The Effects of Winter Feeding Systems on Beef Cow Performance, Soil Nutrients, Crop Yield and System Economics

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ABSTRACT

A study was conducted on an annual cropped field near Lanigan, Saskatchewan over two years (2005-2006, 2006-2007) to evaluate the effects of three extensive winter feeding systems (bale grazing (BG), swath grazing (SG) and straw-chaff grazing (ST-CH)) and one intensive winter feeding system (drylot (DL)) on cow performance, soil nutrients, crop yield and system cost of production.

Differences in BW ($P<0.05$) were observed during the 2005-2006 study period with the greatest difference occurring with cows in the SG feeding system. Cows grazing swaths (SG) had a BW loss of 8.0 kg over the 78 d trial period, however these cows consumed 15% less DM and 13% less TDN than cows bale grazing, grazing crop residue or fed in drylot pens. Differences in BW change ($P<0.05$) were also observed during Yr 2 between the cows fed drylot and cows grazing barley straw-chaff, 32.9 and 6.5 kg, respectively. This difference in body weight change (BWΔ) and lower TDN consumption may be attributed to inaccessibility of the straw-chaff feed in the field, due to inclement weather and would suggest a lengthy acclimation period for extensive field grazing systems.

The effects of extensive winter feeding system on soil nutrients and soil structure were determined the following spring after winter grazing. NO_3-N levels at the low slope position in the 0-15 cm depth were 53% higher on the BG sites than the ST-CH sites. This may be attributed to the larger concentration of feed, thus feed nutrients, in the BG feeding system. Phosphorus levels on the BG wintering sites were 34% higher than levels in the SG or ST-CH sites. Crop biomass measured on the BG sites was consistent with soil nutrients captured, resulting in a 15% increase in biomass compared to ST-CH and

SG sites. Soil nutrient and crop biomass distribution was consistent among winter grazing sites with the ST-CH sites having the most uniform distribution of nutrients and crop biomass, and the BG sites having the least.

LIST OF ABBREVIATIONS

BG	Bale grazing
SG	Swath grazing
ST-CH	Straw-chaff grazing
DL	Drylot
N	Nitrogen
P	Phosphorus
K	Potassium
S	Sulphur
NO_3-N	Nitrate nitrogen
NH_4-N	Ammonium nitrogen
DMI	Dry matter intake
TDN	Total digestible nutrients

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

1.0 INTRODUCTION

Producers use several management systems for wintering beef cows, each system having a different impact upon the plant-animal-soil interface, and the sustainability of the operation. Least cost production systems are essential when dealing with the economics associated with animal agriculture. In addition, agriculture has been criticized concerning negative impacts on the environment. The need for environmentally sensitive, low cost feeding systems is crucial; however research information regarding winter feeding systems for beef cattle is limited. Through proper management of nutrients, producers can strive to maintain a positive whole farm nutrient budget and thus increase their economics and decrease the environmental concerns pertaining to agriculture (Van Horn et al. 1996). Manure is a valuable resource and must be managed properly to ensure adequate utilization of its nutrients. Implementing techniques such as proper manure handling and application, sustainable wintering sites, and composting can benefit producers economically as well as decrease the environmental impact.

Historically, many producers have wintered the beef herd using what is termed a traditional drylot feeding system. The winter feeding period for beef cattle (*Bos taurus)* in western Canada is typically 200 d per year (Mathison 1993). Therefore a large cost is associated with supplying feed nutrients to pregnant beef cows. Studies have shown that harvested forage, such as hay, costs between$15 and $40 per tonne of dry matter which is double the cost for the same amount of nutrients from pasture (Kallenbach 2000). The cost of feeding bales has been reported by Volesky et al. (2002) to be 37% of the cost of harvesting the hay. This then leads to a substantial increase in cost of production per kilogram of beef for the producer. The producer will also have extra expenses related to corral cleaning, manure handling and facilities maintenance. Studies have shown that fall grazing annuals can result in improved cow body condition and postpone the onset of weight loss, as well as decrease costs by $47 per head (Willms et al. 1993). Hutton et al. (2004) reported that cows grazing windrowed oats maintained body condition and back fat similar to cattle fed a traditional winter ration. A recent study at the Western Beef Development Centre's, Termuende Research Ranch at Lanigan, Saskatchewan, compared field wintering systems on pasture land, to traditional drylot wintering systems. The study reported that wintering systems (bale grazing and bale processing) had no effect on cow weight or condition and field systems reduced costs by up to $0.58 per cow per day (Jungnitsch et al. 2004). Lardner (2005) has shown that wintering systems can have a positive effect on nutrient cycling of a pasture stand; however research pertaining to feeding cows on annual cropped land is limited.

The objectives of this review are to:

1. Examine beef cattle nutrition and nutrient requirements in relation to winter feeding practices.
2. Examine the environmental impact of winter feeding systems with respect to manure management, soil nutrient cycling, and soil density.

2.0 LITERATURE REVIEW

2.1 Beef cattle nutrition

Managing the pregnant beef cow during the winter feeding season represents a large cost for western Canadian cow-calf producers. Many producers are looking to decrease production costs with feeding systems that utilize annual crops, such as swath grazing, bale grazing, and grazing crop residue, however the foremost goal in any winter feeding system must be to ensure adequate nutrition of the animals. The animal must be supplied with adequate levels of nutrients in order to meet maintenance, reproductive and weight gain requirements. The level at which these nutrients are required depends on whether the animal is being fed to maintenance, maintenance plus production, or maintenance plus reproduction (NRC 1996). Mature gestating animals are fed, in most cases, for maintenance plus reproduction, and this will be the focus of this review paper.

2.2 Beef cow nutrition in winter feeding systems

As stated previously, supplying the beef cow with adequate nutrition throughout the winter is the most important aspect to maintain performance of the animal. Ensuring appropriate nutrition of the beef cow promotes proper growth and development of the growing fetus (NRC 1996). Lack of proper nutrition, can lead to a decrease in productivity due to a decrease in rebreeding performance, lower birth weights, delayed postpartum estrus, and depressed conception rates (Ferrell 1995). During times of nutrient restriction, nutrients are mobilized from maternal stores in order to sustain fetal growth (Holland and Odde 1992), and restriction of nutrients in gestating heifers has been reported to cause mobilization of fat and protein stores (Hough et al. 1990). Hough et al. (1990) reported that calves born from dams with restricted nutrient intake had higher serum cortisol levels. The authors suggested that this was due to an endocrine compensation of the calf because of the nutritional stress the fetus received during the last trimester of pregnancy. The cows in this study lost an average of 3.7% body weight; however the researchers reported no negative effects on postpartum days to rebreed or on weaning weights of the calves. Since this is contrary to the findings of other studies, it was suggested that the weight loss was not severe enough to cause a treatment effect

(Hough et al. 1990). Shell et al. (1995a) determined that low energy dense diets resulted in significant mobilization of body reserves in order to maintain pregnancy when compared to cows on high energy diets.

Prepartum nutrition can have significant effects not only on cow body condition, but also calf birth weight (Holland and Odde 1992) and calf immunoglobulin production (Blecha et al. 1981). Each of these factors can have considerable effects on the health and subsequent survival of the offspring (Shell et al. 1995b). Contradicting results of the effect of prepartum nutrition on calf birth weight have been reported by Shell et al. (1995a) in which low energy diets of the dam were not seen to affect calf birth weight. It was suggested that cows can receive as low as 70% of NRC requirements during the prepartum period without seeing any negative effects on birth weight. This is contradicted by Boyd et al. (1987) who determined that there is a direct correlation between prepartum nutrition and calf birth weight. Shell et al. (1995b) determined that contrary to other studies, prepartum nutrition did not affect lactation production of the dam. However they stipulated that the animals in the study were not nutritionally stressed. They concluded that animals with low energy diets (70% NRC total energy intake) produced elevated concentration of immunoglobulins (IgG) in their colostrum compared to animals on a high energy diet. Therefore it could be speculated that even though colostrum volume is reduced due to lack of proper nutrition, the amount of IgG in the colostrum will be adequate. The researchers go on to speculate that if adequate postpartum nutrition is supplied, the animal will be able to compensate for lack of nutrition during the prepartum period (Shell et al. 1995b).

2.3 Energy requirements

There are many terms used to define energy and methods involved in determining energy requirements. Gross energy (E) is the heat or combustible energy that is released when organic matter is oxidized to carbon dioxide and water. When fecal output is subtracted from E, the resulting energy is termed digestible energy (DE) (NRC 1996). The proportion of the feed that is digestible depends on the quality and processing of the feed and is augmented as these factors increase. Digestible energy is relatively easy to measure, however it is unable to account for energy that is associated with the digestion and metabolism of food. Metabolizable energy (ME) is viewed as the energy that is left after fecal energy (FE), urinary energy (UE) and gaseous energy (GE) are subtracted from DE (NRC 1996). This is an approximate of the energy available to the animal, however it still demonstrates weaknesses, in that UE and GE are predictable from DE leaving ME highly correlated to DE. Another factor to consider is microbial fermentation, which is the chief source of GE, and a major producer of heat energy. By using the energy balance equation, ME is equal to heat energy plus retained energy (RE), and in this sense is used as a reference point from which the net energy (NE) concept can be based (NRC 1996). Net energy has been classified as the change in RE divided by the change in intake energy (IE). Use of this method proposes that RE and IE are linearly correlated, however, Garrett and Johnson (1983), proved that the connection is curvilinear. The relationship is illustrated by two straight lines, with the intersect representing RE = 0, and is labeled maintenance (Pond et al. 1995).

2.4 Factors affecting energy requirements

Net energy for maintenance (NE_m) is the amount of energy that is required to maintain body temperature regulation, metabolic processes and physical activity, without a net gain or loss of energy from body tissues. NE_m is closely correlated to a fractional power of the animals' empty body weight (EBW), $EBW^{0.75}$, and is referred to as metabolic body weight (NRC 1996). Metabolic body weight can be used as a reference point when comparing the metabolism of different species. The amount of energy required for maintenance varies depending on breed, sex, age, temperature, body weight, previous nutrition, physiological state, and season (NRC 1996). The NRC (1996) calculates energy requirements for maintenance by adjusting the base requirements for breed, physiological state, activity, and heat loss, with the use of the equation:

Equation 2.1 $$NE_m = SBW^{0.75}*[\{0.077* BE*L*(0.8+((CS-1)0.05))\}] + 0.0007(20-T_p)]$$

Where NE_m is net energy for maintenance, SBW is shrunk body weight, BE is breed effect on NE_m requirement, L is lactation effect on NE_m requirement (1 if dry), CS is condition score (9 point scale), T_p is previous average monthly temperature (°C) (NRC 1996).

2.4.1 Breed

Several researchers have reported variation in energy requirements between different breeds of cattle. Garrett (1971) found that Holstein steers have a net energy requirement 23 percent higher than Hereford steers. This difference among breeds has been proven in multiple studies throughout the years, however, direct comparisons between studies is not viable due to dissimilar methodologies, conditions and diversity of breeds. Nevertheless, some general inferences can be made, such as the guideline that *Bos* *indicus* cattle require 10 percent less energy for maintenance than *Bos taurus* cattle (NRC 1996). Further conclusions can be made supporting the idea that a positive relationship exists between productivity (ie. growth or milk production) and maintenance requirements (Montano-Bermudez et al. 1990).

2.4.2 Season

The effects of season have characteristically been coupled with effects of temperature (NRC 1996). However, Birkelo et al. (1991) noted that fasting heat production (FHP) of animals was lower in the fall, winter and spring months than in the summer.

Ambient temperature, has a significant effect on maintenance requirements of beef cattle. Temperatures above the upper critical temperature (UCT) and below the lower critical temperature (LCT) can affect animal performance. Both these values will change depending on the animal's rate of heat production in thermal neutral conditions, as well as their ability to conserve or dissipate heat. Heat production occurs due to microbial fermentation, as previously discussed. This heat must be dissipated when climatic conditions are above UCT, and is used to maintain body temperature when climatic temperatures are below LCT. The ability of the animal to do so can depend on feed intake, physiological state, sex, genotype, and level of activity (NRC 1996).

2.4.3 Age and sex

Age has thought to play a role in differences found in maintenance requirements of cattle. Commonwealth Scientific and Industrial Research Organization (CSIRO) (1990) adopted the principle that maintenance declines 3 percent per year up to 6 years of age at which time 84 percent of initial values are reported. However, there are contrasting views related to the topic of age effects on maintenance requirements.

Negligible differences of net energy requirements for maintenance between male and females have been reported. Agriculture Research Council (ARC) (1980) and CSIRO (1990) both determined that the fasting metabolism between castrated steers and heifers was similar. However, differences are seen when comparing the maintenance requirements of bulls, which are estimated to be 15 percent higher than that of steers or heifers (ARC 1980; CSIRO 1990).

2.4.4 Physiological status

Physiological state plays an important role in the nutrient requirements of the animal, particularly in the gestating or lactating animal. Heat production is seen to increase during pregnancy (Brody 1945), however increased heat production is attributed strictly to the process of pregnancy (NRC 1996) and measurable differences in maintenance requirements have not been determined (Ferrell et al. 1976). An increase in requirements of 30 percent for lactating animals when compared to non-lactating was reported by Neville and McCullough (1969), however the NRC (1996) guidelines indicate on average lactating cattle require 20 percent more ME than non-lactating animals.

2.4.5 Activity

Differences in the amount of activity an animal performs can also have a significant impact on their maintenance requirements. The difference between a grazing animal and a drylot animal can lead to substantial differences in the amount of energy expended and the requirements needed to maintain body condition. CSIRO (1990) suggested that animals in a grazing situation have 10 to 20 percent greater energy requirements than those kept in a drylot situation. This is similar to McCartney et al. (2004) who determined that cattle in a field feeding situation require 18-21% more energy than those maintained in a drylot. NRC (1996) suggests that maintenance requirements increase by 50% depending on the topography of the land, as well as factors such as distance to water.

2.5 Prediction of feed intake

Prediction of intake is essential when determining liveweight gain of animals, as well as predicting the nutrient requirements of animals (NRC 1996). Many factors can influence animal intake and these factors must be addressed in order to understand and predict feed intake. There are many techniques available to measure estimated dry matter (DM) intake, each having its own advantages and disadvantages depending on type of trial, time and labor available. *Ad libitum* intake is associated with feed quality, however there is a vast variation between animals concerning intake, which makes it difficult to obtain accurate standardized intake values (Van Soest 1994).

2.5.1 Factors affecting feed intake

Body composition can affect intake and has been shown to decrease intake as the animal matures (NRC 2000). Percent body fat has been shown to play a very important role in determining intake as reported by Fox et al. (1988), who determined on average a decrease in dry matter intake (DMI) of 2.7 % could be observed for every 1 percent increase in body fat over 21.3 to 31.5 % empty body fat (EBF). Due to this strong relationship, percent body fat has been used in many feedlot situations to determine when animals reach slaughter weight. Frame size and breed of the animal have also been shown to affect DM feed intake. Fox et al. (1988) determined that prediction of feed intake should be adjusted for frame size, and that intake calculations should be increased by 8% for Holstein animals, due to breed effects.

Age and physiological status can both play a role in determining feed intake. Older animals have reportedly higher intake levels than younger animals, when determined on a percent bodyweight (BW) basis (NRC 1996). Fox et al. (1988) determined that cattle started on feed as yearlings required 10% more feed than cattle started on feed as calves. Lactating animals have been reported to require up to 50 % increase in DMI when compared to non-lactating animals (ARC 1980). The amount of milk produced will also have an effect on DMI levels. Beef breeds that are prone to higher milk production will have greater DMI than those cows that don't produce as much milk (NRC 1996). Stage of pregnancy can also affect DMI as cows in the last trimester of gestation, particularly the last 30 d of gestation will have depressed intakes (NRC 1996).

2.5.2 Estimation of total apparent intake

Estimation of apparent feed intake is essential to determine the productivity and performance of beef cattle and manage economics. Cordova et al. (1978) stated that an estimation technique of some sort must occur when determining animal intake. Ratio techniques use an indigestible marker to determine the ratio of digestible forage to fecal material. These indigestible indicators may be a natural component of the forage, such as acid detergent lignin, or they may be administered to the animal, such as chromium or ytterbium (Morse et al. 1992; Teeter et al. 1984). Fecal output is measured by a total fecal collection over a period of time (Morse et al. 1992). Once digestibility is determined a simple equation can be performed in which the fecal amount is divided by the percent of indigestible forage to determine intake (Cordova et al. 1978, Volesky et al. 2002).

2.6 Measuring beef cattle performance

Beef cow performance must be measured in order to evaluate the impact of winter feeding systems, since the operation's profitability is reflective of animal performance.

In order to evaluate cow performance in a winter feeding or extended grazing system, measurements of performance or weight change must be made. Beef cow production can be categorized into growth, lactation, and reproductive efficiency, essentially all relating to the overall energy balance of the animal. For mature gestating beef cattle the main objective is to sustain a state of maintenance with no net gain or loss of energy from tissue (NRC 1996), while at the same time perpetuating fetal growth. In order to measure beef cattle performance energy reserves need to be measured. Three techniques are available; live body weight measurements, ultrasound measurements for body composition, and body condition scoring (BCS). Each technique has its own benefits and limitations which must be taken into account when evaluating beef cow performance.

2.6.1 Body weight

Body weight change is one of the easiest means to obtain indicators of cattle performance, and is used extensively in most research studies. Although this measurement can be taken with relative ease, it is prone to error and bias (Corbett 1978). Gut fill can significantly result in fluctuations in body weight, leading to biases in live weight measurements. Animals with similar live weights can have substantial differences in gut fill volume. Changes in the amount of digesta in the gastro intestinal tract (GIT) of up to several kg can occur from day to day or within a 24 h period. Changes in diet, such as introduction of a new feed or a more digestible feed can lead to changes in passage rate and gut fill (Corbett 1978). In addition, changes in diet, the amount of feed available and the time of feeding can also have significant effects on gut fill.

Standardization of weighing procedures can help to diminish the error associated with this procedure. One strategy is to graze or feed animals from different treatments a similar ration for a few weeks pre and post trial. This is called an adaptation period and will limit variability in gut fill. However there may be some negative effects on treatment results (Hughes 1976). Many research trials try to minimize error by averaging 2 or 3 successively recorded weights. This however, leads to increased stress for the animal and more labor, without increasing the accuracy of the measurements (Hughes 1976). Sorting and handling losses were estimated to lead to shrink percentages of 2-3% if the animals were near the weigh station (Barnes et al. 2007). In contrast, increasing the numbers of animals in the trial will increase the accuracy of the measurements (Corbett 1978).

The composition of gain or loss can also vary from animal to animal. Body weight changes are observed in the amount of lean vs. fat tissue on the animal, due to the difference in heats of combustion, 40 and 4 kJ/g for fat and protein, respectively (Corbett 1978) and the fact that protein accretion is energetically expensive (Brethour 2004) . This will lead to a difference in body energy content and the amount of energy that is required to put on fat or lean muscle (Corbett 1978). The percentage of protein, fat and water in the body can lead to substantial differences in energy content per kg of live weight, and body tissue changes of up to 100% for water and 90% for fat can occur (Reid and Robb 1971). Differences in carcass traits, and lean to fat ratio of the animal, can be partially explained by breed differences and genetic potential of the animal (Marshall 1994).

Boisclair et al. (1986) concluded that live weight measurements do not allow for accurate prediction of the amount of stored energy reserves or the ability of the animal to mobilize those reserves. This is due to differences in gut fill, repartitioning of nutrients and replacing fat reserves with water.

Although live weight is an effective and easy measurement, it alone is insufficient in determining the state of the animal on a research trial. Body weight alone does not take into account frame size and cannot decipher between a large frame, thin cow and a small frame fat cow (Corbett 1978). Therefore, other methods are needed in conjunction with live weight measurements to make an accurate conclusion of animal performance.

