Chapter

Alternative Intensive Animal Farming Tactics That Minimize Negative Animal Impact and Improve Profitability

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Abstract

Animal agricultural businesses strive to improve efficiencies, reduce input costs, and maintain healthy animals with minimal disease control intervention. Bovine respiratory disease is a disease complex that increases when cattle are reared in confinement costing the North American beef cattle industry three-billion dollars or more annually. Principles of soil health define the need to reduce tillage, keep the soil surface covered, rotate crops and plant cover crops for greater plant diversity, maintain living roots in the soil for as long as possible, and integrate livestock grazing into cropping systems. As beef calves age they experience more viral and microbial challenges which stimulate an immune system response resulting in greater disease resilience and well-being when commingled with unfamiliar cattle for confinement feedlot finishing. Wintering calves after weaning in November for modest growth of 0.59 kg/day (1.30 lbs./day) combined with integrated grazing of a sequence of native range and annual forages grown in a diverse multi-crop rotation is a management mechanism that increases calf age (200$^+$ days), promotes structural growth, and delays feedlot entry. Retaining ownership using a vertically integrated business model from birth to slaughter accounting for all business inputs and outputs has resulted in improved environmental balance and business profitability.

Keywords: beef cattle, bovine respiratory disease, sequential grazing, reduced concentrated feeding, integrated crop-livestock system, regenerative agriculture, animal welfare, reduced production cost, net return, profitability

1. Introduction

In animal agriculture, well managed businesses are structured around important intricacies that maintain and improve efficiencies, and managers of beef cattle enterprises continually strive to reduce production cost. The cow-calf business generates calves from which the entire remaining cattle industry relies upon and as such initial management weighs heavily on how feeder cattle perform from weaning to final harvest. Sound management is key to animal wellbeing and the methods used to minimize stress. Bovine respiratory disease (BRD) in North America is the most studied beef cattle illness costing the beef cattle industry in excess of three billion dollars annually due to reduced animal performance and depressed carcass quality, death loss, pharmaceuticals, and expenses related to treatment [1]. Due to stressors such as commingling, transportation and dehydration a number of calves will experience BRD after feedlot arrival. To reduce the risk of early onset BRD, feedlot operators will administer antimicrobials to animals during processing. This process known as metaphylaxis or prophylactic use is applied to all animals in the high-risk group [2]. Abrupt weaning is a stressful event, when coupled with commingling on the ranch of origin adds further stress that increases the risk of BRD. Therefore, stepwise pre-weaning management strategies to reduce stress prior to weaning that includes specific vaccination protocols, and commingling prior to weaning will reduce the impact of separating calves from their dams. In addition to calf hood vaccination protocols at one to two months of age, a 42-day pre-weaning vaccination preconditioning program beginning six and three (booster) weeks before weaning that includes introduction to dry feed (self-fed creep feed supplement) reduces stress and results in a greater number of animals developing a protective immune response before weaning. An extensive BRD metanalysis review conducted by Taylor et al. [3] revealed inconsistencies that made across study evaluations difficult when evaluating processing methods, vaccination, preconditioning, nutritional factors, and prophylactic methods that include administration of antimicrobial metaphylaxis. The authors concluded that BRD can be best managed using preconditioning techniques coupled with weaning before selling and that calf age is important. Calves that experience more viral and microbial challenges develop immune defenses with aging and are more resilient to viral and microbial insults after feedlot arrival.

The beef cattle industry is segmented into geographical regions based on available feed, water, labor supply, environment, and ease of ground transport. Confinement cattle feeding businesses cannot operate without a supply of feeder cattle from cow-calf producers. For the most part, cows that produce a supply of calves for the cattle feeding industry are managed in geographical regions unsuitable for crop production and from mixed crop and livestock farms. As such, cow-calf producers selling calves as the first point of sale is the time that new wealth is generated. All future purchases and sales are based on a buy/sell margin plus interest expense culminating in either profit or loss. Based on market conditions and the potential for future profit (loss), cow-calf producers can decide to sell 6–8-month-old calves after weaning and repeat the cycle annually, or retain ownership through a growing period (backgrounding) and sell their calves after approximately 100 days on feed. Thus, producers are subject to a series of keep/sell marketing management decisions occurring from weaning through finishing and final harvest. Keep/sell decisions parallel seasonal management and availability of sufficient winter feed supply, spring-summer-fall pasture, and market projections that either do, or do not, support retained ownership. With respect to BRD morbidity and mortality, weaning prior to sale is the largest contributor to the reduction in BRD morbidity. Therefore, when calves have been weaned, processed (viral and clostridial pathogen vaccinations, castration, and dehorned) and fed post-weaning diets for at least six weeks (preconditioned), the incidence of BRD morbidity and mortality is reduced 4.5 times, but not eliminated [4].

Retaining ownership in a vertically integrated business model from birth to final harvest has been shown to result in enhanced compensatory gain and efficiency, reduced days on feed and breakeven expense, and profitability increase, when feedlot entry was delayed until after extended grazing of forages [5–7]. Research involving the integration of a diverse multi-crop farming system coupled with beef cattle grazing was designed to evaluate the impact of combining the two enterprises on extensive rearing and animal health, soil health, crop production, grazing animal performance and economics, and the effect of delayed feedlot entry on system profitability.

2. Beef cattle management in the United States

To better understand the manner in which alternative intensive animal farming tactics can minimize negative effects on animal health, it is important to understand the multiple ways beef cattle and calves are managed and marketed after weaning.

