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Livestock Manure Production and Disposition: South Dakota Feedlots-Farms-Ranches

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LIVESTOCK MANURE PRODUCTION AND DISPOSITION: SOUTH DAKOTA FEEDLOTS-FARMS-RANCHES

by

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SUMMARY AND CONCLUSIONS

Nature of concentration in the U.S. fed cattle industry

The U.S.'s fed cattle industry today is much more geographically concentrated than it has ever been. For example, within the U.S., cattle feeding is heavily concentrated within just five states in the Central and Southern Plains (Texas, Nebraska, Kansas, Colorado, and Oklahoma). The share of total national fed cattle production in these five states increased from 49% in 1973 to 66% in 1993. The vast majority of this increase has been at the expense of cattle feeding in the Southwest and Midwest, with the two states suffering the greatest losses being Iowa (1.5 million fewer cattle) and California (1.2 million fewer cattle). Also, the population of cattle and calves on feed per unit of farmland nationally today is roughly four times what it was in the early 1930s.

Within the U.S.'s 13 major cattle feeding states, which include South Dakota, the average number of cattle and calves on feed per acre of cropland ranges from 241 in Arizona to 15 in South Dakota and Illinois and 14 in Minnesota. The average number of fed cattle marketed per feedlot varies among the 13 states from about 34,350 in Arizona and 15,000 in Washington and California to less than 100 in the three Midwest-heartland states of Iowa, Illinois, and Minnesota. South Dakota is at the small end of the average size-of-feedlot continuum, with an average of 121 fed cattle marketed per feedlot in 1993. Compared to 1973, average feedlot sizes increased by 7.7 times in Washington, doubled in South Dakota, and decreased 2-18% in the three Midwest-heartland states.

Feedlots which market 4,000 fed cattle or more per year account for 90% or more of total fed cattle marketed in 7 of the 13 major cattle feeding states: Texas, Arizona, Oklahoma, California, Washington, Kansas, and Idaho. At the other extreme are the three Midwest-heartland states, in which the "under 1,000 head size-of-feedlot category" accounts for over 70% of fed cattle marketings. South Dakota's size-of-feedlot distribution is much more like that in the Midwest than in the other 7 states--especially in regard to its having very few large feedlots. However, in South Dakota--compared to the three Midwest-heartland states--substantially fewer cattle come from feedlots with under 1,000 head (only 25% versus over 70% in the other states) and substantially more come from feedlots with 2,000 head or more (61% versus 7-15% in the other states).

In South Dakota, fed cattle numbers peaked at 685 thousand in 1985 and have since decreased rather steadily to 485 thousand in 1993. The number of fed cattle marketed from feedlots with under a 1,000 head capacity in South Dakota peaked in 1981 at 466 thousand. It has since dropped steadily at an annual average rate of nearly 29 thousand. The number of fed cattle marketed from feedlots in South Dakota with 4,000 head or more has fluctuated widely since 1973, ranging from 73 thousand in 1978 to 300 thousand in 1985. The number of cattle marketed from this large-feedlot category has trended down since 1985, dropping below 200 thousand in 1993 for the first time in the last 10 years. Growth during the past decade in South Dakota fed cattle marketed, on the other hand, has been registered with the 1-2,000 and 2-4,000 head feedlot categories, with the growth most steady and greatest for the 2-4,000 head feedlot category.

In summary, compared to the U.S.'s major cattle feeding states in the Central and Southern Plains and the West, South Dakota's concentration of fed cattle per acre of cropland and per feedlot is limited. Iowa, Illinois, and Minnesota--along with South Dakota--are way at the other end of the U.S. fed cattle concentration continuum. Compared to these three Midwest-heartland states, however, developments in South Dakota's fed cattle industry over the past two decades have been greatly different. In 1993, compared to 1973, the average number of fed cattle marketed per feedlot in South Dakota has doubled, whereas in the three Midwest-heartland states it has decreased by 2-18%. In 1993, over 70% of total fed cattle in Iowa, Illinois, and Minnesota were from feedlots which marketed under 1,000 head each. In South Dakota, on the other hand, 61% of fed cattle were from feedlots marketing 2,000 head or more. Since the mid-1980s, the number of fed cattle marketings in South Dakota from feedlots with 4,000 head or more has decreased by one-third, whereas it has increased rather steadily in feedlots marketing from 1,000 to 4,000 fed cattle per year.

Thus, compared to the U.S.'s other major cattle feeding states in the Plains and West, the concentration of cattle in South Dakota is far less. However, in contrast with the three major cattle feeding states in the Midwest-heartland whose fed cattle marketings per feedlot have trended down since 1973, South Dakota's fed cattle marketings per feedlot have doubled. These increases are primarily limited to feedlots marketing between 1,000 and 4,000 fed cattle per year, rather than to mega-feedlots marketing several tens of thousands of head per year each, as is occurring with the vast majority of cattle marketed from the other major cattle feeding states in the Plains and West.

Rationale for livestock concentration

The central factors underlying the increased **national concentration** of fed cattle (i.e., the increased number of cattle per unit of overall land area in the U.S.) since the 1930s have been (1) the increase in the aggregate demand for meat and meat-related products by Americans and (2) technological developments conducive to expanded beef cattle production. The increase in demand for meat has arisen because of population increases in the U.S. and consumers making dietary substitutions of red meat and poultry for grains.

The shift of **regional concentration** of fed cattle from the Midwest and Southwest to the Central and Southern Plains has been prompted by a number of interrelated "push" and "pull" factors. Factors pushing cattle from the Midwest include high feedgrain prices in the 1970s and government commodity price support programs, new crop production technologies, and large-scale farm machinery. Factors pushing cattle from the Southwest include rising land and water prices and increased concerns over soil, water, and air pollution. Factors pulling cattle to the Central and Southern Plains include the drier and warmer climate in these areas, new irrigation and hybrid seed technologies, and rail and truck rate deregulation.

