Fertilizer value of manure

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TABLE OF CONTENTS

Executive summary

Increased fertilizer prices and a more stringent regulatory climate have led to greater interest in capturing value of manure through from cattle feeding operations.

As expected, feedlot designs that capture more manure either diluted with bedding materials such as bed pack designs or in a pit recover the greatest amount of nutrients per head space yearly.

Guideline values utilized by engineers and other consultants are adequate estimates of manure nutrient yield per head space yearly.

Greater fertilizer prices starting in 2008 served as incentives to build feedlots with greater capacity to capture the value of manure as fertilizer.

The value of manure as fertilizer has contributed to making cattle feeding operations competitive with corn farming only operations in the past decade.

Corn grain, feeder and fed cattle prices, fertilizer prices and corn grain yield interact to determine profit from feeding corn grain to cattle vs selling corn grain at market price.

High fed cattle prices relative to corn grain prices with greater than average corn grain yields at current high fertilizer prices favor feeding corn grain to cattle rather than selling in the market place.

Introduction

Design, construction and management of cattle feeding operations have evolved dramatically over the last 20 years. The quest for improved cattle comfort for consistent and predictable performance drove this process initially. Concurrently, changing regulatory climate towards greater environmental protection, particularly water quality protection by preventing or eliminating excessive nutrient or waste discharges to state or federal waters expedited development and adoption of new facility designs that would both provide cattle comfort for consistent performance and environmental protection.

Further, changing global economic conditions resulting from a bio-fuel-based economy and recent economic recession accelerated the need to make cattle feeding a more resource-efficient process. Taken together, these factors have contributed to attributing greater economic value to manure derived from cattle feeding operations. This, in turn, promoted closer evaluation of cattle feedlot designs that would capture greater manure value; thereby, achieving a better matched nutrient cycle between soil, plants and animals while preventing contamination of state and federal water resources.

In spite of this, and because much of the recent developments in cattle feedlot design, construction and operation have arisen from the private sector, no public information exists where impact of feedlot design on measured nutrient value of manure produced. Therefore, one of the objectives of this manuscript is to provide an in-depth analysis of the impact of feedlot design on manure nutrient values to aid feedlot owners and managers in the decision to select a feedlot design consistent with their objectives for crop land and manure management. A second objective is to demonstrate the impact of the value of manure as fertilizer on corn production destined as cattle feed and to determine how corn grain, fertilizer and cattle prices interact to determine sustainability of the land, cattle, crop and manure system.

Phosphorus: a diminishing resource

Incentives to retain manure nutrients in a complete soil-plant-livestock cycle are further derived from the state of the World's supply of phosphate fertilizer. According to various researchers, World supply of phosphate fertilizer is either reaching a peak in 2033 (Cordell et al., 2009) or it did so in 1989 (Dery and Anderson, 2007). For the years between 2011 and 2015 FAO (2011) projected over three fourths of the increase in phosphate fertilizer production will occur in Eastern Europe, Central and Western Asia, Africa, and Latin America. Most of these countries also represent the greatest increase in phosphate fertilizer users for the same time period. Therefore, realistic concerns over global food security resulting from reduced accessibility to phosphate fertilizer exist. Scientists (Cordell et. al., 2009; Morrigan, 2010) who have forecast these trends for phosphate fertilizer suggest, amongst other things, that recycling nutrients from animal manures is by one of the single most important priority items to prevent food scarcity derived from reduced phosphate fertilizer supplies.

Benefits of recycling manure nutrients are not confined to recovering P from manure. Other manure nutrients and organic matter are important to maintaining soil health and structure. A nutrient receiving special attention due to its decline from atmospheric concentrations is sulfur. Sulfur deficiencies in corn and soybean production have been identified and are currently remedied using chemical fertilizer (Strock, 2010; Camberato et al., 2012; Sawyer et al., 2012). Corn or soybean yield responded to application of 25 lb S/acre in moldboard and strip-tilled fields (Strock, 2011) or 10 to 30 lb S/acre (Sawyer et al., 2012). Soybean and alfalfa yield also responded to addition of 40 lb S/acre (Sawyer et al., 2012). Considering that inclusion of ethanol and sweetener production co-products contain moderate to high concentrations of S, benefits of recycling cattle manure from cattle feedlots may not be contained to adding organic matter or preserving phosphate fertilizer only.

Feedlot design and manure nutrient content

Cattle feeding operations represent a specialized industry characterized by (oversimplifying) one of three types of feedlot designs (open with runoff control, confinement with bedding packs, and confinement with deep pits). In the Great Plains, climate conditions permit use of commercial open lots built on large acreages where cattle are in pens accommodating as many as 500 hd (250 ft^2/hd) with unpaved surfaces, except for concrete aprons behind feeding bunks and around water troughs, contoured to manage runoff caused by precipitation via earthen storage basins; solid manure is removed regularly. In contrast, due to presence of inclement weather (cold temperatures and high precipitation) for some months of the year, feedlot design in northern climates ranges from open to full confinement designs. Within the total confinement design, several manure management systems may be used: solid manure aided by heavy use of bedding materials (manure bed pack barns using straw, cornstalks, sawdust, etc.) or slurry manure management using an underground deep pit under concrete slatted-floors (pit barns).