Initially, beef cattle producers are faced with the marketing decision of when to sell calves. The decision comes down to whether calves will be sold immediately after weaning, preconditioned for a period of 42-days before selling, or ownership retained for a longer period of time. Before the backgrounding period begins, the producer must determine that there is sufficient feed available to feed the calves and when the projected backgrounding period will end. The next questions the producer must answer are: 1) do I sell the calves at the end of the backgrounding period, or 2) keep the calves and put them on spring and summer pasture for summer grazing. The market timing decision is important, because dietary energy level during the growing period effects future performance, especially cattle destined for summer grazing. Steers and heifers destined to go to the feedlot after the growing period can be fed dietary energy levels that support average daily gain (ADG) of 1.14 to 1.36 kg/hd/day (2.5 to 3.0 lb/hd/day). However, if steers and/or heifers are destined for summer grazing of perennial and annual forages, then (ADG) of 0.59 kg/hd/day (1.30 lb/hd/day) is a more appropriate confinement pre-grazing growth rate, because although early spring vegetative pasture grasses are highly nutritious, high water content (≥80%) of early spring vegetative grasses and the quantity of available forage can restrict the animals' ability to consume a sufficient quantity of dry matter for maintenance and growth [8–10]. Steers and heifers fed higher energy diets for more rapid growth during the drylot wintering period, in the Northern Great Plains, will have greater body fat that cannot be maintained when transitioned to a grazing environment. Therefore, a high energy pre-grazing dietary regimen is inappropriate for animals destined for a grazing environment, because body condition will decline until a grazing growth equilibrium is attained. The amount of time for equilibrium to occur depends on the degree of fatness and forage quality. In addition to appropriate pre-grazing body condition, beef cattle heifers placed on grass that are not intended for breeding purposes will experience reduced ADG due to physical activity associated with estrus activity. Estrus activity is easily alleviated with ovariectomy conducted by a licensed veterinarian. At the end of the summer/fall grazing period, the producer determines whether to continue grazing late into the fall period, sell, or retain ownership and place the yearlings in the feedlot. Grazing late into the fall and early winter period in the Northern Great Plains region of the United States results in slower than desired ADG due to declining forage quality. When retaining ownership late into the fall/early winter period, an alternative to grazing low quality pastures is to feed harvested round baled hay in a free-ranging environment using a technique referred to as "bale grazing". In this situation, the animals are not confined to feedlot pens, but are allowed to range freely while being fed high quality baled hay. For intensified animal agriculture, feeding areas might range from 65.0 to 135.0 ha in size; however, the feeding areas can be sized to fit a given number of feeder cattle. Upon completion of the bale grazing period, the producer decides whether to continue retaining ownership by placing the feeder cattle in a feedlot or to sell. Assuming the decision is to retain ownership, another decision needs to be made that will affect how the animals are to be fed. That decision is whether the cattle will be forage finished using a forage-based diet and non-starch finishing supplement [11] or fed a high-caloric grain-based feedlot energy diet designed for 2.15 to 2.27 kg/hd/day (4.75 to 5.0 lb/hd/day).

3. Climate, crops and regenerative agriculture, diversified cropping system

3.1 Climate

The semi-arid region of the Northern Great Plains is known for wind, cold winters, and warm summers; however, relatively low humidity. Growing season (April – October) precipitation averages 311.9 mm. Maximum and minimum mean temperatures range from a high of 23.8 °C to a low of 8.5 °C [12].

3.2 Crops and regenerative agriculture

A wide range of crops are grown in the region for grain, oilseed, and forage including numerous varieties of, but are not limited to: cereal grains (spring wheat, winter wheat, corn, barley, oats, rye, flax, triticale, lentil, chickpea, grain sorghum, dry beans, dry pea), oilseeds (soybean, sunflower, canola, safflower, crambe), and forages (alfalfa, clover, millet, hairy vetch).

Alternative approaches to minimizing animal health issues focuses on methods whereby cattle are managed to spend upwards of 85% of their lives outside of feedlot confinement. Initially, pasture stocking rate for cows and calves that will be grazing a given range resource is determined. Secondly, the number of cow-calf stocking spaces that retained ownership yearlings will replace needs to be determined. For crop and livestock farms, an integrated diversified multi-crop rotation system can provide additional grazing without a large reduction in the ranch's cow-calf carrying capacity.

When designing the annual cropping system, complementary attributes were considered from the perspective of the following: minimum soil disturbance using no-till seeding and planting, suitability for cattle grazing, water conservation, crops that form associations with arbuscular mycorrhizal fungi (AMF), improving soil quality through soil nutrient cycling, including legume crops or mixes with a high percentage of legumes in the mix, crops that have high root mass, deep cycling crops, and crops that maintain a living root in the soil long after freezing conditions set in. More recently, coalescing these non-traditional practices and applying them to farming and ranching has become referred to as regenerative agriculture. This is not a term often heard around traditional farming circles. However, among holistic farmers and ranchers, regenerative agricultural practices focus on melding this wide range of practices together in ways that are good for the land and the people who farm the land. Soil is a living organism and must be managed carefully, because soil coupled with water, solar radiation, and microbial derived nutrient cycling sustains all plants and living creatures. Regenerative agriculture has a foundation in the five principles of soil health: Soil Armor, Minimizing Soil Disturbance, Plant Diversity, Maintaining a Continual Live Root in the Soil as Long as Possible, and Livestock Integration [13].

The soil surface is fragile and subject to wind and water erosion as well as impact from insults such as hail and solar heat that kills soil surface microbes. Protection for soils comes from plant cover of pastures, farmed land with domestic no-till or reduced-till crop production and residues, cover crop mixes that help keep the land covered and provide forage for haying and grazing, and reduced weed infestation.

3.3 Diversified cropping system

Considering the wide array of crops that could be grown and demonstrate complementarity, the diversified multi-crop rotation consisted of spring wheat, dual winter and summer cover crop, forage corn, field pea-forage barley mix, and sunflower. Within these crops, cool- and warm-season grass and broadleaf crops are represented that are adapted to the semi-arid region. Crop characteristics associated with crops selected for inclusion in the diverse crop rotation are shown in **Table 1**. The characteristics listed include Crop Type (Cool- or Warm-season Grass and Broadleaf types), crop water use requirement (Low, Medium, High), Grain Crude Protein %, Residue C:N Ratio, Nitrogen Scavenging Ability, and whether the crop forms an association with Arbuscular Mycorrhizal Fungi. Some excellent crops were excluded that did not meet the requirement for livestock grazing or did not form relationships with AMF. For example, canola is an excellent oilseed crop; however, the crop is not suitable for grazing and does not form a relationship with AMF. Nonetheless, within a wider rotation of six to seven crops canola and soybean would be logical crop rotation additions.