The increased **farmland concentration** of fed cattle (i.e., the increased number of fed cattle per acre of cropland) has been associated with greatly increased numbers of cattle being fed far from the farmland on which their feed is raised. Main factors underlying the separation of fed cattle from farmland have been the availability of relatively cheap synthetic fertilizers; development and use of high yielding, fertilizer-responsive crop varieties; and government commodity programs and subsidies which have tended to reduce commodity farm price and income risks.

The primary driving force behind greater **individual feedlot concentration** is economies-of-size in cattle feeding and marketing. Such economies arise primarily from the spreading of fixed feedlot investments and production and marketing management across the larger number of cattle in larger feedlots. Additional factors favoring large-scale cattle feeding are (1) availability of biological products to help counteract potential health problems otherwise inherent in feeding large numbers of cattle confined in small spaces and (2) federal tax regulations that, until 1986, provided significant tax cost-savings favoring investments in large feedlots and large batches of cattle.

Limitations of livestock concentration

However, economies-of-size are not infinite in any production or manufacturing situation. There comes a point at which management no longer can effectively and efficiently supervise and coordinate all the expanded activities and personnel in a continuously growing enterprise. Further potential limitations of geographically concentrated livestock production include (1) a possible intensification of animal health problems for cattle living in very close proximity with each other; (2) a loss of soil fertility enhancement and insect-disease-weed control when legume- and grass-based rotations and animal manure applications to farmland are no longer followed because crop production is physically separated from livestock production; and (3) a breakdown in natural nutrient recycling that can result, among other things, in intensified problems of soil and water pollution.

In traditional polyculture crop-livestock systems, crops are fed to livestock, the livestock produce manure which is used to augment the fertility of farmland, and the farmland in turn is used to produce crops. With the development of "modern" agriculture, this basic nutrient recycling system has been interrupted. To obtain higher production, fertilizers are manufactured and imported from outside the system to augment and, in many cases--especially in monoculture cropping systems--to completely replace animal manures. In the many instances in which livestock production has become separated from crop production, manure often is a bulky waste product which cannot be economically transported for application to distant farmland. In the extreme, manure must be treated and disposed.

With concentrated livestock production, environmental concerns can arise in connection with waste run-off from feedlots ("point pollution") and with nutrients from manure in excess of those required by crops leaching into soil and water ("non-point pollution"). Possibilities for both types of pollution are often greater if cattle are fed in large feedlots. Point pollution may increase because of the large amounts of feedlot waste available as potential run-off into ground and surface water sources in the immediate vicinity of large feedlots. Non-point pollution may increase because the economic disincentives for transporting manure long distances from its point of origin may result in "excessively heavy" manure applications on farmland close to large feedlots. Such pollution can give rise to a variety of health and growth problems for plants, animals, and humans.

Eastern South Dakota has been determined to be located in one of four areas nationally in which livestock--and, hence, potential problems of animal waste disposal--are heavily concentrated. Further, environmentally sensitive surficial aquifers and glacial lakes are rather common in this part of the state. Thus, a study of livestock manure production and disposition in eastern South Dakota is of particular interest to environmentally-concerned participants in and observers of the state's livestock industry. This study also is responsive to one of the findings in the National Research Council's recent study, "Soil and Water Quality: An Agenda for Agriculture," in which the Committee on Long-Range Soil and Water Conservation drew attention to "increased national concerns about the effects of non-point sources of pollution on water quality" and the consequent need for research on "how and when animal wastes are applied to pasture and croplands and at what rates" (Batie, 1993, p 411).

Non-point pollution potential from livestock manure produced on South Dakota feedlots-farms-ranches

The non-point pollution potential from livestock manure produced in South Dakota was investigated through a case study of 78 feedlots-farms-ranches in the state. The feedlot design capacity for the 78 cattle feeders ranges from 11 to 6,665 head and averages 890 head.[1] These feedlots average nearly 12 times the average feedlot-size in South Dakota of 75 head. The average cropland area for the 78 cattle feeders is 1,475 acres, which is 2.4 times the average of 605 acres for farms and ranches throughout the state. Thus, the average concentration of fed cattle per acre of cropland for the feedlots covered in this study is roughly five times that for feedlots on the average in the state. Of the 78 feedlots covered in this report, 75 are located east of the Missouri River. Thus, the 78 feedlots-farms-ranches are (1) much above-average for the state in both feedlot design capacity and density of fed cattle per acre of cropland and (2) heavily concentrated in the eastern part of the state.

In addition to fed cattle, 51 (65%) of the 78 feedlot operators have other livestock enterprises. The most common other livestock enterprise involves beef cows. Forty-five (58%)

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[1] "Design capacity" refers to the one-time capacity of feedlots to accommodate cattle on feed. Since many feedlots feed more than one batch of cattle per year, average fed cattle marketings per feedlot per year commonly exceed feedlot design capacities.

of the 78 cattle feeders maintain beef cow herds ranging in size from 11 to 550 head and averaging 135 cows each. These beef cow enterprises average about 1.7 times the state-wide average herd-size of about 80 cows. Between 3% and 19% of the cattle feeders under study also have various swine, dairy, sheep, and poultry enterprises. In estimating the amounts of manure produced on the 78 feedlots-farms-ranches, attention was given to the manure produced by both fed cattle and the animals represented in these other livestock enterprises.

