263.34/heifer for the SF group and $315.89/heifer for the LF group. Market prices used in the analysis were obtained from the United States Department of Agriculture-Agricultural Marketing Service (USDA-AMS) website. Beginning heifer values in October 2010 were computed by multiplying the average heifer weight of each group by the North Dakota weekly average auction market price for each group (USDA-AMS, 2010). Non-pregnant ending heifer values were computed in the same manner using the North Dakota weekly average auction market price for September 2011 (USDA-AMS, 2011). The net cost/pregnant heifer was calculated using the formula developed by Feuz (1992) and also used by Larson et al. (2011). The total value of all non-pregnant heifers was subtracted from the total costs of all heifers in each development group. That adjusted development cost value was divided by the number of pregnant heifers in each group to determine the cost of developing each pregnant heifer.

Statistical analysis

The data was analyzed using the generalized least squares mixed analysis procedure of SAS (SAS, 2002). The main effect included heifer frame score treatment (fixed) and pen group (random) served as the experimental unit for the study. Least square means were used to partition treatment effects and differences were considered significant at $p \leq 0.05$.

5. Effect of Grazing Cover Crops, Stockpiled Improved Grass, and Crop Residues on Cow Wintering Performance, Economics, and Calving Rate

One hundred forty-four, medium-large frame, 3-10 year old May-June calving cows were used to evaluate two approaches for extending the grazing season as methods for reducing winter feed cost.

Compared to feeding hay and supplement to control (C) gestating cows fed in confinement, one group of cows grazed a sequence of forages beginning with a 7-species cover crop followed by corn and sunflower residues (CC&RES), and a second group of cows grazed stockpiled crested and bromegrass pastures followed by corn residue (GRAS&RES). There were three pen replicates of C cows and three field replicates of each forage type grazed. There were 8 cows in each pen or field replicate for a total of 24 cows/treatment. When each grazing treatment sequence was completed, the cows were moved to confinement and fed hay until the wintering study was completed in April.

Cover crop and crop residues grazed in the study were grown as part of in an integrated crop and beef cattle study (SARE project LNC 11-335) in which unharvested corn had been previously grazed with yearling steers and sunflower was harvested for oilseed. For the CC&RES treatment, the residues and 7-species cover crop (Table 1) were warm- and cool-season annuals. The stockpiled GRAS&RES treatment was comprised of perennial improved grasses (bromegrass and crested wheatgrass) and forage corn residue. The corn residue grazed in both grazing treatments had been previously grazed by yearling steers. The C cows were moved to drylot pens after weaning and were fed hay until the end of the study in April. The two cow grazing treatments (CC&RES and GRAS&RES) grazed their respective forage-residue sequences and when sufficiently grazed the cows were moved to drylot and fed hay until the end of the study.

The 7-species cover crop blend, pounds/acre seeded, cost/acre, and grazing cost/cow is shown in Table 1. Cow body weight and body condition score (BCS) change during grazing and drylot (hay) after grazing is show in Table 2, for the CC&RES and GRAS&RES systems, and weight and BCS change for the 134 day wintering period has been summarized in Table 3. The breeding season for the May-June calving cows in the study started on August 10 each year for calving to begin approximately May 20 each year. The effect of wintering treatment on calving cycle and total percent of cows calving is shown in Table 4. The system wintering treatments were designed to reduce the amount of hay fed, which was replaced with forage and residue grazing. Cows in all treatments were fed and average 1.74 lb (DM) of a 32% CP supplement ($339.25/T). The total amount fed in each treatment group was 214 lb/cow and cost $36.30/cow. The hay price used was $65/T. The amount of hay fed, 32% CP supplement, and total winter cost/cow for each system is shown in Table 5.

For the system cost analysis, all annual forage crop expenses were charged to the previous enterprises (cropping and yearling steer grazing) and land was considered to be owned land. The only direct farming expenses were incurred for cover crop production in the CC&RES treatment and property tax was incurred for both of the grazing treatments.

6. Bulk density comparison within a crop rotation in Western North Dakota

The study sites are located at the Dickinson Research Extension Center (DREC 14^{o}' 11' 40" N 102^{o} 50' 23" W) located in Dunn County, North Dakota. The fields in the study area were previously farmed with tillage, but are now in a no-till system. Before the changeover to no-till fields had become compacted from the equipment and the crop rotation was put in place to help reduce the compaction. This site is also used for another study on cattle production. The corn fields and the cover crops are used during the fall till around December for cattle grazing. The calves are moved to different fields during this time where the ground is cold enough to where compaction is not an issue. Cow manure is a great source of fertilizer. It replenishes the soil of the nutrients it needs to aid in plant growth in the future. Not only are the cattle great for nutrients they also help to increase the speed of breakdown of the forage for organic matter by stepping on and tearing up the forage. There are three blocks and each block contains six crop fields, 3 continuous spring wheat control fields and 15 crop rotation fields totaling 18 fields (Figure 1). The crop rotation system consists of the following crops: Year 1 - spring wheat (cash crop) and after harvest winter triticale/hairy vetch is planted in early September for hay the next spring, Year 2 – triticale-hairy vetch hay; cover crop planted after hay harvest between June 15 and July 1 (fall grazed), Year 3 – corn (fall grazed), Year 4 – field pea-barley (late summer grazed), Year 5 - sunflower (cash crop). The crop rotation is compared to the continuous spring wheat control. Each field is replicated three times for statistical analysis. Therefore, there are three fields of each crop; one in each block. This integrated crop and livestock system started in 2010 and this is the first time BD has been measured. Soil samples for BD were obtained from field using a GPS (Garmin handheld device) to locate soil sample collection areas. Within each field three collection sites were randomly located. Six different soil samples from each field were collected. Three were collected at 0-4 inches and the other three were collected at 7-11 inches using a slide hammer soil collection core sampler (Figure 2). The core sampler is a metal sliding hammer with a cylinder attached to the bottom. The cylinder has a second cylinder inside with a volume of 427 cm^3. When the soil surface is free of debris, the sampler is set on the ground with the cylinder down and the sliding hammer pointed up. The sliding hammer was used to pound the cylinder into the ground to a certain depth then it is dug out to prevent damage to the sampler and prevent soil loss from the cylinder (Figure 4). Once the cylinder was out, the main cylinder was unscrewed from the sliding hammer and the second cylinder came out. To get accurate measurements, the soil had to be leveled off on both ends of the cylinder and then the soil was put into a marked bag with the field name, date and depth (Figure 3). For this specific research, samples from three different native rangelands (Figure 5) were taken using the GPS to locate sample sites, and then collected six soil samples from each of the three rangeland sites. Three samples were collected at depths of 0-4 inches and three samples collected at 7-11 inches. Once all the samples were collected from the fields, they were taken to Dickinson State University in Dickinson, North Dakota and transferred from the bags to beakers. They were then weighed right away to get the wet soil weight in grams. After the wet weight was recorded, the samples were placed in a drying oven. The samples were left in the oven for 24 hours at 105 degrees Celsius, and then taken out and reweighed to obtain a dry soil weight. After all the soil weight was collected, the weights were put into an Excel spread sheet calculate the BD weight. The BD is calculated by dividing the dry soil weight by the volume of the cylinder from the soil core sampler according to the following formula: g/cm^3=dry soil weight (g)/soil volume (cm^3). The soil samples were saved to determine soil texture (Figure 7). Soil texture is important in determining root limiting. The results of the soil texture test (Table 2 & 3) were compared to Table 1 to conclude any root limitations with in the crop fields and the native range. The method that was used to determine soil texture was based on Brady and Weil (2008) and Dr. Brevik's soil lab handout, a sample from each individual soil was moistened to form a ball of soil. After a ball of soil was formed, then the ball is squeezed between the thumb and forefinger to make a ribbon until it breaks from its own weight (Figure 8). The texture by feel were determined as follows:

1. Soil will not stick in a ball- sand
2. Soil forms a ball but will not form a ribbon- loamy sand
3. Ribbon is dull, breaks off when less than 2.5 cm long, and:
    a. Grinding noise is prominent, feels gritty- sandy loam
    b. No grinding noise, smooth floury feel- silt loam
    c. Minor grinding noise, slightly gritty- loam
4. Soil forms a ribbon 2.5 to 5 cm long and:
    a. Grinding noise is prominent, feels gritty- sandy clay loam
    b. No grinding noise, smooth floury feel- silty clay loam
    c. Minor grinding noise, slightly gritty- clay loam
5. Soil shows significant stickiness and firmness, forms shiny ribbon longer than 5 cm and:
    a. Grinding noise is prominent, feels gritty- sandy clay
    b. No grinding noise, smooth floury feel- silty clay
    c. Minor grinding noise, slightly gritty- clay

The statistical analysis for this study the analysis of variance (ANOVA) was used to compare the means between the bulk densities of the different crop fields and to determine whether any of those means are significantly different from each other. If the variability between groups is large relative to the variability within groups, then the means of the populations from which the data were drawn are significantly different. When the results are significantly different, it indicates at least one group differs from the other groups. The Tukey test was used to get pairwise comparisons between the means.

7. Seasonal soil nitrogen mineralization within an integrated crop and livestock system

The study site is at the DREC Ranch near Manning, ND on a complex of Savage (fine, smectitic, frigid vertic Argiudolls), Daglum (fine, smectitc, frigid vertic Natrustolls), Vebar (coarse-loamy, mixed, superactive, frigid typic

Haplustolls), and Parshall (coarse-loamy, mixed, superactive, frigid pachic Haplustolls) soils. A diverse 5-year crop rotation is being utilized to provide both cash crops as well as summer grazing for livestock. The rotation includes: i) sunflower (SF); ii) hard red spring wheat (HRSW); iii) fall seeded winter triticale-hairy vetch (THV), spring harvested for hay/spring seeded 7-species cover crop (CC); iv) corn (C) (85-90 day var.); and, v) field pea-barley intercrop (PBY). The HRSW and SF are harvested as cash crops and the PBY, C, and CC are harvested by grazing cattle. The THV is hayed and fed to the livestock. No supplemental fertilizer N is being applied. All cropping treatments are replicated three times in a randomized complete block arrangement with the blocks arranged by soil type. All of the crops are managed as no-till crops. Triplicate plots in nearby undisturbed grassland pastures with similar soils are also being monitored as a control in this study. The vegetative cover in the pasture is dominated by western wheatgrass (Pascopyrum smithii (Rydb.) A. Love), blue grama (Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths), little bluestem (Schizachyrium scoparium (Michx.) Nash), and Switchgrass (Panicum virgatum L.). During the 2014 growing season, soil N was monitored by collecting multiple soil samples in each treatment plot to a depth of 2 feet (24 inches) as recommended by the NDSU Soil Testing Laboratory and NDSU Extension Service. Samples were collected on a 15 day schedule except where weather (extreme soil wetness) interfered with sampling. Once the crops were established, three 8-inch aluminum rings were randomly driven into the ground to a depth of 2 feet in each plot to provide sampling areas where crop roots are excluded from N uptake. This was to establish an index of the total N mineralized without plant uptake. However, the N in the isolated areas was still subject to natural leaching, volatilization or immobilization processes in the N cycle. The soil samples were analyzed by the NDSU Soil Testing Laboratory for ammonium-N (NH_4-N) and nitrate-N (NO_3-N). A total of 8 sampling times were evaluated. Soil organic matter was also evaluated on the samples from the initial sampling date.

Results and Discussion

1. Effect of spring wheat yields when grown continuously or as a component within a diverse crop rotation

The primary objective of the study was to employ the principles of soil health and determine the effect on hard red spring wheat (HRSW) production and economics when grown in a diverse crop rotation (ROT - HRSW, double cropped winter triticale-hairy vetch followed by a 7-species cover crop in the same year, corn, field pea-barley, and sunflower) and compare it to HRSW grown continuously (Control). All crops in the study were sowed using no-till seeding and planting equipment. After 5 crop years, the 5-year average HRSW yield was the same for both treatments (Control 40 vs. Rotation 41 bu/ac). But how that occurred during the 5-yr ROT is a clearly a demonstration of the soil's power to *grow nutrients* resulting from crop rotation and animal grazing. Yields for crop years 1-5 were the same year 1, but in year 2, control wheat yield was 24.4% higher than rotation wheat (56 vs. 45 bu/ac). Change that started when the rotation was initiated became more evident year three, when the yield margin between the two management practices began to narrow, but remained 20.5% higher for the control (47 vs. 39 bu/ac). Yield reversal became fully realized by year 4, when the rotation wheat yield was 9.1% higher (44 vs. 48 bu/ac), and by the 5th crop year rotation wheat yield was 38.9% higher than the control wheat yield (36 vs. 50 bu/ac). The 5-yr average input cost (CTRL $193 vs. ROT $178/ac) and gross return (CTRL $263 vs. ROT $258/ac) resulted in a net return that was $10 higher for rotation HRSW compared to the control HRSW (CTRL $70 vs. ROT $80/ac). There were no differences in protein (CTRL 13.9 vs. ROT 13.3 %) or test weight (CTRL 61.8 vs. ROT 62.0 lb/bu). Rotation crops were evaluated on their grain, oilseed, and forage production input cost, gross return, and net return. Net return was 80, 50, 62, 90, $147/ac for HRSW, cover crop, corn, pea-barley, and sunflower, respectively ($P=0.11$). The 5-yr net return from the CTRL, ROT, and Combined ROT Crops was 70, 80, and $86/ac suggesting that growing continuous HRSW is less intensive, but also 22.9% less profitable.

2. Consequence of perennial and annual forage grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass measurements, meat evaluation, and system net return

The results of this yearling steer alternative production systems evaluation have been summarized in Tables 1-6 and forage crude protein decline, during each forage grazing period, is depicted in Figures 1-4.

Steer growth rate for the PST and ANN steers was 1.71 and 2.21 lb/ day, respectively ($P = <0.0001$) for the 182 day grazing season; resulting in a total grazing season gain of 309 and 405 lb/steer ($P = <0.0001$) for the PST and ANN extended grazing system treatments, respectively. Total grazing cost for the ANN treatment was higher; however, the grazing cost/lb of gain for the PST and ANN systems was similar ($0.5571 vs. $0.5924 for PST and ANN, respectively; $P = 0.14$).

Grazing annual forages (PBLY > CN) after native range improved economically important carcass measurements prior to feedlot entry. When measured with ultrasound at the end of the grazing season, ribeye area (P = <0.0001), fat depth (P = <0.0001), and the percent of intramuscular fat (P = 0.0003) were significantly greater for the ANN than the PST systems (Table 2), which contributed to a numerically greater number of ANN steers having carcasses grading Choice or better.