Cover crops were initially promoted by USDA/NRCS for purpose of controlling water and wind erosion prescribed by Practice Code: 340: Growing a crop of grass, small grain or legumes primarily for seasonal protection and soil improvement [14]. Ancient alternatives to fertilizers were the use of green manure crops that were used by farmers in Chinese, Greek, and Roman societies [15]. In the infancy of cover crop use the recommendation was that the crop would be seeded following a primary cash

Crop	**Spring wheat**	**Multi-specie cover crop**	**Corn**	**Field pea/ barley mix**	**Sunflower**
Crop Type	Cool-Grass	All Crop Types	Warm-Grass	Cool- Grass & Broadleaf	Warm-Broadleaf
Water Use	Medium	Medium	High	Low/Low	High
Crude Protein % (Grain)	12-16	Mixed	8-9	24/13	20-28
Crop Residue C:N Ratio	90	30-45	57	27/80	68
N Scavenging Ability	Very Good	Very Good Varies with mix	Deep soil mining	Fixation/ Very Good	Deep soil profile mining
Forms Arbuscular Mycorrhizal Fungi Association	Yes-Medium	Yes-High	Yes-High	Yes-Medium	Yes-Medium

Table 1.
Multi-crop rotation crop characteristics.

crop, which has not been very successful in the semi-arid regions. This is because dry soil conditions are common after a primary crop is harvested and germination is impeded reducing biomass production. Mixed-specie cover crops are gaining popularity among crop and livestock producers for their aid in not only controlling wind and water erosion, but also as full-season annual forage crops used for haying or grazing that provide for both above and below ground biomass. Cover crops provide numerous soil system services beyond protecting the soil surface from erosion. Soil system services also include increasing fertility from soil organic matter and subsequent nitrogen supplied from decaying roots and surface residue, symbiotic and asymbiotic nitrogen fixation, increased soil aggregation and decreased compaction, increased soil water infiltration through the use of tillage-type radish and turnips that create tunnels for soil water infiltration, weed control to some extent, grazing season extension, and protective cover for wildlife. To accomplish these many soil system services within the research investigation, the diverse crop rotation employed a dual winter and summer cover crop planting. The winter cover crop was seeded during the first two weeks of September each year and consisted of a winter triticale/hairy vetch mix. The crop was harvested mid-June each year for hay. Following hay harvest, the fields were burned down with Glyphosate and seeded to a 7-way cover crop mix (**Table 2**) that was harvested with yearling beef cattle steers. Plant root diversity as well as plants that form association with AMF are important for inclusion in cover crop seed blends. Sunflower, oat, pea, and hairy vetch are crops with roots that develop associations with AMF. Whereas rape, cabbage, and turnip are included in the 7-way mix to provide diversity, nitrogen scavenging, and aid in reducing compaction; however, do not form AMF associations. Fifty percent of the crop species included in the cover crop blend were legumes. The importance of legumes in cover crop mixes cannot be over emphasized, because their nitrogen fixing characteristics provide a nitrogen source for the subsequent crop through microbial nutrient cycling.

The cropping system consisted of crops with small seed size (spring wheat, cover crop, pea, barley) that were seeded using a John Deere 1590 No-Till drill (row spacing: 19.1 cm) and crops with large seed size (corn and sunflower) that were planted using a John Deere 7000 No-Till planter (row spacing: 0.762 m) (Deere & Company, Moline, IL USA). Spring wheat was planted to achieve 3.09 million plants per ha and the corn and sunflower crops were planted to achieve plant populations of 7,692 plants per ha. The mixed crop of field pea (Arvika, var.) was seeded at 67.2 kg/ha and the forage barley (Stockford, var.;) was seeded at 44.8 kg/ha, i.e., 60.0% pea – 40% barley.

Crop	**kg/ha**	**Percent**
Sunflower	10.9	4.01
Oat (var. Everleaf)	108.7	40.01
Winter Pea (var. Flex)	108.7	40.01
Hairy Vetch	27.2	10.01
Forage Rape (var. Winfred)	5.4	1.99
Ethiopian Cabbage	5.4	1.99
Hunter Leaf Turnip	5.4	1.99

Table 2.
Seven-Way cover crop mix.

The order in which crops occurred in the rotation was based on plant season of growth (cool- or warm-season), water use, and residue C:N ratio. Starting with spring wheat as the first crop in the rotation, the crop is rated as medium for water use and was followed by the multi-specie cover crop that contained a high level of legume plants with low C:N ratios. Under normal precipitation in the region the cover crop would be expected to breakdown due to microbial nutrient cycling making plant nutrients available to the subsequent corn crop. Corn is a warm-season grass crop and sunflower is a warm-season broadleaf crop, and both crops are rated as high water use crops; therefore, a cool-season mixed grass and broadleaf intercrop mix (field pea-forage barley) suitable for grazing was placed between corn and sunflower, because both crops in the mix are rated as being low water use crops and the mix was 60% legume. The high concentration of legume in the crop mix with a low C:N ratio was expected to provide nitrogen and other nutrients for the following sunflower crop.