Amounts of manure produced by the various species and types of livestock and poultry found on the 78 feedlots-farms-ranches available for application to farmland were estimated. This included attention to estimated (1) amounts of manure initially voided by each category of livestock, (2) percentages of dry matter in raw manure produced by different species of livestock, and (3) manure storage and handling losses prior to field application. Decisions also were made on the proportion of total manure produced by each species and type of livestock that was assumed to be scraped, collected, and spread on cropland versus the proportion that was assumed to drop directly from grazing animals onto pasture land.

Estimated annual spread manure application intensities on cropland for the 78 feedlots-farms-ranches range from 0.4 to 28.1 tons/acre and average 6.1 tons/acre. Ten percent of producers spread an estimated average of less than 1.0 ton/acre. At the other extreme, 8% of producers apply an estimated 15.0 tons or more per acre of cropland.

Levels of manure nitrogen applied per acre of cropland range among producers from 6 to 507 lb/acre and average 98 lb/acre. The most common range of manure N application rates is 35-65 lb/acre, with nearly one-fourth of producers making applications within this range. At the high end of the manure N continuum, 14% apply 140-225 lb/acre and 10% apply 225 lb/acre or more. Levels of manure phosphorus estimated to be applied per acre of cropland range among producers from 2 to 159 lb/acre and average 31 lb/acre. Ten percent apply 65 lb/acre or more.

Based on literature sources indicating certain "scientific" and "regulatory" threshold levels for overall manure applications and manure N and P application intensities, I conclude that the average application of 6.1 tons/acre for the 78 feedlots-farms-ranches in this study is far less than any "danger-level" cited in the studies. Even the maximum spread manure application rate of 28 tons/acre of cropland for one cattle feeder in this South Dakota study falls far short of the 40 tons/acre of cropland maximum permitted in Missouri. However, the maximum permitted application rate for manure nitrogen in Indiana of 225 lb/acre is exceeded by 10% of the feedlots-farms-ranches in this study.

Although the literature-based reference points are indicative only, it would appear that the intensity of manure applications for the vast majority of the feedlots-farms-ranches covered in this study is not likely to be in an environmental danger-zone. This finding is particularly significant in view of (1) the average design capacity of the feedlots covered in this study being 12 times the average for all feedlots in South Dakota, (2) the average concentration of fed cattle per acre of cropland for the feedlots covered in this study being five times that for all feedlots in the state, and (3) eastern South Dakota (in which 75 of the 78 feedlots in this study are located) being included in one of four production areas nationally in which there exist possible excessive animal wastes because of heavily-concentrated livestock production.

Thus, this study provides evidence that the non-point pollution implications of cattle feeding in South Dakota are likely to be rather limited. Although South Dakota's cattle feeding industry is becoming more concentrated--with feedlots marketing between 1,000 and 4,000 head per year gaining much at the expense of feedlots marketing less than 1,000 head--this type of structural adjustment is on a far smaller scale than that in other major cattle producing states in the Central and Southern Plains and the West where the role of mega-feedlots marketing tens of thousands of fed cattle each year has increased greatly over the past 1-2 decades. As public concerns with environmental pollution continue to grow across our nation, it is critical to realize the major comparative advantage--relative to possible soil and water pollution from animal wastes--that arises from the unique structure of South Dakota's fed cattle industry.

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INTRODUCTION

Attitudes in the U.S. toward livestock manure have changed greatly over the past several decades. Until the third or fourth decade in the 20th Century, manure was considered as a significant natural resource for use in agricultural production. As a result of changes in technologies, institutions, and price relationships during the past four to five decades, however, manure has come to be viewed by many livestock producers as a waste product (Batie, 1993, p 399-400; Kaffka, 1992, p 47; Wadman et al., 1987). Nevertheless, especially in recent years, a perhaps relatively small minority of producers is again viewing manure as a resource with positive economic and social value--from the standpoint of its ability to replace synthetic chemical fertilizers and serve as a resource to augment soil fertility, rather than to be a waste product (Honeyman, 1991, p 65; Nelson and Shapiro, 1989, p 2).

The purposes of this report are two-fold. The first is to examine factors underlying changes in attitudes over time toward the economic and social value of livestock manure in the U.S. This includes attention to (1) changes over time in the geographic concentration of the fed cattle industry in the U.S.'s major cattle feeding states, including South Dakota; (2) the rationale for and limitations of increasingly geographically-dense cattle populations in the U.S., and (3) a consideration of the possibilities for substituting livestock manure for synthetic chemical fertilizers as a fertility source for crop production. Ways in which fed cattle concentration in South Dakota differs from that in the U.S.'s other 12 major cattle feeding states are noted.

The second purpose is to report results of a preliminary exploration of whether South Dakota's fed cattle industry appears to be suffering from a limitation that has arisen in several other cattle feeding states, namely, pollution from livestock waste of the state's soil and water resources. The investigation reported here pertains only to the non-point pollution potential of manure disposal, not also to possible point pollution from soil and water contamination in the immediate vicinity of feedlots. The study purpose is fulfilled through estimation of rates of nitrogen and phosphorus from livestock manure applied on the farmland associated with 78 feedlots in the state. Separate attention is given to manure spread on cropland versus that which is dropped by grazing cattle directly on pasture land.

CONCENTRATION IN THE FED CATTLE INDUSTRY

"Concentration" is a term commonly used to characterize development of the U.S. livestock industry during the 20th Century. The term has at least three different dimensions which, for beef cattle, are as follows:

* **Meat-packer concentration**, in which only a small number of meat packers is purchasing an increasingly large proportion of the cattle slaughtered in the U.S., e.g., in only 8 years between 1980 and 1988, the share of total cattle slaughtered by the U.S.'s four largest packers nearly doubled from 36% to 70% (Ward, 1990, p 15);

* **Regional fed cattle concentration**, in which the geographic focus of cattle feeding has shifted rather dramatically over the past two decades--from the Midwest and Southwest to the Central and Southern Plains (Albin and Thompson, 1990, pp 12-13; Krause, 1991, pp 4-8);[2] and

* **Localized fed cattle concentration**, in which the proportion of cattle fed in very large feedlots has increased dramatically (Barkema and Drabenstott, 1990, p 49; Krause, 1991, pp 13-25).