2.6.2 Body fat composition

Ultrasound measurements of carcass fat have been found to correlate well with carcass composition (Greiner et al. 2003), and body condition scores (Domecq et al. 1995), proving it can be an effective tool for estimating animal productivity. Although ultrasound has been used extensively throughout the medical and radiology fields (Perkins et al. 1992a), it has also been used throughout the animal science industry for many years. Ultrasound assessment is a rapidly accessible, non invasive technique (Schröder and Staufenbiel 2005) that emits electrical pulses as high frequency sound waves. The sound waves are then converted to images, illustrating different densities of the tissues being examined (Houghton and Turlington 1992). Typical measurements include measurements of back fat from the lumbar, thurl, and tail head, as well as numerous rib measurements, most commonly between the 12th and 13th ribs (Domecq et al. 1995). It should be noted that tail head measurements were found by Domecq et al. (1995) to have a low correlation with BCS and were difficult to obtain accurate measurements. Included in the measurement is the skin thickness, which must be subtracted from the total measurement in order to obtain the amount of subcutaneous fat. A change in back fat of 1 mm equals 5 mm in total body fat content and measurements below 6 mm indicate low to zero body reserves (Schröder and Staufenbiel 2005).

Although ultrasound measurements prove to be useful in measuring body composition, some amount of error can be associated with this technique. Differences between operators and machines have raised many questions and controversy regarding the accuracy of this technique to determine body composition and cow performance (McLaren et al. 1991). Smith et al. (1992), determined that ultrasound measurements were inaccurate in evaluating longissimus muscle. In contradiction, Herring et al. (1994) stated that qualified technicians could obtain accurate measurements, however fatter animals can be more difficult to gather accurate measurements. Perkins et al. (1992b) also stated that given experienced and well trained technicians, accurate measurements could be made.

2.6.3 Body condition

Body condition scoring (BCS) is a subjective evaluation of the outer appearance of the cow correlating with body fat reserves and therefore the energy balance of the animal. It is a visual and physical estimation, in which the animal is evaluated based on palpitation and visual assessment at certain locations on the body. Typically, in Canada a 5 point scale is used. However a 9 point scale is also used in the United States (Lowman et al. 1976; Marlowe et al. 1962; Tennant et al. 2002). Domecq et al. (1995) stated that BCS had been criticized in the past due to the subjective nature of the technique and the lack of validation by quantitative techniques. Questions raised include the ability of the technician to obtain accurate measurements over a period of time, leading to any changes recorded over time being the result of the technician, not the cow itself. Domecq et al. (1995) validated BCS with the quantitative measurements of ultrasound and concluded that BCS are valid measurements when taken over a period of time.

Knowledge concerning the body condition of the cow at certain times of the production cycle can help to increase the productivity of the animal, such as its reproductive efficiency. DeRouen et al. (1994) determined that cows with higher BCS at calving had higher pregnancy rates and a fewer days to pregnancy interval. Days to pregnancy interval was increased by 10 to 18 d ($P<0.05$) for cows with a condition score of 4 (scale 1-5) at time of calving (De Rouen et al. 1994). In order to maintain a positive energy balance, knowledge of the maintenance requirements of the animal are essential, and correlations can be drawn between body condition and fasting heat production (FHP) allowing for producers to ensure adequate nutrition at peak times in the production cycle. Fasting heat production equates to the net energy required for maintenance (NE_m) of the animal (NRC 1996). Birnie et al. (2000) determined that FHP was higher for cows that had a lower body condition score. As well, Birnie et al. (2000) stated that cows with lower condition scores may utilize more protein than cows with higher condition scores, thus bringing the energetic efficiency of fat vs. protein utilization into question. Cows with a low BCS will have a higher FHP than cows with a higher condition score and more fat to catabolize (Birnie et al. 2000). Bullock et al. (1991) determined that condition score alone was a useful tool in determining the reserve status of the animal, however they stipulated that this is a very subjective technique and it is better used in combination with other techniques.

2.7 Feedstuffs used in winter feeding systems

Traditionally, in western Canada, preserved perennial forages are used in winter feeding programs for beef cows. However, with increasing costs associated with winter feeding, many producers look to extending the grazing season, by incorporating annual forages in addition to perennial forages into their grazing systems.

2.7.1 Annual forages

Spring seeded annual cereals, such as barley, oats, triticale, or rye can lengthen the grazing season and can help to offset shortages of perennial pasture in certain years (McCartney et al. 2008). Oat and barley typically are spring cereals of choice for grazing, however pea mixtures have shown to extend the grazing season by upwards of 30 d (Lardner 2002b). Winter cereals, such as fall rye are proving to have advantages over spring cereals because they can be grazed twice if managed properly. Fall rye can be grazed in the fall after initial germination, and if not grazed too closely to the ground can be grazed again in the spring, after spring emergence (McCartney et al. 2008). Winter cereals can also be seeded in the spring, and tend to mature slower than spring cereals, therefore allowing for better late season feed quality (McCartney et al. 2008).

Typically, annual crops are seeded later in the growing season and swathed in the mid dough stage (McCartney et al. 2008). By delaying the seeding date, the crop will not fully ripen and will remain in the soft dough stage when swathed in the fall. This soft dough stage of plant maturity will potentially provide cows with the highest quality forage (Hutton et al. 2004). Delaying the seeding date may have little effect on the total biomass produced, (May et al. 2007), however effects of early seeding on weathering loss and palatability of the forage have not been studied (McCartney et al. 2008).

2.7.2 Perennial forages

Perennial forages such as alfalfa and certain native grasses can be stockpiled and used as an economic alternative to traditional winter feeding systems allowing for an extended grazing season (Baron et al. 2004). However, perennial species must be chosen carefully due to reductions of dry matter yield and quality (Ocumpaugh and Matches 1977), with largest losses typically associated with legumes such as alfalfa (Baron et al. 2004). Research has shown that by stockpiling grass pastures, cattle will maintain body condition and body weight, and production costs will be reduced (Adams et al. 1994).

As in all winter feeding systems, supplementation may be required to meet maintenance requirements of pregnant cows in order to retain body condition for calving (Willms et al. 1993; Clanton and Zimmerman, 1970). A highly degradable protein can be given as a supplement, however this can be a very expensive part of the grazing system, therefore its crucial to know the amount of ruminally degradable protein supplied by the forage in order to reduce over-supplementation, which will prove uneconomical (Hollingsworth-Jenkins et al. 1996).

2.8 Soil nutrient cycling

Nutrient cycling describes the cycling of a nutrient through different pools within the environment or farm operation. These cycles are not closed and there can be many inputs and outputs at each stage of the cycle (Russelle 1992).

2.8.1 Nutrient inputs

Atmospheric deposition of nutrients occurs by the deposition of nitrogen into dust and precipitation, however this is usually a minor source of nutrient return to the soil.

Nitrogen (N) is deposited in the form of ammonium (NH_4^+) or nitrate (NO_3^-), as well as, other organic compounds (Russelle 1992).

Non-symbiotic nitrogen (N_2) fixation can also play a role in N input, however those inputs tend to be minimal, contributing to less than seven kilograms per acre (Floate 1987). This process is considered to have the biggest impact in moist tropical areas containing large plant biomass thus leading to high populations of N_2 fixing micro organisms (Stevenson 1986), and is not of major importance in western Canada.

Symbiotic N fixation can also be a source of nutrient input and unlike non-symbiotic fixation it contributes a significant amount of N to a system. Symbiotic fixation occurs in plants that have N fixing bacteria in their tissues, such as legumes. The relationship between legumes and *Rhizobium* bacteria largely defines the N fixation rate, however weather and soil conditions, disease, grazing management and inorganic N supply can also have a substantial affect on the fixation rate (Hoglund and Brock 1987). During the grazing period, the N fixation potential of the forage stand is reduced due to a reduction in photosynthetic activity. Grazed legume plants will not be able to compete with non legume plants and the N fixation ability of these plants will decrease dramatically (Matches 1991; Coleman 1991). Legumes in stand can absorb inorganic N from the soil and NH_3 from the atmosphere. Legumes match the amount of N fixation occurring with the inorganic N supply helping to buffer the nitrogen cycle. Hoglund and Brock (1987) reported that the amount of fixation occurring would remain stable until the amount of inorganic N was reduced.

Nutrients from livestock manure are also a part of the nutrient cycle that exists within a farm operation. The amount of nutrients excreted by cattle is directly related to the nutrient use efficiency of the animals. To determine the use efficiency, the amount of nutrients in the feed is compared to the amount of nutrients excreted in the feces and urine. For budgeting purposes, nutrient excretion can be estimated by a simple input/output subtraction of the nutrients in the feces, urine and milk from the nutrients in the feed. It should be noted that manure nutrients should be estimated from manure that is originally excreted, not recovered later allowing for nutrient losses (Van Horn 1996). Nitrogen conservation or use efficiency by cattle is retained in the protein of the milk and meat produced, while the surpluses are excreted in feces and urine (Rotz 2004). Differences in use efficiency can be seen depending on the type of animal. For example grazing beef cattle have a N use efficiency of less than 10 percent (Hutchings et al. 1996). Excretion of nutrients through animals can be reduced by increasing the nutrient use efficiency of the animals (Rotz 2004). By providing the right balance of protein, or N, needed to meet the nutritional requirements of the animal, the gap between the supplied amount and the required amount is reduced. This in turn reduces the excretion of N in the manure. Eliminating dietary excess is one of the easiest ways to reduce nutrient excess and nutrient losses through animals (Van Horn et al. 1996) and therefore decrease environmental concerns associated with animal production.

2.8.2 Transfer among nutrient pools

Transfer of nutrients among different pools by beef cattle is an important aspect when discussing the nutrient inputs and N cycle. Animals remove herbage and deposit the nutrients in the form of excreta, leading to a transfer of the nutrients within the whole farm balance (Petersen et al. 1956).

The decomposition of roots and root nodules results in the release of N and subsequent transfer of N to neighboring plants. Perennial ryegrass was seen to acquire 6 to 12% percent of its N from white clover (Haystead and Marriott 1979). The amount of transfer that occurs depends on the legume to grass ratio (L:G) and the distance between the plants (Brophy et al. 1987).

2.8.3 Nutrient removal by plants

Luxury consumption of nutrients by plants can have a direct affect on the whole farm nutrient budget. Van Horn et al. (1996) showed that total N harvested from plants continued to rise with subsequent higher N applications, even after DM yield of plants had peaked. Luxury phosphorus (P) consumption however, was not as noticeable as N consumption (Van Horn et al. 1996). Soils have the ability to bind or “fix” certain nutrients, such as phosphorus. Fixation of the anion P is attributed to cations such as calcium (Ca), aluminum (Al), and manganese (Mn). However, the amount of P that is fixed by the soil depends on certain properties of the soil, such as amount and type of clay, soil pH, organic matter and ultimately is dependent on the number of sites on the soil particles that are able to bond with P ions (Brady and Wiel 2002). Van Horn et al. (1996) suggests that the soil binding capacity for certain nutrients should be considered a sink when formulating a manure management plan. A management plan should consider the affinity of the soil for the nutrient. Additionally, the plan must take into account applications of the nutrient, movement capability of the nutrient in the soil, and field conditions (Van Horn et al. 1996).

2.9 Soil density

Soil compaction can also pose problems in land management, as cattle distribute a large amount of weight and pressure to the land or wintering site. Compaction is defined as a measurement of bulk density and a ratio of 50:50, (porous spaces to solid particles) is ideal. As the porous spaces decrease the amount of water infiltration also decreases and plant root growth is diminished (Plaster 1985). Compaction issues can also lead to erosion and damage of streams or dugouts used as water sources, thus negatively impacting the water quality (AAFRD 2000). This can also have an impact on the whole ecosystem as fish spawning grounds and other wildlife nesting habitats are also affected (AAFRD 2000).

2.10 Manure as a source of nutrients

Since ancient times, livestock excreta have made an important contribution to soil nutrient inputs, although their relative importance has decreased as the use of mineral fertilizers has increased (Sheldrick et al. 2003). Manure is an important source of nutrients in many cropping systems and when managed properly, can improve the productivity and quality of the soil and plants.

2.10.1 Nutrient composition

The mature cow will produce 28 kg of feces (0.4% N and 0.2% P) and 9 kg of urine (1.1% N and 0.01% P) per day (Beirman et al. 1999). This leads to a substantial input of nutrients to the soil from excreta. A major difference between commercial fertilizers and manure is that manure nutrients are in the organic form and must be mineralized to become available to the plants (Schoenau et al. 2000). Also, manure nutrients are not as effective until they are in the inorganic form (Wijnands et al. 1987). However, it is the organic matter derived from manure application that is speculated by Lardner (2003) to have a larger impact on eroded soils than the nutrients, thus showing the beneficial aspects to applying manure as fertilizer. This is supported by Young and Mutchler (1976) who stated that manure acts as a mulch helping to reduce soil erosion and therefore runoff, when applied and incorporated in the fall.

The primary nutrients found in beef cattle manure are nitrogen (N), phosphorus (P), potassium (K), and sulphur (S) (Schoenau et al. 2000). By understanding the forms and amounts in which these nutrients are contained in manure, proper steps can be taken in managing manure as a fertilizer. Usually mineral fertilizers can be customized to match the needs of the land; however manure provides various ranges and concentrations of nutrients (Prins and Snijders 1987). Inconsistency in nutrient content is associated with different manure types and analysis of manure properties is beneficial to apply the correct rate that meets the needs of the plants or soil (Schoenau et al. 2000). Concentration of nutrients, especially phosphorus (P), calcium (Ca) and magnesium (Mg), is very dependent on dry matter content of the feces (Prins and Snijders 1987).

Properly matching the application rate of the manure with the crop demand is important to maximize nutrient utilization. This will involve analysis of the nutrient requirements of the crop or pasture (Schoenau et al. 2000). Over application will lead to environmental problems such as accumulation of nutrients in the soil, leaching and eutrophication (Jongbloed and Lenis 1998).

2.10.2 Methods of manure application

Manure application techniques are important in order to maximize nutrient utilization of the manure and minimize environmental concerns. In the case of solid manure, coming from a feeding corral or wintering facility, broadcasting the material should be followed by immediate incorporation into the soil, thus reducing losses from volatilization (Rotz 2004). However volatilization losses are seen to be higher in manure containing large amounts of N in the ammonium form (NH_4^+) (Schoenau et al. 2000). The largest losses of nutrients are seen when irrigating with slurry, as the N is in contact with the air before touching the plant or soil (Rotz 2004).

Urine provides N to the plants as the urea contained in the urine is hydrolyzed to NH_4^+ and then oxidized to NO_3^- in the soil (Ball et al. 1979). These forms of N are available to the plant but must be managed carefully (Russelle 1992) as rapid hydrolyzation of the N in urine can occur and losses up to 66% have been reported (Jarvis et al. 1989). Most excreted N is found in urine which is a concentrated solution consisting of 10 g of N per litre. This suggests that urine is an important aspect when looking at increasing nutrient absorption from animal wastes. Urine is rapidly hydrolyzed, and substantial losses can be seen in the forms of volatilization (Ball et al. 1979). Depending upon the type of wintering system, different amounts of N will be lost out of the system, thus validating the importance of proper management techniques.

2.10.3 Management techniques

Many different management techniques can be used to increase the utilization of nutrients and decrease the risk of environmental impact. These include following government regulated management practices such as those outlined by Saskatchewan Ministry of Agriculture. Under the Agriculture Policy Framework (APF), regulations for Environmental Farm Plans (EFP's) have been set in place that will affect the impact agriculture has on soil, water and air, and biodiversity of the ecosystem (SMA 2005).

2.10.3.1 Season of application

The season of application is very important when planning to apply manure on a surrounding land base. Winter application of manure may provide some economical benefits to the producer, as well as decreased labor costs; however concerns arise pertaining to losses due to spring runoff and eutrophication of water (AAFRD 2003). Hodgkinson et al. (2002) supports this theory suggesting that increased P losses due to drainage are seen when manure is applied during the winter and fall. Stout et al. (1997) supported this view reporting that greater nitrate (NO_3^-) leaching was seen in fall applied urine compared to spring or summer applied urine. Thus, spring application of manure is a beneficial practice for both the producer as well as the environment, as it maximizes nutrient utilization from the manure and decreases environmental hazards (AAFRD 2005). Spreading manure on frozen land has been criticized for its potential to increase the amount of runoff from those lands. Young and Mutchler (1976), found that up to 20% of the N and 16% P in the manure spread on frozen soils was removed by runoff in the spring, whereas only 3% of the N and 4% of the P were removed in systems where manure was applied to a plowed field. In addition, applying manure on top of snow in comparison to before snow fall increases the risk of nutrient loss (Young and Mutchler 1976).

2.10.3.2 Wintering Sites

Location of livestock wintering sites is an important consideration when trying to minimize environmental concerns and maximize nutrient utilization. Feeding and wintering cattle beside bodies of water may lead to potential spring runoff and contamination of the water. Providing off-stream water sources for cattle has been reported to decrease the amount of time spent sourcing water by an average of 24 min per animal per day (Miner et al. 1992). Producers may find that providing shelter away from water bodies may also decrease the damage done to stream banks and water bodies (AAFRD 2000). Portable shelters allow the manure to be spread across the field minimizing accumulations in one spot (Hutton et al. 2004). According to the Alberta Agriculture Operation Practices Act (AAFRD 2003), wintering sites must be located 30 m away from water bodies. If this is not achievable, then action must be taken to ensure reduced environmental impact. Producers need to construct a ditch between the wintering site and water body to avert any runoff away from the water, or the manure and bedding must be removed before runoff occurs (AAFRD 2005), however this would be extremely difficult to achieve. Wintering cattle in treed areas may pose additional problems as cattle will deposit high amounts of feces and urine in the area and removing the manure may be difficult (Hutton et al. 2004). The type of wintering system a producer uses will determine the wintering site and manure management techniques used.

2.10.3.3 Composting

Composting manure has recently been shown as a beneficial way to increase the potential use of manure nutrients, by increasing nutrient availability, while at the same time decreasing environmental risks. During the composting process, heat and various gases are given off, as well as moisture. Throughout the curing process the manure reduces in weight and volume, thus increasing its handling ability. The heat occurring during this process benefits the producer by destroying weed seeds and pathogens contained in the manure (Lardner 2002a). Benefits from applying compost on pasture can be realized through increased animal gains and grazing days, due to an increase in forage production, when compared to non treated pasture (Lardner 2003).

2.10.3.4 Phosphorus based application

Many types of manure are phosphorus (P) rich when compared to N concentration of the same material. This occurs due to large losses of N through volatilization, denitrification, and the luxury consumption of N by plants (Van Horn et al. 1996). Many budgeting systems use a N based system which can lead to increased P content in the soil. Therefore using a P based manure management system might be required to help reduce the amount of P build up in soils. In a P based system the manure is applied to meet the P needs of the soil and subsequent crop. This type of management system usually does not provide enough N to meet the needs of the crop, so additional N may have to be applied (Stout et al. 2003). Qian et al. (2004) determined that cattle manure should be applied to the soil based on the P requirement of the crop, with additional N fertilizer applied to achieve the appropriate N:P ratio, in order to increase P removal by the plant.

2.11 Environmental concerns

With an increasing world population, concerns regarding the environment and agriculture’s impact on the environment have been debated. Agriculture’s impact on soil, water, and air quality must be monitored to ensure biodiversity within these three facets of the environment continues to flourish.

Large amounts of P in surface water bodies can lead to increased bacterial growth subsequently increasing the rate of eutrophication and decreasing water quality (Owens and Shipitalo 2006). Even though eutrophication is a normal aging process of water bodies (Young and Mutchler 1976), eutrophication of water bodies leads to oxygen depletion, loss of vegetation, opaque water color, as well as altered feeding networks (Boesch et al. 2001), and the rate by which it occurs can be increased by certain agricultural processes (Young and Mutchler 1976). Increasing animal densities on land that is connected to freshwater sources has been suggested as a potential hazard for increased eutrophication of those water bodies (Jensen et al. 2000). Dixon et al. (1980) concurred with this ideology stating that by increasing stocking rates, pollutant losses from wintering areas have a tendency to increase. Water extractable P (WEP) will increase as levels of P increase in the soil, subsequently leading to increased potential for runoff of P to surface water (Stout et al. 2003). Hodgkinson et al. (2002) stated that factors leading to the amount of P losses from agricultural land include the amount of P that is soluble in water, the type of soil macropore structures, and the moisture status of the soil. The type of P applied to the soil does not seem to have an effect on the amount of P lost from the system. Jensen et al. (2000), determined that all P forms resulting from feces should be considered susceptible to leaching and managed accordingly.