There is an increasing body of evidence indicating that retention of nutrients is 25% to 50% greater from manure management systems where cattle and manure containment is more extensive (Farran et al., 2006; Lawrence et al., 2001; Zehnder et al., 2000) as is the case with semi-confinement and confinement systems. Nutrient content, retention, release into the soil, and ultimate availability for plant uptake are high-impact aspects of economic and environmental importance to cattle feeders where a cropping operation is managed concurrent with cattle feeding. In addition, challenges with weather and, in some cases, as a direct result of environmental protection rules that govern manure management, cattle feeders in the upper Midwest are in a unique position to manage operations in a manner consistent with greatest manure nutrient capture and utilization after soil application. However, the results on manure nutrient value of the interaction of cattle type (genetics), utilization of corn co-products from ethanol production, heavier finishing weights, more aggressive growth implants, and longer days on feed with facilities under which cattle are finished are not known. Knowledge of the impact of modern feeding factors with facilities types on manure nutrient value will greatly enhance the ability of feedlot operators to match crop nutrient needs with manure nutrient value under several cattle finishing facilities types. This should result in a reduction in chemical fertilizer inputs, greater carbon capture in the soil, and a greater understanding of the economic and nutritional value of manure from cattle feeding operations.

Concurrently, as a result of a clear move to expand or modernize feedlot operations in the Upper Midwest, there is increased interest in matching manure management plans resulting from facilities types with crop nutrient needs. An extensive dataset containing manure nutrient value analyses with corresponding facility, diet and cattle type description from where manure was derived was kindly provided by Extended Ag Services, Inc. of Lakefield, MN.

Manure nutrient analysis (as-is) results from solid samples (689) collected at open feedlots, manure bed packs from confinement feedlots, mostly monoslope structures, stockpiled manure and results from liquid manure samples (186) from feedlot pits under slatted-floors and lagoons from 2010 to 2014 were made available. Data were further categorized by cattle type (beef or dairy) and targeted dietary energy value (grower or finisher diets). Only samples for which all three categorical descriptions existed were retained for a statistical analysis to determine effects of feedlot design (outdoor or manure pack feedlot or slatted floor feedlot on a pit), cattle type (beef or dairy) and targeted dietary energy value (grower or finisher). A single dataset containing data for either liquid or solid was analyzed for effects of feedlot design, cattle type and dietary energy value on manure nutrient content. Manure nutrients were expressed as lb nitrogen (N), phosphate (P_2O_5) or potash (K_2O)/ton of as-is material (solid) or as lb of these nutrients/1,000 gal (liquid). Because only finisher type diets were contained in the liquid dataset effect of energy value was dropped from the model. In addition, a combined dataset (n = 483) was analyzed were projected annual cattle manure production values of 3 and 5 ton/hd or 2,500 gal/hd, respectively, for outdoor or manure pack or slatted floor feedlot on a pit were estimated to compare effects of facility design on manure nutrient contributions per head space.

Effects of year and month of sample collection were retained in a mixed model as random in procedure MIXED of SAS (SAS Institute, Cary, NC). Effects of month and year were evaluated by conducting a secondary analyses in which effects of these variables were ignored. By comparing the Sawa's Bayesian Information Criteria (BIC) value (lower values are considered a best estimate of the measure between the model and "true" underlying model) determinations were made on the model that best fit the data. Values for BIC between models containing month and year as a random effect against those ignoring the effect of month and year were similar. This finding indicates that within feedlot design sampled, sampling year or month has no effect on manure nutrient content.

Means of liquid or solid manure nutrient concentrations for various feedlot designs, cattle types and targeted energy values are presented in Table 1. Liquid manure sample from lagoons was expectedly lower in nutrient concentration than those sampled from feedlot pits (Table 1). Cattle type affected ($P < 0.10$) nutrient concentration of liquid manure samples. Concentrations of N were greater ($P < 0.05$) and those of phosphate tended ($P < 0.10$) to be greater for Holstein steers. This observation may reflect longer days on feed for Holstein than beef type cattle.

Feedlot design had no impact on N or potash concentration from either stockpiled manure or that derived from manure packs or outdoor feedlots (Table 1). Stockpiled manure samples contained greater concentrations of phosphate than those derived from open lots or manure pack buildings. Stockpiled manure samples included pen scrapings. This may contribute to a greater concentration of phosphate observed in these samples. Indeed, concentrations of potash were also numerically greater (P = 0.1127) than those of stockpiled manure samples.

Greater concentrations of N, phosphate and potash were observed in manure samples derived from pens when beef cattle types were housed (Table 1). This finding is in direct contrast to the observation that liquid manure samples from Holstein cattle housed on slatted floors over pits contained more N and tended to contain more phosphate than those from beef cattle types. These observations may simply reflect dilution of manure nutrients over time. Holstein cattle types are kept on feed longer thus diluting concentrations of nutrients in manure capture systems where bedding is used (a result of longer feeding periods requiring more bedding material and bedding material diluting manure nutrients). In contrast, pit capacity is limited by pit dimension, thereby leading to greater concentration of manure nutrients with time on feed when Holsteins are fed longer days on feed.