Steer system feedlot performance is summarized in Table 3. Overall, steer feedlot performance for either of the extended grazing systems (PST and ANN), was superior to the FLT control steers. The FLT control steers averaged 3.81 lb/day and reach slaughter weight earlier than the PST and ANN forage grazing systems, however, once the grazing system steers entered the feedlot their ADGs were significantly faster than the FLT control. FLT control steers were 18.1 months of age at slaughter compared to 21.4 and 22.1 months of age for the ANN and PST systems, respectively. Although grazing increased the number of days from birth to slaughter, grazing (PST and ANN) dramatically reduced the number of DOF in the feedlot. Compared to the FLT control that averaged 142 DOF, the ANN steers reached final slaughter weight after a short 66 DOF and the PST steers required 91 DOF. This difference in the number of DOF to reach final slaughter weight is a direct result of combining perennial and annual forages in a sequence in which the ANN steers grazed higher quality forage throughout the extended grazing season (Fig 1-4). Compared to the ANN treatment that grazed PBLY and CN beginning in mid-August of each year, forage quality decline in the native range pastures significantly reduced ribeye area, fat depth, and percent intramuscular fat among the PST system steers (Table 2), which required the PST system steers to be on feed in the feedlot for an additional 25 days before reaching final harvest end point.

Despite reaching slaughter end point sooner, feedlot performance for the conventional FLT control system was inferior in most of the economically important categories measured. Compared to the FLT control, extended grazing systems that delaying feedlot entry resulted in better ADG (P = 0.006), feed efficiency (P = 0.018), feed cost/steer (P = <0.0001), and feed cost/lb of gain (P = 0.005).

Carcass closeout measurements are summarized in Table 4. Hot carcass weight for the FLT system was 78 lb lighter (P = <0.0001) than the average of the two pasture systems, which no doubt contributed to the numerically fewer number of FLT steer carcasses grading Choice or better. Although there was a numerically small number of carcasses grading Choice or better, there was no statistical difference between the systems treatments for quality grade. Steer carcasses from the PST and ANN forage systems tended to have greater ribeye area (P = 0.078), as well as greater fat depth (P = 0.033). The FLT control steers were leaner resulting in lower yield grade values (P = 0.042) compared to the PST and ANN system carcasses; however, marbling score (P = 0.58) and quality grade (P = 0.31) did not differ.

Meat tenderness and sensory panel evaluations of strip loin steaks showed that there was no difference between systems treatments for Warner-Bratzler shear force (P = 0.109) and cooking yield (P = 0.062); and the sensory panel evaluation of steaks showed that there was no difference between steaks for perceived tenderness (P = 0.3998), juiciness (P = 0.2601), and flavor (P = 0.2451).

The systems 2-year average income, expense, and net return are shown in Table 6. The ANN extended grazing system was the only system with a positive net return of $9.09, whereas, the PST system lost $30.10; a difference of $39.19 between PST and ANN. The PST system net loss is attributed to slower ADG resulting from maturing native range forage quality decline associated with the advancing late summer and fall season. The control feedlot system lost -$298.05.

The results of this NCR-SARE study indicate that extended grazing systems can reduce the cost of production among steers held for retained ownership. The ANN extended grazing system that included grazing annual forages during the late summer and early fall seasons prior to feedlot entry was a profitable system without using risk management tools, which was an underlying objective in the study.

The decision for cattlemen with access to both pasture and crop land will be determined by several factors such as the implications of crop insurance, adequate fencing, and reliable water source. Water can be hauled to locations where permanent water is not developed, but the logistics may be prohibitive. A decision for whether to graze or not to graze crop land will also depend on the predicted value of a harvested crop for cash sale compared to selling beef from a an integrated crop-livestock system.

3. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics

Results of this systems investigation show that over the two year period the SF steers tended to grow slower under grazing (P = 0.069) and grew significantly slower in the feedlot control treatment (P = <0.0001). Under grazing conditions, the SF steers had a lower cost/steer ($292.90 vs. $303.14); however, due to their slower growth rate, grazing cost/lb of gain was higher ($0.5979 vs. $0.6582). In the feedlot, feed cost/lb of gain was significantly higher for both the LF and SF FLOT treatment steers compared to the GRAZ treatment steers (P = 0.0155). Delaying feedlot entry until after 219 days of grazing reduced the finishing period to 70 DOF and associated finishing costs were also reduced. Comparing the average FLOT and GRAZ systems feed cost/lb of gain, finishing feed cost/lb of gain for the GRAZ system averaged 31.8% less (P = 0.0155).

Carcass trait measurements collected at Cargill Meat Solutions, Ft. Morgan, Colorado, identified economically important differences and similarities. Hot carcass weight (HCW) were numerically different, but did not differ statistically (P = 0.15). Dressing percent was greater for LF and SF FLOT treatment steers compared to GRAZ treatment steers (9 = 0.018). Regardless of system treatment, LF steers had larger ribeye area (P = 0.05). Marbling score among SF steers was numerically greater, but the difference was not statistically significant (P = 0.46). Percent Choice carcass quality grade ranged from 89.6 to 97.9% across treatments. The percent of LF GRAZ systems steers grading Choice or better was lower compared to the other system treatments (P = 0.05). Although there were fewer LF GRAZ system steers that graded Choice or better, LF GRAZ treatment steers returned the highest gross return per carcass of $2223.67 (P = 0.001).

Meat tenderness measured using the Warner-Bratzler shear force test identified numerical differences between FLOT and GRAZ treatments for LF and SF steers; however, there was no statistical difference between treatments (P = 0.483). Meat cooling loss was also measured and there was no difference measured between treatments for LF and SF steers (P = 0.432).

Systems net return has been summarized in Table 6. To determine system net return, expenses (e.g. steer placement cost, grazing and feedlot finishing expenses, transportation and brand expenses) were deducted from the gross carcass value. The 2-year average systems net return was $188.01, $112.98, $526.50, and $344.75 for the FLOT LF and SF, and GRAZ LF and SF, respectively. The combination of lower grazing and feedlot expenses and compensatory growth among GRAZ system steers resulted in greater net return than that received for the FLOT system steers. The data indicates that a much longer grazing season and a significantly abbreviated finishing period favors profitability.

4. Effect of heifer frame score on growth, fertility, and economics

The pre-trial management growth and cost for the two heifer frame score groups, which were managed as a common group for production Phases P1 and P2, are shown in Table 2 and were critical steps in preparation for the final P3 growing and breeding trial (Table 3). Phase 1 heifer gains grazing dormant forage corn and corn residue plus supplemental medium-quality mixed hay were restricted during the 209 d period (0.26 vs 0.22 kg/d for the SF and LF, respectively). Compared to restricted gain of P1, P2 grazing of spring and early summer CWG pasture improved ADG of the SF heifers by 81% and the LF heifers by 172%. Comparing ADG during P3 with that of P2, the SF and LF heifer gains improved 62% and 81%, respectively. During the P3 growing-breeding period in drylot (Table 2), ADG between the SF and LF heifers did not differ (0.85 vs 0.97 kg/d, respectively, p = 0.09). Although there was no difference in ADG between the SF and LF heifers, DMI for the SF heifers was 20.1% less than the LF heifers (9.44 vs 11.34 kg/hd/d, respectively; p = 0.001). The relationship between ADG and DMI, for the two heifer treatment groups, resulted in a feed to gain ratio between the SF and LF heifers that did not differ (11.14 vs 11.75 kg/kg gain, respectively; p = 0.41).

Economically important live animal measurements were obtained using real-time ultrasound for LMA, ratio of LMA/unit of BW (cm^2), 12th rib fat thickness, and percent IMF (Table 4). The LMA for the LF heifers was larger in May (p = 0.002) and October (p = 0.04). However, when the ratio of LMA/unit of BW (cm^2) (45.4 kg) was compared in May and October, SF LMA was greater than LF heifers in May (p = 0.02) and in October (p = 0.003). Rib fat thickness (e.g., between the 12th and 13th ribs) did not differ between SF and LF heifers either in May (p = 0.67) or October (p = 0.63). There was a tendency for SF heifers to have greater percent IMF in May (p = 0.07), but there was no difference in October (p = 0.59). During the grazing and drylot period from May to October, the percent IMF deposition increased 44.4% and 42.3%, respectively, for the SF and LF heifers, providing supportive evidence that the heifers were on a positive plane of nutrition leading up to and during the breeding season.

The effect of the heifer development procedure on puberty, percent of mature BW at the start of the breeding season, breeding cycle pregnancy rate, and overall reproductive performance are shown in Table 5. At the start of P2 on May 10, the heifer percent of mature BW was 48.7% and 46.8% respectively, for the SF and LF heifers, and compared to the SF heifers, a greater number of LF heifers had reached puberty (18.0% vs 40.0%, respectively; p = 0.02). Then, during the 93 d period from May 10 to the start of the breeding season on August 11 (e.g., P2 and the first 36 d of P3), the number of SF heifers that had attained puberty increased 5-fold, whereas the increase was 2.4 times for the LF heifers. However, there was no difference in the percent of SF and LF heifers that were pubertal at the start of the breeding season (90.0% vs 96.0%, respectively, p = 0.07). This is presumed to be influenced by frame score and not age. Using the DREC cow herd database, the percent of mature BW attained by the start of the breeding season was 57.8% and 57.3% for the SF and LF heifers, respectively, and did not differ between groups (CHAPS, 2000). Using natural service and a 50 d breeding period, first 21 d (p = 0.53), second 42 d (p = 0.40), and third 63 d (p = 0.49) breeding cycle pregnancy rates did not differ between SF and LF heifers. Furthermore, overall pregnancy rate for SF and LF heifers was 86.0% and 84.0%, respectively and did not differ between groups (p = 0.62).

Based on economic assumptions for feed cost calculated during P1 and P2 between SF and LF heifers, feed cost for SF heifers was lower for the entire 352 d development period, and feed cost per day for the SF heifers was 19.9% less than the LF heifers. Economic analysis comparing SF and LF heifers (Table 6) was conducted according to the procedure of Feuz (1992), which accounted for the sale of non-pregnant heifers, and determined the net cost per pregnant heifer to be $745 for the SF heifers and $899 for the LF heifers (p = 0.004); a difference of $154.

5. Effect of Grazing Cover Crops, Stockpiled Improved Grass, and Crop Residues on Cow Wintering Performance, Economics, and Calving Rate

The 7-species cover crop blend, pounds/acre seeded, cost/acre, and grazing cost/cow is shown in Table 1. Cow body weight and body condition score (BCS) change during grazing and drylot (hay) after grazing is show in Table 2, for the CC&RES and GRAS&RES systems, and weight and BCS change for the 134 day wintering period has been summarized in Table 3. The breeding season for the May-June calving cows in the study started on August 10 each year for calving to begin approximately May 20 each year. The effect of wintering treatment on calving cycle and total percent of cows calving is shown in Table 4. The system wintering treatments were designed to reduce the amount of hay fed, which was replaced with forage and residue grazing. Cows in all treatments were fed and average 1.74 lb (DM) of a 32% CP supplement ($339.25/T). The total amount fed in each treatment group was 214 lb/cow and cost $36.30/cow. The hay price used was $65/T. The amount of hay fed, 32% CP supplement, and total winter cost/cow for each system is shown in Table 5.

For the system cost analysis, all annual forage crop expenses were charged to the previous enterprises (cropping and yearling steer grazing) and land was considered to be owned land. The only direct farming expenses were incurred for cover crop production in the CC&RES treatment and property tax was incurred for both of the grazing treatments.

Grazing length was greatest for the GRAS&RES treatment (107 days) compared to the CC&RES treatment (73 days). Cows grazing GRAS&RES gained more weight during the 107 day period compared to the CC&RES treatment (P=0.0001). Although there was a grazing difference measured for body weight there was no difference observed between treatments for BCS (P=0.76). In drylot after grazing, the CC&RES cows were fed hay for 61 days compared to the GRAS&RES cows that were fed hay for 27 days. The BCS of the CC&RES cows increased 0.80 BCS score, which was a significant increase compared to the GRAS&RES cows that increased 0.30 BCS (P=0.0001). Overall, total gain during the 134 day wintering period for the C, CC&RES, and GRAS&RES treatments was 205, 146, and 112 lb., respectively. Body condition score change for the C and CC&RES were 0.79 and 0.71 score change/cow, respectively, which was significantly greater than the GRAS&RES condition score that did not change over the wintering period (P=0.05).

Reproductive performance was based on the percent of cows calving in the first through third calving cycles, percent of non-pregnant cows, and the total percent of cows calving (Table 4). There were no differences measured for 1st (P=0.12), 2nd (P=0.15), and 3rd (P=0.26) calving cycles, percent of non-pregnant cows (P=0.47), and the total calving percent calving (P=0.46). Since the cows in this study were calving on lush spring grass and the breeding season for these May-June calving cows did not begin until August 10 each year, grazing nutrition and environmental conditions supported high reproductive efficiency.

Wintering cost for the three wintering methods compared was markedly different (Table 5). Hay cost/cow for the C, CC&RES, and GRAS&RES was $172.51, $67.74, and $29.94/cow, respectively (P=0.0001). Combining expenses for supplement, hay, cover crop (seed, farming, and property tax), and stockpiled grass on owned land (property tax), total wintering cost for the C, CC&RES, and GRAS&RES was $208.81, $140.59, and $73.33/cow, respectively. Comparing wintering cost of the C cows with the CC&RES cows, the wintering cost was reduced by $68.22/cow. But when the wintering cost for C cows was compared to the GRAS&RES cows that grazed stockpiled brome and crested wheatgrass fields, the wintering cost/cow was reduced $135.48. In other words, feeding harvested hay for the entire 134 day wintering period cost 2.8 times more than grazing stockpiled improved grasses and corn residue.

This greater margin of savings for grazing GRAS&RES compared to the CC&RES resulted from the combination of grazing established perennial improved grasses, longer grazing time, and fact that there was no cover crop establishment cost.

The results of this cow wintering research imply that wintering costs can be reduced when suitable forages, protein supplement, frost free water, fencing, and winter wind protection are available. The results also suggest that May-June calving cows can be fed lower quality forage for an extended period of time, when supplemental protein is fed, without negatively impacting rebreeding and calving performance.