4. Forage grazing sequence and steers

4.1 Forage grazing sequence

Spring seeded annual forages require adequate growing time before grazing suitability is reached; therefore, yearling steers grazed native range pasture until annual forages were ready for grazing. On average, the steers grazed native range for approximately 108 days between the first week of May and mid-August. Western North Dakota native range pasture grass specie composition consists of both cool- and warm-season grasses: cool-season: western wheatgrass (*Pascopynum smithi*), slender wheatgrass (*Elymus trachycaulus*), prairie junegrass (*Koeleria macrantha*), bluebunch wheatgrass (*Pseudorognerta spiacata*), green needlegrass (*Nassella viridula*), slender wheatgrass (*Elymus trachycaulus*), warm-season: prairie sandreed (*Calamovilfa longifolia*), indiangrass (*sorghastrum nutans*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), and little bluestem (*Schizachyrium scoparium*). For the research, control groups grazed native range for the full grazing season; however, grazing groups that were assigned to graze annual forages began grazing field pea-barley (*Pisum sativum*, var. Arvika; *Hordeum vulgare*, var. Stockford) as the first annual forage in the grazing sequence followed by corn and cover crop grazing. Crop grazing readiness for pea-barley was determined when the barley grain was in the early milk stage and peas were small and soft (2–3 mm).

4.2 Steers, stocking density, and grazing management

Over the course of multiple experiments steers of differing frame score have been used as grazing animals and described as small frame (SF: Frame Score Range: 3.77–3.82) and large frame (LF; Frame Score Range: 5.53–5.63). Frame score determination is computed according to the formula: $-11.548+(0.4878 * Ht) - (0.0289 * Age) + (0.00001947 * Age^2) + (0.0000334 * Ht * Age)$, where age = days, and height = inches [16]. For one research evaluation [17] only one steer frame score type was used (LF), and in other studies [18, 19] steers of both SF and LF types were used. Grazing equivalents for steers used in these research investigations were computed from a reference cow (454 kg) nursing a six-month old calf [20]. Grazing equivalents for each steer type were calculated by conversion of reference animal cow weight and SF and LF steer weights to metabolic weight, which resulted in grazing steer equivalents of 0.840 and 0.934 for steers categorized as being of SF and LF. Each of the pastures in the grazing sequence were 1.74 ha in size, replicated three times and each pen replicate stocking rate was 0.2138 ha per steer. The field pea-forage barley intercrop mix was grazed for 27–32 days and varied by year. The mixed intercrop maturity progresses rapidly from seeding to full maturity and it was determined that extending the grazing period beyond 27–28 days resulted in a decline in steer gain performance. For some of the studies, the intercrop mix was windrowed to capture forage quality before the onset of grazing and in other studies the crop was grazed as standing crop. Windrowing was not always successful. Above average precipitation one year resulted in moldy feed in the windrows, which was undesirable. Therefore, windrowing was suspended for subsequent research projects. Corn grown for sequence grazing was unharvested (not combined residue) vegetative actively growing plant of a forage-type categorized as being later maturing and used for silage due to the plant's stalk to leaf ratio and soluble sugar content. Days of forage corn grazing ranged from 52 to as much as 71 days and was largely dependent on the amount of rain received. Cover crop mix was the last crop grazed in the sequence and the amount of above ground biomass available for grazing was more variable than the preceding pea-barley and corn crops. The observed variability is directly related to available soil moisture and precipitation following harvest of the winter triticale-hairy vetch cover crop mix. Insufficient soil moisture delayed germination for as much as four to five weeks before precipitation was received, which negatively impacted total above ground biomass for grazing.

Upon completion of sequence crop grazing, bale grazing was initiated. For bale grazing, cover crop hay is produced using a full-season cover crop consisting of oats, peas, sorghum-sudan, and clover (crimson var. and berseem var.). Nutrient analysis of the cover crop bales and the starting and ending forage analysis for the other sequence crops that were grazed are shown in **Table 3**. Native range, field pea-barley, corn, cover crop mix, and cover crop baled hay were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), invitro organic matter

	CP, %	NDF, %	ADF, %	IVOMD, %	IVDMD, %	Ca/Phos, %	TDN, %
Native Range							
Start	9.7	64.7	35.4	57.5	58.7	0.27/0.13	55.5
End	6.9	58.8	38.9	47.4	48.6	0.31/0.11	52.6
Field Pea-Barley							
Start	11.0	55.0	30.2	69.6	68.5	0.50/0.23	59.7
End	8.2	67.0	37.9	54.8	54.1	0.37/0.25	53.5
Corn (Whole Plant)							
Start	7.7	56.6	29.5	78.0	77.6	0.32/0.24	60.1
End	4.6	69.2	38.2	64.7	63.6	0.17/0.20	53.2
Cover Crop							
Start	11.8	50.5	31.5	43.0	69.3	0.75/0.34	58.7
End	12.3	52.8	34.5	64.3	61.9	0.83/0.31	56.4
Cover Crop Bale	12.8	54.4	31.4	72.5	72.3	0.48/0.22	59.0

Table 3.
Forage nutrient analysis for grazing sequence crops and cover crop bales.

disappearance (IVOMD), invitro dry matter disappearance (IVDMD), calcium and phosphorus (Ca/Phos), and total digestible nutrients (TDN).

5. Alternative integrated systems research

Integrated systems research has focused on three primary areas of interest: crop production, beef production, and soil health within the systems' evaluation. The ensuing discussion will look into each area of interest and the complementary aspects of the holistic regenerative approach to the systems' integration.