A tendency for greater potash concentrations in manure samples derived from cattle fed growing diets was observed for potash concentrations—greater concentrations were reported for pens housing cattle fed grower than finisher diets (Table 1). This finding may simply reflect a tendency for greater reliance on forages and greater concentrations of K in grower diets.

Table 1. Least square means ± standard errors of liquid or solid manure nutrient concentrations (as-is) for samples collected from pens within various feedlot designs

	Nitrogen	Phosphate, P_2O_5	Potash, K_2O
Liquid manure		--------------------------------lb/1,000 gal-------------------------	
Lagoon [a]	8.9 ± 5.7 [a]	5.1 ± 3.6 [a]	14.0 ± 9.3 [a]
Indoor pit [b]	49.9 ± 5.7 [b]	22.6 ± 3.6 [b]	36.6 ± 9.4 [b]
Cattle type			
Beef	26.0 ± 5.6 [a]	12.6 ± 3.5 [x]	22.8 ± 9.3
Dairy	32.9 ± 5.8 [b]	15.1 ± 3.6 [y]	27.8 ± 9.5
Solid manure		-----------------------------------lb/ton-----------------------------	
Outdoor lot	16.6 ± 1.0	11.1 ± 1.1 [a]	14.8 ± 1.0 [x]
Manure pack	16.3 ± 1.0	9.3 ± 1.1 [b]	14.9 ± 1.1 [x]
Stockpile	17.2 ± 1.0	12.0 ± 1.1 [a]	16.2 ± 1.0 [y]
Cattle type			
Beef	18.0 ± 0.9 [a]	12.8 ± 1.0 [a]	16.4 ± 0.9 [a]
Dairy	15.4 ± 1.0 [b]	8.8 ± 1.1 [b]	14.3 ± 1.1 [b]
Energy value			
Finisher	16.4 ± 0.7	11.6 ± 0.9 [b]	14.3 ± 0.8 [y]
Grower	17.0 ± 1.3	10.1 ± 1.4 [b]	16.3 ± 1.3 [y]

[a, b] Means within category or source with uncommon superscripts differ ($P < 0.05$).
[x, y] Means within category with uncommon superscripts differ ($0.05 > P < 0.10$).

This analysis revealed that concentrations of manure nutrients are fairly consistent in liquid manure storage pits. Similarly, concentrations of N are not affected by feedlot design (outdoor lot or manure pack) or whether samples were collected after stockpiling manure. This is an important consideration when determining what feedlot design to choose when planning new construction or expansion. The observation that cattle type influenced manure nutrient content may be influenced (biased) by age and weight of cattle housed in facilities where solid manure is derived. Given the area of influence were these samples were derived, dairy cattle types represented in the sample likely were being staged to finish in a slatted-floor on a pit confinement feedlot. Dairy types in this sample likely represent young, lightweight cattle. This would explain the apparent greater nutrient concentration in beef type cattle housed in manure pack or open lot design feedlots found in this analysis.

Although not available, estimates of manure production from feedlot designs evaluated herein were determined from field observations, and were used to confirm guidelines used by engineers and consultants. Estimates of annual manure yield (as-is) were 3 or 5 ton/hd (solid manure from outdoor lots or manure packs) and 2,500 gal/hd (liquid manure from pits). These estimates were multiplied by concentrations of manure nutrients in each respective sample to yield annual nutrient production in manure derived from each of the three feedlot designs evaluated.

As expected, greater manure nutrient capture is estimated to occur from feedlots that rely on manure packs or have slatted-floors on pits. Manure production estimated from pits yields greater amounts of N than that estimated from either manure bed pack or outdoor feedlots. This is a result of greater potential to retain N in a pit than from a bed pack or an exposed outdoor lot, which is reflected by a greater N concentration in liquid manure.