6. Bulk density comparison within a crop rotation in Western North Dakota

From 2010 to 2013 18 crop fields were converted from a tillage system to a no-till system. From October 15-31, 2013, six soil samples were collected within each of 18 (n=108) crop fields and three native range sites (n=18) totaling 126 soil samples were used to measure BD. The results of this study (Table 4) showed that compared to the spring wheat control and crops in the rotations, there were no BD difference when native range was contrasted with the spring wheat control and rotation crops there was no difference in BD except for corn. The BD of corn was similar to native range (P=0.178). The BD values for corn and native range were 1.473 and 1.375, respectively. When expressed as a percent and compared to the spring wheat control, the BD value for native range was 12.9% less and corn was 5.36% less. After evaluating the data, it has been determined that there has been little change in BD compared to the spring wheat control (P>0.10). However, when native range was compared to all of the crops, BD of native range was less (P<0.001) except for corn that was similar to the native range (P = 0.178). In the current study, our data shows that BD change is slow, but that some change is becoming evident. The fact that fields seeded to corn in 2013 were similar to native range, which is the most stable no-till system, shows that combined effect of the winter triticale-hairy vetch crop followed by the cover crop in the same cropping season that preceded the current year corn crop contributed to reducing soil BD. In the future, we would expect BD within the spring wheat control and rotation crop fields to follow the decline observed with corn to also occur over time. The results of this current study are similar the finding of in the study that was previously stated in the literature review. Pikul et al. (2003) found that BD was highest in crop lands when compared to native range. Results had shown that there had been no obvious trends over time and could not recommend any specific rotation phase. The results did show that under a no-till system, soil aggregates formed better and will later help enhance soil quality and decrease BD. While it would be difficult to make crop rotation recommendations at this point in the SARE study, placement of the cover crop year (winter triticale-hairy vetch crop followed by the cover crop) prior to a high value, high input cost crop such as corn appears to be a desirable placement in the crop rotation used. Urea nitrogen fertilizer applications to corn, based on NDSU Soil Testing Laboratory results, have not been reduced, but recommendation reductions are expected in the future. One issue that is not addressed, when using soil testing techniques, is the potential for growing season nitrogen mineralization that makes nitrogen available for the growing crop. This soil derived nitrogen cannot be detected in the conventional soil test, but is available and can be calculated from the organic matter value shown in the standard soil test result. The change in BD clearly indicates that future reductions in nitrogen recommendations may be forthcoming in future years of the study. An experiment was done in two areas in Illinois. They used a crop rotation with continuous corn, corn-soybean, corn-soybean-wheat, and continuous soybean. The treatments that were used were chisel tillage and no-till. Both sites contained silt loam and silty clay loam soils. Results showed that bulk density under the no-till system had a greater significance than the tillage system in the 0-4 inch soil depth, but not significant at greater depths. In the no-till system, BD at the surface had no difference from the soil profile below 8 in. Under the tillage system, BD was significantly lower at the surface compared to deeper depths. Results also showed that the continuous corn and continuous soybean had the highest BD values. The two year rotations, corn and soybean, was second in the BD values. The three year rotation with corn, soybean, and wheat had the lowest BD values of all the rotations used. They concluded that the BD decreases the most when more crop species are added to a rotation (Zuber, Stacy M. 2013). Based on the results that are occurring in the current study that employs a diverse crop rotation, we would agree that BD decline may be more easily accomplished when more crop species are included in the crop rotation and to go one step further, using a multi-species cover crop is more effective than using a single crop (USDA/NRCS/Farming in the 21st Century, 2010). Purdue University in Indiana conducted a study to determine long-term crop yield potential using four tillage systems and four cropping methods. Another goal was to determine any changes in crop growth and soil characteristics that maybe associated with crop yield. The tillage systems used were: plow, chisel, ridge and no-till systems. Four rotations were used: continuous corn, corn following soybean, soybean following corn, and continuous soybean. The soil texture at the site was silty clay loam. Results showed that tillage had an influence on BD above 12 inches. No-till had significantly higher values than for plow between 0-12 inches. BD of convention tilled soils tended to be lower than those of a no-tilled soil in the upper 12 inches. Bulk density values can vary depending on soil type and growing vegetation. Coder (1998) summarized root limiting bulk density (g/cc) for tree root growth in various soil textures and showed that in clay soils root limitation was 1.4 g/cm^3 and were as high as 1.8 g/cm^3 for sand soils. It is important to note that there are noticeable differences in crop yield in different soil textures within soil types. In the current study crop rotation, crop yields vary between years depending on available moisture; however, yields overall have been very good indicating that the BD values obtained in our study would be considered very acceptable. This is evident based on crop yields shown in Table 6. Yields have been increasing since the study started and fertilizer applications have been reduced, which is indicative of improving soil quality. The BD values obtained are obviously not limiting root development. The foundation research project is a long-term (10 year) investigation to determine the impact on soil quality, among other things, and how the crop rotation used in the study, along with no-till farming and grazing, are collectively improving crop yields while inputs are being reduced. Bulk density is one soil measurement that can be used to measure a soil's potential to limit root growth and penetration and is influenced by organic matter content, porosity, and soil structure. Based on our data, we conclude that the combination of no-till, crop rotation, cover crops, and cattle grazing are collectively resulting in soil quality improvement. The BD measured was not different when the spring wheat control was compared to the rotation crops, but when the rotation crops were compared to native range, corn was not different and pea-barley also tended to not be different. Earth worms are commonly found in healthy soils and contribute to healthy soils. We found earth worms in many of the soils as BD samples were collected and a few of the samples contained earth worms. We conclude that the cropping and grazing methods employed in the study are working and that we expect that BD will continue to decline becoming more like native range over time. How long this will take is unknown, but since change in soil characteristics occur slowly over time we would expect this to be many years.

7. Seasonal soil nitrogen mineralization within an integrated crop and livestock system

The seasonal changes are shown for NO_3-N, NH_4-N, and total mineral N (NH_4-N + NO_3-N) in Figures 1 through 3, respectively.

Figure 1 shows soil NO_3-N availability across the growing season. The grassland began the season with an availability of 22 lbs NO_3-N/A, then declined slightly, but remained relatively constant throughout the growing season. This is to be expected because the grasslands have reached a relative equilibrium between organic matter deposition and decomposition in the absence of soil disturbance. The average cropland NO_3-N levels were 47 lb /Ac at the beginning of the growing season but decreased to levels near the grassland levels by mid-July. This represents a period of rapid crop growth and N uptake. After mid-July, a slight increase occurred till early September and then showed a slight decrease. The slight increase may have been due to heavy rainfall during August stimulating N mineralization during a time of the year that is normally dry. The NO_3-N in the samples collected from the isolated plots spiked to 67 lb/Ac by mid-August and then declined during the rest of the season. Due to the extremely wet weather during August and early September, the decline in the isolated plots may represent leaching and or denitrification during the wet period.

Figure 2 presents a summary of NH_4-N levels in the soil across the growing season. The NH_4-N levels at the beginning of the growing season were 63 and 105 lb N/Ac for the grassland and cropping system plots, respectively. These levels rapidly dropped to less than half of the original levels by the next two sampling dates. A spike occurred at the mid-July sampling but then dropped to relatively low levels for the rest of the season. The July spike may have been due to rainfall events which stimulated microbial activity resulting in an increase in mineralization of organic matter. From July on, the NH_4-N levels in the cropped and grassland were similar and paralleled each other. The NH_4-N in the isolation plots was similar to the non-isolated areas across the remainder of the season.

Figure 4 illustrates the relationship between soil organic matter (SOM) and average seasonal available mineral N. The relationship shows that each % increase in SOM is equivalent to approximately 8 lb N/Ac However, the relationship is relatively weak because due to the location and climate of soils in western North Dakota are highly variable but relatively stable regarding the soil biological environment.

Figure 3. A seasonal summary of total soil mineral N (NH_4 + NO_3-N) availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake. The data shown in these figures illustrates the fact that significant amounts of N are available in the soil across the growing season. However, not all of the N is available to plants at a given point in time. Each sampling point is a point in time and the N values for that sampling date would be what the plant has available at the time of sampling. Plant growth stage influences root development and distribution so that plants cannot access soil N where roots are not growing. In addition, new roots do not grow in dry soil so that, again, plants cannot access N in dry soil. Plants also do not access N well in excessively wet soils because of a lack of soil oxygen affects root activity. Wet or dry weather (soil) changes the potential for microbial mineralization, immobilization, or N transformations in soil as well as N movement into or out of the rooting zone as soil moisture conditions change. All of these affect the availability of N to crops. Further research is necessary to better establish how the N availability changes from season to season in response to changing conditions over time.

Impact of Results

1. Effect of spring wheat yields when grown continuously or as a component within a diverse crop rotation

The impact of HRSW grown continuously compared to HRSW grown in a 5-crop rotation is shown in Figures 1-7

Figure 1. Control and rotation HRSW yields (2011-2015).

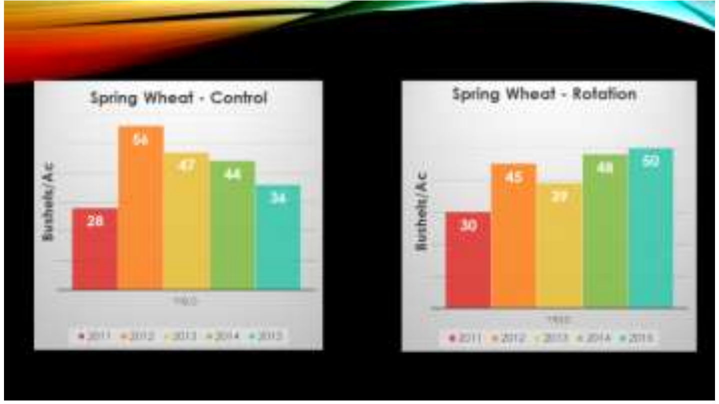


Figure 2. 5-Yr average control and rotation HRSW yield.

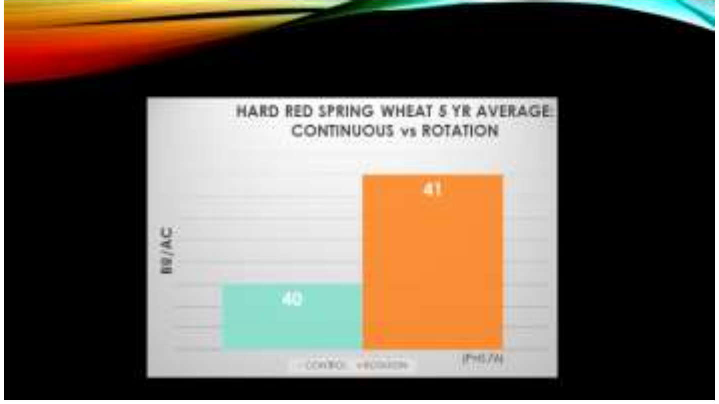


Figure 3. Multi-species cover crop yield within the 5-crop rotation.

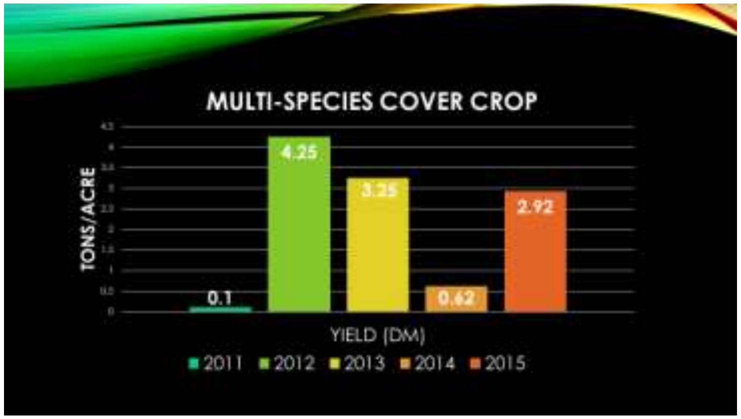


Figure 4. Crop rotation corn grain and silage yield (2011-2015).

Figure 5. Crop rotation sunflower yield and oil content (2011-2015).

Figure 6. Crop rotation field pea-barley intercrop forage yield (2011-2015).

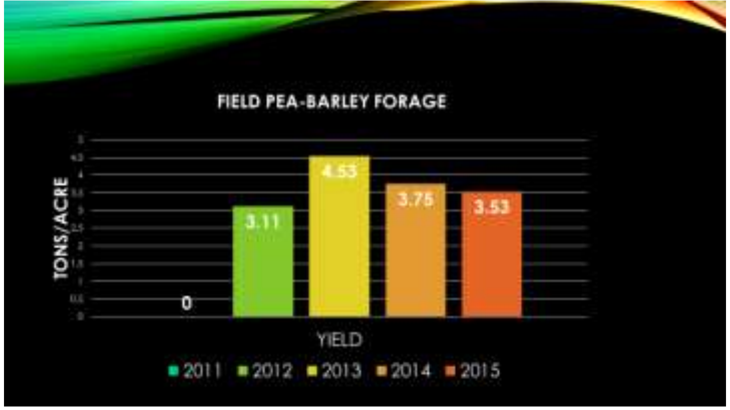
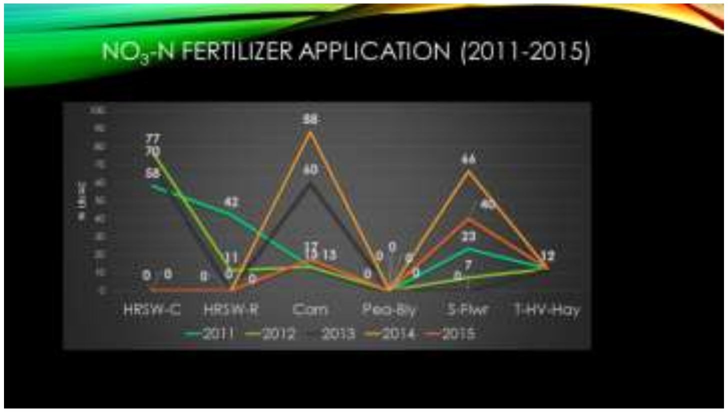


Figure 7. Seasonal Fertilizer Recommendations



NO$_3$-N FERTILIZER APPLICATION (2011-2015)

2. Consequence of perennial and annual forage grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass measurements, meat evaluation, and system net return

Forage sequence crude protein change is shown in Figures 1-4.