To many observers of the U.S. beef cattle industry, "concentration" has negative connotations. Some research shows that meat-packers use oligopsony power as a means to lower the price they pay for cattle (Connor, 1989; Menkhaus et al., 1981; Quail et al., 1986), but other research does not (Ward, 1982). Some people are concerned about possible adverse implications of dense fed cattle populations to animal health and welfare (CAST, 1981; Clancy, 1986; Jacobson, 1992; Mickley and Fox, 1987), whereas others see the added care animals receive in confinement to be more important than possible shortcomings from animals living in close proximity to one another (Curtis, 1987). Concerns about implications of the shifting and intensified concentration of cattle feeding to (1) reduced economic development potential in regions which have suffered cattle feeding losses (Caneff, 1993, p 1; Loy et al., 1986) and (2) the increased potential for soil and water pollution from concentrated manure disposal in areas of major cattle feeding, however, are generally rather widespread (Baker et al., 1990, p 39; Batie, 1993, p 403; Benbrook, 1991, p 49; Logan, 1990, p 604; Mathers and Stewart, 1984, p 1025; Pesek, 1989; p 144; Sweeten, 1990, p 63).

This report is focused on only the last issue, namely, on whether non-point soil and water pollution seems to be arising from the disposal of livestock manure on the farmland associated with feedlots in South Dakota.

In this section, the nature, rationale, and limitations of increasingly concentrated cattle feeding in the U.S.'s major cattle feeding states, including South Dakota, are discussed. In succeeding sections, (1) the possibilities for the substitution of livestock manure for synthetic chemical fertilizers are explored conceptually and (2) the estimated intensities of nitrogen and phosphorus application from livestock manure to the farmland operated by selected feedlot operators in South Dakota are reported.

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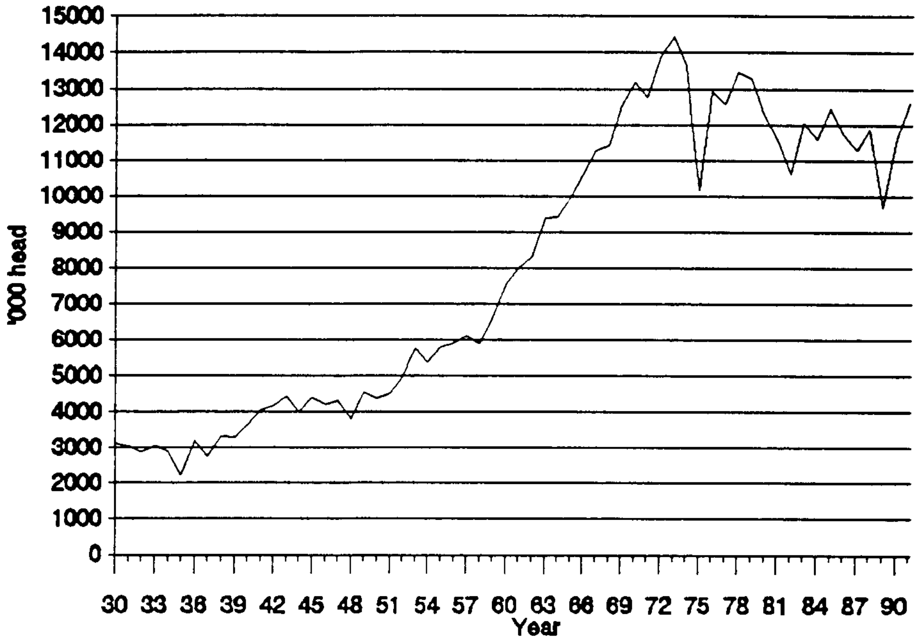
[2]Within the Plains, fed cattle growth over time has been much greater in the Central Plains (Nebraska and Kansas) than in the Southern Plains.

Nature of concentration

The nature of fed cattle concentration in the U.S. is explored at four successively decentralized levels: national, regional, cropland in major cattle producing states, and individual feedlots.

National concentration. Since the early 1930s, the number of "cattle and calves on feed" in the U.S. has increased a great deal (Figure 1).[3] Early inventory levels were in the area of 3.0 million head. Numbers gradually increased to about 5.0 million in the early 1950s. From 1953 to 1973, the rate of increase picked up, with the number of cattle and calves on feed increasing from 5.5 million to 14.4 million. During the past 20 years the numbers of cattle and calves on feed have dropped some, stabilizing in the general area of 11.5-12.0 million.[4] Since the amount of land in the U.S. has remained essentially the same, the population density of fed cattle per unit of land nationally has increased roughly four times since the early 1930s.

Figure 1. Cattle and calves on feed, U.S., January 1st, 1930-1991.



Source: Agricultural statistics, 1950. U.S. Dept of Agric. Washington, D.C.: U.S. Government Printing Office, p 360 (also the following annual volumes: 1961, p 314; 1965, p 312; 1980, p 306; 1992, p 252; 1993, p 293 (in press).

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[3]The "cattle and calves on feed" reported in this publication are "animals for slaughter market being fed a full ration of grain or other concentrates and are expected to produce a carcass that will grade Select or better" (USDA, 1993a, p 252).

[4]Because of heavier dressing and carcass weights, however, the pounds of beef produced have more or less plateaued in recent years.