The greatest loss in a manure handling system occurs from volatilization (Rotz 2004). Volatilization depends largely upon temperature, moisture, pH and air movement. Besides being an economic loss to the producer, volatilization is also considered an environmental concern as it leads to atmospheric pollution from released ammonia (NH_3) into the atmosphere (Jarvis et al. 1989). Losses can occur from both urine and feces, as the process involves the hydrolysis of the urea to ammonium carbonate (Jarvis et al. 1989). However, urine N is more vulnerable to volatilization as fecal N is insoluble in water (Whitehead 1995). Urine is a concentrated solution (Ball et al. 1979) with the N portion consisting of about 70% urea (Doak 1952). Volatilization can occur rapidly under a urine patch due to a decrease in soil pH and therefore plants utilize very little of this form of nitrogen (Ball et al. 1979; Russelle 1992). Losses generally increase with temperature and the rate of loss is minimal at temperatures of 0° Celsius (Sommer et al. 1993). When animals are housed in a drylot the excreta is immediately subject to urea hydrolysis as the presence of soil required to retain ammonium (NH_4^+) is not available (Whitehead 1995).

The loss of N from the soil through gaseous emissions also occurs through the process of denitrification (Whitehead 1995). Denitrification is a process where enzymes convert the inorganic form of nitrogen into the gaseous forms, which are then emitted into the atmosphere (Russelle 1992). Denitrification occurs in an anaerobic environment, with the presence of nitrates, soluble carbons, and denitrifying organisms (Prasad and Power 1997). In some soils, certain bacteria are responsible for the denitrification process and these bacteria represent 1 to 5 % of the genera found in the soil (Steele 1987).

The amount of urinary N that is recovered by plants is usually only about 25 to 35 %, depending upon the soil and climatic conditions (Ball et al. 1979). The amount of denitrification that occurs from a urine patch also depends upon whether the urine penetrates the soil zone where denitrification occurs. Limmer and Steele (1983) found this zone to be the top 30 mm of soil depending upon the type of soil.

Other factors involved in denitrification include temperature, bacterial populations, and soil type. Temperature has been seen to increase or decrease the amount of denitrification that occurs, as very little denitrification takes place when temperatures are below 10° Celsius (Whitehead 1995). High amounts of NO_3^- concentrations in the soil, as well as a high concentration of certain bacteria can also play a role in denitrification and are both found to be conducive for denitrification (Limmer and Steele 1983). Soil texture and drainage availability can also affect the amount of denitrification that occurs. In most pastures and grasslands, denitrification is seen to be only a small part of the N losses (Steele 1987).

Leaching of nutrients occurs when a soil receives more moisture than its holding capacity, usually occurring during the winter. The excess moisture moves downward, as the soil is already saturated and cannot hold the moisture (Whitehead 1995). Factors affecting the amount of leaching include high levels of nutrients such as N, uneven cycling of that nutrient or increased stocking density (Ball and Ryden 1984; Stout et al. 1997). Stumborg et al. (2007) stated that when applied at agronomic rates, both hog and cattle manure are beneficial to the soil and subsequent crop. However when applied in excess, issues associated with nutrient loading of the soil and loss of NO_3^- - N due to leaching were found. Urine and fecal spots are subject to leaching, especially urine spots since the amount of N applied in the urine patch far exceeds the requirements of the land (Steele 1987). Studies have shown N losses of 18, 28 and 31% when urine was applied in the spring, summer, and fall, respectively. This is in contrast to a 2% loss in fecal N when applied during the same time period (Stout et al. 1997).

Runoff occurs when heavy moisture follows the application of either organic or inorganic fertilizer. This occurs predominantly to urea and nitrates which are very soluble and move easily out of the soil (Whitehead 1995).

2.12 Summary of literature review

During an economic and industry recession, producers search for strategies to mitigate monetary losses, and economically sustainable. In doing so, questions arise on the impact of these alternative strategies on animal performance and environmental factors. Many options for winter feeding beef cattle are available to producers, such as swath grazing, straw-chaff grazing and bale grazing, but each system has differences that must be considered by the producer before choosing a system. After choosing a system, proper management is essential to ensure that economic and environmental benefits of the system are fully realized.

The hypothesis for the research presented in this thesis is that extensive winter feeding systems will have no impact on cow performance and reproductive efficiency, soil nutrients and density, or annual crop production. In addition, extensive winter feeding systems will not differ in system cost of production compared to drylot feeding.

3.0 GENERAL MATERIALS AND METHODS

3.1 Introduction

With feed costs rising every year, reducing cost of production (COP) is crucial in order to maintain sustainable production and growth of cow-calf operations in western Canada. While COP is a primary concern for producers, issues regarding the environmental implications of agriculture continue to be debated. In order to be economically and environmentally sustainable, producers must explore low cost feeding alternatives, and at the same time ensure a high degree of management. In attempts to reduce costs associated with winter feeding practices, producers have moved towards extensive winter feeding systems. While these may be beneficial for the producer, questions have been raised regarding the impact of these systems on cow performance, soil management and subsequent crop production.

This study was conducted to evaluate the effects of extensive winter feeding systems on cow performance, soil nutrients, crop yield and system cost of production. This involved comparing field data from 4 types of winter feeding systems defined as 3 extensive systems and 1 intensive system. In addition, small plot research was conducted comparing composted and raw manure application on soil nitrogen and phosphorus, soil compaction and crop production.

3.2 Location

The winter feeding study was conducted at the Western Beef Development Center's (WBDC) Termuende Research Ranch (TRR) located 8 km east of Lanigan, Saskatchewan, Canada. This area is located in the east central area of the province on the

Saskatchewan Plain and consists primarily of Chernozemic Black Oxbow soils (Saskatchewan Soil Survey 1992). This location had a lengthy history of heavy solid manure application, thus increasing basal soil nutrient levels.

In June of 2005 and 2006, 40 ha of forage barley (cv. Ranger) was seeded at 124 kg ha^{-1}, along with 56 kg ha^{-1} actual nitrogen. The field was further divided into ten, 4 ha paddocks separated by electric fence, with 36 ha used for the winter feeding trial and 4 ha used for a manure application trial. The barley crop was swathed at soft dough stage for either round bale greenfeed or swath grazing. The remaining straw-chaff paddocks were left to mature and the grain harvested in September of each year. A whole-buncher (AJ Manufacturing, Calgary, AB, Canada) (unit attached to the back of the combine to collect chaff and straw) was attached to the combine to collect piles of the straw-chaff residue weighing 20-30 kg (dry matter (DM) basis) each.

3.3 Experimental animals

The cows used in the study were obtained from the main herd of the WBDC. Cattle were stratified based on body weight (BW), body condition score (BCS), rib fat, age and pregnancy status and were randomly allocated to 1 of 4 winter feeding systems. In 2005, 180 dry pregnant commercial cows (primarily Black Angus) were on trial with an average weight of 630.51 ± 3.89 kg, average BCS of 2.77 ± 0.06 (five point system), average rib fat of 6.00 ± 0.28 (mm), and average gestation of 110 ± 17.69 days. In 2006, 180 cows (primarily same cows) with an average weight of 598.64 ± 7.71 kg, average BCS of 2.61 ± 0.08 (five point system), average rib fat of 4.95 ± 0.93 (mm), and average gestation of 92.99 ± 4.99 d were randomly allocated to 1 of 4 winter feeding systems. All cattle were cared for in accordance with the Canadian Council of Animal Care guidelines

(CCAC 1993). After the 2005-2006 study period, 28% of the cows were culled prior to start of the 2006-2007 study due to reasons unrelated to this study.

Each year all cows were pregnancy checked by a veterinarian prior to the start of trial (SOT) to eliminate any open cows. Bull placement occurred on 1 July of each year with the first calving cycle estimated to start at 12 April of each year. The trial consisted of 4 replicated treatments (n=3), each replicate group consisting of 15 cows. The 2005-2006 study period ran from 19 November 2005 to 2 February 2006 (76 d), and the 2006-2007 trial ran from 30 November 2006 to 21 December 2006 (21 d), due to inclement winter weather which severely affected animal access to feed in the extensive field feeding systems.

3.4 Winter feeding systems

Cows were allocated feed in each winter feeding system based upon environmental conditions and stage of pregnancy. The amount allocated was based on cow weight and feed nutrient density in accordance with the National Research Council's (NRC) (1996) nutrient requirements of beef cattle. The amount allocated was intended for maintenance of body condition, with no weight gain above that of conceptus growth. In each system, feed was allocated *ad libitum* every 3 d, with a 10% carryover allowed. The feeding systems included; swath grazing (SG) where the barley crop was swathed at the mid dough stage and the cows grazed the feed in the windrows; bale grazing (BG) where the barley crop was baled in greenfeed round bales and the cows consumed the feed in the field in baled form; straw-chaff grazing (ST-CH) where the barley crop was allowed to mature, grain was harvested and the straw-chaff residue was collected and the cattle grazed in the field on residue; and traditional drylot (DL) where the cattle were fed stored barley greenfeed round bales in corral pens with open faced sheds.

All system feeds were analyzed by Norwest Laboratories, Alberta, Canada (Appendix A.1). In 2005-2006 BG diets consisted of barley greenfeed round bales (83.0% DM, 61.4% total digestible nutrients (TDN) and 12.7% crude protein (CP). DL diets consisted of barley greenfeed round bales (85.8% DM, 65.4% TDN and 12.7 % CP). SG diets consisted of swathed whole plant barley (62.4% DM, 61.3% TDN and 13.8% CP). ST-CH diets consisted of straw/chaff residue (56.7% DM, 49.8% TDN and 10.2% CP), plus a supplemented range pellet at 3.57 kg cow^{-1} d^{-1} (Appendix A.2). The composition of the range pellet was 88.4% DM, 75.0% TDN and 19.6% CP.

In 2006-2007 (Appendix A.1) diet forage for the BG consisted of barley greenfeed round bales (81.1% DM, 70.8% TDN and 14.0% CP). DL diets consisted of barley greenfeed round bales (80.4% DM, 70.7% TDN and 13.7 % CP). SG diets consisted of swathed whole plant barley (79.3% DM, 66.6% TDN and 14.1% CP). ST-CH diets consisted of straw/chaff residue (58.2% DM, 45.5% TDN and 9.3% CP), plus a supplemented range pellet at 4.10 kg cow^{-1} d^{-1} (Appendix A.2). The composition of the range pellet was 87.7% DM, 79.0% TDN and 16.2% CP. Year to year variation in feed quality is most obvious in the straw-chaff & swath graze treatments with large differences in percentage dry matter (Appendix A.1). These differences in DM reflect the extreme variability in feed moisture levels in these two systems and must be taken into account when allocating forage in these winter feeding systems. In both years cows had *ad libitum* access to a commercial 2:1 mineral (FeedRite Hi C-N-Z (2:1) (with Se), FeedRite Ltd., Humboldt, SK, Canada) (Appendix A.1)

3.5 Feeding system layout and design

Cattle in the intensive treatment (DL) were housed in 3 outdoor pens (15 cows per pen), surrounded by wooden slatted fences. Each pen contained an open faced shed (cattle shelter) and a round bale feeder. Wood chips were used for bedding for comfort of the animal, based on the judgment of the herdsperson.

Cattle in the extensive field feeding systems (BG, SG and ST-CH) were managed in a 36 ha field, further divided into 9, 4 hectare replicate (n=3) paddocks (15 cows per paddock). The outer parameter of each paddock was fenced with high tensile electric wire and feed was allocated on a 3 d feeding period using low tensile electric fence. Water was supplied in troughs and portable wind breaks (10 x 6 m) were supplied for each replicate group of cows.

3.6 Crop dry matter yield

Standing crop DM yield was estimated each year, using 2 different techniques. First, a direct method using 0.25 m^2 quadrat samples (n=15) was determined within each replicate paddock each fall prior to swathing the crop for greenfeed or swath grazing. The second technique included DM yield estimates of available feed in each system by randomly weighing (a) 10, 30 x 3m sections of swath in each SG paddock were placed on a tarp, weighed and replaced, (b) 40, straw/chaff piles in each ST-CH paddock were placed on a tarp, weighed and replaced; and (c) 12 round bales in each BG paddock and DL pen were weighed using a portable scale. Both techniques were followed as outlined in Volesky et al. (2002) and Baron et al. (2006).

3.7 Forage samples

Available forage was sampled from each replicate pen and paddock prior to start of test (SOT) and every 21 d throughout the trial to determine changes in feed moisture and quality. All forage samples were placed in a forced air oven at 55ºC for 3 d to obtain DM content, then ground to pass through a 1-mm screen using a Christie-Norris mill (AOAC 1990). All samples were submitted for laboratory analysis to Norwest Laboratories, Alberta, Canada, where TDN was calculated from acid detergent fiber (ADF) using the Pennsylvania State equation (Adams 1995).

3.8 Laboratory analysis

Forage analysis included moisture (Association of Official Analytical Chemists (AOAC), method 935.29), neutral detergent fibre (NDF) (FAP, method 5.1), and acid detergent fibre (ADF) (AOAC, method 973.18). Crude protein (CP) was analysed by Leco (AOAC method 990.03), and minerals (AOAC, method 985.01).

In addition, 2005 feed samples were analyzed in duplicate at the Department of Animal and Poultry Science laboratory at the University of Saskatchewan for comparative purposes. Analysis included moisture (Association of Official Analytical Chemists (AOAC), method 930.15), ether extract (EE) (AOAC, method 920.39), acid detergent fibre (ADF) (AOAC, method 973.18) and acid detergent lignin (ADL) (AOAC, method 973.18) (AOAC 1990). Neutral detergent fibre (NDF) was analysed according to the procedure of Van Soest et al. (1991). Heat stable α- amylase (A3306, Sigma Chemical Co., St. Louis, MO) was included in the NDF procedure at 0.17 ml per 0.5 g sample. Crude protein (CP) was analysed by Kjeldahl nitrogen (AOAC method 976.05) using a Kjeltec 1030 auto analyser, which was also used to analyse acid (ADFIP) and neutral detergent fibre insoluble protein (NDFIP) (AOAC, method 984.18) with residues recovered on Whatman No. 54 paper.

3.8.1 Dietary energy predictions

For the 2005-2006 feed samples, 2 methods were used to determine total digestible nutrients (TDN) or energy levels throughout the feeding period. The first method involved using the Pennsylvania State equation which predicts percent total digestible nutrients (TDN) based on acid detergent fiber (ADF) (Adams 1995).

Equation 3.1

$$\mathrm{TDN} = 4.898+\{89.796*[1.0876-(0.0127*\mathrm{ADF})]\}$$

where ADF is expressed on a DM basis.

The second method calculated TDN according to Weiss et al. (1992).

Equation 3.2

$$\mathrm{TDN} = \{0.98*(1000-\{(\mathrm{NDF}*10)-(\mathrm{CP}*\mathrm{NDFIP}/10)+[0.7*(\mathrm{CP}*\mathrm{ADFIP}/10)]\}-(\mathrm{CP}*10)-(\mathrm{ash}*10)+[0.7*(\mathrm{CP}*\mathrm{ADFIP}/10)]-(\mathrm{EE}*10))+[-0.0012*(\mathrm{CP}*\mathrm{ADFIP}/10)]^{2}*(\mathrm{CP}*10)+2.25*[(\mathrm{EE}*10)-10]+0.75*(\{(\mathrm{ADL}*10)-(\mathrm{CP}*\mathrm{NDFIP}/10)+[0.7*(\mathrm{CP}*\mathrm{ADFIP}/10)]\}-(\mathrm{ADL}*\mathrm{NDF}/10))*[1-((\mathrm{ADL}*\mathrm{NDF}/10)/\{(\mathrm{NDF}*10)-(\mathrm{CP}*\mathrm{NDFIP}/10)+[0.7*(\mathrm{CP}*\mathrm{ADFIP}/10)]\})^{(0.667)}]-70\}/10$$

where neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), ether extract (EE), and ash are expressed as dry matter (DM); neutral detergent fiber insoluble protein (NDFIP) and acid detergent fiber insoluble protein (ADFIP) were expressed as CP; and acid detergent lignin (ADL) was expressed as NDF.

3.9 Statistical analysis

3.9.1 Animal data

Statistical analysis of cow data was conducted using a one way analysis of variance (ANOVA) of the Proc Mixed Model procedure of SAS (1989). Cow data (body weight (BW), body condition score (BCS), rib fat (RF), and apparent dry matter intake (DMI)) was analyzed using a completely randomized design (CRD). Treatments were the winter feed systems which include swath graze, bale graze, straw-chaff graze and drylot. Each cow in the trial was considered a sampling unit for a total of 180 sampling units. Each replicate group of cows was considered an experimental unit for a total of 24 experimental units over the two year study. In addition, a one way ANOVA of the Proc Mixed Model procedure of SAS (1989) with a two way (year by treatment) interaction analysis was conducted on cow performance data (body weight, body condition score, and rib fat) from the first 21 d of the 2005-2006 trial period and the total 2006-2007 trial period (21d) due to the difference in trial length in each year.

Reproductive data (calving interval and calf birth weight) was conducted using a one way ANOVA of the Proc Mixed Model procedure of SAS (1989), using a completely randomized design (CRD). Each cow in the trial was considered a sampling unit for a total of 180 sampling units. Each replicate group of cows was considered an experimental unit for a total of 24 experimental units over the 2 year study. Each cow’s calving date was assigned a number (1 to 63) corresponding with calving span in order to provide numeric data to analyze statistically.

For all cow data, Tukey's multiple range test was applied to determine whether the treatment means were different and differences were considered significant when $P<0.05$ (Steel et al. 1997).

3.9.2 Soil and crop data

Statistical analysis of soil and crop data was conducted using a one way ANOVA of the Proc GLM Model procedure of SAS (1989). Soil data (soil nutrients) and crop biomass (DMY) from the winter feeding trial was analyzed using a completely randomized design (CRD). Treatments included swath graze, bale graze, and straw-chaff. Analysis was done to determine the effect of treatment on soil nutrient profile, soil compaction and crop biomass. Each replicate is considered an experimental unit for a total of 12 experimental units over a one year period. Soil nutrient data was also analyzed to determine slope by treatment interaction.

Soil data (soil nutrients) and crop biomass from the manure application trial was analyzed using a randomized complete block design (RCBD). Treatments included a check (no manure applied), 1X rate of manure (22.4 t ha^{-1}) and 1X equivalent rate of compost (6.72 t ha^{-1}). Analysis was done to determine the effect of treatment on soil nutrient profile. Each replicate was considered an experimental unit for a total of 12 experimental units over the 1 year period.

For all soil and crop data an LSD multiple range test was applied to determine whether the treatment means were different. Differences were considered significant when $P<0.10$ (Steel et al. 1997).

3.10 Environmental data

Daily minimum and maximum temperatures were obtained from Agriculture and Agri-Food Canada, as well as daily precipitation data obtained from Environment Canada for the Lanigan area. These data were then averaged in order to obtain mean monthly temperature and precipitation (Appendix Tables B.1 – B.3).

4.0 EFFECT OF WINTER FEEDING SYSTEM ON COW PERFORMANCE AND ESTIMATED DRY MATTER INTAKE

4.1 Introduction

Maintaining animal body weight and performance throughout a winter feeding season is the primary concern in any beef cattle operation. Several techniques are used to determine effects of winter feeding on cow performance, including measure of body weight change, ultrasound rib fat measurements, body condition scoring and reproductive performance. During the winters of 2005-2006 and 2006-2007 winter feeding trials were conducted at the Termuende Research Ranch located 8 km east of Lanigan, SK, to evaluate the effects of four winter feeding systems on beef cow performance and estimated dry matter intake.