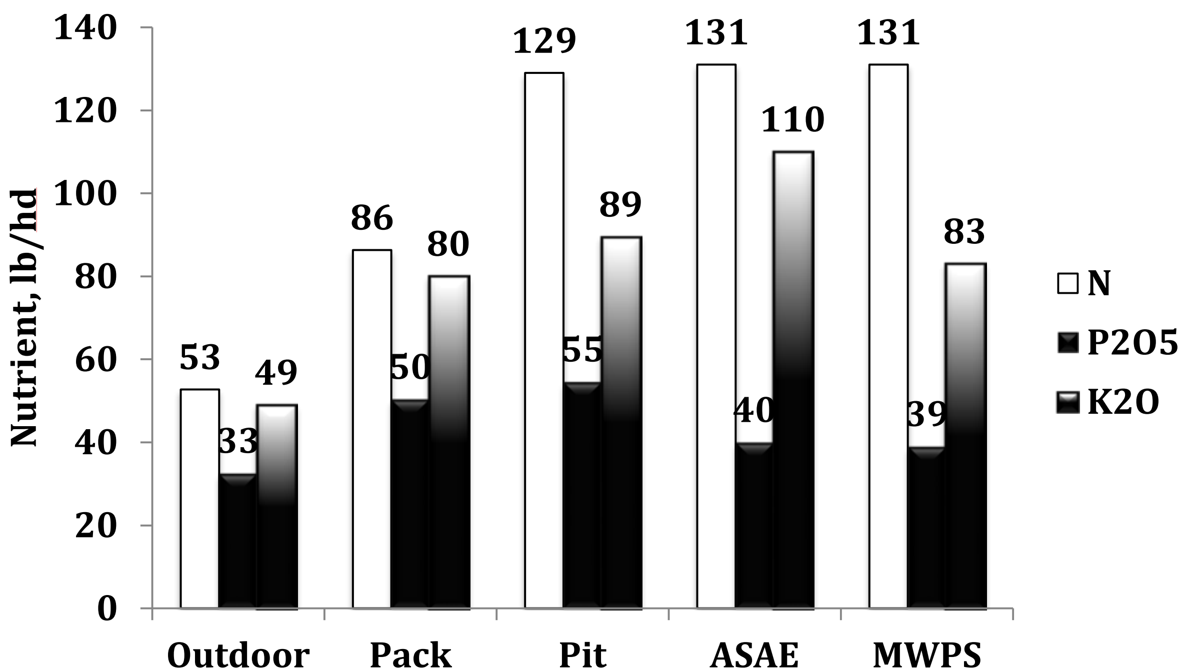


Figure 1. Estimated annual manure nutrient yield (lb/hd) derived from outdoor lot (manure yield: 3 ton/hd), manure pack (manure yield: 5 ton/hd) or confinement pit (manure yield: 2,500 gal/hd) cattle feedlots. Manure N or potash yield differed ($P < 0.05$) across feedlot design. Manure phosphate yield was only different ($P < 0.05$) between outdoor lot and confined feedlot designs. Estimates of manure nutrient yield derived from commonly accessed publications (ASAE D384.2 MAR 2005; MWPS-18 Sec. 1, 2nd ed. 2004) are provided as a reference.

Using ASAE D384.2 wherein values were derived from simple production of urine and manure to represent the maximum manure N recovery values, estimated manure N yield from slatted floor feedlots on pits using manure samples contained in this dataset demonstrated a recovery of 98% of the total N excreted by a single animal unit space yearly. Applying the same logic, and ignoring the contributions of bedding material in manure bed pack barns, these barns recover 66% of the total N excreted by a single animal unit space yearly. Zehnder et al. (2000) demonstrated that N recovery values approached 75% in manure bed pack buildings in the winter while only 50% of N produced by the animal was recovered in the summer. Corresponding N recovery value for outdoor feedlots using this approximation is 40%. Values generated for yearly manure yield using data obtained from the current analyses, particularly for feedlots using manure bed packs or those for slatted-floors on pits, agree well with those used by many agricultural engineering firms, consultants and feedlot owners and operators.

As indicated previously, manure nutrient recycling provides value-added benefits beyond nutrients commonly considered helpful for crop production. Analysis of effects of feedlot design on manure S concentration were conducted within the liquid (n = 120) and solid (397) manure sample dataset. Feedlot design had significant impacts on the concentration of solid or liquid manure (data not tabulated). Manure samples derived from stockpiled manure contained the most S concentration (4.5 ± 0.5 lb/ton) while the concentration of S in samples derived from open or manure pack feedlots were similar (3.6 ± 0.5 and 2.9 ± 0.6 lb/ton). As for other nutrients, manure from pits contained more S than that from lagoons (9.7 ± 0.6 vs 2.6 ± 0.7 lb/1,000gal). Given these observations, a manure application rate from outdoor or manure pack feedlot of 7 ton/corn acre (120 lb N/acre) would provide nearly 20 lb S/acre. Similarly, applying 2,400 gal liquid manure/corn acre to achieve 120 lb N/acre would provide 23 lb S/acre. These S fertilization rates are well within S fertilization ranges recommended for enhanced corn yield.

Feedlot design and manure nutrient value

Using the least square means for nutrient concentrations derived from Table 1, fertilizer prices, and hauling costs, a net value per head space can be calculated to determine differences in net nutrient value as influenced by feedlot design and fertilizer cost (Table 2). Fertilizer prices used ranged from $379 to $847/ton for anhydrous ammonia (82% N), from $276 to $850/ton for diammonium phosphate (46% P_2O_5 and 18% N), and from $181 to $853/ton for potash (60% K_2O), respectively. Costs were $3 or $4/ton to haul manure from open or manure bed pack feedlots, respectively. Costs were $0.015/gal to haul manure from feedlots with slatted-floors on pits. Resulting net yearly values for nutrient yield from either feedlot design varied dramatically based on fertilizer price. Net yearly value increased almost five-fold for manure derived from monoslope confinement and over four-fold for manure derived from confined barns with slatted floors on pits from 2007 to 2008.

Fertilizer prices have remained high since that time fueling interest in retaining manure value from cattle feeding operations. This may explain the nature of current feedlot expansion based largely on buildings either as manure pack or on slatted floors over pits.

Although greater manure nutrient was reflected by this analysis for feedlots with slatted-floors on pits, the reader must be reminded that this observation represents only a partial cost-to-benefit ratio. Location, capacity, siting, permitting, construction, management, bedding material choice and procurement, cattle type, days on feed, dietary ingredients and diets, feedlot life expectancy and many other factors influence the decision to choose a feedlot design over another. Feedlot owners or operators considering building a new feedlot or expanding are well advised to spend considerable time visiting other existing feedlots and talking with other feedlot owners and operators before making the initial appointment with and agricultural engineer and appropriate regulatory officer in their state and county to gather information on other advantages and disadvantages in each feedlot design available today.