Fig. 1 Crested Wheatgrass CP change

Fig. 2. Native range CP change

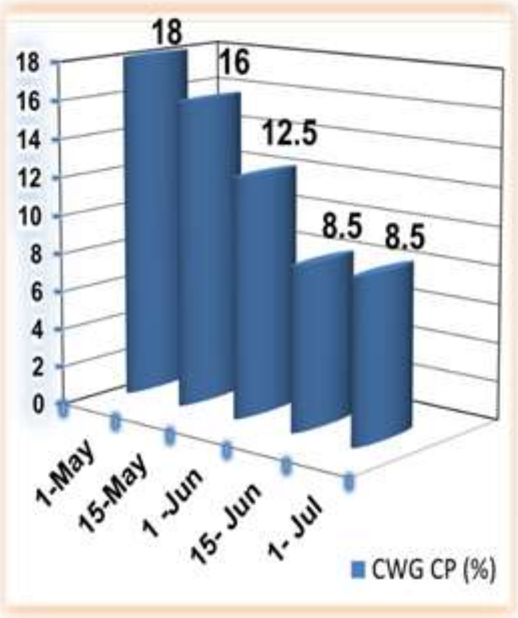


Fig. 3. Field Pea-Barley CP change

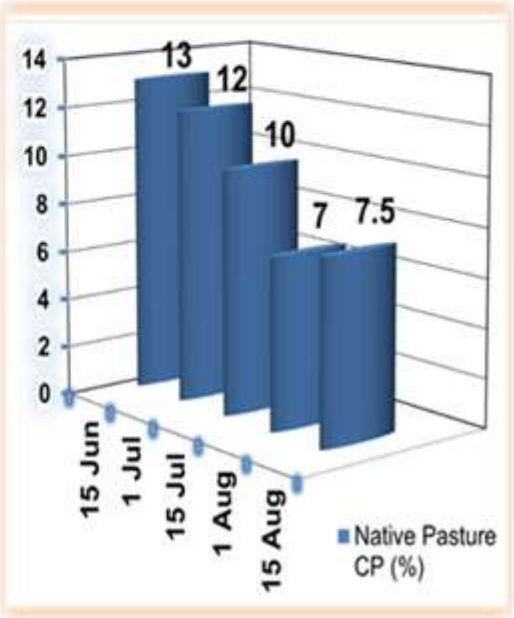
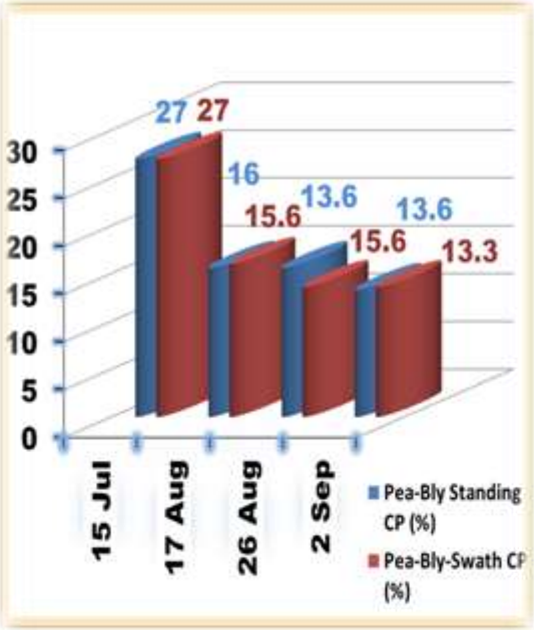


Fig. 4 Unharvested corn CP change



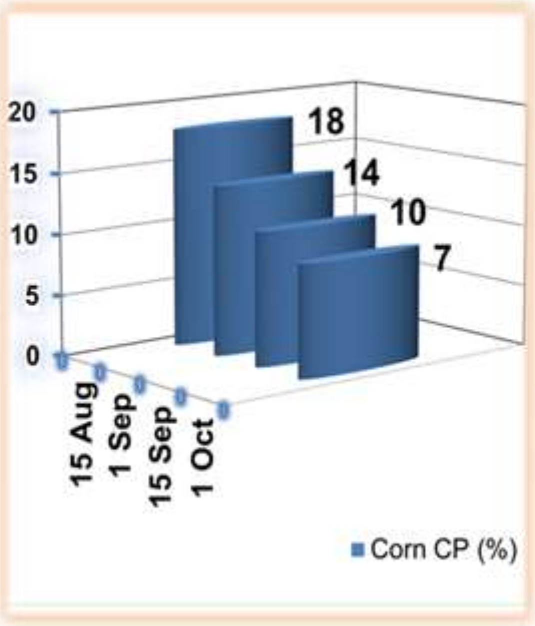


Table 1. Effect of extended grazing system on yearling steer pasture performance

				P-Value		
	PST[e]	ANN[e]	SE	Trt	Yr	Trt x Yr
No. Steers	48	47				
Pasture:						
Days Grazed	181	183				
Start Wt., lb	814	826	5.59	0.058	<0.0001	0.76
End Wt., lb	1122[a]	1231[b]	8.39	<0.0001	0.004	0.002
Gain, lb	309[a]	405[b]	5.54	<0.0001	<0.0001	0.0001
ADG, lb	1.71[a]	2.21[b]	0.03	<0.0001	<0.0001	0.0003
Cost/Head, $[c, d]	157.19[a]	238.36[b]	0.81	<0.0001	0.36	0.005
Cost/Lb Gain, $	0.5571	0.5924	0.015	0.14	<0.0001	0.001

[a-b] Means within a row with different superscripts differ ($P < 0.05$).

[c] Field Pea-Barley Crop Input Cost – Seed $25.40/ac, Seeding $15/ac, Innoculant $5.08/ac, Pre-Plant Chemical $3.18/ac, Windrowing $10/ac, Land Rent $30/ac = ($88.66/ac x 13.5 ac)/24 Steers = $49.87/Steer; Mean Days Grazed: 26 days

[d] Unharvested Corn – Seed $47.82/ac, Planting $15/ac, Fertilizer (Urea $37.85/ac, MESZ $28.69/ac, Potash $4.96/ac), Chemical $3.43/ac, Land Rent $30/ac = (167.75/ac x 13.5 ac)/24 Steers = $94.36/Steer; Mean Days Grazed: 52 days

[e] PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot

Table 2 Effect of extended grazing forage system on ribeye area, fat depth, and percent intramuscular fat

				P-Value		
	PST[a]	ANN[a]	SE	Trt	Yr	Trt x Yr
Ultrasound Measurement:						
Ribeye Area, sq. in.						
Start	7.57	7.60	0.024	0.47	0.005	0.47
End	8.66[a]	10.86[b]	0.11	<0.0001	0.54	0.01
Difference	1.09	3.27	0.11	<0.0001	0.18	0.01
Pct. Difference, %	14.4	43.1	1.48	<0.0001	0.13	0.0009
Fat Depth, in.						
Start	0.16	0.16	0.0061	0.67	0.20	0.75
End	0.23	0.33	0.0076	<0.0001	<0.0001	0.0006
Difference	0.07	0.17	0.007	<0.0001	<0.0001	0.0003
Pct. Difference, %	42.8	109.2	4.66	<0.0001	<0.0001	0.0005
Pct. Intramuscular Fat, %						
Start	3.37	3.43	0.065	0.33	0.005	0.46
End	3.22	4.13	0.11	0.0003	0.047	0.25
Difference	-0.15	0.70	0.11	0.0007	0.008	0.39
Pct. Difference, %	-5.9	19.9		0.0008	0.004	0.43

[a] PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot

Table 3. Feedlot performance, efficiency, and cost of gain comparison between extended grazing and feedlot direct systems

					P-Value		
	PST[e]	ANN[e]	FLT[e]	SE	Trt	Yr	Trt x Yr
No. Steers[d]	48	47	46				
Feedlot Days on Feed	91	66	142				
Kill age, Months	22.1[a]	21.4[b]	18.1[c]	0.043	<0.0001	0.0001	0.003
Feedlot Start Wt., lb	1073[a]	1189[b]	808[c]	15.1	<0.0001	0.65	0.002
Feedlot End Wt., lb	1488[a]	1479[a]	1350[b]	18.1	0.0002	0.71	0.21

Feedlot Gain, lb	416^{a}	290^{b}	538^{c}	12.1	<0.0001	0.27	0.014
Feedlot ADG, lb	4.59^{a}	4.41^{a}	3.81^{b}	0.15	0.006	0.33	0.006
Feed/Head, lb	2605^{a}	1859^{b}	3701^{c}	64.27	<0.0001	0.03	0.002
Feed/Head/Day, lb	28.0^{a}	26.9^{a}	25.3^{b}	0.52	0.01	0.04	0.19
Feed:Gain, lb	6.23^{a}	6.15^{a}	6.91^{b}	0.24	0.018	0.19	0.0001
Feed Cost/Head, $	381.18^{a}	276.12^{b}	578.30^{c}	7.62	<0.0001	<0.0001	0.0002
Feed Cost/Lb Gain, $	0.9283^{a}	0.9550^{a}	1.08^{b}	0.035	0.005	0.003	0.001

$^{a-c}$Means within a row with different superscripts differ ($P < 0.05$).

^{d}Annual Forage, one steer died of bloat after entry into unharvested corn; Feedlot Control, one steer bloated and died each year.

^{e} PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot; FLOT – control system; feedlot growing-finishing

Table 4. Carcass closeout and quality grade comparison between extended grazing and feedlot direct systems

					P-Value		
	PST^{e}	ANN^{e}	FLT^{e}	SE	Trt	Yr	Trt x Yr
No. Steers	48	47	46				
Hot Carcass Weight	854.5^{a}	850.7^{a}	774.8^{b}	9.30	<0.0001	0.14	0.032
REA (Ribeye Area)	13.0^{a}	12.54^{b}	12.10^{c}		0.078	<0.0001	0.16
SE^{d}	(0.22)	(0.20)	(0.33)				
Fat Depth	0.51^{a}	0.50^{a}	0.37^{b}		0.033	0.91	0.001
SE^{d}	(0.022)	(0.021)	(0.032)				
Marbling Score	516.0	529.7	501.2		0.58	<0.0001	0.82
SE^{d}	(19.2)	(18.1)	(27.5)				
Yield Grade	2.93^{a}	2.82^{a}	2.41^{b}		0.042	<0.0001	0.0001
SE^{d}	(0.083)	(0.077)	(0.123)				
Percent Choice or Better, %	82.1	86.5	65.6		0.312	0.017	0.023
SE^{d}	(6.15)	(5.70)	(9.46)				

$^{a-c}$ Means within a row with different superscripts differ ($P < 0.05$).

^{d} SE: hot carcass weight used in covariate analysis

^{e} PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot; FLOT – control system; feedlot growing-finishing

Table 6. Effect of yearling steer growing and finishing production system on Warner-Bratzler shear force, cooking yields, and sensory panel evaluation of beef loin

Treatment^{a}	WBSF, lbs	Cooking Yield, %
Annual Forage	6.93 ± 0.266	84.2 ± 1.04
Grass	7.78 ± 0.266	81.0 ± 1.04
Feedlot Control	7.30 ± 0.266	82.5 ± 1.04

	P = 0.109[c]	P = 0.062[c]

Treatment[a]	Tenderness[b]	Juiciness[b]	Flavor[b]
Annual Forage	5.02 ± 0.11	5.53 ± 0.10	5.87 ± 0.09
Grass	5.10 ± 0.11	5.63 ± 0.10	5.78 ± 0.09
Feedlot Control	5.54 ± 0.11	5.78 ± 0.10	5.91 ± 0.09
	P = 0.3998[c]	P = 0.2601[c]	P = 0.2451[c]

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[a] PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot; FLOT – control system; feedlot growing-finishing

[b] 1 = extremely tough, dry, bland; 8 = extremely tender, juicy, flavorful

[c] Means within a row with different superscripts differ ($P < 0.05$).

3. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics

Table 1. Native range pasture custom grazing rate calculation[1]

GRAZ SF[2]	Grazing Cost/Lb	Weight	Cost/day	Days	Period Total	Grazing Cost/ Steer/Day
Date In		In Weight				
May 1	0.001125	652	$0.73	54	$39.61	
Date Out		Out Weight				
Aug 17	0.001125	890	$1.00	55	$55.07	
Pasture Cost/Steer				109	$94.68	$0.87
GRAZ LF[2]						
Date In		In Weight				
May 1	0.001125	757	$0.85	54	$45.99	
Date Out		Out Weight				
Aug 17	0.001125	1033	$01.16	55	$63.92	
Pasture Cost/Steer				109	$109.90	$1.01

[1] 2-Year Average on a per steer per day basis.

[2] SF; Small Frame, LF; Large Frame.

Table 2. Farming input cost for annual forages pea-barley and unharvested corn that were grazed[1]

	Pea Barley	Unharvested Corn
Custom Drilling or Planting/ac, $	12.00	15.00
Custom Chemical Application/ac, $	5.00	5.00
Custom Fertilizer Broadcast Application/ac, $	-	5.00
Windrowing/ac, $	10.00	-
Fertilizer/ac, $	-	40.25
Seed (Perfection pea, Haybet Barley; Pioneer P9690R Corn)/ac, $	47.00	62.50
Innoculant/ac, $	4.33	-
Chemical – Pea-Barley (Glyphosate, AMS, Helfire, Rifle D)	12.62	
Chemical – Corn (Glyphosate, AMS, Helfire)		7.92
Crop Insurance/ac, $	15.00	15.00
Land Rent/ac, $	35.00	35.00
Subtotal	140.95	185.67
Interest, 5.0%	7.05	9.28
Total Crop Input Cost/ac, $	148.00	194.95
Cost/Steer, $	83.25	104.79

[1] 2-Year average crop expenses.

Table 3. Effect of frame score on extended grazing performance and cost[1]

	GRAZ[2] LF[3]	GRAZ[2] SF[3]	SEM[4]	P Value
Number of Steers	24	24		
Frame Score	5.44[a]	3.60[b]	0.18	0.021
Days Grazed	219	219		
Growth Performance:				
Start Weight, lb	757	652	39.17	0.059
End Weight, lb	1264	1097	49.48	0.093
Gain, lb	507	445	15.07	0.13
ADG[4], lb	2.32	2.03	0.069	0.13
Grazing Cost:				
Perennial Pasture (109 Days), $	108.74	93.68		
Field Pea-Barley (30 Days), $	78.99	83.25		
Unharvested Corn (75 Days), $	104.23	104.79		
32% Crude Protein Suppl. (0.81 lb/d), $	11.18	11.18		
Grazing Cost/Head, $	303.14	292.90		

Grazing Cost/Lb of Gain, $	0.5979	0.6582		

[a-b] Means with unlike superscripts differ significantly $P \leq 0.05$.

[1] 2-Year average.

[2] GRAZ steers grazed a forage sequence of native range, field pea-barley intercrop, and unharvested corn.

[3] SF; Small Frame, LF; Large Frame.

[4] SEM; Pooled Standard Error of The Mean, Trt; Treatment, Yr; Year, Trt x Yr; Treatment x Year, ADG; Average Daily Gain.

Table 4. Effect of steer frame score and extended grazing on feedlot finishing performance, efficiency, and economics[1]

	FLOT[2]	FLOT[2]	GRAZ[2]	GRAZ[2]		P-Value		
	LF[3]	SF[3]	LF[3]	SF[3]	SEM[4]	Trt[4]	Yr[4]	Trt x Yr[4]
Number of Steers	24	24	24	24				
Frame Score	5.54	3.67	5.44	3.60	0.231	0.0012	0.014	0.62
Growth Performance:								
Grazing Days	-	-	219	219				
Feedlot Days Fed	222	222	70	70				
Start Weight, lb	750[c]	660[d]	1228[a]	1105[b]	39.94	0.0004	<0.0001	0.53
End Weight, lb	1501	1290	1566	1407	53.88	0.140	0.0002	0.69
4% Shrunk Slaughter Weight, lb	1441[b]	1238[d]	1503[a]	1351[c]	54.80	0.022	<0.0001	0.743
Gain, lb	751[a]	630[b]	338[c]	302[c]	18.17	<0.0001	0.316	0.98
ADG[4], lb	3.38	2.84	4.83	4.31	0.123	0.094	0.82	0.22
Feed Intake and Efficiency:								
DM[4] Feed/Steer/Day, lb	26.08[a]	21.94[b]	26.04[a]	24.00[c]	0.656	<0.0001	<0.0001	<0.0001
DM Feed/lb of Gain, lb	7.72[a]	7.73[a]	5.39[b]	5.57[b]	0.231	0.007	<0.0001	<0.0001
Finishing Economics:								
Feed Cost/Steer, $	632.12[a]	541.01[b]	193.88[cd]	177.92[d]	11.87	<0.0001	<0.0001	0.057
Feed Cost/Steer/Day, $	2.85	2.45	2.55	2.34	0.069	0.149	<0.0001	0.128
Feed Cost/Lb of Gain, $	0.84[a]	0.86[a]	0.57[b]	0.59[b]	0.0248	0.0155	0.0021	0.397

[a-d] Means with different superscripts within a line are significantly different, ($P \leq 0.05$)

[1] 2-Year average.