5.1 Crop production and soil health

The cropping system [21] consisted of hard red spring wheat grown continuously on the same replicated fields for the entire investigation and is designated as HRSW-C. The spring wheat control is compared to hard red spring wheat grown in the five-crop rotation and has been designated as HRSW-R. The continuous spring wheat control is a very important part of the research, because wheat farmers in the region have grown spring wheat on the same land for decades (30 to 50 years). Under these conditions, the only possible way to raise a good crop of spring wheat is to apply fertilizer based on soil test results for a given yield goal (44.8–56 kg/ha). The alternative is to employ a holistic approach that considers the principles of soil health that includes multi-crop diversity and integration of beef cattle grazing. The crop rotation of spring wheat, cover crop, corn, field pea-barley mix and sunflower with three of the rotation crops being harvested by grazing has the potential to reduce the cost of production and enhance profitability. At the start of the research, urea nitrogen fertilizer was applied according to soil test results to both the control and rotation spring wheat fields. The HRSW-R fertilizer application was discontinued after two years and after three years fertilization of the HRSW-C was discontinued. Soil fertility was evaluated by creating root restriction zones in the replicated spring wheat fields using aluminum irrigation pipes (20.3 × 61.0 cm) pressed into the soil with an industrial type construction front-end loader. Soil samples were collected from inside and outside the irrigation pipe restriction zones. Economic analysis was carried out with the assistance of the ND Farm and Ranch Business Management Education program budgets in which actual incurred expenses that include fertilizer, chemicals, seed, and crop insurance premiums were entered into the budgets. From the budgets, calculations for individual crop expense, gross return, and net return were determined. Improving soil health through integration of complementing crop types and cattle grazing reduced reliance on mechanical harvesting while aiding in the enhancement of soil nutrient cycling consuming less fuel and fertilizer, and adding value to yearling steers prior to feedlot entry.

Control and rotation HRSW yield did not differ for the five-year cropping system period between 2011 and 2015. Although there was no difference in grain yield, protein percent or test weight, mean grain yield does not fully explain soil health changes that occurred due to the effect soil microbial nutrient cycling had on nutrient supply without the addition of exogenous N fertilizer.

Corresponding to soil nutrient cycling after N fertilizer (urea) was discontinued resulted in a yield transformation whereby spring wheat-control yield was greater initially (**Figure 1**) followed by a continual decline whereas the soil derived nutrient supply supported continued yield increases (**Figure 2**) years 4 (8.4%) and 5 (32.6%) as depicted by chart trendlines.

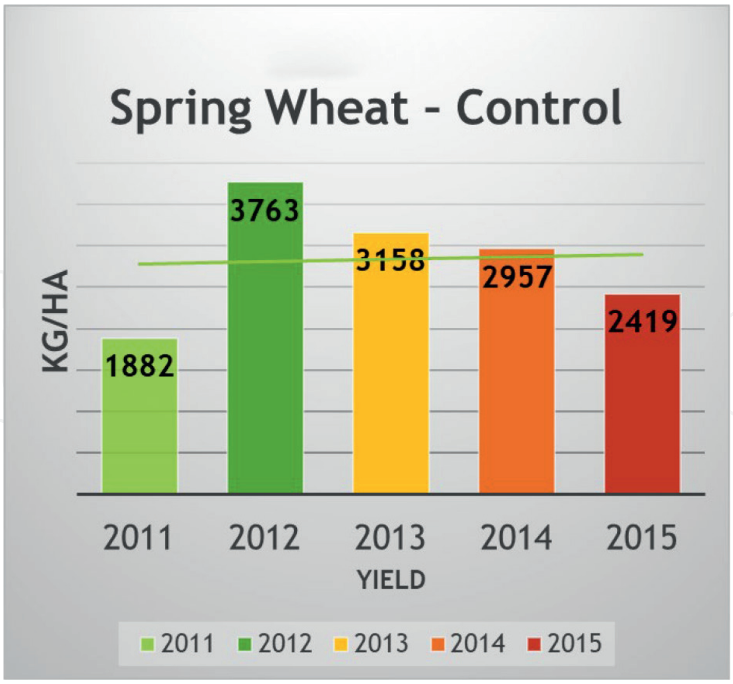

Figure 1.
Spring wheat – control.

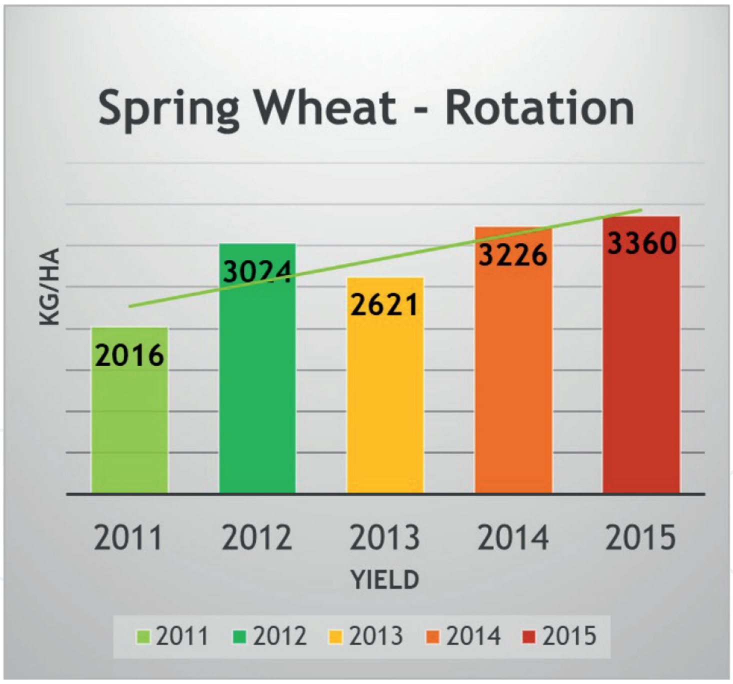

Figure 2.
Spring wheat – Rotation.

Economics for the crop production (**Table 4**) suggest an advantage for the holistic production such that rotation spring wheat had a $6.00/ha greater net return at the time the analysis was performed. The combined net return economic advantage for crops grown in the integrated system was $2,036 compared to $1,514 for the control indicating that although growing spring wheat continuously on the same land year after year requires less intensive management profitability is reduced 34.5%.