Regional concentration. In 1988, 13 states accounted for 85% of the cattle and calves on feed nationally (USDA, 1989, p 47). Data on the number of fed cattle marketed in these major cattle feeding states during 1973-75 and 1991-93 are shown in Table 1 and Figure 2.[5] The data reflect a strong concentration of cattle feeding in the Central and Southern Plains, a concentration that has become accentuated during the past two decades.

For example, in 1973-75, Kansas, Nebraska, and Texas accounted for 39% of the total fed cattle marketed nationally.[6] The two other major cattle feeding states from the Central and Southern Plains, Colorado and Oklahoma, accounted for an additional 10% of total fed cattle marketed. Thus, in 1973-75, the Central and Southern Plains accounted for 49% of total national fed cattle production.

Table 1. Changes in the number of fed cattle marketed, 13 states covered by Livestock Marketing Information Center project, 1973-75 to 1991-93.

State	Average number of fed cattle marketed ('000 head)[a] 1973-1975	1991-1993	Change from 1973-75 to 1991-93 No. of head ('000)[a]	Percent
States gaining in cattle numbers				
Kansas	2,335	4,228	+ 1,893	+ 81
Nebraska	3,252	4,837	+ 1,585	+ 49
Texas	3,793	5,055	+ 1,262	+ 33
Oklahoma	548	832	+ 284	+ 52
Colorado	1,962	2,240	+ 278	+ 14
Idaho	356	632	+ 276	+ 78
Washington	328	441	+ 113	+ 34
Sub-total	12,574	18,265	+ 5,691	+ 45
States losing in cattle numbers				
South Dakota	568	497	- 71	- 13
Minnesota	834	483	- 351	- 42
Illinois	867	475	- 392	- 45
Arizona	846	337	- 509	- 60
California	1,865	652	- 1,213	- 65
Iowa	3,044	1,543	- 1,501	- 49
Sub-total	8,024	3,987	- 4,037	- 50
13-state total	20,598	22,252	+ 1,654	+ 8

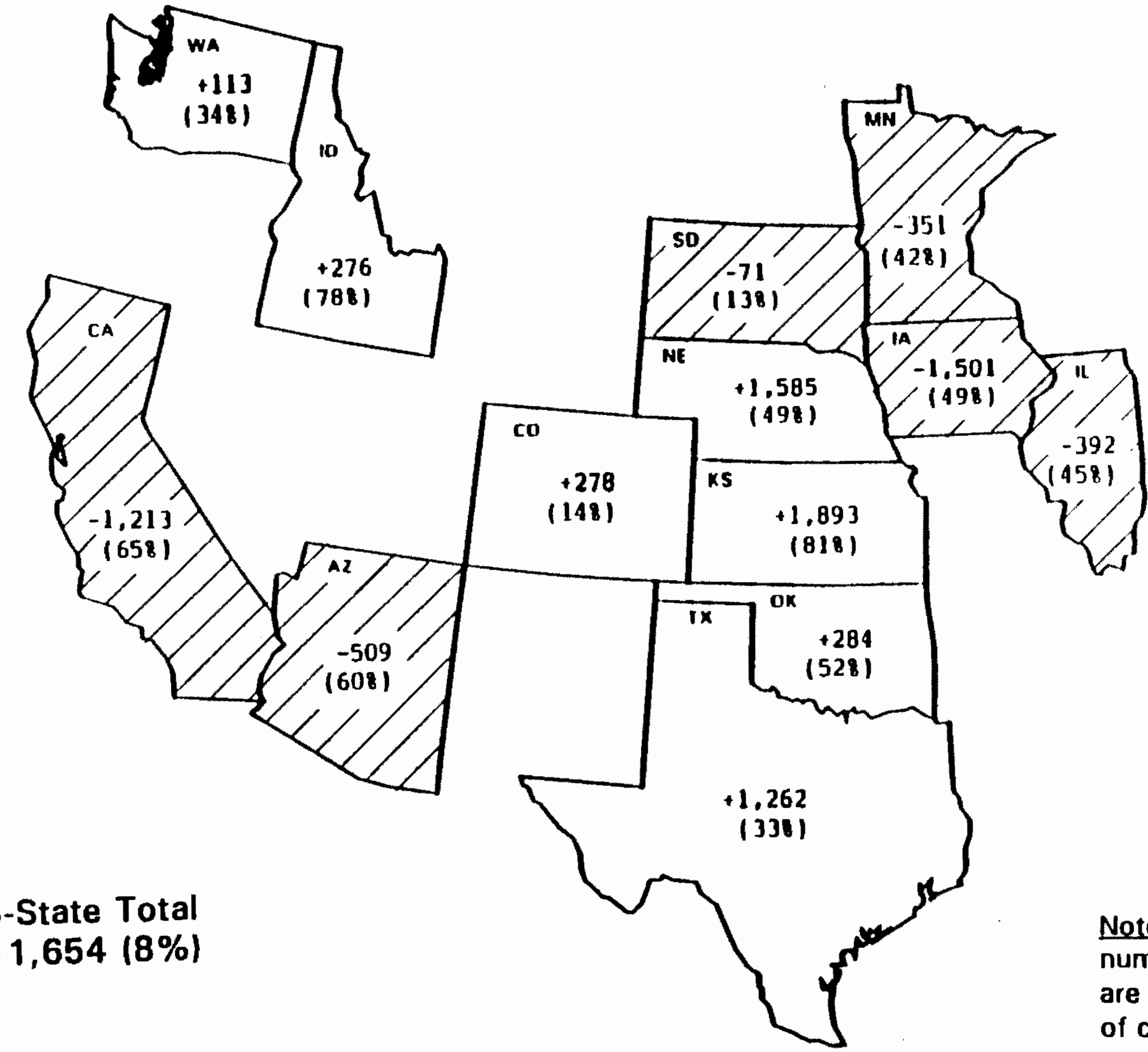
[a] Source of data used in calculations: LMIC, 1994, pp 1-7.