[2] FLOT steers moved directly to the feedlot for growing and finishing; and GRAZ steers grazed a sequence of native range, field pea-barley intercrop, and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3] SF; Small Frame, LF; Large Frame.

[4] SEM; Pooled Standard Error of the Mean, Trt; Treatment, Yr; Year, Trt x Yr; Treatment x Year, ADG; Average Daily Gain, DM; Dry Matter.

Table 5. Effect of steer frame score and extended grazing on carcass trait measurements and value[1]

	FLOT[2]	FLOT[2]	GRAZ[2]	GRAZ[2]		P-Value

	LF[3]	SF[3]	LF[3]	SF[3]	SEM[4]	Trt[4]	Yr[4]	Trt x Yr[4]
Number of Carcasses								
Hot Carcass Weight, lb	867	752	882	774	32.66	0.154	<0.0001	0.948
Dressing Percent, %	60.23^{a}	60.7^{a}	58.7^{b}	57.3^{b}	0.319	0.018	0.0002	0.148
Fat Depth, in	0.45	0.48	0.33	0.42	0.018	0.469	<0.0001	0.915
Ribeye Area, sq. in	13.2^{a}	12.0^{b}	13.2^{a}	12.3^{b}	0.277	0.050	0.0002	0.282
USDA Yield Grade	2.41	2.61	2.07	2.24	0.089	0.139	<0.0001	0.019
Marbling Score	595	646	573	635	10.82	0.459	0.0019	0.990
Percent Choice, %	91.7^{a}	95.8^{a}	89.6^{b}	97.9^{a}	2.811	0.050	0.0004	0.163
Carcass Value/Steer, $	2073.33^{b}	1820.33^{d}	2223.67^{a}	1974.17^{c}	77.78	0.001	<0.0001	0.017
Warner-Bratzler Shear Force, lb	5.36	5.32	5.81	5.81	0.135	0.483	<0.001	0.291
Cooking Loss, %	17.85	17.61	17.50	15.40	1.17	0.432	<0.001	0.115

[a-d] Means with different superscripts within a line are significantly different, ($P \leq 0.05$)

[1] 2-Year average.

[2] Steers were slaughtered at the Cargill Meat Solutions packing plant, Ft. Morgan, Colorado

[2] FLOT steers moved directly to the feedlot for growing and finishing; and GRAZ steers grazed a sequence of native range, field pea-barley intercrop, and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3] SF; Small Frame, LF; Large Frame.

[4] SEM; Pooled Standard Error of the Mean, Trt; Treatment, Yr; Year, Trt x Yr; Treatment x Year.

4. Effect of heifer frame score on growth, fertility, and economics

Table 1. Forage, Hay, TMR, and Co-Product Supplement Nutrient analysis, and co-product supplement composition (DM)

	Forage & Hay						Co-Product supplement			
	Unharvested Corn[a]	Corn Residue[a]	Mixed Hay[a]	Spring CWG[b]	Alfalfa Hay[c]	Feedlot TMR[h]	Composition [d]		Analysis[e,f]	
CP (%)	9.72	7.75	11.3	11.3	18.4	18.9	DDGS (%)[g]	30.23	CP (%)	20.39
ADF (%)	29.3	41.8	37.3	34.4	32.0	28.6	BMS (%)[g]	30.00	ADF (%)	13.88
NDF (%)	51.1	70.2	56.7	63.6	43.3	42.5	WM (%)[g]	15.00	NDF (%)	36.65
TDN (%)	67.4	56.3	62.1	59.0	63.4	67.8	SH (%)[g]	7.75	Crude Fat (%)	13.14
IVDMD (%)	74.1	50.0	67.1	68.1	72.1	77.1	Fat (%)	7.5	Fiber (%)	11.85
IVOMD (%)	72.5	46.6	66.9	67.9	69.7	74.5	Molasses (%)	5.00	Starch (%)	5.99
Calcium (%)	0.21	0.21	1.22	0.39	1.55	1.29	Sodium Phos (%)	3.25	Calcium (%)	0.19
Phosphorus (%)	0.33	0.09	0.16	0.24	0.19	0.43	Salt (%)	0.75	Phosphorus (%)	1.56
NEm Mcal/kg	1.67	1.30	1.41	1.42	1.55	1.65	Urea (%)	0.35	NEm Mcal kg^{-1}	2.07
NEg Mcal/kg	0.95	0.64	0.69	0.70	0.83	0.95	TM Pre-Mix (%)	0.15	NEg Mcal kg^{-1}	1.41
ME Mcal/kg	2.51	2.29	2.20	2.22	2.37	2.51	Vit. Pre-Mix (%)	0.025	ME Mcal kg^{-1}	3.07

[a] Unharvested corn, corn residue, and supplemental hay fed during the 209 d period between October and May 2011.
[b] Crested wheatgrass grazed during the early spring and summer prior to feedlot confinement for growing and breeding.
[c] Alfalfa hay fed during the 85 d feedlot confinement growing and breeding period.
[d] Composition of co-product supplement fed with alfalfa hay during the feedlot confinement growing and breeding period.
[e] Trace Mineral Content: Potassium, 0.77%; Sodium, 1.33%; Chloride, 0.64%; Magnesium, 0.19%; Sulfur, 0.41%; Manganese, 169.13 ppm; Iron, 103.22 ppm; Copper, 106.01 ppm; Zinc, 377.64 ppm; Cobalt, 1.81 ppm; Iodine, 8.86 ppm.
[f] Vitamin Content: Vitamin E, IU 22.12; Vitamin A, IU 22.12; Vitamin D_3 2.21; Thiamine, 1.98 mg.[g] DDGS-distiller's dried grain with solubles, BMS-barley malt sprouts, WM-wheat middlings, SH-soybean hulls.
[h] TMR: 80% alfalfa and 20% co-product supplement

Table 2. Phases 1 and 2 pre-trial management growth performance and production cost

	Treatments[a]	
	SF	LF
Number of heifers	50	50
Phase 1 – fall-winter dormant grazing:		
Days (Oct 13-May10)	209	209
Start weight (Weaning, kg)	216	267
End weight (kg)	270	312
Gain (kg)	54	45
Average daily gain (kg)	0.258	0.215
Feed cost/heifer ($)	110.04	137.72
Feed cost day ($)	0.53	0.66
Phase 2 - spring crested wheatgrass grazing:		
Days (May 10-July 6)	58	58
Start weight (kg)	270	312
End weight (kg)	297	347
Gain (kg)	27	35
Average daily gain (kg)	0.466	0.603
Grazing cost/heifer ($)	18.13	21.05

[a] SF – Small frame heifers; LF – Large frame heifers.

Table 3. Phase 3 Growing-breeding period growth, efficiency and cost per day

	Treatments[a]			
	SF	LF	SEM[b]	P-value[c]
Number of heifers	50	50		
Heifer frame score	3.50	5.56	0.33	0.001
Growing-breeding growth				
Days (July 6 to Sept.29)	85	85		
Start weight (kg)	297	347	22.46	0.001
Start breeding weight (Aug 11) (kg)	320	382	24.33	0.001
End weight (kg)	369	429	28.68	0.001
Gain (kg)	72	82	8.63	0.09
Average daily gain (kg)	0.85	0.97	0.10	0.09
Growing-breeding feed efficiency (DM):				
Feed head/day (kg)	9.44	11.34	0.74	0.001
Feed:gain (kg)	11.14	11.75	0.48	0.41
Feed cost/heifer ($)	135.18	157.12	5.00	0.03
Feed cost/day ($)	1.5906	1.913	0.056	0.001
Feed cost/kg of gain ($)	0.87	0.91	0.037	0.41
Combined grazing and feedlot cost				
Total cost/heifer ($)	263.34	315.89		
Cost heifer/day (352 Days) ($)	0.75	0.90		

[a] SF – Small frame heifers; LF – Large frame heifers.

[b] SEM – Pooled standard error of the mean.

[c] Means are considered different at ($p \leq 0.05$).

Table 4. Effect of frame score on economically important ultrasound live animal measurements

	Treatments[a]			
	SF	LF	SEM[b]	p-value[c]
L. dorsi area (cm^2)				
May	35.12	37.89	0.895	0.002
October	46.42	50.62	1.01	0.04
Change	11.30	12.73	0.735	0.19
L. dorsi area/45.4 kg BW (cm^2)[d]				
May	2.20	1.78	0.113	0.02
October	1.56	1.26	0.081	0.003
Change	-0.64	-0.52	0.044	0.10
12th Rib Fat Thickness (mm)				
May	0.218	0.236	0.029	0.67
October	0.467	0.457	0.023	0.63
Change	0.249	0.221	0.035	0.48
Intramuscular Fat (%)				
May	2.23	2.20	0.007	0.07
October	3.22	3.13	0.129	0.59
Change	0.99	0.93	0.128	0.68

[a] SF – Small frame heifers; LF – Large frame heifers.

[b] SEM – Pooled standard error of the mean.

[c] Means are considered different at ($p \le 0.05$).
[d] Ratio contrasting L. dorsi muscle area/45.4 kg of BW.

Table 5. Effect of frame score on puberty, percent of mature BW, and reproductive performance

	Treatments[a]			
	SF	LF	SEM[b]	p-value[c]
Start breeding heifer age [d]	505	499	2.93	0.14
May heifer weight (kg)	270	312	21.02	0.003
May percent cycling (%)[d]	18.0	40.0	7.55	0.02
May percent of mature cow BW (%)[e]	48.7	46.8		
August start breeding weight (kg)	320	382	24.33	0.0002
Start breeding percent cycling (%)[d]	90.0	96.0	2.83	0.07
Start breeding percent of estimated mature cow BW (%)[e]	57.8	57.3		
Breeding cycle pregnancy (%)				
First cycle (21 d)	62.0	70.0	9.33	0.53
Second cycle (42 d)	16.0	10.0	4.80	0.40
Third cycle (63 d)	8.0	4.0	3.87	0.49
Total	86.0	84.0	5.57	0.62
Non-pregnant	14.0	16.0	5.57	0.62

[a] SF – Small frame heifers; LF – Large frame heifers.

[b] SEM – Pooled standard error of the mean.

[c] Means are considered different at ($p \le 0.05$).
[d] Serum progesterone assay recovered10 d apart. See text for assay details.
[e] Estimated mature cow BW from Dickinson Research Extension Center cow database: SF – 554 kg; LF – 667 kg.

5. Effect of Grazing Cover Crops, Stockpiled Improved Grass, and Crop Residues on Cow Wintering Performance, Economics, and Calving Rate

Table 1. 7-species cover crop blend, cost/Ac, and grazing cost/cow

Crop Blend	lb/Ac	Cost/lb, $	Cost/Ac, $
Sunflower	2	4.50	9.00
Everleaf Oat - 114	20	0.37	7.40
Winter Pea	20	0.40	8.00
Hairy Vetch	5	1.75	8.75
Winfred Forage Rape	1	3.50	3.50
Ethiopian Cabbage	1	4.00	4.00
Hunter Leaf Turnip	1	3.50	3.50
Total Seed Cost/Ac, $			44.15
Farming Cost & Property Tax/Ac, $			23.85
Cover Crop Cost/Ac, $			68.00
Grazing Cost/Cow, $			36.55

Table 2. Cow wintering treatment effect on grazing and drylot hay body weight and condition score change

				P –Value[3]		
	CC&RES[1]	GRAS&RES[1]	SEM[2]	Trt	Yr	Trt x Yr
Grazing:						
Number of Cows	48	48				
Number of Days Grazed	73	107				
Start Weight, lb	1500	1470	59.61	0.36	0.24	0.24
End Weight, lb	1518	1536	42.3	0.58	0.29	0.94
Gain, lb	18.0[a]	66.0[b]	19.12[c]	0.0001	0.84	0.0003
ADG, lb	0.25[a]	0.62[b]	0.19[c]	0.0001	0.40	0.0001
BCS						
Start BCS	5.6	5.4	0.16	0.10	0.006	0.94
End BCS	5.5	5.2	0.16	0.15	0.51	0.46
BCS Change	-0.10	-0.20	0.11	0.76	0.05	0.29
Drylot - Hay:						
Number of Cows	48	48				
Number of Days Fed Hay	61	27				
Start Weight, lb	1518	1536	42.3	0.58	0.29	0.94
End Weight, lb	1646	1582	46.5	0.06	0.90	0.84
Gain, lb	128[a]	46[b]	5.58[c]	0.0001	0.0001	0.21
ADG, lb	2.10	1.70	0.25	0.18	0.40	0.53
BCS						
Start BCS	5.5	5.1	0.15	0.13	0.58	0.52
End BCS	6.3	5.4	0.14	0.0001	0.60	0.45
BCS Change	0.80	0.30	0.088	0.0001	0.69	0.0009

[1] CC&RES: Cover Crop & Residue (Corn and Sunflower Residues), GRAS&RES: Stockpiled Grass & Residue (Corn Residue)

[2] SEM: Pooled standard error of the mean

[3] P-Values: Trt; (Treatment), Yr; (Year), and Tr x Yr; (Treatment x Year interaction)

[a-c] Means with different superscripts within a line are significantly different, ($P \leq 0.05$)

Table 3. Combined grazing and drylot hay wintering treatment effect on body weight and condition score change

					P- Value[3]		
	C[1]	CC&RES[1]	GRAS&RES[1]	SEM[2]	Trt	Yr	Trt x Yr
Number of Cows	48	48	48				
Total Winter Feeding Days	134	134	134				
Start Weight, lb	1490	1500	1470	59.8	0.62	0.15	0.40
End Weight, lb	1695	1646	1582	47.1	0.87	0.58	0.55
Gain, lb	205^{a}	146^{b}	112^{c}	17.3	0.0001	<0.0007	<0.0001
ADG, lb	1.53^{a}	1.10^{b}	0.84^{c}	0.13	0.0002	0.23	<0.0001
BCS							
Start BCS	5.7	5.6	5.4	0.25	0.57	0.0008	0.93
End BCS	6.5	6.3	5.4	0.21	0.38	0.10	0.30
BCS Change	0.79^{a}	0.71^{a}	0.0^{b}	0.15	0.05	0.15	0.49

[1] C: Control (Drylot Hay), CC&RES: Cover Crop & Residue (Corn and Sunflower Residues), GRAS&RES: Stockpiled Grass & Residue (Corn Residue)

[2] SEM: Pooled standard error of the mean

[3] P-Values: Trt; (Treatment), Yr; (Year), and Tr x Yr; (Treatment x Year interaction)

[a-c] Means with different superscripts within a line are significantly different, ($P \leq 0.05$)

Table 4. Cow wintering treatment effect on calving cycle and total calving percent.