Confined feedlots with slatted-floors on manure pits provide a thorough nutrient capture system. However, they must be managed for inherent issues associated with housing cattle on concrete—leg and joint issues particularly in newly placed cattle. Due to this, continuous and keen observation of cattle in these facilities (at least once daily walking through the pen) is recommended. A new threat to cattle health in confinement whether it is in a manure bed pack or slatted floor barn on a pit is the increasing incidence of hairy heel warts (digital dermatitis or papillomatous digital dermatitis). Other emerging issues with management of confinement buildings with slatted-floors on pits are pit gases and pit foaming both of them extremely dangerous to humans and livestock.

Table 2. Impact of fertilizer price [a] on value of manure [b] from three feedlot designs

				Feedlot Design		
Crop Harvest Year	**Ammonia, 82% N**	**DAP, 46% P_2O_5**	**Potash, 60% K_2O**	**Manure pack**	**Open lot**	**Slatted floor on pit**
2004	$379.00	$276.00	$181.00	$2.62	$5.49	$1.73
2005	$416.00	$303.00	$245.00	$7.42	$8.45	$8.74
2006	$521.00	$337.00	$273.00	$10.73	$10.49	$16.00
2007	$523.00	$442.00	$280.00	$10.74	$10.50	$16.07
2008	$755.00	$850.00	$561.00	$48.39	$35.23	$69.14
2009	$680.00	$638.00	$853.00	$55.87	$38.72	$76.15
2010	$499.00	$508.00	$511.00	$30.86	$23.34	$39.96
2011	$749.00	$703.00	$601.00	$44.66	$32.29	$64.46
2012	$783.00	$726.00	$647.00	$48.28	$34.53	$69.93
2013	$847.00	$640.00	$595.00	$42.13	$30.39	$64.38

[a] Fertilizer (DAP = diammonium phosphate) prices from USDA NASS.

[b] Contributions of N, phosphate and potash from Table 1 adjusted for first-year availability, yield (5 ton or 3 ton/hd space yearly for manure pack or open lot, respectively, or 2,500 gal/hd space yearly for slatted floor confinement on pit) and hauling costs ($4 or $3/ton for manure pack or open lot, respectively, or $0.015/gal for slatted floor confinement on pit).

Additionally, matching manure nutrient production and crop production needs must be considered when planning expansion or new cattle feeding operations. These are vital elements of a manure management plan—a requirement in all states for operation of livestock facilities. As feedlot managers or owners consider starting or expanding their operations, they are well advised to consult with agricultural engineers and soil scientists on the balance of nutrients and best methods of manure application. Both these areas are highly sophisticated and, just as with other issues in the feedlot such as animal health and nutrition, professional advise must be sought.

Environmental and financial sustainability through cattle and manure management

Conventional agricultural practices have been under scrutiny recently as they are perceived to be major contributors to environmental decay through increases in pollution and as contributors to greenhouse gas emissions. Much has been written elsewhere about these issues and the reader is referred to an excellent source on environmental impact of the beef industry presented elsewhere (Capper, 2007).

The debate as to whether conventional practices impact the environment will continue for as long as there are gains to be made by shock-and-awe approaches many activists, pseudo-scientists or scientists employ for gains that benefit interests beyond those of the industry or consumers. A thorough and complete evaluation of modern production practices is extremely difficult to conduct by individuals or groups who assume or derive values of many factors in production agriculture without properly weighing their contribution to the overall production totals, and/or fail to include complete or modernized systems.

Table 3. Historic corn grain, corn yield, hay, fertilizer and cattle prices used to determine corn grain worth (Figure 2)

Crop Harvest Year	Corn price, $/bu	Hay/bedding price, $/ton	Ammonia, 82% N	DAP, 46% P_2O_5	Potash, 60% K_2O	Corn yield, bu/acre	Feeder price	Fed Steer price
2004	$2.06	$92.00	$379.00	$276.00	$181.00	160.4	$96.73	$84.30
2005	$2.00	$98.20	$416.00	$303.00	$245.00	148.0	$111.47	$86.51
2006	$3.04	$110.00	$521.00	$337.00	$273.00	149.1	$114.57	$85.65
2007	$4.20	$127.00	$523.00	$442.00	$280.00	151.1	$108.78	$91.94
2008	$4.08	$152.00	$755.00	$850.00	$561.00	153.8	$109.22	$93.21
2009	$3.55	$108.00	$680.00	$638.00	$853.00	164.7	$100.97	$83.35
2010	$5.18	$114.00	$499.00	$508.00	$511.00	152.8	$104.37	$93.57
2011	$6.22	$178.00	$749.00	$703.00	$601.00	147.2	$121.85	$114.91
2012	$6.89	$187.00	$783.00	$726.00	$647.00	123.4	$145.80	$122.40
2013	$4.45	$185.14	$847.00	$640.00	$595.00	158.8	$143.70	$126.41

Sources: Corn grain price and yield, hay price and fertilizer (DAP = diammonium phosphate) prices from USDA NASS. Cattle performance, yardage costs (not tabulated) and feeder and fed cattle prices were those published by Purina Animal Nutrition (http://www.beeflinks.com/articles.htm).