4.2 Materials and methods

Animal data in the extensive field feeding systems (BG, SG, ST-CH) was collected using a portable field handling and weighing system and cow data from the intensive (DL) system was collected using the weigh scale facilities at the Termuende Research Ranch. Body weight (BW), body fat reserves, and body condition (BCS) were used as indicators of cow performance and treatment effect. All measures were taken on each animal over 2 consecutive days at the start of test (SOT) and at the end of test (EOT). In 2005-2006, body weights were also taken every 21 d throughout the trial. Length of trial in Yr 2 (2006-2007) did not allow for 21 d weights. Cow BW was taken in the morning prior to feeding and watering to account for gut fill variability. In order to maintain accuracy and for a fair comparison of both years (Yr 1 to Yr 2), cow performance data was analyzed using the first 21 d of the 2005-2006 trial period (Yr 1) and total trial length (21 d) from the 2006-2007 trial period (Yr 2). Data from the entire 2005-2006 (78 d) feeding period was also analyzed in order to show trial length effect on animal performance. All cow BW data was adjusted to account for conceptus growth according to the following (NRC 1996) equation:

Equation 4.1 Conceptus weight (kg)=(CBW*0.01828)*e$^{[(0.02*t)-(1.43e-005*t*t)]}$

Where CBW = calf weight at birth and t = days of pregnancy

This equation can be used to determine pregnancy adjusted live weight for the cow at any stage of pregnancy.

Rib fat measurements were taken each year by an independent technician. An Echo Camera SSD-500 diagnostic real time ultra-sound (RTUS) unit (Overseas Monitor Corporation Ltd., Richmond BC) equipped with a UST 5044 - 17 cm 3.5 MHz linear array transducer was used at a location (between 12th and 13th rib fat) to estimate body reserves. Cow BCS was determined by an independent technician who scored the cows using the short ribs as a measurement site, on a scale of 1 to 5 (1 = emaciated to 5 = grossly fat) (Lowman et al. 1976).

Cows were pregnancy checked prior to start of test to ensure all animals on trial were pregnant. Reproductive data collected included calf birth date and calf birth weight. This data was used to determine treatment effects on calf birth weight, and calving span. Each calving date was assigned a number with 12 April equal to day 1 (first day of 1st calving cycle) and 13 June equal to day 63 (last day of 3rd calving cycle). This numeric data was then used to run statistical analysis to determine treatment effects on calving interval.

Estimated apparent (DM) intake and feed utilization was determined for both years of the study. Reference points used to determine amount of feed offered in the field systems included, (i) estimation of crop DM yield (as outlined in Section 3.6 according to the techniques described in Volesky et al. (2002) and Baron et al. (2006), (ii) feed quality values from laboratory analyses; and (iii) rations formulated for dry pregnant beef cows at start of second trimester of pregnancy according to NRC (1996). Residual or leftover (refusal) feed was estimated each spring by randomly weighing remaining residue in each feed system paddock and pen area. Fecal and foreign debris not associated with the residue were removed. Number of residual samples weighed included; (a) 12 bale sites in each bale graze (BG) replicate, (b) 10, 30 x 3 m sections of swath in each swath graze (SG) replicate, (c) 30 straw-chaff piles in each straw-chaff (ST-CH) replicate and, (d) 12 bale sites per drylot (DL) replicate. Residual feed weight was then subtracted from the weight of offered feed to predict apparent animal intake based on a 3 d feeding period represented by the following equation:

Equation 4.2 $\mathbf{(\text{kg DM } p^{-1} \text{ allocated} - \text{kg DM } p^{-1}\text{residual})/n^{-1}/p}$

where p = 3 d feeding period, n = 15 cows per experimental unit;

Feed utilization was compared between treatments to determine average percent utilization (Appendix A.4). All estimates were determined and reported on a DM basis.

4.3 Results and discussion

4.3.1 Animal performance

During the 2005-2006 study period (Yr 1) cows were able to graze the field systems from 17 November 2005 to 2 February 2006 (78 d), with snow arriving the first week of December. In the second year of the study (2006-2007) (Yr 2) the cows grazed from 1 December 2006 to 21 December 2006 (21 d). During the 2006-2007 feeding period, large amounts of snow were received prior to the trial start date and totaled 825 mm from October to the end of the study period (December). In contrast, in Yr 1 no snowfall was received prior to trial start and only 470 mm was received throughout the trial period (Environment Canada, Appendix B.1). Management of cattle in the field feeding systems was difficult due to inaccessibility of the feed, from freezing rain, frozen and drifting snow.

Initial body weight (BW) during both years of the study did not differ significantly between treatment systems, however BW were different between the two years ($P<0.05$) (Table 4.1). Statistical analysis of the first 21 days of the 2005-2006 trial and 2006-2007 study periods, proved a significant ($P<0.05$) year x treatment interaction of BW change (BWΔ), however not BCS change (BCSΔ) and RIB change (RIBΔ) (Table 4.1).

Table 4.1 Effect of winter feeding system on beef cow performance over 21 d period

Item[z]	Year			Treatment					p-value		
	2005-2006	2006-2007	SEM[y]	BG[x]	SG	ST/CH	DL	SEM	Y[w]	T	Y*T
Weight (kg)											
Start of trial	630.5*a*	598.6*b*	2.02	615.0	614.0	616.0	613.3	2.86	<0.05	0.91	0.97
End of trial	623.4	619.2	3.31	618.6	616.1	616.1	634.3	4.68	0.39	0.05	<0.05
Change	-6.3*b*	20.6*a*	2.44	4.13*b*	3.26*b*	0.02*b*	21.00*a*	3.44	<0.05	<0.05	<0.05
Body condition (1-5)											
Start of trial	2.8*a*	2.6*b*	0.02	2.7	3.0	2.7	2.7	0.03	<0.05	0.95	0.33
End of trial	2.7*a*	2.7*b*	0.02	2.7	2.7	2.6	2.7	0.03	<0.05	0.25	<0.05
Change	-0.05*b*	0.04*a*	0.02	0.02	0.03	-0.05	-0.02	0.03	<0.05	0.26	0.33
Body fat (mm)											
Start of trial	6.0*a*	5.0*b*	0.18	5.5	5.5	5.0	5.9	0.25	<0.05	0.17	0.17
End of trial	5.7*a*	4.8*b*	0.17	5.8*a*	5.2*a*	4.1*b*	6.0*a*	0.23	<0.05	<0.05	0.06
Change	-0.28*b*	0.15*a*	0.11	0.20*a*	-0.20*ab*	-0.66*b*	0.41*a*	0.16	<0.05	<0.05	0.50

[z] Item = body weight adjusted for conceptus

[y] SEM=standard error of the mean

[x] BG = balegraze; SG = swathgraze; ST-CH = straw/chaff; DL = drylot

[w] Y = year effect; T = treatment effect; Y*T = year by treatment interaction

[a-b] Within row means having the same letters do not differ significantly (P<0.05)

The interaction in body weight change occurred due to the difference observed in from the 2005-2006 trial period, in which cows in the extensive feeding systems had a negative BW change in comparison to the 2006-2007 trial period where cows had a positive body weight change (Figure 4.1). The difference in results from Yr 1 to Yr 2 suggests a lengthy acclimatization and environmental effect occurred in the extensive feeding systems during the 2005-2006 year. Differences in annual weather patterns (Appendix Table B.1) and feed quality (Appendix Table A.1) may increase management difficulties in these types of field feeding systems. Differences in feed quality and accessibility of feed were also reported by Baron et al. (2006) who determined that daily cow DM intake varied by 33% over the feeding period. During the current study, cows were offered feed every 3 d and amount of feed offered was continually adjusted through the first 21 d of the trial in order to meet daily maintenance requirements. Variations in DM intake and feed quality throughout the 3 d feeding period may have affected animal body weight. The calculated difference in amount TDN consumed (kg DM cow^{-1} d^{-1}) by the SG system cows from Yr 1 to Yr 2 was 2.58 kg d^{-1} (Table 4.2), thus suggesting an explanation for the observed difference in BW change of cows on the SG system between the two trial years and the year x treatment interaction.

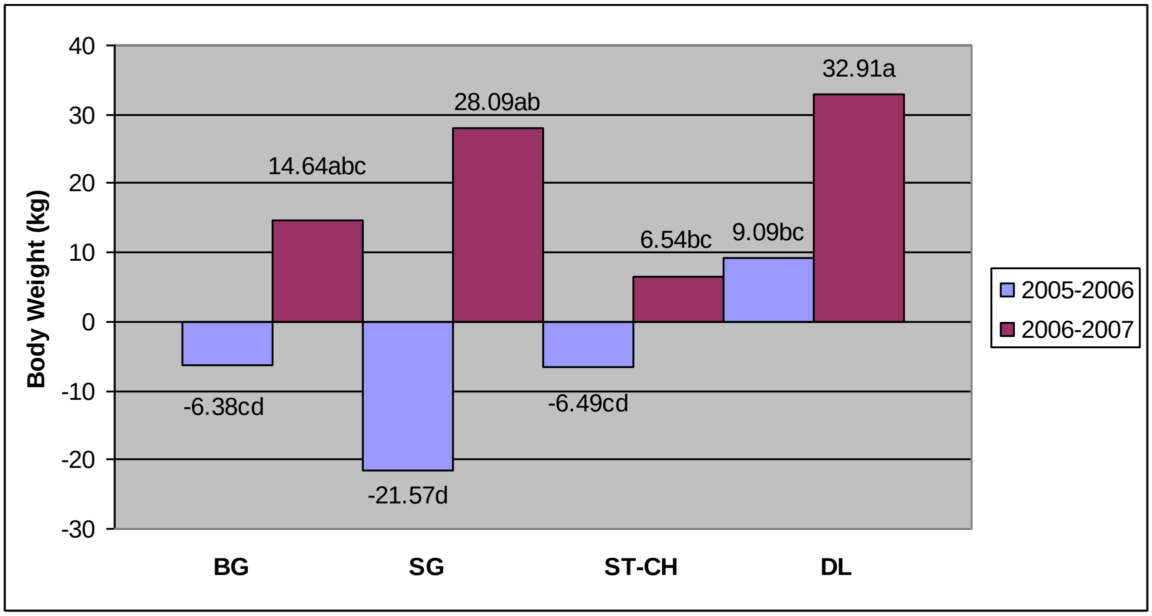


Figure 4.1 Year by treatment interaction observed for body weight change (kg) over 21 d trial period for two years

[a-d] Means having the same letters do not differ significantly (P<0.05)

Table 4.2 Effect of winter feeding system on apparent dry matter intake and body weight change

	Dry matter intake (kg d^{-1})	TDN[z] (kg d^{-1})	BWΔ[y] (kg)
2005/2006, 78d			
Swath graze	10.30	6.31	-7.96*b*
Bale graze	12.70	7.80	10.31*ab*
Straw-chaff	11.84	6.79	9.37*ab*
Drylot	11.64	7.15	23.36*a*
SEM[x]	0.47	0.29	4.21
2006/2007, 21d			
Swath graze	13.34	8.89*ab*	28.91*ab*
Bale graze	13.90	9.84*a*	14.64*ab*
Straw-chaff	13.56	7.54*b*	6.54*b*
Drylot	14.30	10.12*a*	32.91*a*
SEM	0.83	0.45	5.18

[z] TDN = estimate total digestible nutrients consumed

[y] BWΔ = body weight change

[x] SEM = standard error of the mean

[a-b] Within a column, means followed by the same letters do not differ significantly (P<0.05)

Analyses of end of trial animal parameters (body weight, body condition, and backfat) of the first 21 d of 2005-2006 and 2006-2007 trial periods, showed a year x treatment trend interaction ($P<0.06$) for end of trial rib fat thickness and significant year x treatment interaction ($P<0.05$) for end of trial body weight and end of test body condition score (Table 4.1, Figures 4.1, 4.2, 4.3). These interactions again would suggest difficulty in managing animal performance in these types of winter feeding systems. The vast differences in weight change observed from Yr 1 to Yr 2 may suggest that animals grazing these extensive systems may have negative weight gain 1 out of 2 years (negative gain in Yr 1 vs. positive gain in Yr2), however more research is required to draw more accurate conclusions.

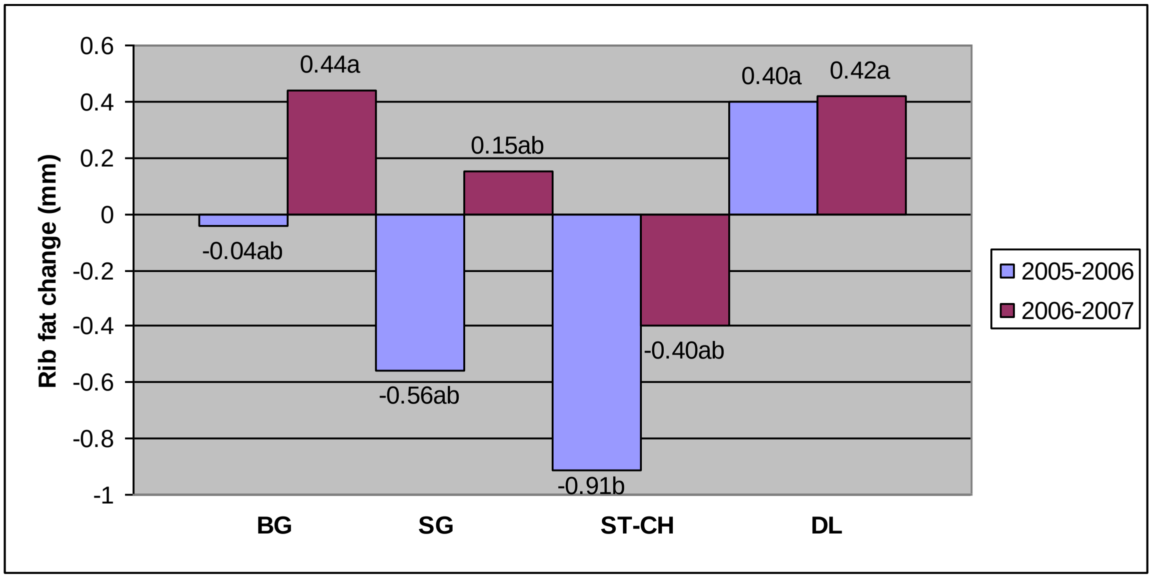


Figure 4.2 Year by treatment interaction observed for rib fat (mm) over 21 d trial period for two years

$^{a\text{-}b}$ Means having the same letters do not differ significantly ($P<0.05$)

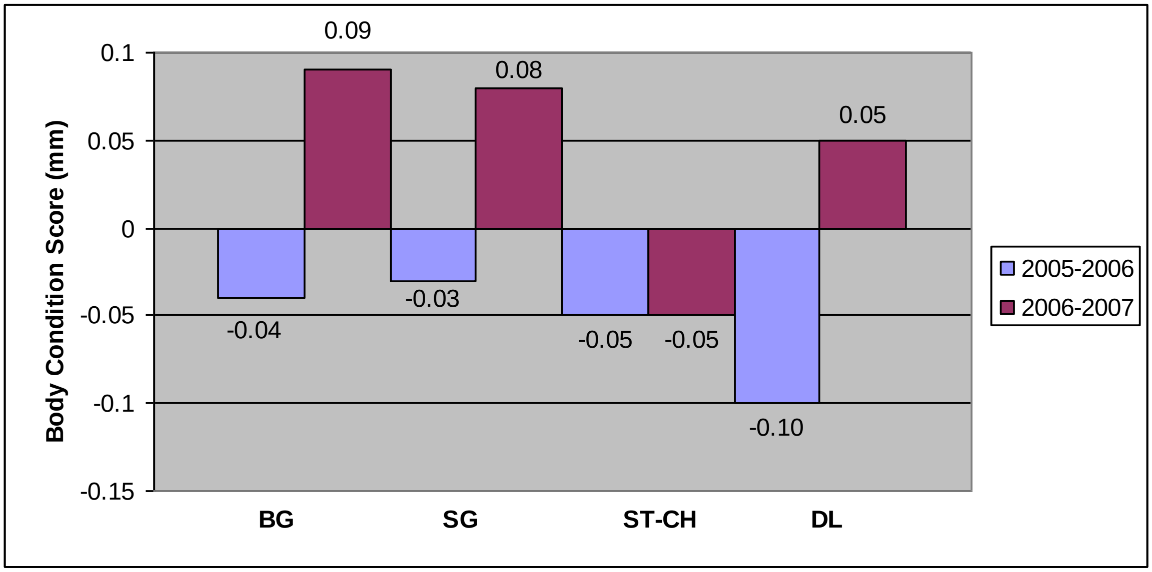


Figure 4.3 Year by treatment interaction observed for body condition score over 21 d trial period for two years

$^{a-b}$Means having the same letters do not differ significantly (P<0.05)

During the 2005-2006 study period there was a 3X greater (P<0.05) increase in body weight change for the DL cows compared to the SG cows, -21.6 and 9.1 kg, respectively (Figure 4.1). Large differences were also observed during the 2006-2007 study period in which there was a significant difference (P<0.05) in body weight change between the DL cows and the ST-CH graze cows of 32.9 and 6.5 kg, respectively (Figure 4.1). This represented a 5X greater increase in BW for the DL fed cows over the crop residue graze cows. These extreme differences in animal performance between years demonstrates the difficulty in managing these types of winter feeding systems and illustrates the annual variations in environment and feed quality. These observed differences in body weight change may be attributed to inaccessibility of the straw-chaff feed, due to inclement weather, similar to differences as reported by Baron et al. (2006), who stated that a decrease in feed quality and inaccessibility of feed resulted in lower average daily gain (ADG) of animals consuming swaths in comparison to baled forage. In the Alberta study, a 33% decrease in cow DMI was reported and was attributed to inaccessibility of the feed due to inclement weather, similar to the current study. These observations can be extrapolated to include straw-chaff grazing and suggest that environment (snow depth) may greatly impact accessibility of straw-chaff crop residue, thereby impacting animal performance. However, in an earlier study Nayigihugu et al. (2002) reported that cow performance was not affected by swath grazing and that this type of winter feeding system provided a valuable alternative to drylot feeding systems.

Volesky et al. (2002) observed a slight increase in BW of cows on swath graze fields compared to cows fed in drylot during a 2-Yr study conducted in Nebraska. However this BW gain was attributed to the large amount of crop regrowth that occured in the swath graze paddocks (Volesky et al. 2002). In contrast, other studies have reported that cows grazing swaths performed at maintenance levels (0.04 kg d^{-1}) whereas animals fed in a more controlled drylot environment had greater gains (0.42 kg d^{-1}) (McCartney et al. 2004; Nayigihugu et al. 2003). The differences observed in these studies combined with the results from the current study suggests that differences in physical characteristics between SG and ST-CH feed may have a greater impact on feed accessibility and suggest yearly variation in forage accessibility for both these feeding systems.

The differences in bodyweight ($P<0.05$) observed in both years (Figure 4.1) of the study between the extensive systems (BG, SG, ST-CH) and intensive (DL) system is not perceived to be a negative aspect of the extensive systems since all cows were allocated feed for maintenance requirements (no net loss or gain of body tissue beyond conceptus growth). The lower weight gain observed in the extensive systems (BG, SG, ST-CH) is similar to that reported by McCartney et al. (2004), in an Alberta study, where cows on a swath graze system gained weight slower than traditional drylot feeding systems. This may also help explain the two-way interaction (P<0.05) which occurred between years in the current study (Table 4.1). The Alberta study also reported that cow weight at pre-breeding was lowest in the swath grazing system compared to the drylot feeding systems, however this was not deemed a negative aspect of the system as cow condition was still adequate for breeding (McCartney et al. 2004).

Statistical analysis of the entire 2005-2006 trial period (78 d) (Table 4.3) indicated numerical differences (P>0.05) in initial BW between treatments with a significant (P<0.05) difference observed in final body weight for cows on DL and SG systems. A difference (P<0.05) was also observed for cow body weight on SG and DL treatments (Table 4.3), -8.0 and 23.4 kg, respectively. However, an increase in BW was observed between d 21 and d 78 for cows on the SG treatment.