					P- Value[3]		
	C[1]	CC&RES[1]	GRAS&RES[1]	SEM[2]	Trt	Yr	Trt x Yr
Number of Cows	48	48	48				
First Calving Cycle, %	72.6	69.3	60.5	3.92	0.12	0.005	0.035
Second Calving Cycle, %	10.4	23.8	20.8	4.66	0.15	0.18	0.52
Third Calving Cycle, %	6.3	2.1	8.3	2.79	0.26	0.004	0.27
Open, %	10.7	4.8	10.4	3.70	0.47	0.45	0.48
Total Calving, %	89.3	95.2	89.6	3.70	0.46	0.44	0.47

[1] C: Control (Drylot Hay), CC&RES: Cover Crop & Residue (Corn and Sunflower Residues), GRAS&RES: Stockpiled Grass & Residue (Corn Residue)

[2] SEM: Pooled standard error of the mean

[3] P-Values: Trt; (Treatment), Yr; (Year), and Tr x Yr; (Treatment x Year interaction)

6. Bulk density comparison within a crop rotation in Western North Dakota

Table 1 Root growth limiting bulk density values by soil texture [a]

Soil Texture		Root Limiting Bulk Density (g/cc)
Sand		1.8
Fine Sand		1.75
Sandy Loam		1.70
Fine Sandy Loam		1.65
Loam		1.55
Silt Loam		1.45
Clay Loam		1.50
Clay		1.4

[a] From Tree Root Growth Control Series: Soil Constraints on root Growth, Kim D. Coder, University of Georgia, 1998, FOR98-10

Table 2. Fields, soil texture, bulk density (BD) values taken at 0-4” and 7-11”

Sample #	Soil Texture	BD		Sample #	Soil Texture	BD
1913 S1 0-4"	Silty Clay Loam	1.32		1918 S2 0-4"	Silt Loam	1.5
1913 S1 7-11"	Silty Clay Loam	1.39		1918 S2 7-11"	Silt Loam	1.43
1913 S2 0-4"	Silt Loam	1.42		1918 S3 0-4"	Silty Clay Loan	1.45
1913 S2 7-11"	Silt Loam	1.38		1918 S3 7-11"	Silty Clay Loan	1.47
1913 S3 0-4"	Silty Clay Loam	1.47		1919 S1 0-4"	Silty Clay Loan	1.47
1913 S3 7-11"	Silty Clay Loam	1.39		1919 S1 7-11"	Silty Clay Loan	1.51
1914 S1 0-4"	Silty Clay Loam	1.43		1919 S2 0-4"	Silty Clay Loan	1.46
1914 S1 7-11"	Silty Clay Loam	1.37		1919 S2 7-11"	Silty Clay Loan	1.34
1914 S2 0-4"	Silty Clay Loam	1.62		1919 S3 0-4"	Silty Clay Loan	1.43
1914 S2 7-11"	Silty Clay Loam	1.35		1919 S3 7-11"	Silty Clay Loan	1.31
1914 S3 0-4"	Silty Clay Loam	1.46		1920 S1 0-4"	Silty Clay Loan	1.51
1914 S3 7-11"	Silty Clay Loam	1.45		1920 S1 7-11"	Silty Clay Loan	1.35
1915 S1 0-4"	Silty Clay Loam	1.56		1920 S2 0-4"	N/A	1.45
1915 S1 7-11"	Silty Clay Loam	1.42		1920 S2 7-11"	N/A	1.37
1915 S2 0-4"	Silty Clay Loam	1.47		1920 S3 0-4"	Silty Clay Loan	1.41
1915 S2 7-11"	Silty Clay Loam	1.41		1920 S3 7-11"	Silty Clay Loan	1.44
1915 S3 0-4"	Silty Clay Loam	1.46		1921 S1 0-4"	Silty Clay Loan	1.58
1915 S3 7-11"	Silty Clay Loam	1.33		1921 S1 7-11"	Silty Clay Loan	1.48
1916 S1 0-4"	Silty Clay Loam	1.49		1921 S2 0-4"	Silt Loam	1.56
1916 S1 7-11"	Silty Clay Loam	1.51		1921 S2 7-11"	Silt Loam	1.41
1916 S2 0-4"	Silty Clay Loam	1.49		1921 S3 0-4"	Silty Clay Loan	1.65
1916 S2 7-11"	Silty Clay Loam	1.51		1921 S3 7-11"	Silty Clay Loan	1.69
1916 S3 0-4"	Silty Clay Loam	1.54		1922 S1 0-4"	Silty Clay Loan	1.66
1916 S3 7-11"	Silty Clay Loam	1.44		1922 S1 7-11"	Silty Clay Loan	1.49
1917 S1 0-4"	Silty Clay Loam	1.47		1922 S2 0-4"	Silty Clay Loan	1.63
1917 S1 7-11"	Silty Clay Loam	1.49		1922 S2 7-11"	Silty Clay Loan	1.52
1917 S2 0-4"	Silty Clay Loam	1.4		1922 S3 0-4"	Silty Clay Loan	1.53
1917 S2 7-11"	Silty Clay Loam	1.45		1922 S3 7-11"	Silty Clay Loan	1.45
1917 S3 0-4"	Silty Clay Loam	1.53		1923 S1 0-4"	Silty Clay Loan	1.6
1917 S3 7-11"	Silty Clay Loam	1.47		1923 S1 7-11"	Silty Clay Loan	1.51
1918 S1 0-4"	Silt Loam	1.47		1923 S2 0-4"	Sandy Loam	1.69
1918 S1 7-11"	Silt Loam	1.46		1923 S2 7-11"	Sandy Loam	1.59

Table 3. Fields, soil texture, bulk density (BD) values taken at 0-4” and 7-11” (continued)

Sample #	Soil Texture	BD		Sample #	Soil Texture	BD
1923 S3 0-4"	Silty Clay Loam	1.64		1928 S3 7-11"	Sandy Loam	1.66
1923 S3 7-11"	Silty Clay Loam	1.54		1929 S1 0-4"	Sandy Loam	1.63
1924 S1 0-4"	Sandy Loam	1.73		1929 S1 7-11"	Sandy Loam	1.55
1924 S1 7-11"	Sandy Loam	N/A		1929 S2 0-4"	Sandy Loam	1.6
1924 S2 0-4"	Sandy Loam	1.47		1929 S2 7-11"	Sandy Loam	N/A
1924 S2 7-11"	Sandy Loam	1.5		1929 S3 0-4"	Sandy Loam	1.64
1924 S3 0-4"	Sandy Loam	1.57		1929 S3 7-11"	Sandy Loam	1.54
1924 S3 7-11"	Sandy Loam	1.55		1930 S1 0-4"	Sandy Loam	1.67
1925 S1 0-4"	Sandy Loam	1.63		1930 S1 7-11"	Sandy Loam	1.61
1925 S1 7-11"	Sandy Loam	1.66		1930 S2 0-4"	Sandy Clay Loam	1.66
1925 S2 0-4"	Sandy Loam	1.58		1930 S2 7-11"	Sandy Clay Loam	1.62
1925 S2 7-11"	Sandy Loam	1.47		1930 S3 0-4"	Silt Loam	1.6
1925 S3 0-4"	Silty Clay Loam	1.63		1930 S3 7-11"	Silt Loam	1.53
1925 S3 7-11"	Silty Clay Loam	1.62		67B-21 S1 0-4"	Sandy Loam	1.14
1926 S1 0-4"	Silty Clay Loam	1.59		67B-21 S1 7-11'	Sandy Loam	1.26
1926 S1 7-11"	Silty Clay Loam	1.57		67B-21 S2 0-4"	Silty Clay Loam	1.07
1926 S2 0-4"	Silty Clay Loam	1.63		67B-21 S2 7-11'	Silty Clay Loam	1.11
1926 S2 7-11"	Silty Clay Loam	1.67		67B-21 S3 0-4"	Silty Clay Loam	1.27
1926 S3 0-4"	Silty Clay Loam	1.42		67B-21 S3 7-11'	Silty Clay Loam	1.52
1926 S3 7-11"	Silty Clay Loam	1.47		69B-16 S1 0-4"	Silty Clay Loam	1.3
1927 S1 0-4"	Silty Clay Loam	1.62		69B-16 S1 7-11'	Silty Clay Loam	1.33
1927 S1 7-11"	Silty Clay Loam	1.44		69B-16 S2 0-4"	Silty Clay Loam	1.41
1927 S2 0-4"	Sandy Clay Loam	1.67		69B-16 S2 7-11'	Silty Clay Loam	1.16
1927 S2 7-11"	Sandy Clay Loam	1.71		69B-16 S3 0-4"	Silty Clay Loam	1.22
1927 S3 0-4"	Sandy Loam	1.71		69B-16 S3 7-11'	Silty Clay Loam	1.36
1927 S3 7-11"	Sandy Loam	1.54		81B-19 S1 0-4"	Sandy Loam	1.63
1928 S1 0-4"	Sandy Loam	1.6		81B-19 S1 7-11'	Sandy Loam	1.6
1928 S1 7-11"	Sandy Loam	1.57		81B-19 S2 0-4"	Sandy Loam	1.56
1928 S2 0-4"	Sandy Loam	1.6		81B-19 S2 7-11'	Sandy Loam	1.58
1928 S2 7-11"	Sandy Loam	1.65		81B-19 S3 0-4"	Sandy Loam	1.54

Table 4. Native range, spring wheat control, and crop rotation bulk density values

	Native Range	Spring Wheat Control	Spring Wheat Rotation	Triticale Hairy Vetch/Cover Crop	Pea-Barley	Corn	Sunflower
Bulk Density (0-11”)[b]	1.375^{b}	1.552^{a}	1.545^{a}	1.538^{a}	1.49^{a}	1.473^{ab}	1.543^{a}

[c] Means within a row with unlike superscripts differ ($P < 0.05$).

Table 5. Bulk density statistical contrasts

Contrasts:	Crops	SEM	P-Value
Native Range		0.0394	0.178
versus	Spring Wheat	0.0394	0.001
	Pea-Barley	0.0394	0.06
	Sunflower	0.0394	0.001
	Triticale-H-Vetch/cover crop	0.0394	0.001
	Spring Wheat Control	0.0394	0.000
Spring Wheat Control	Corn	0.0394	0.407
versus	Spring Wheat	0.0394	1.000
	Pea-Barley	0.0394	0.725
	Sunflower	0.0394	1.000
	Triticale-H-Vetch/cover crop	0.0394	1.000
	Native Range	0.0394	0.000

Table 6. Crop yields

	2011	2012	2013	Average
Corn	15.00	55.30	88.90	52.74
Spring Wheat	30.10	45.10	34.30	36.50
Pea-Barley	-	3.11	4.52	3.82
Sunflower	891	1590	1959	1480
Triticale-H-Vetch	2.71	1.59	0.00	1.43
Cover Crop	0.00	4.25	2.84	2.36
Spring Wheat Control	28.03	55.70	45.17	42.97

7. Seasonal soil nitrogen mineralization within an integrated crop and livestock system

Figure 1. A seasonal summary of soil NO_3-N availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake

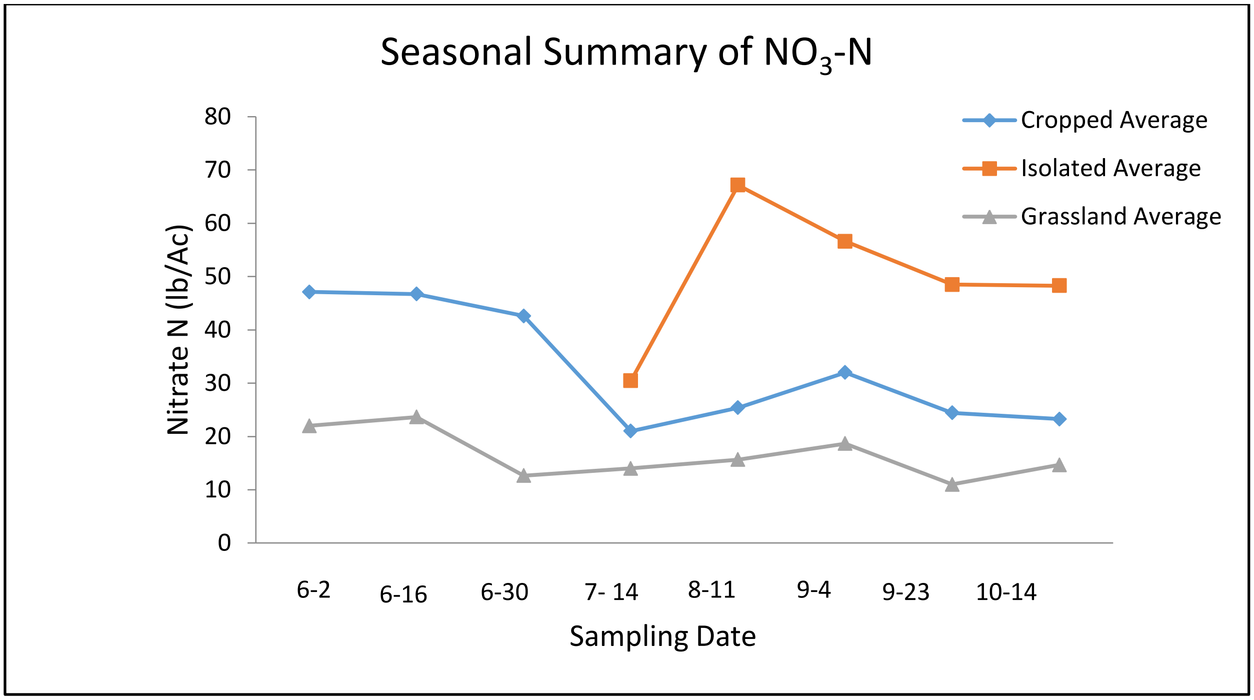


Figure 2. A seasonal summary of soil NH_4-N availability comparing the cropping systems with grassland pasture. The isolated N average is from areas in the cropping systems that are isolated from crop root uptake

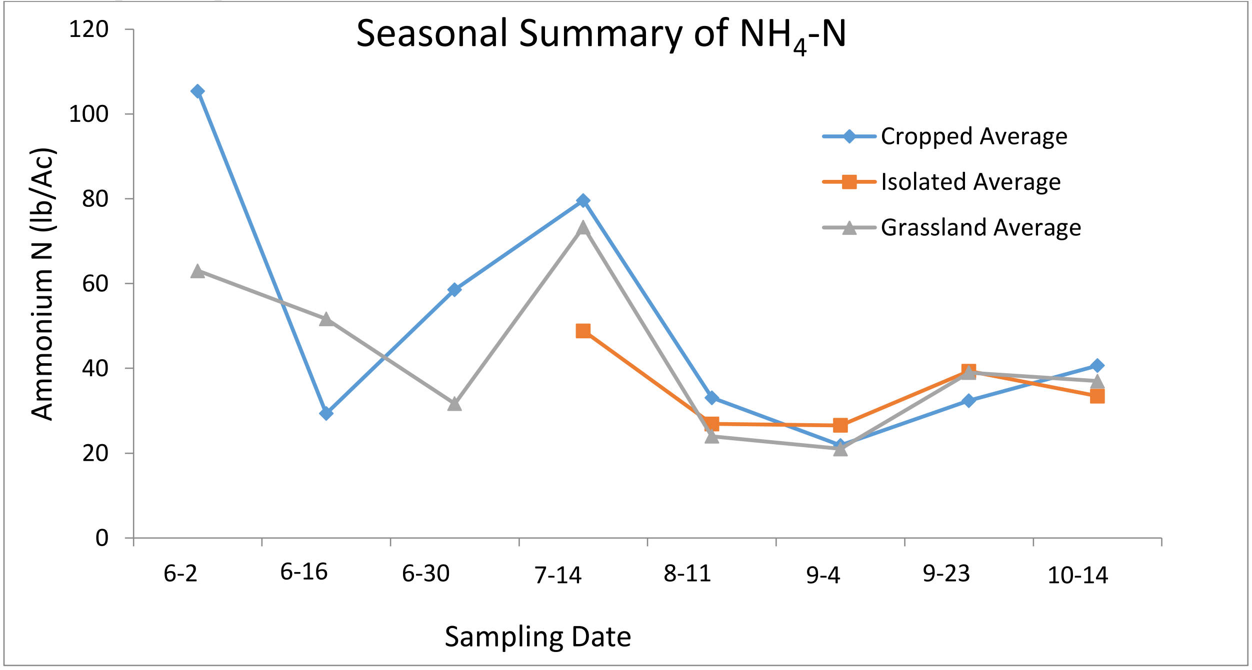


Figure 3. Shows the sum of the total plant available NH_4-N and NO_3-N in the soils across the growing season. The differences between the cropped plots and grassland and cropped plots and isolated plots reflect the combined information from Figures 1 and 2