[5]The source of these data is the Livestock Marketing Information Center (LMIC), formerly known as the Western Livestock Marketing Information Project (WLMIP). LMIC/WLMIP has maintained annual data on the number of fed cattle marketed in the U.S.'s 13 major cattle feeding states since 1973.

Because of rather substantial year-to-year variations in the numbers of fed cattle marketed, 3-year averages rather than single-year values were used to mark the two end-points of the times series.

[6]The 39% is the percentage of the 13-state total fed cattle marketed represented by cattle in Kansas, Nebraska, and Texas, adjusted for the fact that the 13 states represent only an estimated 85% of the total cattle on feed nationally. It was computed as follows: [(2,335 + 3,252 + 3,793)/20,598] * 100 * 0.85. The same general procedure was used for calculating the other percentages reported in this and the following paragraph.

Figure 2. Changes in the Average Number of Cattle Marketed, 13 states covered by Livestock Marketing Information Center project, 1973-75 to 1991-93.



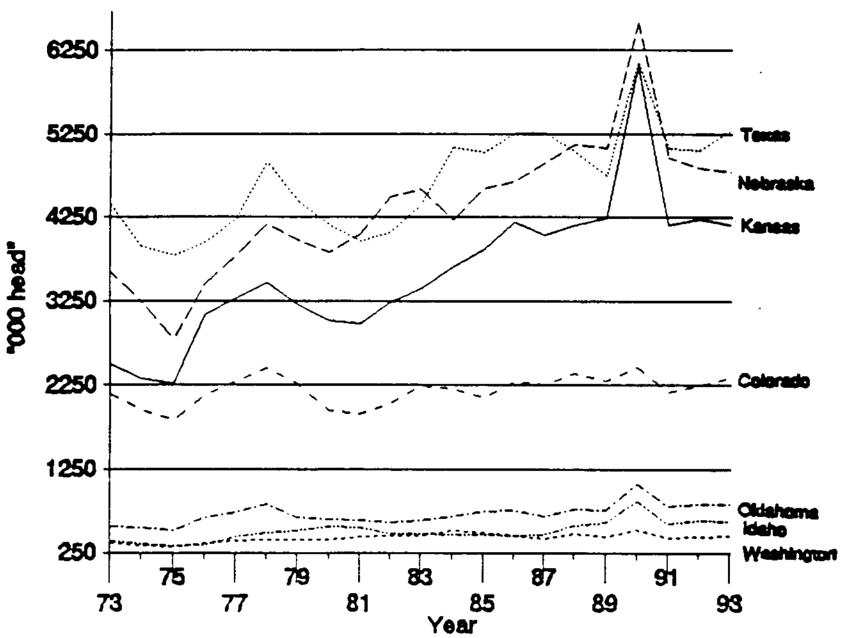
13-State Total
+1,654 (8%)

Source of Data Used in Calculations: LMIC, 1994, pp 1-7.

Note: Data on changed cattle numbers for the various states are shown in thousands of head of cattle. The change for each state is also expressed as a percentage of the number of cattle marketed in 1973-75.

Between 1973-75 and 1991-93, the number of fed cattle marketed in Kansas, Nebraska, and Texas increased by 4.74 million head (Table 1 and Figure 3). The total 18-year increase for the five states comprising the Central and Southern Plains was 5.30 million head. These 5.30 million head represent the vast majority (namely, 93%) of the number of increased cattle fed in the nation's major cattle feeding states. Further, between 1973-75 and 1991-93, the share of total national fed cattle production represented by the "big-three" cattle feeding states rose from 39% to 54%. The share for the five-state Central and Southern Plains area rose from 49% to 66%.

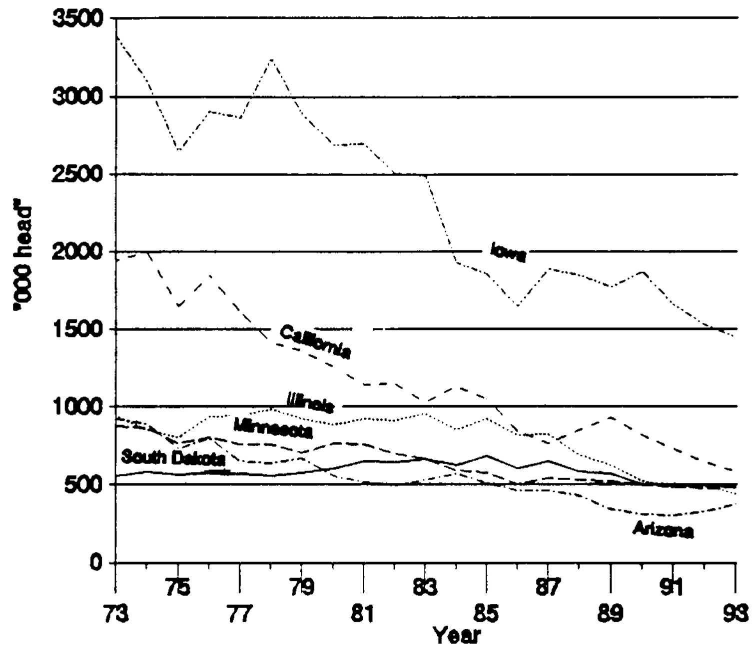
Figure 3. States covered by LMIC project with increases in the number of fed cattle marketed, 1973-1993.



Source: Livestock Marketing Information Center, 1994, pp 1-7.