Utilizing USDA National Ag Statistics Service data for U.S., average corn grain yield and prices in the 10-year period encompassed between 2004 and 2013 crop years, we analyzed their impact and those of roughage price (hay), ammonia, diammonium phosphate and potash, feeder and fed cattle price on corn grain worth realized by a feeder with no land base, who buys corn grain and feeder cattle, and sells fed cattle (also purchases roughages and manure value is not recovered), or a feeder-farmer who has crop land where they plant corn for cattle feed (crop residue use is debited given its fertilizer value, credited for its roughage value, and manure value is credited; Table 3). The premise of this analysis was to compare the market price of corn grain with corn grain worth realized after feeding cattle only (feeder with no land base) or feeding cattle in a crop production system (feeder with land base).

Worth of corn grain is defined as the gross value resulting from the difference between fed cattle income and non-corn grain use expenses (feeder cattle, yardage, veterinary medicine, trucking, roughage and supplement costs). In a system where corn crop land produces roughage from crop residue and uses manure from cattle feeding, appropriate debits for roughage use (fertilizer value of residue), credit for use as roughage (bedding or hay substitute) and manure value credit as fertilizer are included in the determination of corn grain worth. Manure credit as a fertilizer was only applied for its contributions to phosphate and potash needs of the following year's crop. This approach prevents over-application of N. Given that feedlot design impacts manure value as fertilizer, a single design (value of manure derived from manure pack feedlots) was utilized through the entire dataset. Cattle feeding systems were modeled using the average performance values for 2004 to 2013 listed on the Purina Animal Nutrition website for cattle fed between 700 and 800 lb and of average performance (http://www.beeflinks.com/articles.htm).

Figure 2 depicts the comparison of corn grain price at market or worth of corn grain realized by a cattle feeder with no land base or one where they benefit from use of crop residue and full value of manure as fertilizer (based on phosphate and potash contributions only). Given value of market price for corn grain and feeder and fed prices, a feeder with no opportunity to benefit from a land base where corn crop residue or fertilizer application needs would have realized a value for corn grain worth lower than market value. This explains why many cattle feeders relied on distillers grains with solubles and other co-products from the production streams of dry and wet milling corn processing plants and soybean crushing plants during the last decade.

In contrast, corn grain worth for a feeder with access to a land base where crop residues are harvested for use as bedding or roughage and fertilizer value of manure is realized is more competitive with corn grain prices at the market place. Across the 10 years analyzed, corn grain worth was $0.67/bu greater than corn grain price at the market place. The three elements contributing to this advantage when feeding cattle corn grain from a closed-system land, cattle, crop and manure nutrient system are crop residue credit for use as bedding or roughage and as fertilizer from feedlot manure application (a debit is always integrated in this calculation for nutrients removed with crop residue for use as bedding or roughage). Therefore, when evaluated as a complete system where land and crops benefit from use of manure derived from cattle feeding, environmental and financial sustainability of the entire system is enhanced. Indeed there were four out of 10 years when corn worth was lower than corn grain price. These years were 2006 and 2008 through 2010, and the average value loss between corn grain worth and price was $0.41/bu. Low fed cattle prices relative to corn grain prices and high fertilizer prices relative to corn grain prices or corn grain yield characterized these years.

Data were further analyzed to study situations where worth of corn grain achieved greater values than corn grain price, thereby enhancing. By identifying these situations, decisions to consider feeding cattle over selling corn as grain or when examining the possibility of expansion should be facilitated.

Figure 3 was generated by plotting the ratio of corn grain worth:corn grain price derived from feeder systems with land base against the ratio of fed cattle price: corn grain price. The latter is a common value used by economists to identify situations under which cattle feeding may or may not be profitable. This value ranged from a low of 20 (low fed cattle price relative to corn grain price) to a high of 56 (high fed cattle price relative to corn grain price). Values under 25 were identified for crop production years 2010 to 2012. Values over 40 were identified for crop production years 2004 and 2005. During years 2010 to 2012 (low fed cattle price relative to corn grain price), corn worth was improved on average $0.64/bu (Figure 3), but 2010 reflected a value loss of $0.09/bu by feeding cattle rather than selling corn at market outlets. In contrast, when fed cattle price was high relative to corn grain price, corn grain worth improved on average $1.35/bu over the price of corn grain. Interestingly, when fed cattle and corn grain price are moderate (ratio ranges between 25 and 40), corn grain worth improved on average only $0.41/bu over the price of corn grain. This average includes three years during which corn grain worth lost from $0.33 to $0.79/bu (2006, 2008 and 2009). During 2008 and 2009 other factors played a role in determining the improvement in corn grain worth after feeding it to cattle: fertilizer prices (particularly phosphate) were high relative to corn grain price or corn grain yield. During 2006, in spite of a favorable fed steer price:corn grain price ratio, extremely high feeder price relative to fed steer price likely impacted the loss in corn grain worth relative to corn grain price.