Table 4.3 Effect of winter feeding system on beef cow performance over 78 d period

Item	Body weight[z] (kg)			Body condition score (1-5)			Rib fat (mm)		
	initial	final	change	initial	final	change	initial	final	change
2005/2006									
Drylot	629.2	652.6*a*	23.4*a*	2.8	2.7*a*	-0.01*a*	6.1	7.0*a*	0.9*a*
Bale graze	632.0	642.4*ab*	10.4*ab*	2.8	2.8*a*	-0.03*ab*	5.8	5.6*b*	-0.2*b*
Straw/chaff	631.1	640.5*ab*	9.4*ab*	2.8	2.5*b*	-0.30*ab*	6.0	3.6*c*	-2.5*d*
Swath graze	629.7	621.7*b*	-8.0*b*	2.7	2.7*ab*	-0.06*b*	6.1	4.9*b*	-1.2*c*
SEM[y]	2.52	4.76	4.21	0.04	0.04	0.061	0.17	0.24	0.20

[z] cow bodyweight weight adjusted for conceptus growth

[y] SEM = standard error of the mean

[a-d] Within column means having the same letters do not differ significantly (P<0.05)

These SG cows had an increased body weight of 13.6 kg over the last 57 d on trial, however the total weight change over the 78 d trial was a loss of 8 kilograms (Table 4.3). The observed increase in BW during the last 8 wk of the trial may be a result of compensatory gain which occurs when nutritionally restricted animals are placed on a higher plane of nutrition and subsequently gain BW faster and have a lower feed to gain ratio than animals not restricted nutritionally (Fox et al. 1972). Although cows in this study were not nutritionally restricted, the acclimation period required for any naïve cows on this treatment may have allowed for compensatory gain once the animals reached a plane of nutrition that was adequate for maintenance throughout the remaining trial period. Previous research has suggested cattle require an acclimation period prior to grazing winter field crops. Research conducted by Fernandez-Rivera and Klofenstein (1989) determined that naïve cattle require a learning period when grazing corn residue. During the 2005-2006 year, cows on the SG system consumed on average 15% less DM and 13% less TDN (Table 4.2) over the trial period (78 d) than the other feeding systems (BG, ST-CH, DL) possibly explaining the observed change in body weight for cows in the SG treatment.

Analysis of the entire 2005-2006 trial period (78 d) showed cows in the 3 extensive feeding systems (BG, SG, ST-CH), had a negative change in body fat, -0.2, -1.2, -2.5 mm, respectively, while cows fed in drylot pens had increased rib fat of 0.9 mm (Table 4.3). These results are similar to McCartney et al. (2004) who observed cows grazing swaths had a lower backfat thickness and reduced weight gain in comparison to cows fed in a drylot. Throughout both years of the current study, a decrease in rib fat was observed in the ST-CH system with a decrease of -0.9 mm and -0.4 mm for Yr 1 and Yr 2, respectively (Figure 4.2). These results could be attributed to the lower dry matter intake

(DMI) and the lower amount of TDN consumed by cows on this system (Table 4.3). Cows grazing crop residue in this trial had minimal weight gain (Tables 4.1 and 4.2), and the loss of back fat was reflected in body weight and condition changes (Figures 4.1 and 4.3). The reduced DMI of the cows grazing straw-chaff piles may have been a result of the environmental and field conditions. A study conducted in the Northern Great Plains, determined that grazing time and forage intake were affected linearly by minimum daily temperature and concluded that adverse weather reduced both grazing activity and subsequent DMI (Adams et al. 1986). Conversely, Olson and Wallander (2002) determined that foraging animals with access to windbreaks may actually have lower gains than those foraging without windbreaks due to differences in time spent grazing. Even though all animals in this study had access to windbreaks, this would suggest that cows having access to windbreaks spend less time grazing and subsequently have lower gains than those cows grazing without windbreaks.

4.3.2 Apparent dry matter intake

Cow body weight change in this section will be discussed for the entire 2005-2006 trial (78 d) and 2006-2007 periods (21 d) (Table 4.2). Due to the length of the trial (78 d) during 2005-2006 trial, forage quality in each winter feeding system was determined and compared at start of test (SOT) and end of test (EOT). Even though forage quality in the extensive feeding systems (BG, SG, and ST-CH) did not decline dramatically throughout the feeding period during Yr 1 of the study (Appendix Table A.5), feed quality differences observed between extensive systems were similar to results reported by Baron et al. (2006) and Volesky et al. (2002). During Yr 1 of the current study, crop residue consumed by the ST-CH cows had 24% lower energy (TDN) at EOT compared to BG, SG and DL forage. In addition, straw-chaff residue also had 17 % lower TDN at SOT, thus demonstrating the need to supplement all the cows in this wintering system (Appendix Table A.5). Forage quality over the 3 d feeding period could also vary, possibly having an effect on animal performance (McCartney et al. 2004). Two different methods for determining feed energy (TDN), the Pennsylvania State equation (Adams 1995), and the Weiss equation (Weiss et al. 1992), are presented in Table 4.4. When comparing the two methods used for determining TDN content of feeds in this study it appears that Weiss et al. (1992) is a more comprehensive approach as the Weiss prediction equation uses several wet chemistry values to determine energy density, thereby reducing any over-estimation of TDN as in the Penn State equation (Equations 3.2 and 3.2; Section 3.8.1). On average the Penn State equation overestimated TDN content of feed by 2 to 5 percent (Table 4.4). Due to the small difference between calculations and the short trial length in 2006-2007, further laboratory analysis was not deemed necessary for the feed samples during the

2006-2007 trial. However it is important to note that methodology differences in TDN calculations combined with inclement weather may have impacted cow performance in 2005-2006.

Table 4.4 Comparison of feed energy values predicted by two methods

Item	Swath Graze	Straw-Chaff	Bale Graze	Drylot
	------------------------------TDN^z (%)------------------------------			
Penn State Equation (%)	61.3	49.8	61.4	65.4
Weiss Equation (%)	58.9	54.3	60.4	62.2

^{z}TDN = total digestible nutrients

Predicted DMI (kg d^{-1}) estimation is explained in Equation 4.2 (Section 4.2). To compare differences in feed and energy (TDN) consumption, TDN (kg DM d^{-1}) and DMI (kg d^{-1}) for each wintering system was determined. Estimated apparent dry matter intake (DMI) (kg d^{-1}) in each year of the study did not differ significantly ($P<0.05$) between feeding systems (Table 4.2). Total digestible nutrient intake (kg DM cow^{-1} d^{-1}) was determined using estimated DMI values and forage energy values from lab analyses.

During the 2005-2006 trial period, no differences were observed ($P>0.05$) in TDN (kg DM d^{-1}) consumed between winter feeding systems. However, cows grazing swaths in the field paddocks consumed 15% less feed and 13% less TDN compared to cows on the BG, ST-CH or DL (Table 4.2). This differed from McCartney et al. (2004) who reported that cows grazing swaths consumed 21.2% more energy than those traditionally fed in drylot. As shown in Table 4.4, differences in feed quality were observed between systems, but consumed TDN (kg DM cow^{-1} d^{-1}) remained similar between the BG, ST-CH and DL treatments (Table 4.2). This is most likely a result of the supplementation provided to the cows in the ST-CH treatment. DMI and TDN levels were sufficient to maintain cow BW in the DL, ST-CH and BG systems (Table 4.2), however decreased consumption of feed coupled with a decrease in TDN consumed resulted in swath graze treatment cows having a body weight loss of 8 kg over the 78 d feeding period.

During the 2006-2007 trial period there were no differences ($P>0.05$) in DMI (kg DM d^{-1}) between winter feeding systems. In Yr 2 of the study, DL cows had the greatest numeric DMI (kg d^{-1}), resulting in the greatest intake of TDN (kg DM d^{-1}) compared to cows in the extensive field feeding systems (BG, SG and ST-CH). This increased consumption of calculated TDN (kg DM d^{-1}) resulted in the greatest positive weight change (32.9 kg) of drylot fed cows.

It has been suggested that animals in a swath grazing field system require 18 to 21% more energy than cows fed in a drylot system due to increased requirements associated with walking, environmental stress, and activities involved with foraging (McCartney et al. 2004). In the current study in Yr 1, the DL cows gained 23.4 kg which may be explained by the high TDN consumption by cows in this winter feeding system. The greater TDN consumption by DL cows may be due to the lack of environmental stress on these animals since grazing activity and forage intake can be reduced in inclement weather (Adams et al. 1986), which may have decreased the DMI of cows in extensive field feeding systems (BG, SG and ST-CH) (Table 4.2).

For the most part, forage consumption or DMI of cows in this study were similar to NRC (1996) requirements for beef cows in similar conditions. Based on a diet containing 60% TDN, cows with a similar weight and gestation stage as the study animals were calculated to have DMI of 11.28 to 11.90 kg (NRC 1996). In Yr 1, cows grazing barley in swaths had 11% less DMI than NRC (1996) requirements, thus possibly resulting in body weight loss, whereas cows grazing in the BG, ST-CH, and DL systems had on average 4 % greater DMI than NRC (1996) requirements (Table 4.2). All cows in the extensive feeding systems had 15 % higher DMI (Table 4.2) than NRC predictions in Yr 2 which is similar to Baron et al. (2006) who reported DMI of swathed barley in excess of NRC (1996) requirements. McCartney et al. (2004) reported DMI of cows fed barley swaths to be 10.9 kg DM cow^{-1} d^{-1}, similar to results seen in this study (Table 4.2).

4.3.3 Reproductive Efficiency

Winter feeding system did not have a significant effect ($P>0.05$) on reproductive performance (calf birth weight or calving span) when analyzed over two production cycles (Tables 4.5 and 4.6). Thompson et al. (1983) reported that even with observed differences in forage energy levels during winter, as long as maintenance requirements were met, varying energy levels did not have an effect on either cow or calf performance throughout the subsequent production cycle. In addition, many studies have reported that winter feeding strategies over several production cycles, showed no significant impact on reproductive efficacy (McCartney et al. 2004; Adams et al. 1994; Willms et al. 1993; Shell et al. 1995a). However other studies have proved that prepartum nutrition can have significant effects on calf birth weight (Holland and Odde 1992; Boyd 1987). Cows on this trial were in the late stages of the 1st trimester and early stages of the 2nd trimester, therefore energy requirements were quite low in relation to the 3rd trimester requirements (8.58, 9.86, and 13.41 Mcal d^{-1} NE), respectively (NRC 1996).

Calving span was not significantly affected ($P<0.05$) by treatment in either year of the study (Table 4.6). Numeric data (calving factor) was assigned to calving dates, with each calving date corresponding to a number within the first three calving cycles (calving factors 1 to 63). Calving date differed by 3 d during the 2005-2006 study with average calving dates of 24 April, 25 April, 25 April, and 27 April for the ST-CH, SG, DL and BG systems respectively. During the 2006-2007 study similar results were observed with average calving dates of 26 April for the SG and ST-CH systems, and 29 April for the BG and DL systems.

Table 4.5 Effect of winter feeding system on calf birth weight over two production cycles

Year	Swath graze	Straw-chaff	Bale graze	Drylot	SEM[z]
	----------------------------------	--kg--	--------------------------------		
2005-2006	45.9	50.0	47.3	46.1	2.09
2006-2007	42.7	42.4	44.0	43.5	1.06

[z] SEM=standard error of the mean

[a-b] Within row means having the same letter do not differ significantly (P<0.05)

Table 4.6 Effect of winter feeding system on calving span[z] over two production cycles

Year	Swath graze	Straw-chaff	Bale graze	Drylot	SEM
	----------------------------------	--d--	--------------------------------		
2005-2006	15	15	18	18	2.3
2006-2007	14	13	16	14	2.1

[z] calving span = numeric data corresponds to date of calving where April 12 = 1 & June 13 = 63

[y] SEM=standard error of the mean

[a-b] Within row means having the same letter do not differ significantly (P<0.05)

4.4 Conclusions

Snow conditions and extreme cold temperatures may reduce grazing time having a subsequent effect on cow DMI (Lawrence and Heinrichs 1974; Adams et al. 1986). Inclement weather patterns throughout this 2-year study, and the large amount of moisture received during the 2006-2007 trial period, impacted animal access to available forage for grazing and the length of the grazing season. These factors may have led to increased variation in feed quality (feed moisture levels changes) throughout the 3 d feeding periods, resulting in periods of energy deficiency (McCartney et al. 2004; Willms et al. 1993). Calculated dry matter intake (DMI) and total digestible nutrients (TDN) consumed were within NRC (1996) requirements for animals at a similar production level, with extensive winter feeding system in excess of NRC (2996) requirements, similar to results presented by Baron et al. (2006).

Animal performance was slightly affected by the swath graze system where cows experienced more negative weight change during the 2005-2006 trial period than cows bale grazing or consuming straw-chaff crop residue. When comparing the first 21 d of the trial in 2005-2006 and 2006-2007, a year by treatment interaction was observed in the extensive field feeding systems (SG, ST-CH, BG). More specifically, cows on the swath graze paddocks had body weight loss during the first year and body weight gain during the second year of the study. The observed loss in Yr 1 may have been due to the lengthy adaptation period required for naïve cows on this wintering system, however numerous studies validate the benefits of extending the grazing season by use of field feeding systems (McCartney et al. 2004; Volesky et al. 2002; Nayigihigu et al. 2002; Adams et al. 1994). The difference in results from Yr 1 to Yr 2 suggests that an adaptation and environmental effect occurred during the 2005-2006 trial, and confirms the management difficulties that may occur using field feeding systems.

Reproductive efficiency (calf birth weight and calving span) was not affected by winter feeding systems since all animals on trial were fed to maintenance and were not nutritionally limited. These results are similar to other studies which report non-significant effects of winter feeding systems on cow reproductive performance (McCartney et al. 2004; Adams et al. 1994; Willms et al. 1993; Thompson et al. 1983).

Length of trial was affected by environmental conditions (inclement weather), subsequently affecting both DMI (feed consumption) and animal performance in the extensive field feeding systems. These factors must be examined in combination when producers are analyzing the nutritional, practical, and management aspects of extensive feeding systems. Although extensive winter feeding systems prove beneficial in many situations, stored feed may still have to be produced in order to mitigate the risk of decreased animal performance due to inclement weather.

5.0 EFFECT OF WINTER FEEDING SYSTEM ON SOIL NUTRIENTS, SOIL DENSITY & CROP YIELD

5.1 Soil nutrient cycling & soil density

5.1.1 Introduction

The effect of extensive winter feeding systems on soil strength and density is an important aspect to consider as elevated soil density could lead to issues such as increased runoff and eutrophication. As well, the addition of “mulch” from manure throughout the winter season will increase the capture of nutrients into the soil (Smoliak 1965). These factors can impact the amount of crop biomass produced the following growing season and have raised questions concerning the impact of extensive feeding systems on the environment. During the winter of 2005-2006 an experiment was conducted to determine the effects of 3 extensive winter feed systems with 3 replicates per system on soil nutrients, soil compaction, and crop biomass production. Extensive feeding systems included bale grazing round greenfeed bales (BG), grazing swathed whole plant barley (SG) or grazing barley crop residue piles (straw + chaff) (ST-CH) in field paddocks.

Traditional manure management involves applying drylot manure to annual cropped land in either composted or raw manure form. This is both a functional aspect to drylot systems as the manure must be cleaned from the pens, and also allows for increased nutrient capture from the manure, thus decreasing input costs. However, loss of nitrogen from the liquid portion of manure can occur (Jarvis et al. 1989) and management strategies must be implemented to decrease losses and increase capture of nutrients from manure. Composted manure has been shown to increase the available nutrients in the manure

(Lardner 2003), while at the same time decreasing environmental risks. During the winter of 2005-2006 a small plot manure application trial was conducted to determine the effects of raw vs. composted manure application on soil nutrients, soil compaction, and crop yield the following growing season.

5.1.2 Materials and methods

Soil nutrient availability was measured in each replicate area (n=9) of the extensive feeding systems (BG, SG, ST-CH) to determine the effects of managing beef cows in extensive winter feeding systems on plant available soil nitrogen (N) and phosphorus (P) according to procedures described in detail by Jungnitsch et al. (2008). Three randomly chosen cores were taken from each replicate plot (n=9) at 0-15 cm and 15-30 cm depth increments at the high, mid and low slopes throughout the plot area. Soil cores were bulked according to slope position and analyzed separately to determine if soil nutrients were affected by slope. Depth increments were bulked together for each plot.

Soil nutrient distribution was also measured to determine the effect of winter feed system on soil nutrient flux and nutrient distribution of N and P using PRS anion exchange membrane probe technique (Qian and Schoenau 2002). A 32 point grid (6.1m X 7.6m) was superimposed randomly on a feeding site in each treatment area. Anion Plant Root Simulator probes (PRS) were inserted into the soil at each grid point for 7 days in May 2006 (post winter feeding), and this data was inputted into a computer programming model called Surfer 8.0™ (Manufacturer). The program then extrapolated outward from each data point to create a visual map of nutrient supply rate distribution throughout the feeding site.

Soil density was measured using the pentrometer technique (Japp 2007). Measurements were taken at each of the 32 grid points. This data then allowed for an estimate of the effect of winter feed system on soil density.

In addition, a randomized complete block (RCBD) small plot study was conducted with 3 treatments and 4 replicates per treatment. Site dimensions for each replicate area measured 30 x 37 m. Treatments included a check (no manure applied), 1X rate of manure (22.4 tons ha^{-1}) and 1X equivalent rate of compost (6.72 tons ha^{-1}). Three cores were collected from each replicate plot (n=12) at the 0-15 cm and 15-30 cm depth increments. Cores were taken at the high, mid and low slopes throughout the plot. These cores were analyzed separately to determine if soil nutrients were affected by slope. Depth increments were bulked together for each plot. Two anion Plant Root Simulator probes (PRS) were inserted into the soil in each replicate for 7 d in May 2006, and this data was used to determine soil nutrient flux.

Soil density was measured using the pentrometer technique. Three measurements were taken from each replicate and this data allowed for an estimate of the manure application on soil density.

5.1.3 Results and discussion

5.1.3.1 Soil nitrogen level on cattle wintering sites

A slope by treatment interaction was analyzed and is presented in Table 5.1. No interactions ($P>0.10$) were observed for nitrogen levels in either the 0-15 or 15-30 cm depth. Effects of winter feeding system on soil extractable nitrate and ammonium nitrogen levels are shown in Table 5.2. Soil extractable nitrate nitrogen (NO_3-N) levels were affected ($P<0.10$) in the low slope position at the 0-15 cm depth (Table 5.2). Levels were highest on the balegraze (BG) system at 61.4 kg ha^{-1} and lowest on the straw/chaff (ST-CH) system (Table 5.2).