Plant diversity within the multi-crop rotation that included spring wheat as well as the other rotation crops (cover crop, corn, pea-barley, sunflower) contributed to

Yield	HRSW-C[1] (kg/ha)	HRSW-R[1] (kg/ha)	WT-HV & CC[1] (T/ha)	CORN SILAGE[2] (T/ha)	PEA BARLEY (T/ha)	SUN-FLOWER (T/ha)
5-yr Avg, ($P = 0.30$)	2,829	2,856	3.7/6.2	8.6	8.4	1.6
5-yr Average Economic Analysis						
Net Return/ ha, $	78.8	95.2	69.22	86.58	110.32	169.12
System Net Return, $[3]	$1,696			$2,279		

[1] *HRSW-CON: Hard Red Spring Wheat – Control; HRSW- ROT: Hard Red Spring Wheat – Rotation; WT-HV&CC; Winter Triticale – Hairy Vetch & 7-Specie Cover Crop*

[2] *Corn silage grain content 2011-2015: 941, 3468, 5519, 2822, 4930 kg/ha (Avg. 3536 kg/ha)*

[3] *Average total 5-year net return for HRSW-C and rotation crops (HRSW- ROT, WT-HV&CC, Corn Silage, Pea Barley, and Sunflower)*

Table 4.
Five-year crop yields and system net return (2011–2015).

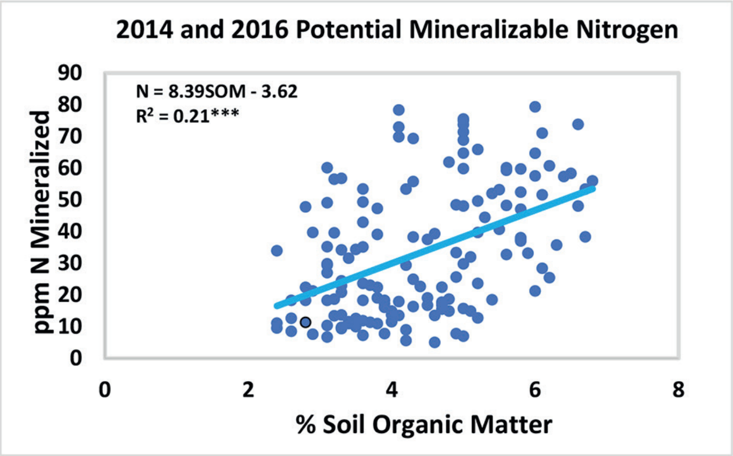

Figure 3.
2014 and 2016 potential mineralizable nitrogen.

an increase in soil organic matter (**Figure 3**.) in the experimental fields that ranged from 2.8 to 6.8% by the end of the five-year period. Contrasting percent SOM with potential N mineralization using regression analysis identified that as the percent of SOM increased there is approximately 8.4 mg N mineralized for each 1.0% SOM increase per kg of soil [22].

Paralleling the systems evaluation were soil properties of interest (water infiltration, wind erodibility, and water stable aggregates). Following five years of cropping history the crop rotation system has numerically greater water stable soil aggregates, reduced potential wind erodibility, and water infiltration rate levels increased (27.1 mm/hr. vs. 19.1 mm/hr.) in the crop rotation indicating that the multi-crop system has a positive effect on soil health.

5.2 Beef production and delayed feedlot entry

The stressors of commingling, transportation, change of feed, new location and dehydration coupled with less developed immune defenses make young cattle less resilient to respiratory pathogen challenges from BRD than older animals with more developed immune systems when challenged by viral and microbial pathogen invasion. Feedlot BRD disease occurrences have been categorized into cohort groupings as being either early-, mid-, or late-feeding stage occurrences that coincide with the first 42-days on feed (DOF), 43–71 DOF, and 72–100 DOF in a mid-western feedlot where mid- and late-stage risk for BRD incidence was evaluated. Incidence for BRD was determined to be greater during the second quarter of the year which coincides with wide temperature fluctuations, summer heat, and humidity [23]. This data set can be contrasted with economist's evaluation [24] using pen-level data (5,773 pens, 636,042 head received) from a Southern Great Plains feedlot where a 2.28% death loss was identified. Sixty percent of the cattle were sourced from auction sale barns. Risk factors for sickness and death loss include sourced from sale barns, travel distance and animal shrink greater than 5.5%, and larger pen size. Customer owned cattle sourced directly from ranches had lower death loss of 1.97% compared to 2.35% among feedlot company owned sale barn sourced cattle. The data also identified that pens of cattle with lighter feedlot arrival in-weights have higher death loss such that for each in-weight increase of 45.4 kg death loss was reduced by 0.2%. Using this percent death loss age reduction statistic, delaying feedlot entry until steers and heifers enter the feedlot weighing 454 to 499 kg (1,000 to 1,100 lbs.) could potentially reduce death loss by 1.1 to 1.3%. Yearling steers involved in integrated crop-beef cattle extended grazing delayed feedlot entry systems research discussed herein are seven to eight months older and 188 to 210 kg heavier upon feedlot arrival than cattle in the Southern Great Plains feedlot data set. Due to greater feedlot arrival weight in the delayed feedlot entry research, the steers reach harvest target condition after 82 DOF, but are not immune from BRD and digestive health death loss. However, death loss is substantially reduced. During the 8-year period (2013–2021), death loss for delayed feedlot entry steers was: BRD 0.86%, bloat 0.35%, and unknown 0.17% for a combined 8-year total of 1.38%. In addition, non-performing "realizer" steers were sold at auction for a net revenue loss.