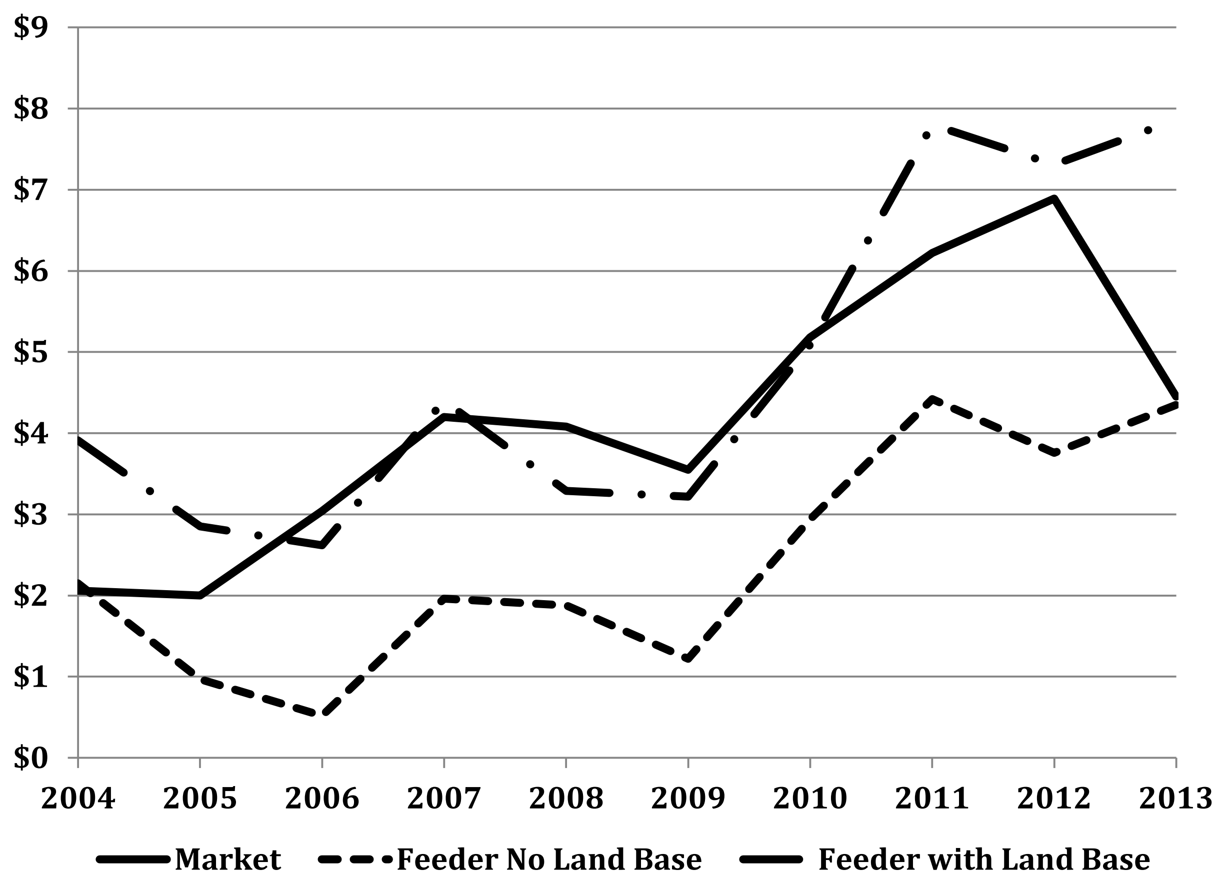
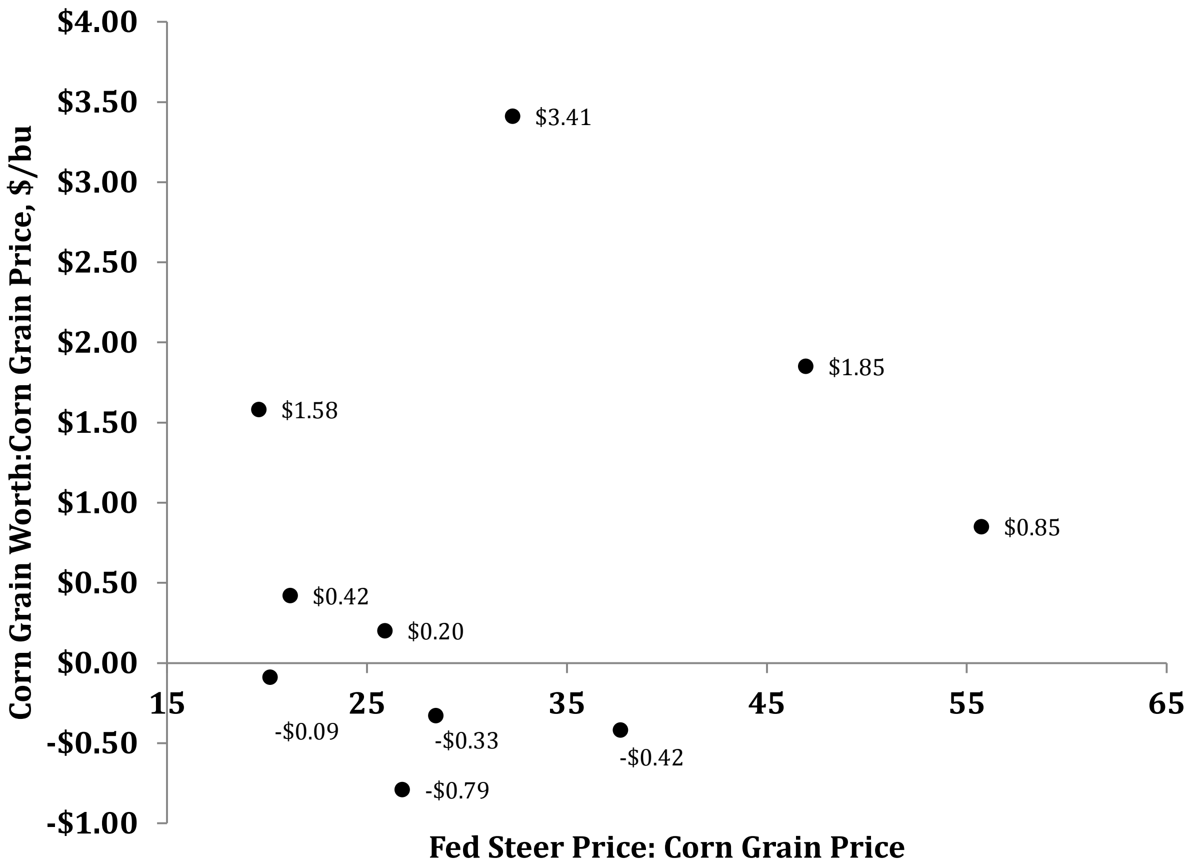