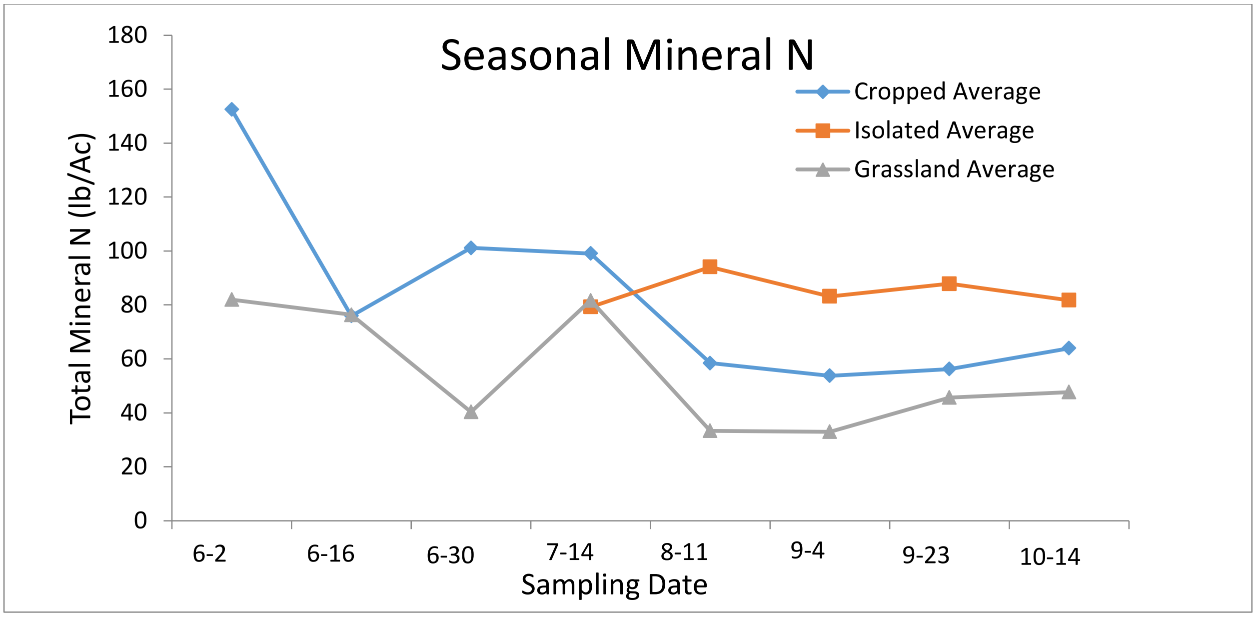
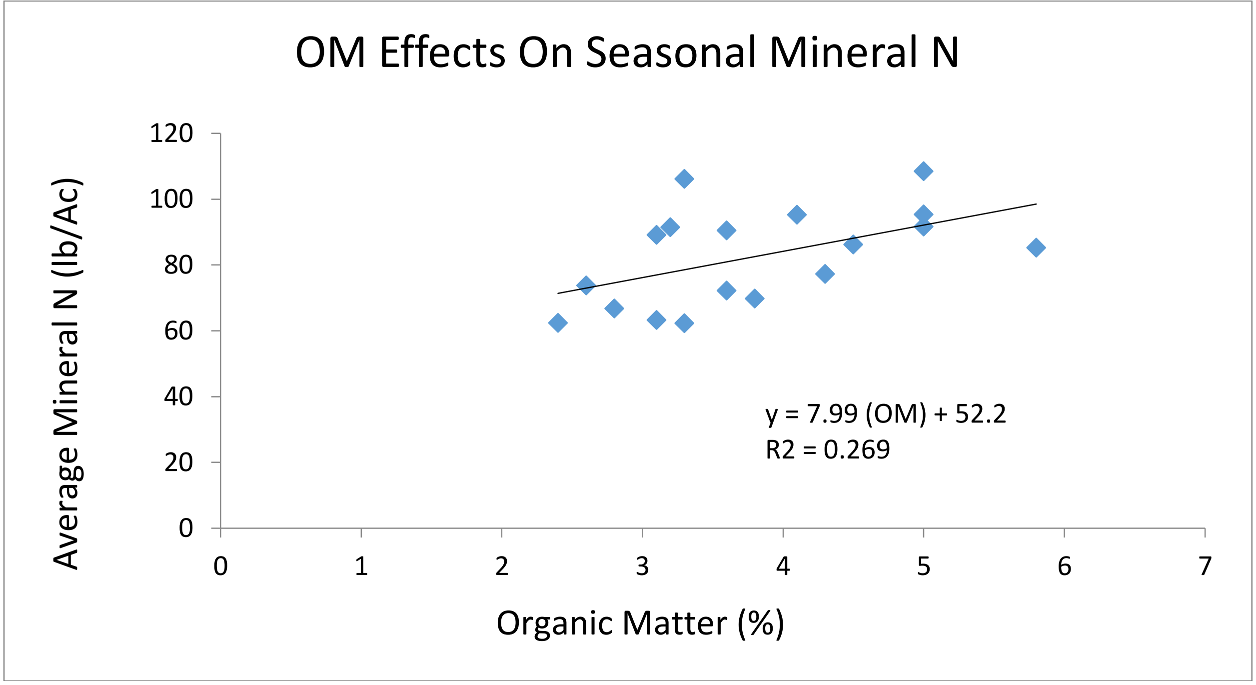


Figure 4. The relationship between soil organic matter and average soil mineral N



Economic Analysis

1. Effect of spring wheat yields when grown continuously or as a component within a diverse crop rotation

Figure 8. Annual control and rotation HRSW input cost and gross return/ac.

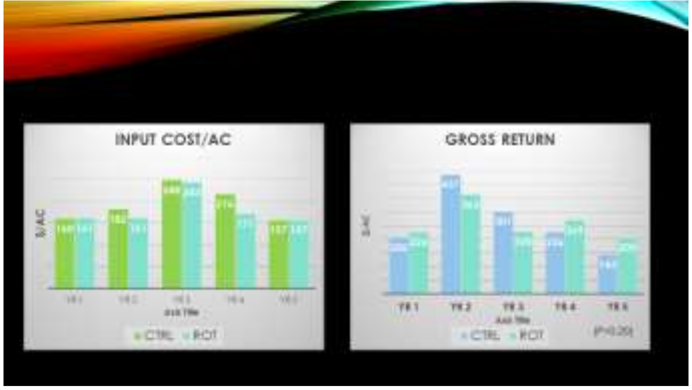


Figure 9. Annual control and rotation HRSW net return/ac.

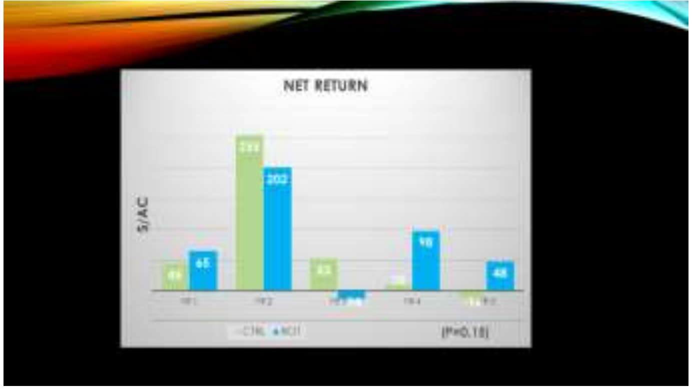


Figure 10. 5-Yr crop rotation input cost and gross return.

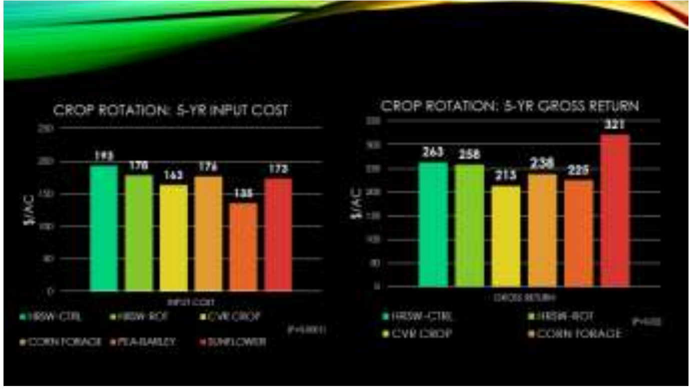


Figure 11. 5-Yr rotation crop average net return/ ac.

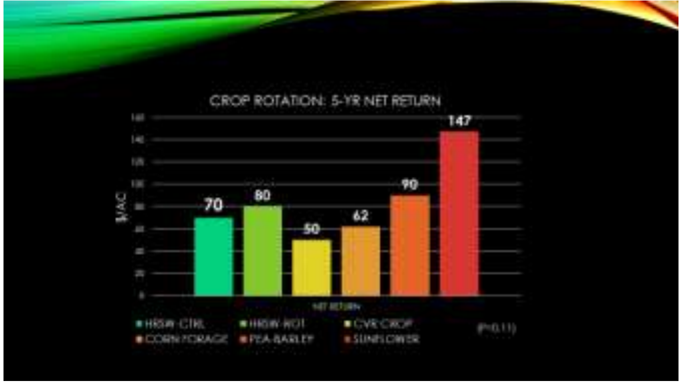
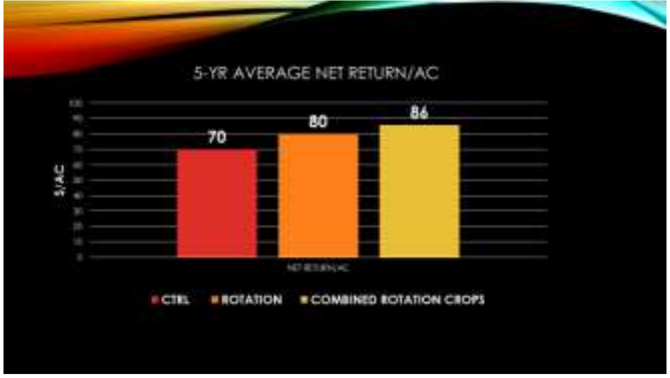


Figure 12. 5-Yr average net return for control and rotation HRSW and the combined rotation crops.



2. Consequence of perennial and annual forage grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass measurements, meat evaluation, and system net return

Table 5. Income, expense, and net return comparison between extended grazing and feedlot direct systems

	PST[a]	ANN[a]	FLT[a]
No. Steers	48	47	46
Income:			
Gross Carcass Value/Head, $	1718.41	1738.93	1497.41
Expenses:			
Steer Cost/Head, $	1041.72	1051.56	1034.02
Wintering Cost/Head, $	60.00	60.00	60.00
Grazing Cost/Head			
Perennial Grass, $	157.19	94.13	
Field Pea/Barley, $		49.87	
Standing Unharvested Corn,$		94.36	
Feedlot Feeding Cost/Head, $	381.18	276.12	578.30
Transportation, Health & Brand, $	108.42	103.80	123.14
Total System Expense/Head, $	1748.51	1729.84	1795.46

Net Return/Head, $	-30.10	9.09	-298.05

[e] PST – crested wheatgrass > native range > feedlot; ANN – crested wheatgrass > native range > field pea/barley > unharvested corn > feedlot; FLOT – control system; feedlot growing-finishing

3. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics

Table 6. Effect of steer frame score and extended grazing on system net return[1]

	FLOT[2] LF[3]	FLOT[2] SF[3]	GRAZ LF[3]	GRAZ SF[3]	SEM[4]	P-Value Trt[4]	Yr[4]	Trt x Yr[4]
Number of Steers	24	24	24	24				
Income:								
Carcass Value/Steer, $	2073.33[b]	1820.33[d]	2223.67[a]	1974.17[c]	77.78	0.001	<0.0001	0.017
Expenses:								
Cost/Steer, $	1229.80	1142.94	1173.06	1131.51				
Grazing Cost/Steer, $	-	-	303.14	292.90				
Feedlot Cost/Steer, $	632.12[a]	541.01[b]	193.88[cd]	177.92[d]	11.87	<0.0001	<0.0001	0.057
Transportation &Brand,$	23.40	23.40	27.09	27.09				
Total System Expense/Steer, $	1885.32	1707.35	1697.17	1629.42				
System Net Return/Steer, $	188.01	112.98	526.50	344.75				

[a-d] Means with different superscripts within a line are significantly different, (P≤0.05)

[1] 2-Year average.

[2] Steers were slaughtered at the Cargill Meat Solutions packing plant, Ft. Morgan, Colorado

[2] FLOT steers moved directly to the feedlot for growing and finishing; and GRAZ steers grazed a sequence of native range, field pea-barley intercrop, and unharvested corn before transfer to the feedlot at the University of Wyoming.

[3] SF; Small Frame, LF; Large Frame.

[4] SEM; Pooled Standard Error of the Mean, Trt; Treatment, Yr; Year, Trt x Yr; Treatment x Year.

4. Effect of heifer frame score on growth, fertility, and economics

Table 6. Heifer frame score development cost

	Treatments[a] SF	LF	SEM[b]	p-value[c]
Heifer value at weaning ($)	525	626	24.51	0.005
Total development cost/heifer ($)	789	939	24.51	0.001
End Heifer Value ($)	1025	1131	35.36	0.005
Net cost/pregnant heifer ($)[d]	745	899	32.30	0.004

[a] SF – Small frame heifers; LF – Large frame heifers.

[b] SEM – Pooled standard error of the mean.

[c] Means are considered different at (P≤0.05).

[d] Net cost per pregnant heifer was determined according to the procedure of Feuz (1992).

5. Effect of Grazing Cover Crops, Stockpiled Improved Grass, and Crop Residues on Cow Wintering Performance, Economics, and Calving Rate

Table 5. Cow wintering treatment effect on feed intake and winter feeding system economics.