In addition to managing animal health and death loss by withholding steers and heifers from feedlot confinement in retained ownership extended grazing growing systems, the extended grazing program must be profitable. Integrating yearling steers into perennial and annual forage grazing protocols have been studied among differing steer groups with different research objectives [17, 18]. For the initial investigation [17] a control group of randomly assigned steer pen replicates were delivered to the feedlot (FLT: 367 kg In-Weight) and were compared to randomly assigned steers that grazed perennial pasture only (PST) and a third group that grazed perennial pasture and annual forages grown in the diverse multi-crop rotation (ANN). The initial integrated systems investigation objectives were designed to determine 1) the number of days grazed and steer performance, 2) the effect of grazing system on live animal muscle area, fat depth, and intramuscular fat change, and 3) the effect of system on delayed feedlot entry growth performance, carcass measurements, and long-term risk analysis. All steers were grown during the fall-winter-early spring period for modest gain $\leq$ 0.454 kg per steer per day. Grazing start weights for the PST and ANN steers was 369 and 375 kg and ending weights were 509 and 558 kg, respectively. PST and ANN steers gained 140 and 183 kg costing $1.12 and $1.30 per kg of gain. The cost per steer was greater for the ANN steers due to farming costs ($157.31 vs $238.46). Grazing live animal muscle and fat measurements for *longissimus dorsi* muscle area (Ribeye Area; cm^2), backfat depth (cm), and intramuscular fat percentage were monitored as the steers grew grazing perennial and annual forages. Ribeye area for ANN system steers was greater (P = 0.04), fat depth did not differ (P = 0.33), and percent intramuscular fat was 0.70% greater (P = 0.001) (Aloka SSD-500V Portable Ultrasound Machine affixed with Aloka UST-5044–3.5 Linear Array Transducer and Standoff, Sentinel Imaging Group Inc.). The PST and ANN grazing groups grazed for a period of 181 days before transfer to the feedlot for finishing. Feedlot days on feed were longest for the FLT control group (142 days), 91 days for the PST group, and 66 days for the ANN integrated system steers. Compared to the FLT control steers starting and ending weight for the PST and ANN steers was naturally greater due to grazing weight gain. Comparing the three treatment groups in the feedlot, there were no differences measured for ADG, dry matter feed intake (DMI), gain to feed ratio (G:F), and feed cost per kg of gain. Control FLT steer cost was $578.30 compared to $276.12 and $381.18 for the ANN and PST, respectively. Carcass measurements were unremarkable for hot carcass weight (HCW), fat depth (FD), marbling score (MS), USDA yield grade (YG), and quality grade (QG). Upon conclusion of this study the cattle market experienced a down turn in commodity price resulting in undesirable net return values for the FLT control that lost −$298 per steer, PST group that lost −$30.10 per steer, and the ANN grazing system steers that netted $9.09 per steer; a margin of $307.09 between the FLT control and the ANN grazing system steers. A ten-year feedlot sensitivity analysis for the period between 2003 and 2012, and hedging against catastrophic loss was conducted. The sensitivity valuation determined that within the ten-year period the FLT control treatment underperformed seven out of the ten years evaluated. Considering the three treatments FLT, PST and ANN, hedging loss protection was rewarding forty, thirty, and twenty percent of the time. This initial investigation evaluating delayed feedlot entry provided positive direction for future investigations into the potential for managing annual forage crop-grazing systems simultaneously.

Sustaining profitability in the cattle business is not easy. Cow-calf producers generate new wealth when calves are born and subsequently marketed, and the entire beef cattle industry in one way or another receives its livelihood from calves born and reared on ranches across the United States. The rancher, therefore, has direct control over mitigating risk by creating greater beef value before the first point of sale. Resource management and retaining ownership coupled with a vertically integrated business model are powerful tools for creating added beef value. Extracting as much beef value from the cow herd that is practically possible begins with matching cow size and yearling steers of differing skeletal frame-size to the range and annual forage resource.

For the second research project in the series of integrated systems investigations [18], the relationship between cow and steer frame-size, performance, market timing, and economics was evaluated. Rearing environment has a profound effect on cow efficiencies. Brood cow biological efficiency is a complex balance of environmental impact resulting from available feed resources, and interaction between cow frame-size, reproductive efficiency, milking ability, and growth performance [25, 26]. The underlying research premise was that a marketing bias towards calves from small-framed cows exists and profitability at the first point of sale is diminished. Our research team hypothesized that in lieu of selling small-framed calves at weaning using a vertically integrated business model, extended grazing of annual forages, and delayed feedlot entry would eliminate market bias and increase profitability. Yearling crossbred steers (n = 288) from small-framed cows (Aberdeen Angus (Lowline) × Red Angus × Angus × Angus) and moderate to large framed cows (Red Angus × Angus × Simmental × Gelbvieh) were randomly assigned to frame-size groups identified as small-frame (SF) and large-frame (LF) treatment groups. One-half of the frame-size groups were identified as feedlot control groups (FLT) and the remaining one-half were identified as extended grazing groups (GRZ). The mean frame sizes for the FLT control groups were SF: 3.82 and LF: 5.63, and for the GRZ groups, mean frame sizes were SF: 3.77 and LF: 5.53. The FLT control steers were on feed for 218 days compared to 212 days of grazing and 82 DOF in the feedlot for the GRZ treatment steers. When assessing SF steers under grazing conditions compared to their larger framed counterparts, growth was less pronounced; however, the cost per kg of gain was 7.8% less. Beef cattle genetics are constantly improving growth performance and efficiency, and are based on gain test evaluations in which high energy grain-based diets are fed. Therefore, grazing steers consuming forage-based diets are unable to express their full genetic potential for growth. Nonetheless, steers grazing perennial and annual forages grow structurally prior to feedlot entry followed by a compensatory growth and efficiency response in the feedlot when high energy grain-based diets are fed. The SF and LF grazing steers grew at the fastest rate of gain in the feedlot (SF: 1.74, LF 2.10 kg/day) compared to feedlot control SF and LF steers (SF: 1.33, LF: 1.56 kg/day) (P = <0.01) and there was no difference in gain to feed efficiency (P = 0.59). Total feedlot cost per kg of gain was markedly lower for the grazing steers (SF: $1.53, LF: $1.44/kg of gain) compared to the feedlot control steers (SF: $1.97, LF $1.99/kg of gain). Hot carcass weights for the LF graze and FLT control were 423 and 398 kg, respectively, and hot carcass weights for the SF graze and FLT control were 374, and 350 kg, respectively. Systems economic analysis using a vertically integrated business model from birth to slaughter is shown in **Table 5** that summarizes annual cow cost and steer expenses returns for winter growing and extended grazing, feedlot expenses, and carcass value for the comparative frame score groups in the FLT and GRZ systems' treatments.