Since the early- to mid-1970s, an additional 5.69 million head of fed cattle are being marketed from the seven major cattle feeding states that have experienced gains in fed cattle numbers. Of this total, 1.65 million head (29%) represent a net increase in the aggregate number of fed cattle marketed from the 13 major cattle feeding states. The other additional 4.04 million head (71%) fed in the seven states experiencing increased fed cattle marketings was at the expense of cattle fed in the six other states. In those states, the number of fed cattle marketed decreased by 50% in just 18 years. Over 67% of the reduction in cattle numbers was limited to two states: Iowa with 1.50 million fewer head and California with 1.21 million fewer head. The years of greatest reduction in cattle numbers in Iowa were 1978 to 1986, whereas in California reductions have been rather steady since the early- to mid-1970s (Figure 4). Regionally, 57% of the reduction in cattle numbers was in the Midwest (Iowa, Illinois, Minnesota, and South Dakota) and 43% was in the Southwest (California and Arizona) (Table 1).

Figure 4. States covered by LMIC project with decreases in the number of fed cattle marketed, 1973-1993.



Source: Livestock Marketing Information Center, 1994, pp 1-7.

Of the nation's 13 major cattle feeding states, South Dakota has been most stable over time in its fed cattle marketings. Even then, the state has registered a 13% decrease from 568 thousand head in 1973-75 to 497 thousand head in 1991-93.

Farmland concentration. Since cattle in the U.S. are finished primarily in confinement, most fed cattle manure is collected and spread on farmland. Thus, the existence of potential non-point pollution from fed cattle manure disposal can be expected to bear some relation to the amount of livestock production relative to acres of cropland.

Data on the total cropland area and three measures of livestock production (cattle and calves on feed, red meat production, and commercial cattle slaughtered) for each of the nation's 13 major cattle producing states are shown in Table 2. The average number of cattle and calves on feed per thousand acres of cropland ranges from 241 in Arizona to 14 in Minnesota. Average fed cattle population densities for the "big-four" cattle feeding states in the Central and Southern Plains (Texas, Nebraska, Kansas, and Colorado) range from 86 to 46. In the midwestern states, the range is from 24 to 14. South Dakota is at the lower end of the range, with an average of 15 cattle and calves on feed per thousand acres of cropland.

Patterns of difference among the major cattle feeding states in the average weight of red meat production per acre of cropland generally are similar to those for cattle and calves on feed per acre of cropland, with (1) Arizona and the "big four" cattle feeding states in the Central and

Table 2. Concentration of livestock relative to cropland area, 13 states covered by Livestock Marketing Information Center project.

State	1987 Total Cropland ('000 acres)[a]	Cattle and calves on feed: Jan 1, 1988 ('000 head)[b]	Cattle and calves on feed: Head per 1,000 acres	Red meat production: 1993 (million lb)[c]	Red meat production: 1,000 lb red meat per acre	Commercial cattle slaughter: 1993 (million lb)[d]	Commercial cattle slaughter: 1,000 lb slaughtered per acre
Texas	35,611	2,250	63.2	4,149	117	6,591	185
Nebraska	23,320	2,000	85.8	5,715	245	7,811	335
Kansas	31,385	1,440	45.9	4,548	145	7,191	229
Colorado	10,989	940	85.5	1,899	173	2,915	265
Iowa	27,291	650	23.8	6,643	243	1,953	72
California	10,895	435	39.9	911	84	1,050	96
Illinois	25,102	380	15.1	2,256	89	n/a	n/a
Arizona	1,454	351	241.4	249	171	416	286
Oklahoma	14,443	320	22.2	56	4	42	3
Minnesota	21,876	310	14.2	2,239	102	1,319	60
South Dakota	19,642	300	15.3	1,156	59	292	15
Washington	8,168	198	24.2	604	74	980	120
Idaho	6,742	195	28.9	457	68	n/a	n/a
13-state sub-total	236,918	9,769	41.2	30,882	130	30,560	149[e]
United States	443,318	11,527	26.0	40,568	92	38,686	87

a/ Source: USDC, 1989b, pp 144-150.

b/ Source: USDA, 1989, p 47.

c/ Source: USDA, 1994, p 9. "Red meat" is the carcass weight of beef, veal, pork, lamb and mutton after slaughter; farm slaughtered livestock are excluded.

d/ Source: USDA, 1994, p 35.

e/ The 13-state ratio of 149 = 30,560,000 ÷ [236,918 - (25,102 + 6,742)]

Southern Plains generally being toward one end of the continuum and (2) South Dakota toward the other end of the continuum. However, in the case of red meat, the concentration of livestock in Iowa is greater than that in all other states except Nebraska, presumably because of very substantial hog production in Iowa.

Patterns of difference among the major cattle feeding states in the average weight of commercial cattle slaughter per acre of cropland generally are consistent with those just discussed. South Dakota ranks second, only to Oklahoma, at the low end of the cattle-to-cropland concentration continuum. The next ranking state has four times more slaughter cattle per thousand acres of cropland than South Dakota.

Individual feedlot concentration. To the extent that cattle are collected together in large feeding units, the potential for pollution of soil and water resources increases. The potential is greater because the manure and urine generated by a certain large number of cattle in one feedlot is concentrated in a smaller geographic area than if that same number of cattle were in several feedlots dispersed over a wider area.[7]

In 1993, an average of 504 fed cattle per feedlot were marketed in the U.S.'s 13 major cattle feeding states (Table 3). Average feedlot sizes vary tremendously among states, ranging from around 34,350 in Arizona and 15,000 in Washington and California to less than 100 in the three midwestern-heartland states of Iowa, Illinois, and Minnesota. The average size of feedlots

[7]Since the level of animal waste management practices in larger feedlots may be superior to that in smaller feedlots, there may be exceptions to the general tendency noted in the text. The fact that the South Dakota Department of Energy and Natural Resources requires only those livestock feeding operations with more than 1,000 animal units to obtain approval of proposed livestock waste management systems (Johnson and Ullery, 1993, p 9) may be significant in this regard.

in the five Central and Southern Plains cattle feeding states ranges from around 8,265 in Texas to 800 in Nebraska. South Dakota definitely is at the small end of the average size-of-feedlot continuum, with an average of 121 fed cattle marketed per feedlot in 1993.