Table 5.1 Effect of slope and winter feeding system on nutrient levels (May 2006)

	Slope			Treatment[y]				P-value		
Item[z]	High	Mid	Low	BG	SG	ST-CH	LSD	S	T	S*T
0-15 cm										
NO_3-N (kg ha^{-1})	47.7	45.3	42.5	56.1	40.7	38.7	22.7	0.92	0.36	0.33
NH_4-N (kg ha^{-1})	7.5	7.3	6.8	7.1	7.5	7.0	1.2	0.64	0.75	0.80
P (kg ha^{-1})	149.5*b*	151.0*b*	197.8*a*	187.4	149.5	161.4	40.7	<0.10	0.28	0.25
15-30 cm										
NO_3-N(kg ha^{-1})	34.0*a*	32.2*a*	25.4*b*	34.8*a*	30.8*ab*	26.0*b*	6.7	<0.10	<0.10	0.38
NH_4-N (kg ha^{-1})	6.7*a*	6.5*ab*	5.9*b*	6.3	6.3	6.2	0.8	0.18	0.96	0.67
P (kg ha^{-1})	17.6	17.9	22.5	21.0	16.9	20.1	5.2	0.21	0.37	<0.10

[z] Item = NO_3-N = Soil extractable nitrate nitrogen, NH_4-N = Soil extractable ammonium nitrogen, P = soil extractable phosphorus

[y] Treatment = BG = Bale Graze, SG = Swath Graze, ST-CH = Straw-Chaff Grazing

[a-b] Within row means having the same letter do not differ significantly according to $LSD_{(0.10)}$

Table 5.2 Effect of winter feeding system on soil extractable nitrogen levels (May 2006)

Item	Swath Graze	Straw-Chaff	Bale Graze	LSD
	---------------kg NO_3-N^z ha^{-1}------------------			
0-15 cm				
High Slope	41.8	29.6	71.8	56.6
Mid Slope	42.0	58.7	35.3	37.8
Low Slope	38.3*b*	27.9*bc*	61.4*a*	14.6
15-30 cm				
High Slope	29.6	32.2	40.1	22.2
Mid Slope	36.6*a*	28.6*b*	31.4*ab*	7.2
Low Slope	26.2*ab*	17.1*b*	33.0*a*	10.7
	-----------------kg NH_4-N^y ha^{-1}----------------			
0-15 cm				
High Slope	8.3	6.8	7.4	2.2
Mid Slope	7.4	7.6	7.4	1.3
Low Slope	6.8	6.5	6.8	1.4
15-30 cm				
High Slope	7.2	6.6	6.5	2.1
Mid Slope	6.0	5.7	5.8	1.7
Low Slope	5.6*b*	6.2*ab*	6.6*a*	0.9

$^z NO_3$-N = Soil extractable nitrate nitrogen

$^y NH_4$-N = Soil extractable ammonium nitrogen

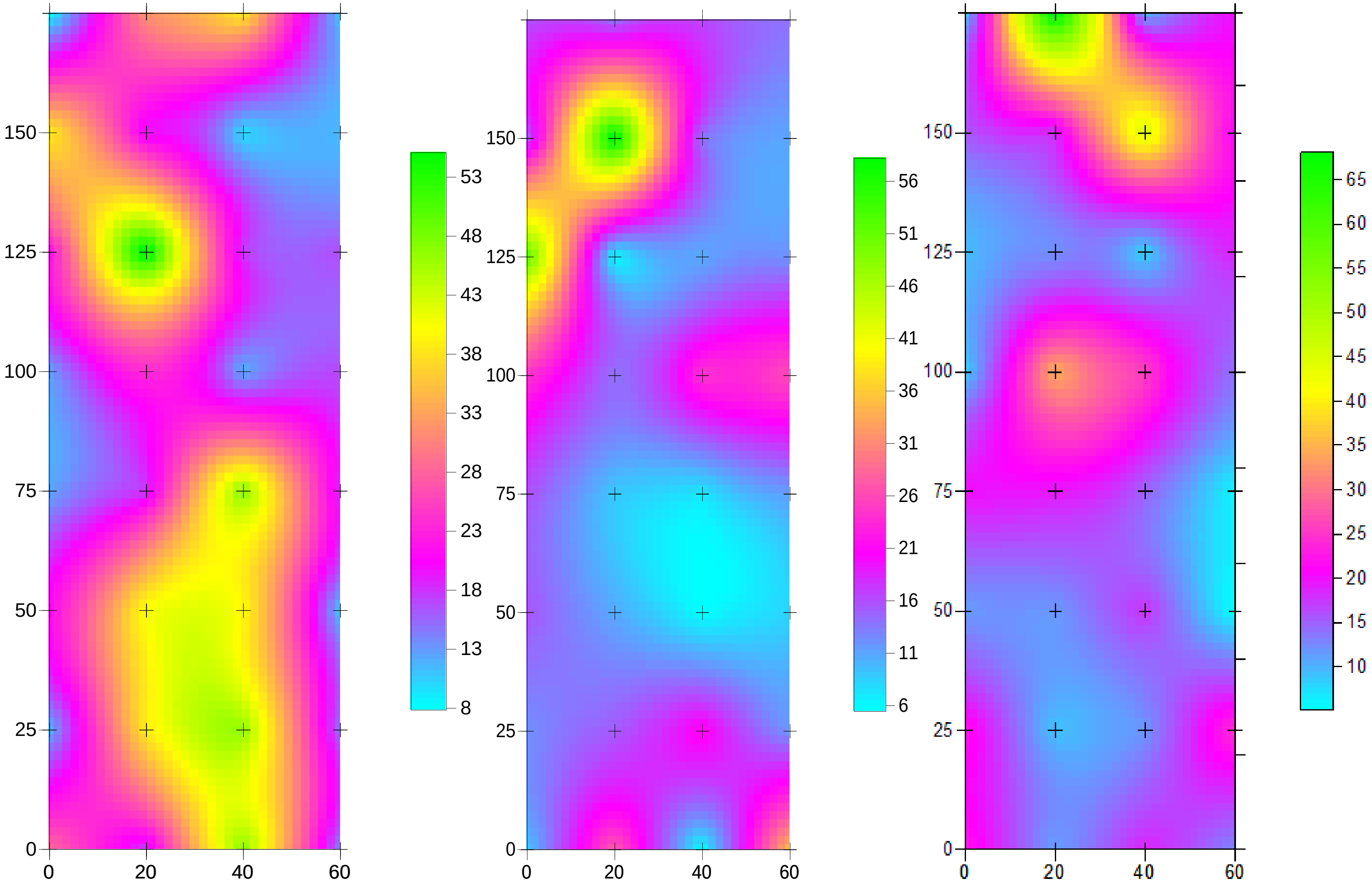
$^{a-b}$Within row means having the same letter do not differ significantly according to $LSD_{(0.10)}$

This could be attributed to the physical attributes of the feeding system. With increased concentration of feed per area in the BG system, the nutrient density per area is increased (Lenehan et al. 2005), thus amplifying the potential leaching of nutrients through the soil profile. There may be increased probability for leaching of NO_3-N in BG systems, since NO_3-N is a negatively charged ion, it is more likely to leach through the soil profile (Brady and Weil 2002). Numerical differences were observed between slope positions within treatment with bale graze areas capturing the largest amount of NO_3-N in the high slope position (Table 5.2) compared to the other treatments. ST-CH and SG treatments maintained higher levels of nutrients in the mid to upper slopes, again indicating the potential for environmental concerns in these systems if not properly managed (Table 5.2).

Levels of NO_3-N at the 15-30 cm depth were affected ($P<0.10$) by feeding system at both the mid and low slope (Table 5.2). This is most likely due to the historical manure application on the study site, thus the land was most likely nutrient saturated increasing the amount of NO_3-N that would move through the soil profile. Low slope NO_3-N levels were higher ($P<0.10$) on the BG system compared to ST-CH feeding area as discussed.

Levels of ammonium nitrogen (NH_4-N) were not affected by treatment or slope (Table 5.2) at either depth except 15-30 cm at low slope ($P>0.10$). This lack of differences may be due to the fact that ammonium ions are positively charged and are subject to adherence to the negatively charged soil colloids, thus decreasing the potential for leaching from the soil profile (Brady and Weil 2002). Levels of NH_4-N at the low slope position were lowest ($P<0.10$) on the swath graze paddocks at the 15-30 depth, however this again may be a result of the historic manure application.

Nitrogen distribution (NH_4-N + NO_3-N) within feed area was more evenly distributed on the swath graze treatment areas, as shown in Figure 5.1. The swath graze wintering system had greater feed distribution, when compared to the bale graze system, thus increasing the uniformity of nutrient distribution across the site. However, on the bale graze and straw-chaff feeding areas, high levels of nitrogen were detected around the feeding site. These patterns of increased N levels can be seen in the upper areas of Figure 5.1. The straw-chaff grazing area shows (Figure 5.1) little to no distinct pattern in nitrogen distribution, possibly due to lack of available N in the crop residue prior to start of trial which would decrease the amount of available N to be captured by the soil. Also, the high amount of carbon (C) associated with the crop residue (straw + chaff) may have tied up available nutrients rendering them unavailable at the time soil samples were taken. A high C:N ratio of residue causes immobilization of nitrogen (Qian and Schoenau 2004) . The amount of immobilization that occurs is directly related to the amount of residue. Cereals that produce a large amount of dry matter, subsequently have larger amounts of residue that will contribute to increased immobilization. Carbon to nitrogen ratios greater than 20 will result in immobilization of nitrogen in the soil. Straw on average contains a C:N ratio of 80, therefore it is most likely that some immobilization occurred in the straw-chaff feeding areas in this study (MAFRI 2007).



Swath graze Straw-chaff graze Bale graze

Figure 5.1 Effect of winter feeding system on pattern of soil N distribution supply (NO_3-N) (μg cm^{-2})

5.1.3.2 Phosphorus on cattle wintering sites

A two-way slope by treatment interaction was analyzed and is reported in Table 5.1, with an interaction ($P<0.10$) in the 15-30 cm depth. This interaction could be attributed to the long history of manure application on the land. The effect of feeding system on soil extractable P levels are presented in Table 5.3. High slope phosphorus levels at the 0-15 cm depth were affected ($P<0.10$) by feeding system (Table 5.3). However, P levels at low slope were greater numerically than high slope across all feeding systems, though not significantly different ($P>0.10$) (Table 5.3). On average across feeding systems, low slope positions had 32% greater P concentration than high slope positions (Table 5.3). These differences may be attributed to a greater stocking density at these feeding sites, which could lead to a nutrient saturated soil, therefore increasing the probability of leaching and runoff of nutrients to lower slope positions (Lenehan et al. 2005). Across treatments the BG paddocks accumulated 34% greater extractable P at the high slope position than SG and ST-CH. This may suggest large stocking densities in this type of winter feeding system may pose long term environmental risk from P loading. At the 15-30 cm depth, a greater ($P<0.10$) P concentration at low slope P levels was observed in the ST-CH paddocks. Due to the immobile nature of phosphorus in the soil profile, this may be attributed to historic manure applications.

Table 5.3 Effect of winter feeding system on soil extractable phosphorus

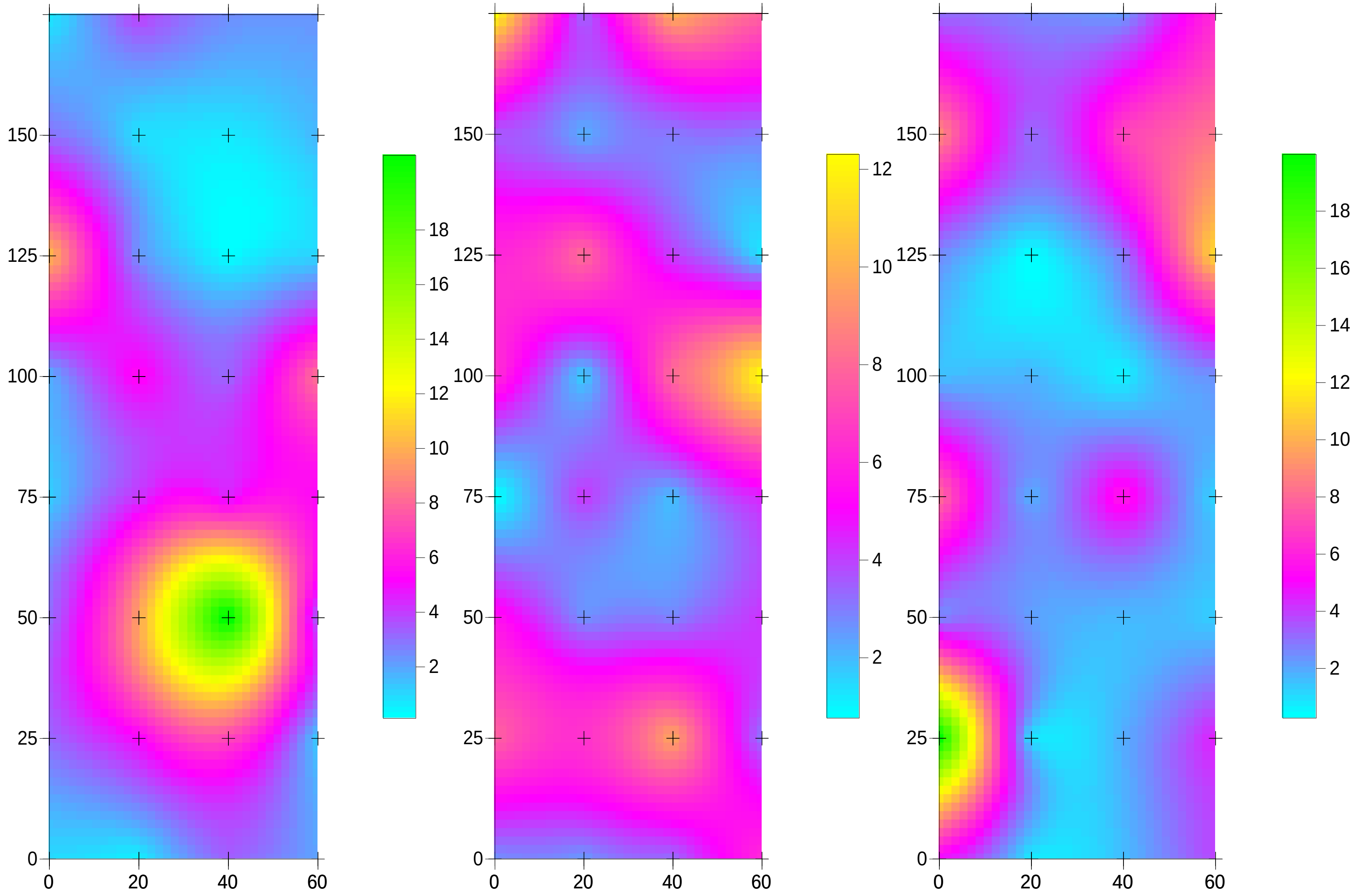
Item	Swath graze	Straw-chaff	Bale graze	LSD
	---------------------kg P^z ha^{-1}	--------------------		
0-15 cm				
High slope	153.7*ab*	100.5*b*	194.2*a*	81.6
Mid slope	136.6	165.0	151.5	117.2
Low slope	158.3	218.7	216.4	70.7
15-30 cm				
High slope	16.7	14.0	22.2	8.6
Mid slope	16.2	14.3	23.1	15.7
Low slope	17.7*b*	32.2*a*	17.7*b*	7.1

[z] P = Soil extractable phosphorus

[a-b] Within row means having the same letter do not differ significantly according to LSD $_{(0.10)}$

Within treatments (feeding systems) at the 0-15 cm depth, a significant difference (P<0.10) was observed at the high slope position, between BG sites which had higher P levels (194.2 kg P ha^{-1}) compared to ST-CH sites which had lower (100.5 kg P ha^{-1}) levels (Table 5.3). As discussed previously, it may be due to the increased forage P content in round bale green feed (BG) or whole plant swath graze barley (SG) (Appendix Table A.1). This may result in higher concentration of excreted P in manure (Powell et al. 2002) and larger amounts of P in the residual forage, which combined may have contributed to a larger amount of P remaining at the soil surface in these feeding areas (Table 5.3). At the 15-30 cm depth ST-CH had a higher (P<0.10) level of soil P than either BG or SG feeding sites, which may have been due to the history of manure application on this site.

Phosphorous distribution patterns correlated with feeding site, and parallels could be drawn between manure distribution and crop biomass the following year (Figure 5.2). Soil P distribution differences were observed between systems, with higher levels of P surrounding the feeding sites in each treatment. This is similar to results reported by Lenehan et al. (2005) who also found higher levels of soil P surrounding feeding sites, levels which decreased with distance from the feeding site. ST-CH grazing showed the greatest visual distribution of P with increased levels of P running horizontally through the feeding site, in relation to the placement of the ST-CH piles (Figure 5.2). This feeding system (cereal crop residue) appears to allow for more evenly distributed nutrients, thus possibly decreasing the potential for nutrient saturation of the soil.



Swath graze

Straw-chaff graze

Bale graze

Figure 5.2 Effect of winter feeding system on pattern of soil P distribution (μg cm^{-2})

The lack of significant differences in soil P levels between feeding systems could be due to the history of past manure application on the study site. The soil nutrients were not limiting, as evidenced by extractable P levels in excess of 100 kg P ha^{-1} in its 0-15 cm depth (Table 5.5). In a similar study by Jungnitsch et al. (2008) where beef cows were wintered on a Russian wildrye pasture, larger differences were noted due to lower background levels related to lack of manure or fertilizer applied to pasture in previous years. Jungnitsch et al. (2008) also had higher animal stocking densities (2080 cow days ha^{-1}), wherein the current study the stocking density was 289 cow days ha^{-1}, a 7X greater stocking density in Jungnitsch's study. The difference in stock density would also result in increased soil P content observed in the Jungnitsch et al. (2008) study. Any increased difference in stocking density would have a significant impact on the level of retained soil phosphorus.

5.1.3.3 Effect of mechanical manure application on N and P levels

Soil extractable nitrate nitrogen (NO_3-N) levels from the raw vs. compost manure application trial are presented in Table 5.4. Nitrate levels were the lowest in the compost treatments, 48.9 kg ha^{-1} and 42.1 kg ha^{-1} at the 0-15 and 15-30 cm depths, respectively. There was a significant difference ($P<0.10$) between the control and compost nitrate levels at the 0-15 depth, with NO_3-N levels at 48.9 kg ha^{-1} on the compost treatment area and 66.2 kg ha^{-1} on the control area. The higher NO_3-N levels on the control could be a result of a high C:N ratio of the compost which would tie up the available N, resulting in a lower amount of soil extractable NO_3-N. This is also evident in the significant difference ($P<0.10$) observed between the raw and compost treatments. The compost treatment had soil extractable NO_3-N levels of 48.9 kg ha^{-1} while the raw manure treatment had levels of 62.6 kg ha^{-1}.

[z] NO_3-N = Soil extractable nitrate nitrogen; NH_4-N = Soil extractable ammonium nitrogen

Table 5.4 Effect of manure and compost application on soil extractable nitrogen levels at two depths

Item	Control	Raw manure	Compost manure	LSD
	---------------kg NO_3-N^z ha^{-1}------------------			
0-15 cm	66.2*a*	62.6*a*	48.9*b*	15.2
15-30 cm	69.7	61.6	42.1	32.0
	-----------------kg NH_4-N ha^{-1}----------------			
0-15 cm	7.3	8.0	7.5	1.5
15-30 cm	6.8	6.9	6.2	1.3

[a-b] Within row means with the same letter do not differ significantly according to $LSD_{(0.10)}$

[z] P = Soil extractable phosphorus

Table 5.5 Effect of manure and compost application on soil extractable phosphorus levels at two depths

Item	Control	Raw manure	Compost manure	LSD
	--------------------kg P^z ha^{-1}-------------------			
0-15 cm	139.6	166.4	144.6	29.6
15-30 cm	18.3	28.1	18.6	16.1

[a-b] Within row means with the same letter do not differ significantly according to $LSD_{(0.10)}$

These results are similar to those reported by Jungnitsch (2008), who found no increase ($P<0.10$) in inorganic nitrogen levels between raw manure application and the control areas the following spring. Again, the site in this study had a history of manure application, which would explain the high levels of NO_3-N on the control treatment site. There was no observed differences ($P>0.10$) in NO_3-N levels between treatments at the 15-30 cm depth or NH_4-N levels at either depth. NO_3-N levels were numerically higher on the control treatment, thus suggesting a elevated base level of this nutrient pre-treatment. This also suggests a high C:N ratio of both composted and raw manure resulting in immobilization of N in these treatments. No significant differences ($P<0.10$) were observed in phosphorus levels between treatments, again attributed to the high nutrient levels in the soil pre-treatment (Table 5.5).

5.1.3.4 Soil density

Winter feeding systems had an effect ($P<0.10$) on soil density the following spring after winter grazing beef cows. Soil density measurements were 219.7, 186.6, and 173.6 N cm^{-2}, for BG, SG and ST-CH systems, respectively (Table 5.6). The straw-chaff graze system had the least effect on soil density at the 5 cm soil depth. Soil density was 22% greater where cows grazed round bales compared to the site where cows grazed straw-chaff, indicating definite differences in soil strength and resistance to penetration by roots and tillage tools between treatments (Figures 5.3 and 5.4). These results may be explained by the increased concentration of feed at each feeding site in the bale graze systems which ultimately resulted in greater animal density per feeding site. Stephenson and Veigel (1987) determined that soil bulk density of pastures with a loam soil texture used for winter feeding was affected as stocking density increased to 40 cows per hectare. In this study stocking density was maintained at 3.75 animals per ha across all systems, however stocking density at the bale feeding site could potentially increase to 136.6 animals per hectare. Each bale was placed on 0.11 hectare leading to 15 cows consuming feed on 0.11 ha, resulting in a potential stocking density of 137 head per hectare. Stephenson and Veigel (1987) determined that damage associated with soil compaction due to winter grazing on pastures, showed a 92% recovery after 2 years of protection from grazing and trampling, validating the importance and length of time needed for full recovery of compacted soils and the attention that is required when implementing certain grazing strategies.