Item	FLT[2] (LF)[3]	FLT[2] (SF)[3]	GRZ[2] (LF)[3]	GRZ[2] (SF)[3]	SEM	P-Value Trt
Cow, calf wintering, & grazing cost, $	755.51	630.64	1040.67	868.75		
End steer market value, $			1570.45[a]	1553.35[b]	7.37	0.01
Net return/steer, $			529.78	684.60		
Net return/ha, $[4]			26.03	36.71		
System Expenses:						
Cow, calf wintering, grazing, & feedlot finishing /steer, $	1452.74	1222.74	1312.09	1107.56		
Income						
Carcass value/ steer, $	2042.47	1753.88	2243.61	2017.51	91.81	0.79
System net return/steer, $	589.73	531.14	931.52	909.95		

[a-b] *Means with different superscripts within a line are significantly different, (P ≤ 0.05).*
[1] *3-Year mean*
[2] *FLT: control steers moved directly to the feedlot for growing and finishing; and GRZ: steers grazed a sequence of native range, field pea-barley, and unharvested corn before transfer to the feedlot at the University of Wyoming*
[3] *SF: Small Frame, LF: Large Frame*
[4] *Net return/ha based on sum of native range and annual forage hectares grazed per steer*

Table 5.
Effect of grazing and retained ownership vertical integration on net return[1].

At the end of the 212-day grazing period, the yearling steers were valued, but not sold to establish an end grazing steer value and calculate net return per ha values before transfer to the finishing feedlot. Small-frame steers cost less to produce and had greater grazing net return per ha. Due to lower placement cost and total system expense, the SF grazing steers cost less to produce and compared to the LF grazing steers that had the highest net return the SF grazing steer net return was a mere 2.32% less. Upon further inspection, comparing the SF grazing steer net return to the SF feedlot steer net return, the SF grazing steer net return was 41.63% greater illustrating the effect that extended pre-feedlot grazing and compensating feedlot gain can have on system net return.

Frame-size evaluation shown here clearly identifies that beef cattle producers in semi-arid regions can maintain cows with smaller frame-size taking advantage of increased stocking rate and greater net return per ha per cow exposed and eliminate calf market bias through retained ownership in a vertically integrated business model from birth to final harvest.

For the third study in the series of investigations into to evaluating extended grazing and delayed feedlot entry [18], the question was asked, “Will withholding yearling steers from feedlot confinement through grazing above average quality cover crop hay after integrated systems grazing has been completed be more profitable than grazing native range only?” Feeding large round hay bales weighing 499 to 635 kg (1,100 to 1,400 lbs.) in spacious non-confined areas was previously described as “bale grazing”. Using the same integrated systems research infrastructure protocol and economic analysis previously defined, replicated groups (3 reps) of yearling steers grazing native range only were compared to replicated groups grazing a sequence of native range and annual forages (pea-barley, corn, and cover crop) was the foundation for the 3-year project. As such, when NR and the sequence of NR and ANN forage grazing was completed bale grazing started. The seasonlong cover crop fed was seeded in May each year consisting of Pea, barley, sorghum-sudan hybrid, crimson clover, and berseem clover and harvested to obtain hay with crude protein value ranging from 12–14% CP. **Table 3**, shows the nutrient analysis of the cover crop hay that had a crude protein value of 12.8% and Total Digestible Nutrient value of 59.0%. Bale grazing withheld the steers from feedlot confinement for an additional 43.7 days. The combination of sequence forage grazing and the additional time steers spent grazing bales resulted in a 43.0 kg weight advantage compared to the NR control steers, which carried through to the end of the finishing period. Gross carcass value over the three-year period of the study was $92 greater ($P = 0.031$) than the NR steers ($1,922 vs $2,014). During the three-year study and economic analysis, ANN forage sequence steers were consistently heavier entering the feedlot and the grazing weight margin gained between the NR control steers and the ANN forage sequence steers did not change appreciably during feedlot finishing resulting in ANN forage system steers fed harvested baled hay before feedlot entry being consistently more profitable.

6. Conclusion

Confining cattle in close proximity to each other greatly increases social stress and animal-to-animal disease transmission. Reducing the use of antibiotics in growing and finishing beef cattle is impossible without significant modification in beef cattle management before confinement feedyard placement. Non-confinement investigations incorporating crop production and beef cattle grazing reported herein have defined successful protocols that reduce the need for using antimicrobials for animal well-being from minimal at weaning to nearly non-existent during grazing. Non-confinement protocols have increased utilization of home-grown crops through crop and beef cattle grazing integration and by employing the five principles of soil health. Employing a diverse multi-crop rotation with beef cattle grazing increased water infiltration and soil water holding capacity as well as improved and reduced reliance on commercial fertilizer application. Additional merits of the systems' integration are found in improved wildlife habitat for birds, small animals, and large game. Beef cattle grazing a sequence of perennial and annual forages improved grazing animal performance, carcass weight and net return. Reducing agronomic inputs that can be replaced with naturally occurring nutrient cycling has the potential to increased profitability for the farm-ranch enterprise and improve revenue for local economies. Moreover, systems analysis has shown that significant modifications to cattle management before the first point of sale using retained ownership and an annual forage grazing integration protocol from birth to slaughter can be profitable for the cow-calf producer. Well in advance of any business model transition to an integrated crop-livestock system from birth to slaughter, ranch managers considering a business model shift are encouraged to conduct an in-depth through feasibility analysis of the proposed change and cash flow that will support the enterprise modification to include infrastructure additions for cropland fencing and water installation as well as establishing bank operating loan repayment schedule during the business model transition.

Conflict of interest

The authors declare no conflict of interest.

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