Figure 2. Average U.S. corn grain price (Market) or worth of corn grain realized after feeding cattle in operations with no land base to access bedding or roughage from crop residues or for manure application (Feed No Land Base) or those with land base to access bedding or roughage from crop residues or for manure application (Feeder With Land Base). Data were derived

Factors affecting the high impact of cattle feeding on corn grain worth for the current time period (2013 to 2014) are not easily identified from the values available. Fertilizer prices are high but not as high, relative to corn grain price or corn grain yield, as they were in 2008. Yet, corn grain yield was only slightly greater than the average for the decade evaluated, and fertilizer prices expressed as fertilizer price:corn grain price or as fertilizer price:corn grain yield were greater than the average for the decade evaluated. The only value for which crop year 2013 is highest is fed cattle price. Thus, a combination of factors reflective of average or slightly better than average corn yield, trends for higher fertilizer values, and decidedly higher fed cattle prices appear to support greatest improvement in corn grain worth over corn grain price.



Conclusion

Much progress has been made in cattle housing in the last 10 years. For the first time in the history of US agricultural production, much of this progress, unfortunately, was not generated from university research. Given reductions in personnel, budget and foresight to continue to serve as a leader for the agricultural community, it is unlikely cattle building research will ever be generated at a Land Grant Institution again.

Instead, much private engineering and consultant time and effort along resourceful and innovative thinking on the part of feedlot owners and operators has resulted in peculiar and effective adaptations implemented in feedlot designs of all types. The challenges of increasing input prices will continue to place pressure on feedlot owners and operators to generate solutions along with their trusted advisors.

Current expansion even in states with the strictest environmental laws is an indication of profit margins achievable in Upper Midwest states due to nearness to grains and forages and of appreciation for nutritive value of manure. Current expansion is also an indication of the understanding and willingness of entrepreneurial, self-started, highly motivated feedlot owners and operators to produce a safe and wholesome product while remaining the best stewards of land and cattle.

Differences do exist in capacity of each feedlot design evaluated to retain nutrients from manure; those on slatted-floors over a pit retaining the most nutrient value. In addition, at application rates to meet N needs of corn manure derived from all feedlot designs evaluated also supplied S fertilization rates within recommendations for enhanced corn yields.

Challenges will continue to exert motivational pressure on feedlot owners and operators and the allied industry that serves them. Because of various issues, there is no single feedlot design that is perfect for every situation. Even the most nutrient-capturing design requires intense management to prevent cattle health issues and potential for hazardous conditions. Therefore, the most sophisticated feedlot design is no substitute for appropriate management. Other items that will require further evaluation and research include mixed design buildings (manure pack and slatted-floors), new flooring materials (e.g., rubber mats), stocking rates, concrete scoring patterns, bunk allowances, monoslope roof angles, curtain design and management, roof materials that permit ultraviolet light penetration, truss materials, hairy heel wart prevention, pit foaming prevention, and liquid or solid manure additives to enhance nutrient retention to name a few.

A review of impacts of cattle, corn grain and fertilizer prices, corn grain yield and performance demonstrated complex relationships amongst these factors on whether corn grain gains value through cattle feeding (increased worth over the price received at market outlets). During the four years, corn grain lost value when fed to cattle; the average value loss was $0.41/bu, while corn grain gained an average of $1.39/bu relative to corn grain price in six out of the 10 years. The current year offers the most interesting study of how these factors interact with each other to increase corn worth when feeding cattle. During this year, corn grain yield is slightly above average, fertilizer prices, fed steer price:corn grain ratio price, and feeder prices are moderate, yet fed steer price is the highest received in the decade analyzed.

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