Table 5.6 Effect of winter feeding system on soil strength

Item	Swath graze	Straw-chaff	Bale graze	LSD
		--------------------- N cm^{-2}--------------------		
Soil Strength	186.6*b*	173.6*b*	219.7*a*	22.77

[a-b] Within row means having the same letter do not differ significantly according to LSD $_{(0.10)}$

The greater distribution of feed in the swath graze and straw/chaff treatments allowed for greater dispersal of animals and therefore decreasing the amount of soil compaction that occurred in these feed systems areas. Although differences in compaction were observed between systems, overall compaction was not an issue in terms of crop production. Heavy harrows were used to break up leftover feed residue, and excellent seedling emergence was observed both years of the study.

Soil compaction was decreased by both the compost and raw manure treatments in comparison to the control (Figure 5.4), thus validating the benefits of manure on soil structure. Compost and raw manure have been proven to have a beneficial effect on the soil structure, through increased porosity, soil microbial populations, and soil aggregation, thereby reducing degradable effects such aa soil crust formation (Pagliai et al. 2004; Dick 1992).

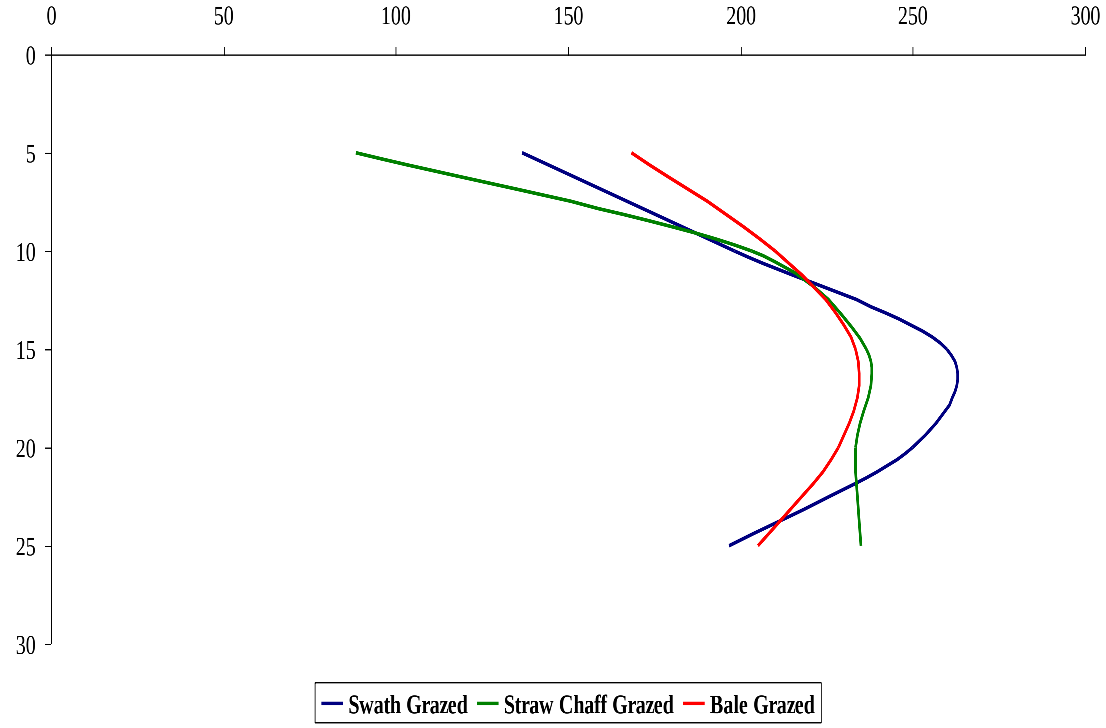


Figure 5.3 Effect of winter feeding system on soil compaction (N cm^{-2})

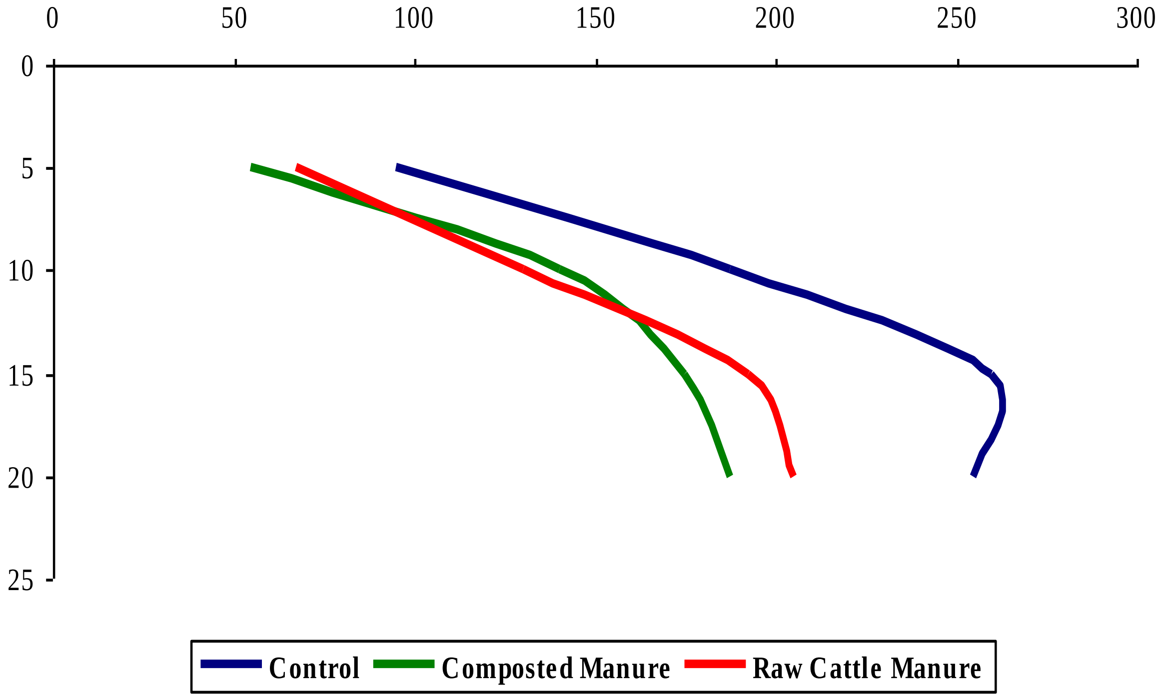


Figure 5.4 Effect of manure and compost application on soil strength (N cm^{-2})

5.1.4 Conclusions

The study site had a long history of manure application and thus the soil was not nutrient limiting which diminished treatment (feed system) effects. Soil extractable nitrate nitrogen (NO_3-N) levels were affected ($P<0.10$) by winter feeding system treatment in the low slope position at the 0-15 cm depth, with levels highest in the balegraze system and lowest in the straw-chaff system (Table 5.2). This may be attributed to the physical attributes of the feeding system and the increased concentration of nutrients surrounding these feeding areas (Lenehan et al. 2005) and may amplify the potential for leaching of nutrients through the soil profile. Levels of ammonium nitrogen (NH_4-N) were not affected significantly by slope at either depth.

Winter feeding treatment had a significant effect ($P<0.10$) on phosphorus levels. The extractable P at the 0-15 cm depth were largest in BG treatment at the high slope position. These differences may be attributed to the large stocking density in this type of feeding system increasing the nutrient saturation of the soil (Lenehan et al. 2005). These increases in P retention in the soil within the BG system may also be explained by the higher quality forage fed in the bale graze system, leading to higher concentration of excretal phosphorus (Powell et al. 2002). Also, lower DMI was observed in the ST-CH treatment compared to the BG treatment would lower nutrients excreted in ST-CH contributing to significantly lower extractable soil P in straw-chaff. Nutrient distribution patterns were correlated with feeding site, and parallels could be drawn between manure distribution and crop biomass the following year.

5.2 Crop yield

5.2.1 Materials and methods

Crop yield was measured using standing crop samples the following growing season to determine effects of winter feeding system on crop DM yield. Square meter (1.0 m^2) quadrats were taken on each winter feed system area (n=5), in order to determine total biomass production. In addition, a 32 point grid was set up in each winter feed system area to determine pattern of biomass growth in relation to feeding site. At each grid point, quarter meter (0.25 m^2) quadrats of the standing crop were collected.

To determine the effect of manure application on crop biomass, crop DM yield was measured using standing crop samples the following growing season. Square meter (1.0 m^2) quadrats were taken in each treatment site (n=5) in order to determine total biomass production.

5.2.2 Results and discussion

Crop biomass the following year differed ($P<0.10$) between feeding systems (Table 5.7). The bale graze sites yielded on average 15% higher than the straw-chaff system areas (Table 5.7). These results are similar to Jungitsch (2008) who reported that bale grazing on an old Russian wild ryegrass pasture increased forage production of Russian wild rye pasture as much as 5X above the control area. Other studies have shown that when straw is applied to pasture, reduced yields are observed in the first year after application, however increased pasture growth can be evident 4 to 8 years after initial application, validating the long term effects of organic fertilization (Smoliak 1965). Data from this study was collected for only 1 year after winter grazing cows, so any long term effects were not measured. The differences in this study between straw-chaff and balegraze areas could be attributed to the large carbon (C) mass associated with the straw which may immobilize available nutrients due to a large C to N ratio. Carbon to nitrogen ratio is an excellent predictor of N availability in manure, which was shown by Qian and Schoenau (2004), who determined that N availability decreased dramatically when C:N ratio increased past 15:1. As already mentioned, straw normally has a C:N ratio of 80:1 (MAFRI 2007), and this may have had an impact on the level of mineralization occurring on the straw-chaff feed sites impacting the subsequent plant available nitrogen and crop growth. The mulch (residual feed) associated with all extensive feeding systems would have had a beneficial effect capturing both moisture and nutrients, whereas effects seen from mechanical manure application can only be attributed to the nutrient and associated mulch (Smoliak 1965). These results may not be apparent in the first year of this study

due to the immobilization of N as discussed previously in this chapter

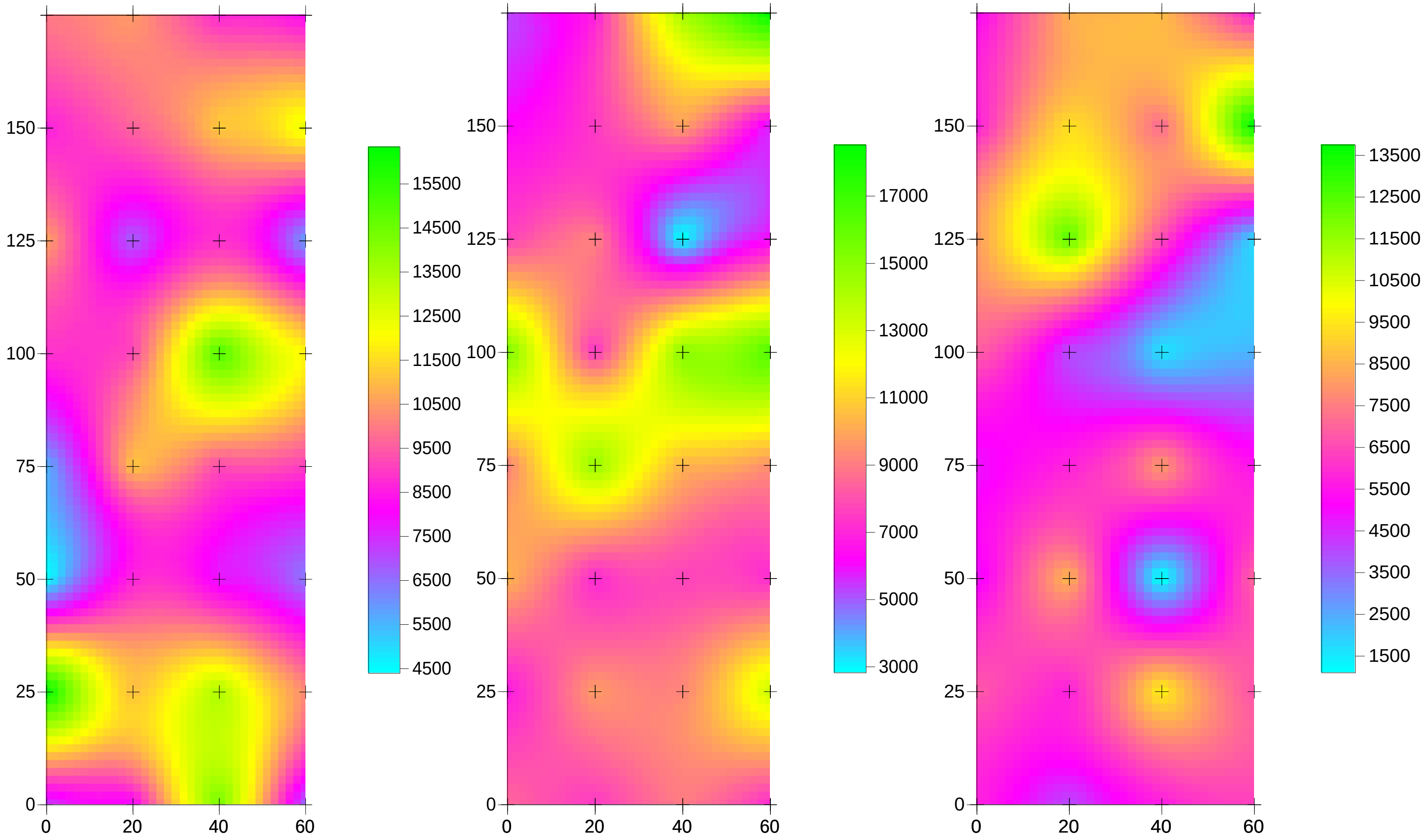
Table 5.7 Effect of winter feeding system on crop biomass (2006)

Item	Swath graze	Straw-chaff	Bale graze	LSD
	---------------------kg DM ha^{-1}	-------------------		
Biomass	6685.3a	6298.7b	7210.0a	700

$^{a-b}$Within row means having the same letter do not differ significantly according to $LSD_{(0.10)}$

The biomass distribution the year following winter grazing is shown in Figure 5.5. The bale graze and swath graze areas appear to have less uniform distribution of crop biomass than the straw-chaff area. In the bale graze system, areas with higher crop growth were circular and corresponded with the shape and placement of the round bales. The swath graze area appeared to have a higher amount of crop biomass centrally located in the biomass grid pattern corresponding with swath locations. The increased distribution of feed (swaths) in this system appears to allow for an increased distribution in biomass growth the following year, a consequence that may prove beneficial for this type of feeding system. The straw-chaff system had more uniform biomass distribution, with a greater proportion of biomass centrally located on the biomass grid, possibly due to a decrease in nutrient distribution (Figure 5.4), which may have decreased the amount of crop biomass distribution. The high C:N ratio in this treatment could also have an effect on nutrient availability, subsequent biomass production, and may have affected the biomass distribution by immobilizing plant available nutrients the first year after winter feeding.

Mechanical manure application (compost vs. raw) had no effect ($P<0.10$) on crop biomass (Table 5.8) the following year. Biomass production was numerically greater on the raw manure application treatment, with compost manure and control treatments slightly lower. These results could be attributed to the long history of manure application on the study site, therefore the soil was not nutrient limited.



Swath graze Straw-chaff graze Bale graze

Figure 5.5 Effect of winter feeding system on crop biomass (kg DM ha^{-1})

Table 5.8 Effect of winter feeding system on crop biomass (2006)

Item	Raw	Compost	Control	LSD
	---------------------kg DM ha^{-1}-------------------			
Biomass	7571.3	7388.8	7317.5	1302.6

$^{a-b}$Within row means having the same letter do not differ significantly according to LSD $_{(0.10)}$

Multiple studies have shown the benefits of raw manure application with increased biomass production ranging from 81 to 131% on pasture land (Lardner 2003; Smika 1960). Smoliak (1965) found that the effects of organic fertilizers were observed up to 8 years after application, with the greatest effect seen after the first year of application. Lardner (2003) reported a large increase in biomass production from compost compared to raw manure application, however larger amounts of compost were applied than levels used in the current study. In a similar study, Jungnitsch (2008) found that applications of raw and compost manure increased biomass production of Russian wild ryegrass pasture by 47% and 74% over the control, respectively. However, rate of application was considerably higher than in the current study and available soil nutrient levels were much lower.

5.2.3 Conclusion

Differences in crop biomass between winter feed systems were observed, with the bale grazes area yielding on average 15% higher biomass yield than the straw-chaff area. These differences may have been attributed to N immobilization by straw and chaff (Qian and Schoenau 2004), with similar studies reporting the beneficial effects of bale grazing on subsequent biomass production, and decreases in biomass production associated with straw management the first year post treatment (Jungitsch 2008; Smoliak 1965).

The bale graze and swath graze system areas appeared to have a less uniform distribution of biomass, than the straw-chaff area, and areas of growth corresponded to feed placement. The increased distribution of feed in system areas appears to allow for increased distribution in biomass growth the following year, a consequence that proves beneficial for these feeding systems. It can be stated that extensive winter feeding systems have a beneficial effect on crop biomass production, thus increasing the productivity of the land the year following winter feeding beef cows on annual cropped land.

Mechanical manure application (compost vs. raw) had no effect on crop biomass the following year. Biomass production was only numerically greater on the raw manure application area, with compost manure and control areas slightly lower. This may have been attributed to a long history of manure application on the study site that resulted in accumulation of high amounts of available nutrients in the soil.

6.0 ECONOMIC ANALYSIS OF WINTER FEEDING SYSTEMS

6.1 Materials and methods

Economic analysis of the winter feeding systems incorporated costs associated with crop production and costs associated with animal grazing. The analysis included costs related to feed production, labor, and equipment for each treatment system. Costs of infrastructure such as capital setup expenses, and maintenance of shelters, temporary and permanent watering systems, temporary and permanent fencing were not included, as these were deemed outside the scope of this project and it was assumed that these would be included in all feeding systems.

Costs were calculated by system and were reported as cost per cow per day. The feed associated with the drylot was stored near the feed sites and costs included the direct daily cost of supplying the feed with no additional costs associated with hauling the feed to the feed site. All feed for the extensive winter feed systems was produced on the feeding sites therefore no costs were incurred for transportation of the feed.

Equipment costs were calculated using Saskatchewan Ministry of Agriculture's Farm Machinery Custom and Rental Rate Guide (SMA 2006 & 2007). Total variable costs included costs associated with repair, fuel, and lube/oil. Total fixed costs were added to total variable costs, which were then used to determine a cost per hour. All equipment costs were based on per hour of use determined by multiplying total cost per hour by the time spent using the equipment to determine total equipment cost. The time spent feeding was measured each year by timing the feeding process, and then determining equipment operation and feeding labor. Labor was calculated at $15.00

hr^{-1}. Custom manure removal was estimated at \$0.03 cow^{-1} day^{-1} similar to study conducted at the same facility in 2004 (Jungnitsch 2008).

6.2 Crop production expenses

Crop production expenses included all costs associated with production of the crop and are listed in Table 6.1. This included land preparation pre-seeding, pre and post seed herbicide application, seed, seeding, swathing, baling, harvesting and transportation of grain, bale hauling, land rent, depreciation of the whole buncher, and were based on custom rates from the Farm Machinery Custom and Rental Rate Guide (SMA 2006 & SMA 2007).