					P- Value[3]		
	C[1]	CC&RES[1]	GRAS&RES[1]	SEM[2]	Trt	Yr	Trt x Yr
Hay & Supplement (DM)							
Hay/Cow, lb	4724^{a}	1824^{b}	891^{c}	44.33	<0.001	<0.0001	<0.0001
Hay/Cow/Day, lb	35.3	30.6	33.1	0.47	0.40	<0.0001	0.002
32% CP Suppl./Cow, lb	214	214	214				
32% CP Suppl./Cow/Day, lb	1.74	1.74	1.74				
Economics (Owned Land)							
Days Hay Fed	133.5	61	27				
Days Grazing	0	73	107				
Hay Cost/Cow, $	172.51^{a}	67.74^{b}	29.94^{c}	1.62	0.0001	0.0001	0.0001
32% CP Suppl Cost/Cow, $	36.30	36.30	36.30				
Cover Crop Cost/Cow, $	-	36.55	-				
Property Tax, $	-		7.09				
Total Winter Feeding Cost/Cow, $	208.81^{a}	140.59^{b}	73.33^{c}	1.9	<0.0001	<0.0001	<0.0008

[1] C: Control (Drylot Hay), CC&RES: Cover Crop & Residue (Corn and Sunflower Residues), GRAS&RES: Stockpiled Grass & Residue (Corn Residue)

[2] SEM: Pooled standard error of the mean

[3] P-Values: Trt; (Treatment), Yr; (Year), and Tr x Yr; (Treatment x Year interaction)

[a-c] Means with different superscripts within a line are significantly different, $(P \leq 0.05)$

6. Bulk density comparison within a crop rotation in Western North Dakota

7. Seasonal soil nitrogen mineralization within an integrated crop and livestock system

Publications and Outreach

Publications:

Landblom, D. G., S. Senturklu, and G. A. Perry. 2011. Effect of skeletal frame size and forage-based stair-step development system on growth and reproductive performance in replacement heifers. In: Dickinson Research Extension Center Annual Report, pp. 243-248.

Landblom, D. G., S. Senturklu, and G. A. Perry. 2012. Evaluation of skeletal frame score and a forage-based stair-step development system on replacement heifer growth and reproductive performance. In: 2012 North Dakota Beef Report, pp. 9-12.

Senturklu, S., D. G. Landblom, R. Maddock, and S. Paisley. 2012. Consequence of two grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass traits, meat acceptance, and net return. In: Dickinson Research Extension Center Annual Report, pp. 213-220.

Senturklu, S., D. G. Landblom, R. Maddock, and S. Paisley. 2013. Consequence of two grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass traits, meat acceptance, and net return. In the North Dakota Beef Report, pp. 37-41.

Landblom, D. G., 2013. Increasing sustainability of livestock production in the Northern Great Plains, In: Dickinson Research Extension Center Annual Report, pp. 275-276.

Senturklu, S., D. G. Landblom, R. Maddock, and S. Paisley. 2013. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics. In: Dickinson Research Extension Center Annual Report, pp. 281-284.
Senturklu, S., D. G. Landblom, G.A. Perry, T. Petry. 2013. Effect of heifer frame score on growth, fertility, and economics. Asian-Australas. J. Anim. Sci. (Abstract), In: Dickinson Research Extension Center Annual Report, pp. 285.
Lauren Pfenning and Doug Landblom. 2013. Bulk density comparison within a crop rotation in Western North Dakota. DSU Undergraduate Student Project (Abstract), In: Dickinson Research Extension Center Annual Report, pp. 286.
Lauren Pfenning and Doug Landblom. 2013. Bulk density comparison within a crop rotation in Western North Dakota. DSU Undergraduate Student Project Manuscript, Dickinson State University, Department of Agriculture and Technical Studies and Dickinson Research Extension Center Cooperating.
Senturklu, S., D. G. Landblom, R. Maddock, and S. Paisley. 2014. Consequence of perennial and annual forage grazing systems before feedlot entry on yearling steer grazing and feedlot performance, carcass measurements, meat evaluation, and system net return. Proc. West. Sec. Am. Soc. Anim. Sci. Vol. 65:106-110.
Senturklu, S., D.G. Landblom, R. Maddock, and S. Paisley. 2014. Evaluation of two yearling grazing systems before feedlot entry. Univ. Wyoming Agric. Exp. Station, 2014 Field Day Bulletin, SAREC Section, pp. 93-94.
Landblom, Douglas, Songul Senturklu, Larry Cihacek, Lauren Pfenning, and Eric Brevik. 2014. Seasonal soil nitrogen mineralization within an integrated crop and livestock system in Western North Dakota, USA. European Geoscience Union Annual Meeting, Soil Science Section 1.1, Vienna, Austria. In: Dickinson Research Extension Center Annual Report, pp. 393-394 (abstract).
Senturklu, Songul, Douglas Landblom, and Eric Brevik. 2014. Senior research connects students with a living laboratory as part of an integrated crop and livestock system. European Geoscience Union Annual Meeting, Soil Science Section 1.1, Vienna, Austria (abstract).
Senturklu, S., D. G. Landblom, R. J. Maddock, and S. I. Paisley. 2014. The combined effect of beef cattle frame score and forage grazing sequence on yearling steer grazing and feedlot performance, carcass trait measurements, and systems economics. In: Dickinson Research Extension Center Annual Report, pp. 395-398.
Senturklu, Songul and Douglas Landblom. 2014. Effect of grazing cover crops, stockpiled improved grass, and crop residues on cow wintering performance, economics, and calving rate. In: Dickinson Research Extension Center Annual Report, pp. 400-404.
Landblom, Douglas. 2014. Increasing sustainability of livestock production on the Northern Great Plains. In: Dickinson Research Extension Center Annual Report, pp. 405-406.
Cihacek, Larry, Douglas Landblom, Songul Senturklu, and Eric Brevik. 2014. Seasonal soil nitrogen mineralization within an integrated crop and livestock system. In: Dickinson Research Extension Center Annual Report, pp. 407-410.
Senturklu, S., D. G. Landblom, G. A. Perry, and T. A. Petry. 2015. Effect of heifer frame score on growth, fertility, and economics. Asian-Australasian J. Anim. Sci. Vol. 28(1):69-78; HTTP//dx.doi.org/10.5713/ajas.13.0833.
Şentürklü, S., D.G. Landblom, R. Maddock, S. Paisley, T. Petry, and R. Taylor. 2016. Effect of Delayed Feedlot Entry and Grazing Forage Sequence on Yearling Beef Steer Performance, Carcass Characteristics, and Systems Economics. J. Anim. Sci. Vol. (xx):xxxx (In preparation).

Outreach:

The Beef Cattle and Forage Field Day/Workshops have been held on August 29, 2012, August 19, 2013, and August 27, 2014, and August 27, 2015. Estimated attendance has been 120, 100, and 70, and 28 people during 2012, 2013, 2014, and 2015, respectively. A post-field day/workshop discussion session with dinner was held at the Center's main office in Dickinson. This session was well attended and people asked a wide variety of questions – some we could not answer –provided great food for thought. This post-field day event was very poorly attended in 2013 and was discontinued in the subsequent years.
2011 Beef Cattle & Forage Field Day Agenda (Doc.)

2012 Beef Cattle & Forage Field Day Agenda (Doc.)
Proceedings Presentations:
Dr. Kris Ringwall, DREC Director
Todd Churchill, President, Thousand Hills Cattle Company – No Proceeding Article

Dr. Chip Poland, DSU Dept. of Agric. and Technical Studies, Chairman
Dr. Songul Senturklu, Short-Term Turkish Research Scholar
Dr. Ron Bolze, Nebraska Grazing Lands Coalition Coordinator
Jerry Doan, Black Leg Ranch, McKenzie, ND
Doug Landblom, DREC Beef Cattle Specialist
Jon Stika, NRCS Soil Scientist
John Snider, PGG Seeds

2013 Beef Cattle & Forage Field Day Agenda (Doc.)
Proceedings Presentations:
Dr. Kris Ringwall, DREC Director
Dr. Allen Williams, Agriculture and Food Industry Consulting & Research
Dr. Songul Senturklu, Short-Term Visiting Research Scholar
Dr. Rob Maddock, NDSU Assoc. Professor, Meat Scientist
Doug Landblom, DREC Beef Cattle Specialist
Dr. Lee Manske, DREC Range Scientist
Lucas Hoff Lazy H Stock and Grain Farm, Richardton, ND
Derrick Dukart – Producer-Cooperator Farm Tour
Chris Augustin, NDSU Area Extension Soil Health Coordinator

2014 Beef Cattle & Forage Field Day Agenda (Doc.)
Proceedings Presentations:
Dr. Allen Williams, Ag. and Food Industry Consul. (Doc.)
Ryan Jepsen, Grass run farms (Doc.)
Dr. Songul Senturklu, Short-Term Turkish Visiting Research Scientist
Jason Gross, UNL Bio. Syst. Engr. (Doc.)
Lucas Hoff, SARE Farmer/Cooperator (Doc.)
Dr. Larry Cihacek, NDSU Soil Scientist (Doc.)
Derrick Dukart, Farmer/Cooperator (Doc.)
Doug Landblom, SARE Project Coordinator (Doc.)

2015 Beef Cattle & Forage Field Day Agenda (Doc.)
Proceedings Presentations:
Doug Landblom, DREC Beef Cattle Specialist
Fara Brummer, NDSU Area Extension Livestock Specialist
Dr. Songul Senturklu, Short-Term Turkish Visiting Research Scientist
Derrick Dukart, SARE Producer-Cooperator
Lucas Hoff, SARE Producer-Cooperator
Larry Cihacek, NDSU Soil Scientist

Short-Term outcomes are being accomplished by increasing awareness among producers and students. Producer demonstration projects are among the most positive and encouraging elements of the project that will help increase awareness of alternative approaches to crop production and cattle management, while improving the environment. Farmer-rancher cooperator demonstration projects at the Lucas Hoff and Derrick Dukart Farms included YouTube videos, www.ag.ndsu.edu/DickinsonREC/livestock-research and farm tours. Lucas Hoff and Derrick Dukart have been annual presenters at the annual field days at the Center and Derrick Dukart has hosted tours at his farm during the field days and discussed his cover crop fields and prospects for summer and winter grazing. Lucas and Jolene Hoff opened their farm and farm shop to host the Growing Beef with Forages program.
Growing Beef with Forages Program Agenda

High School Vo-Ag Field Day/Workshops have been attended by 50-60 students each year. Students are very interested in the integrated beef cattle and cropping systems research.
2012-2014 High School Vo-Ag Field Day/Workshop Program Agendas (Document)
High School Workshop Live Animal Tissue Evaluation by Dr. Songul Senturklu and Doug Landblom (Doc. 21)
Project PI, Doug Landblom program presentations:

Livestock Waste Management Annual Meeting: Invited Speaker: Effect of Extended Grazing Management on Economics & Manure Distribution (Doc.)
Southeastern Montana "Winter Series Meetings": Invited Speaker: "Winter Series Meetings" – Crop Diversity, Cover Crops, and Beef Production (Doc.)
Growing Beef with Forages Workshop: Program Speaker: Grazing Annual Forages, Cover Crops & Residues to Improve Your Bottom Line (Doc.)
Little Beaver Conservation District, NRCS, Soil Health Workshop: Invited Speaker: Soil Fertility, Cropping Systems, and Beef Production with Forages (Doc., ,)
County Agent and Livestock Specialist Training: Grazing Annual Forages, Cover Crops, Stockpiled Forage & Residues (Doc.)
DREC Advisory Board Meeting (Doc.)
Principles of Crop Production, PLSC-225, Invited Speaker: SARE Research: Integrated Crop and Livestock Grazing (Doc.)
Winter Grazing Workshop: Invited Speaker: Integrated System Approach to Fall & Winter Grazing (Doc.)

5. Popular press articles
Successful Farming, Mid-February 2013, pg. BI-2, "Corn-Feeding 2.0 Reboot" (Doc.)
Feedlot Magazine, February 2014, pg 18-19 (Doc.)
Farm and Ranch Guide, Friday, March 21, 2014, pg. 6A-7A: "Cover Crops: Multi-species best way to renovate soils" (Doc.)

Farmer Adoption

Transition from conventional farming practices to the combination of no-till, crop rotation, multi-species cover crop plantings, and beef cattle grazing will improve soil health characteristics over time. This research has shown that after as few as three years the effects of rotation on HRSW were beginning to emerge. Then in the 4th and 5th years of the study HRSW in rotation surpassed control HRSW by 38.9% as the amount of N fertilizer was reduced to zero. Producers are looking at the information and some are adopting more diverse crop rotations, using cover crops, and using cattle grazing to some extent. Grazing is much larger hurdle to get over, especially for producers that farm large tracts of land and do not have cattle. Cooperating with other farmers that do have cattle is certainly a way to introduce grazing into farms that do not raise cattle; however, strictly crop producers have often removed fences and have limited water resources making grazing very challenging. So, there are two very distinct polarized groups of producers. One group is the very large farmers that would like to incorporate the principles, but have difficulties managing large enterprises. Of course, it can be done, but many continue using traditional practices. Extremely low commodity prices in 2014-2015 may encourage farmers that have not considered fully adopting alternative cultural practices to make a changes and allow the soil to grow nutrients and compete more competitively with weed populations. The other group of producers are fully onboard and challenged to see just how much the soil can do for them. And then there are those producers that are in the middle. Producers that have tried using cover crops and incorporated into a makeshift rotation that didn't work out very well the first try and threw up their hands in disgust. The crop rotation in this study was not very successful the first year, but even though soil changes were not visible based on production, change was beginning and by the 4th year turnover was fully implemented. There is no question that producers are aware and have been exposed to the merits of alternative crop and livestock production. Now, producers need to attend meetings, visit with their neighbors that are actively making changes and begin to evolve into improved farming practices that take advantage of the soil's productive power when give a chance.

Areas Needing Additional Study

Minimizing reliance on harvested feeds through grazing and extending the grazing season beyond that which is typical in western ND is a management strategy that enhances economic and environmental stability, especially when grazing is integrated into a diverse crop rotation. Systems integration in this project (LNC11-335) identified that labor and inputs were reduced, soil fertility and crop yield improved, delayed feedlot entry of yearlings reduced days on feed and increased profitability, cow winter feed cost was reduced, and quality of life improved. Consumer demand for forage-finished beef is increasing by 25-30% per year and integrating forage-finished beef into the established crop rotation is a logical research succession, which needs to be continued to capture the long-term effect of integration on forage-finished beef grazing management, soil quality, nitrogen mineralization, carbon sparing, profitability, and farmer-family quality of life. The previous project established baseline soil bulk density, OM levels, seasonal soil nitrate-N fertility and end of season NO_3-N levels. Since soil dynamics change slowly, it is relevant to measure grazed and ungrazed soil quality dynamics in much greater detail. That is, maintenance of short and long-term carbon pools, water soluble soil organic nitrogen, seasonal soil NO_3-N fertility, residual soil nitrogen pools, microbial CO_2-C and soil C:N ratio change between crops within the rotation, soil GHG emissions, soil bulk density change, and soil water dynamics. On-farm cooperator projects are a very useful way to develop awareness and educate producers and certainly need to be a component of future research.