Crop production costs were identical across all treatments for the initial growth stage of the crop with differences in costs associated with the final harvesting stage of production. Costs were similar for each year of the study (2005 and 2006), with costs increasing slightly in the second year (2006) due to increases in seed, custom rates, and input prices. Total crop production costs (\$ ha^{-1}) for 2005 were 269.24, 364.91, 26.09, and 373.74 for SG, BG, ST-CH and DL, respectively. For 2006 total crop production costs (\$ ha^{-1}) were 268.83, 397.59, 24.96, and 403.50 for SG, BG, ST-CH and DL, respectively (Table 6.1)

Table 6.1 Crop production costs

Crop Production Expenses	Swath Graze	Bale Graze	Straw/Chaff	Drylot
2005-2006	---------------------------------- $ ha $^{-1}$			--------------------------------
Land preparation	5.66	5.66	5.66	5.66
Pre-seed herbicide	25.30	25.30	25.30	25.30
Seed	9.88	9.88	9.88	9.88
Seeding	22.81	22.81	22.81	22.81
Fertilizer	47.85	47.85	47.85	47.85
Post-seed herbicide	50.43	50.43	50.43	50.43
Swathing/cutting hay	33.16	36.67	33.16	36.67
Land rent	74.13	74.13	74.13	74.13
Combining			51.40	
Hauling grain			21.42	
Baling		71.41		71.41
Bale placement/hauling		20.75		25.21
Grain revenue			323.38	
Depreciation (whole buncher)			7.41	
Total	269.22	364.89	26.07	369.35
2006-2007				
Land preparation	5.19	5.19	5.19	5.19
Pre-seed herbicide	22.81	22.81	22.81	22.81
Seed	14.83	14.83	14.83	14.83
Seeding	27.60	27.60	27.60	27.60
Fertilizer	48.44	48.44	48.44	48.44
Post-seed herbicide	46.28	46.28	46.28	46.28
Swathing/cutting hay	29.55	38.10	29.55	38.10
Land rent	74.13	74.13	74.13	74.13
Combining			55.95	
Hauling grain			21.42	
Baling		99.46		99.46
Bale placement/hauling		20.76		26.69
Grain revenue			328.65	
Depreciation (whole buncher)			7.41	
Total	268.83	397.60	24.96	403.50

The BG and DL treatments had extra costs associated with baling, placement and hauling of the bales which increased the cost of production for these systems. Expenses for bale placement was determined as the amount of time the tractor took to place the bales and multiplying this time by the custom tractor rate from Farm and Machinery Custom and Rental Rate Guide (SMA 2006 & SMA 2007). The ST-CH treatments had the added cost of combining and hauling grain, however this was offset by the revenue generated by the grain harvested. Total crop production costs for this system were on average 92% lower than the other systems, thus validating the economic benefits of using crop residue as a source of feed for wintering beef cows (Table 6.1). Depreciation of the whole buncher for the ST-CH treatment was added each year for a total cost of \$7.41 ha^{-1}.

6.3 Grazing expenses

Grazing expenses included the cost of the feed, feed residue associated with each feeding system, supplementation required by the ST-CH system, labor, and equipment (Table 6.2). Labor includes total hours for moving fences, cows, portable windbreaks, and daily watering of cows. The cost of the feed was determined by the crop production costs per kg of feed produced multiplied by the kg of feed consumed. For both years of the study the BG and DL treatments had the greatest feed cost, due to the increased equipment usage required for crop production. Feed expenses (\$ kg^{-1}) (Table 6.3) were the lowest for the ST-CH treatments (0.02 \$ kg^{-1}) due to the revenue associated with the harvested grain from this treatment. However, the added cost of supplementation increased the total cost of production for this system, and therefore a least cost feed source should be used in the future for this type of feeding systems. Feed costs (\$ kg^{-1}) were similar to Jungitsch

(2008), who reported costs of .076 and .061 $ kg^{-1} for bale graze and drylot treatments, respectively.

Table 6.2 Total cost of production of winter feeding systems

	Swath Graze	Bale Graze	Straw-Chaff	Drylot
2005-2006	------------------------------$ cow^{-1} day^{-1}	----------------------------		
Feed	0.36	0.66	0.14	0.62
Residue	0.08	0.30	0.03	0.37
Supplementation	0	0	0.73	0
Labor	0.23	0.04	0.13	0.04
Equipment	0.25	0.08	0.29	0.13
Manure cleaning	0	0	0	0.03
Total cost	0.92	1.08	1.32	1.19
2006-2007				
Feed	0.42	1.01	0.18	1.06
Residue	0.03	0.28	0.09	0.15
Supplementation	0	0	1.01	0
Labor	0.18	0.08	0.09	0.04
Equipment	0	0	0	0.14
Manure cleaning	0	0	0	0.03
Total cost	0.63	1.38	1.38	1.42

[z] Supplement = range pellet fed in Straw-chaff system

Table 6.3. Feed costs for winter feeding systems

	2005-2006			2006-2007		
System	Consumed	Cost		Consumed	Cost	
	kg cow^{-1} day^{-1}	$ kg^{-1}	$ cow^{-1}	kg cow^{-1} day^{-1}	$ kg^{-1}	$ cow^{-1}
Swath graze	10.30	0.04	0.36	13.33	0.03	0.40
Bale graze	12.70	0.05	0.66	13.93	0.07	0.98
Straw-chaff	7.19	0.02	0.14	9.46	0.02	0.27
Supplement	3.57	0.21	0.73	4.10	0.25	1.01
Drylot	11.64	0.04	0.62	13.87	0.07	0.97

For both years of the study labor was the lowest in the BG and DL systems. This was due to the labor associated with moving of fences and cattle every 3 d for the SG and ST-CH systems. However, the added costs associated with these systems did not negate the low feed cost of the feed in these systems which in turn reduced the overall cost of production for the SG and ST-CH systems.

During the first year of the study (2005-2006) more equipment was used to move windbreaks, fences and provide water to the cows, which resulted in increased equipment costs associated with the extensive (BG, SG, ST-CH) feeding systems. However, during the second year (2006-2007) equipment costs were reduced since less equipment was used to provide water and move fences.

Feed residue was measured in the spring and was used to assign a value to the amount of feed left uneaten (orts or residue). Residue costs were the highest in 2005-2006 in the DL system at \$0.37 cow^{-1} d^{-1} with the BG system having the second highest residue amount with an associated cost of \$0.30 cow^{-1} d^{-1} (Table 6.2). In the first year (2005-2006) of the study the ST-CH system had the lowest cost associated with residue, \$0.03 cow^{-1} d^{-1}. These costs were reversed in the second year of the study where the swath graze treatment had the lowest associated residue cost of \$0.03 cow^{-1} d^{-1}. Although feed residue is considered an economic cost, the beneficial effects observed in soil improvement and subsequent crop growth indicate that nutrients captured from remaining feed, manure, and urine in extensive winter feeding systems partially negate the costs associated with feed wastage (Jungnitsch 2008).

Straw-chaff costs were very dependent on the cost of supplementation (Table 6.3). The total cost of the straw-chaff system could have been reduced with a more economical supplement and cow-calf producers should be encouraged to source least costs forms of supplementation. For example if \$2.50 per bushel (\$0.05/lb) barley was fed at 10 lbs cow^{-1} d^{-1}, the cost of supplementation would be \$0.50 cow^{-1} d^{-1}. This would have decreased the cost of supplementation on average over the two year study by 50 percent, thus showing the importance of choosing an economical source of supplementation.

6.4 Conclusions

Feed costs were reduced substantially by managing beef cows in the extensive winter feeding systems, with the greatest reduction in cost of production (COP) observed in the SG system. Reduced cost for feed residue, labor and equipment usage allowed for decreased cost of production combined with a total reduction of feed costs. On average all extensive feeding systems (SG, BG and ST-CH) had a 15% lower COP than the drylot system. The SG system had the lowest cost of production (COP), resulting in reduced overall costs of 23 and 55% when compared to the other systems in 2005-2006 and 2006-2007, respectively. This is similar to the results reported by McCartney et al. (2004), who reported swath grazing resulted in a 46% reduction in total feed costs when compared to a traditional (DL) feeding system.

Extensive field feeding systems provide an economic alternative to drylot pen systems, allowing for reduced costs associated with labor, equipment, feed and grazing expenses. With the potential to reduce drylot feeding costs by nearly 50%, producers can be more economically efficient, allowing them to adapt to increased machinery, fuel, and fertilizer prices.

7.0 GENERAL CONCLUSIONS

From these results of winter feeding trials over two years, it can be suggested that feeding cattle throughout the winter on annual crops is a viable alternative to decrease winter feed costs and obtain increased utilization of manure nutrients. Heavy snowfall and cold temperatures throughout the winter may impact cow performance in extensive field feeding systems and this must be managed accordingly. Feed quality of grazed or stockpiled annuals is sufficient allowing for minimal or no body weight change throughout the winter grazing period, however environmental conditions will dictate accessibility of the forage and ultimately cow performance. These yearly variations in climatic conditions will impact animal performance due to inaccessibility of feed particularly in swath and straw-chaff grazing systems. This suggests unreliability of these systems during years of extreme weather events and therefore careful management must be considered when using these winter grazing systems (SG, ST-CH) later in the wintering season in Western Canada. However, the economic benefits to these systems may outweigh the risks and many producers will have to choose the optimal winter feeding system, based on their operations requirements and environmental conditions.

Nutrient capture differed between systems, with bale grazing accumulating greater levels of soil extractable P at the high slope position. This may indicate that at high stocking densities, bale graze winter feeding systems may pose a greater environmental risk due to increased amounts of water extractable phosphorus. Further research needs to be done on these types of winter feeding systems to determine safe stocking densities to reduce nutrient loading and environmental risk.

Bale grazing may have a greater impact on crop biomass in the first year after feeding beef cows in the field. This may be due to higher levels of nitrogen left in the round bale residue and greater DMI and nutrient excretion. Additionally, high levels of carbon associated with the straw-chaff crop residue could immobilize available nitrogen for a short period of time. However, nutrient distribution may be increased in straw-chaff systems, potentially decreasing subsequent system losses. Again system costs will play an important role in a producer's choice of wintering system and this may offset some of the discrepancies observed between winter feeding systems effects on nutrient distribution and crop yield. More research is needed to further analyze these effects on soil nutrient capture and annual crop production. Differences in feed nutritive value, supplementation strategies and cow stocking density will alter systems effects on nutrient capture and environmental risk. In addition, limited research is available determining the effects of extensive winter feeding systems on young growing cattle. Opportunities exist to research the effects of winter feeding as alternatives to traditional backgrounding and finishing systems.

Costs were significantly lower in the field feeding systems, thus validating the cost benefits of grazing beef cows during winter months. Choosing an economical supplement is dependant on the price of feed grains each year. However, supplement choice and strategy are important steps to ensuring the economic viability of extensive winter feeding systems. At a time when production costs are rising, and agriculture practices are under public scrutiny, field feeding systems may be an economical and environmentally sensitive alternative to traditional pen feeding systems. Wintering beef cows in extensive field feeding systems may be cost effective, however the benefit of increased levels of nutrient capture may be of concern in some situations. Finally, a holistic approach must be taken when evaluating these systems, since neither economics, nutrient capture, or cow performance alone can dictate the benefits or detriments of these systems.

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9.0 APPENDIX A

Table A.1 Chemical composition of feeds in cow wintering systems

Item[z]	DM(%)	CP(% DM)	TDN(% DM)	DE(Mcal kg^{-1})	Ca(% DM)	P(% DM)
2005-2006						
Swath Graze	62.4	13.8	61.3	2.7	0.5	0.3
Straw-Chaff	56.7	10.2	49.8	2.2	0.5	0.3
Bale Graze	83.0	12.7	61.4	2.7	0.4	0.3
Drylot	85.8	12.7	65.4	2.9	0.4	0.3
2006-2007						
Swath Graze	79.3	14.1	66.6	2.9	0.4	0.3
Straw-Chaff	58.2	9.3	45.5	2.0	0.4	0.1
Bale Graze	81.1	14.0	70.8	3.1	0.4	0.2
Drylot	80.4	13.7	70.7	3.1	0.4	0.3

[z] DM = dry matter, CP = crude protein, TDN = total digestible nutrients, DE = digestible energy, Ca = calcium, P = phosphorus
Analyzed by Norwest, TDN calculated using Penn State equation.

Table A.1 Chemical composition of supplement fed to cows

Item	% of DM
2005/2006	
Dry Matter (%)	88.4
TDN (%)	75.0
Protein (%)	19.6
Calcium (%)	0.9
Phosphorus (%)	0.5
Magnesium (%)	0.3
Potassium (%)	0.9
Sodium (%)	0.4
2006/2007	
Dry Matter (%)	87.7
TDN (%)	79.0
Protein (%)	16.2
Calcium (%)	1.0
Phosphorus (%)	0.7
Magnesium (%)	0.3
Potassium (%)	0.8
Sodium (%)	0.2

Table A.3 Chemical composition of cobalt ionized salt and 2:1 mineral

2:1 Mineral		Cobalt Iodized Salt	
Ingredient	Analysis	Ingredient	Analysis
Calcium (%)	22	Salt (Min)	99%
Phosphorus (%)	14	Sodium Actual	39%
Vitamin A (KIU kg^{-1})	200	Iodine Actual	150 mg kg^{-1}
Vitamin E (IU kg^{-1})	40	Cobalt Actual	100 mg kg^{-1}
Copper (mg kg^{-1})	4000	Salt (Min)	99%
Magnesium (mg kg^{-1})	5300		
Zinc (mg kg^{-1})	10000		
Iodine (mg kg^{-1})	125		
Cobalt (mg kg^{-1})	40		
Iron (mg kg^{-1})	450		

Table A.4 Effect of winter feeding systems on feed utilization of beef cows

Item^z	Allocated	Consumed	Residual	Utilization
	----------------------------kg DM	----------------------------		%
2005-2006				
SG	12.5	10.3	2.2	82.7
BG	18.4	12.6	5.8	68.5
ST-CH	8.6	7.2	1.4	83.9
DL	18.5	11.6	6.8	63.0
2006-2007				
SG	14.4	13.3	1.1	92.6
BG	17.8	13.9	3.9	78.2
ST-CH	14.2	9.5	4.8	66.5
DL	16.3	14.3	2.0	87.6

^{z}BG = bale graze, SG = swath graze, ST/CH = straw/chaff, DL = drylot

^{z}TDN = total digestible nutrients; SOT = start of trial, EOT = end of trial, CP= crude protein.

Table A.5 Forage total digestible nutrients and crude protein over 78 d 2005/2006

	2005/2006			
Item^z	BG^y	SG	ST/CH	DL
TDN, %				
SOT	59.5	61.2	50.4	61.2
EOT	57.2	58.0	43.5	58.0
CP, %				
SOT	13.4	14.7	11.5	13.5
EOT	13.1	13.3	8.9	11.9

^{y}BG = bale graze, SG = swath graze, ST/CH = straw/chaff, DL = drylot

10.0 APPENDIX B

Table B.1 Snowfall and total precipitation throughout trial period[z]

Month	Snowfall (mm)	Precipitation (mm)
2005-2006		
October	-	17.4
November	-	-
December	54	-
January	242	-
February	174	-
Total	470	17.4
2006-2007		
October	260	7.2
November	420	-
December	145	-
January	316	-
February	180	-
Total	1321	7.2

[z] Obtained from Environment Canada

Table B.2 Temperature data for 2005/2006 trial (°C)[z]

	October		November		December		January		February	
Date	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1	10.0	3.8	7.3	-1.1	-12.3	-20.5	-3.1	-4	-8.9	-19.3
2	8.1	2.5	2.8	-1.9	-11.6	-17.9	-1.3	-8.3	-9.4	-23.5
3	4.2	-5.0	1.3	-4.4	-15.4	-21.6	-6.7	-13.4	-5.6	-21.9
4	7.1	-7.3	0.7	-0.9	-15.7	-28	-6.6	-15.1	-3.2	-14.2
5	7.3	-6.4	2.0	-0.6	-17.5	-24.5	-2.4	-18.7	-0.7	-0.7
6	9.6	-7.4	2.0	-6.5	-16	-25.4	1.2	-8.8	-4.4	-4.4
7	12.4	0.6	-1.1	-8.8	-16.1	-26.1	-2.3	-9	-12.8	-12.8
8	14.8	-1.9	-0.1	-3.1	-5.5	-17.9	-3	-7.7	-4.2	-4.2
9	17.2	-1.2	-0.7	-5.3	5.9	-5.7	-0.3	-7.6	-1.1	-1.1
10	15.2	-2.5	5.5	-2.3	2.8	-2.2	-3.1	-13.7	-6.1	-6.1
11	15.6	1.8	5.4	-0.9	5.2	-5.1	-2.3	-6.6	-5.8	-5.8
12	15.2	-1.5	4.9	-4.7	-0.8	-9.6	-2.8	-11.8	0.6	0.6
13	18.1	0.9	-0.3	-10.7	-1.9	-7.5	-6.4	-11.6	2.9	2.9
14	14.4	-1.7	-2.7	-6.6	-7.1	-8.8	-4.7	-8.4	-2.5	-2.5
15	17.0	-2.2	-6.6	-26	-7.9	-15.1	-7.2	-12.4	-18.0	-18.0
16	12.6	-1.8	-10.2	-28	-15.1	-22	-5.7	-10.9	-28.7	-28.7
17	12.3	-5.8	0.6	-10.2	-20.3	-28	-7.9	-15.7	-19.6	-19.6
18	12.7	-4.3	6.2	-2.7	-15.4	-28.2	-5.4	-13	-12.1	-12.1
19	14.8	-4.2	10.3	-5.1	-8.1	-19.6	-6.1	-25.3	-5.9	-5.9
20	6.8	-1	0.9	-2.4	-8.3	-20.8	-14.5	-26.5	-6.3	-6.3
21	6.0	-4.1	9.3	-5.2	1.5	-20.2	-15.7	-29.8	-7.8	-7.8
22	4.9	-6.6	4.9	-5.3	0.3	-7.9	-6.8	-21.4	-11.8	-11.8
23	8.2	-5.6	-3	-9.3	0.3	-8.2	2.7	-10.1	-8.2	-8.2
24	15.4	-1.6	-4.2	-9.1	1.2	-9.6	-3.9	-12.1	-14.0	-14.0
25	13.4	-4.3	-2.1	-8.6	3.2	-6.2	1.9	-8.4	-11.8	-11.8
26	15.7	-2.9	-4.5	-11.6	2.2	-5.7	2.3	-7.5	-15.3	-15.3
27	11.8	-1.7	-5.6	-11	-2.3	-7.7	-5.1	-20.5	-11.5	-11.5
28	5.5	1.8	-9.5	-10.4	-2.2	-3.3	-4.3	-17	-8.2	-8.2
29	13.4	-2.6	-11	-11.3	-2.3	-5.3	-2.2	-15.4	-	-
30	6.8	-5.4	-3	-18.6	-4.3	-6.6	-0.9	-8.7	-	-
31	8.1	-8.1	-	-	-2.2	-4.6	-2.4	-19.1	-	-
Mean	11.4	-2.6	0.2	-7.8	-6.0	-14.2	-4.0	-13.0	-8.6	-21.6

[z] Obtained from Agriculture and Agri-Food Canada

Table B.3 Temperature data for 2006/2007 trial (°C)[z]

	December		January	
Date	Max	Min	Max	Min
1	-	-	-7.8	-18.7
2	-	-	3.2	-7.8
3	-	-	3.5	-1.6
4	-	-	0.5	-9.4
5	-	-	-6.8	-12.7
6	-16	-25.3	-2.6	-13.7
7	-6.6	-24.6	-5.5	-15.2
8	-0.9	-10	-8.5	-19.7
9	-3.8	-15.9	-8.4	-22.7
10	-4.3	-16.8	-11.5	-23.6
11	-4.8	-10.2	-23.6	-34.8
12	3.1	-9.3	-20.9	-35.2
13	-2.1	-9	-16.5	-28.6
14	-5.1	-15.5	-23.5	-34.9
15	1.7	-11.9	-17	-28.7
16	-2.1	-10.7	-3.4	-17
17	-9.2	-20.9	-3.8	-9.5
18	-6	-22.7	-8.9	-17.5
19	-0.3	-8.3	-11.1	-22
20	-4.5	-13.1	-7	-18.2
21	-0.8	-8.9	-7.2	-15.7
22	-1.7	-14	-6	-13.1
23	-5	-16.8	-1.1	-13.4
24	-4	-20	-4.2	-16.1
25	-2.2	-18.8	2.2	-7.6
26	-6.2	-17	-0.2	-18.5
27	-10.5	-19.1	-15.1	-26.5
28	-6.4	-17.6	-6.6	-18.8
29	-14.9	-23.9	-18.7	-27.1
30	-6.2	-15.2	-9	-25.8
31	-5.9	-17.7	-8.7	-24.7
Mean	-4.79	-15.89	-8.2	-19.32

[z] Obtained from Agriculture and Agri-Food Canada