Table 3. **Number of fed cattle marketed per feedlot, 13 states covered by Livestock Marketing Information Center project, 1973 and 1993.**[a]

	Average number of fed cattle marketed per feedlot		Change from 1973 to 1993	
	1973	1993	No. of head	1993 as a multiple of 1973
Arizona	19,146	34,364	+ 15,218	1.79
Washington	1,973	15,100	+ 13,127	7.65
California	10,729	15,000	+ 4,271	1.40
Texas	2,878	8,266	+ 5,388	2.87
Colorado	3,521	7,932	+ 4,411	2.25
Idaho	695	4,464	+ 3,769	6.42
Oklahoma	1,000	3,884	+ 2,884	3.88
Kansas	385	1,733	+ 1,348	4.50
Nebraska	210	798	+ 588	3.80
South Dakota	61	121	+ 60	1.98
Iowa	100	94	- 6	0.94
Illinois	63	62	- 1	0.98
Minnesota	74	61	- 13	0.82
13-state sub-total	232	504	+ 272	2.17

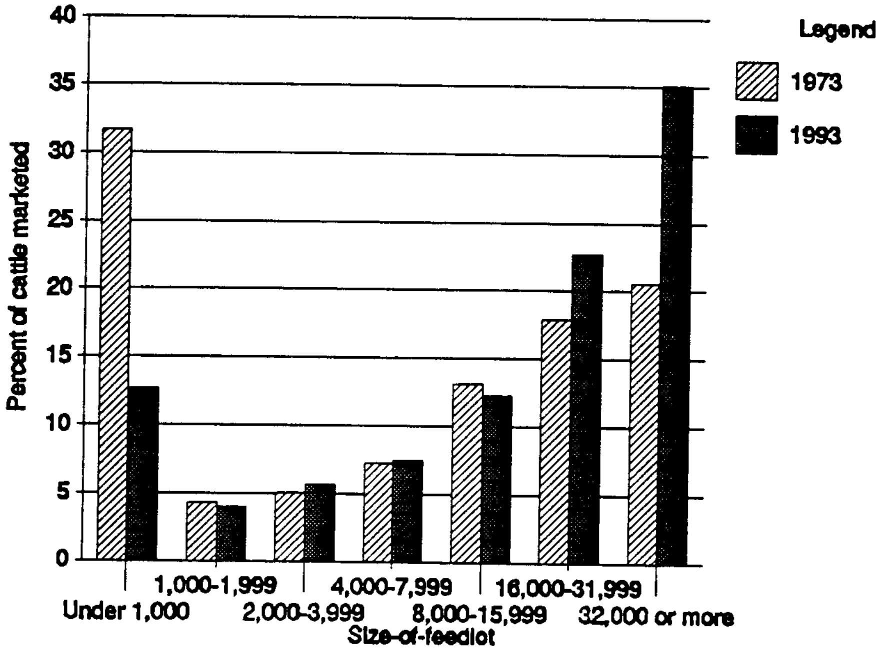
[a] Source: LMIC, 1994, pp 1-7.

In 1973, the average number of fed cattle marketed per feedlot in the U.S.'s 13 major cattle feeding states (232 head) was less than one-half what it was in 1993. Changes in average feedlot size over the past 21 years have been very uneven among states. At one extreme, average feedlot sizes in Washington and Arizona have increased by roughly 13-15,000 head each; these increases are 7.7-fold in Washington and 1.8-fold in Arizona. In South Dakota, the average feedlot size has doubled from 61 in 1973 to 121 in 1993. This structural change reflects the closure of many of the state's small feedlots. In the three midwestern states, on the other hand, average feedlot sizes actually have decreased--by 2-18% over the past 21 years.

The percentages of fed cattle marketed by various size-of-feedlot categories for the 13 major cattle feeding states collectively in 1973 and 1993 are shown in Figure 5. In 1993, feedlots with a capacity for 32,000 or more head accounted for 35% of total fed cattle marketed in the 13 states.[8] Those with a 16,000-31,999 head capacity accounted for 23% of total marketings. The smallest size-of-feedlot category, feedlots with a capacity of under 1,000 head, accounted for 13% of marketings.

[8] Krause (1991, p 24) reports that feedlots with capacities of 1,000 head or more represented only 3.5% of the feedlots in the U.S.'s 13 major cattle feeding states in 1989, but they fed 84% of the cattle produced in those states that year. Albin and Thompson (1990, p 12) report that 9 of the top 10 "feeding concerns" in the U.S. in 1989 were in the Central and Southern Plains states of Texas, Oklahoma, Kansas, Colorado, and Nebraska. These 9 feeding concerns ranged from having seven feedyards with a one-time capacity of 330,000 head to three feedyards with a 130,000 head capacity.

Figure 5. Size-of-feedlot distributions in the number of fed cattle marketed, 13 states covered by LMIC project, 1973 and 1993.



Source: Livestock Marketing Information Center, 1994, p 7.

In 1973, the relative importance of these three size-of-feedlot categories was greatly different. The under 1,000 head category accounted for 32% of total marketings, or 19 percentage points more than in 1993. Counterbalanced against this was a relatively lesser importance in 1973 of the two largest size-of-feedlot categories. On the other hand, the percentages of fed cattle marketed from each of the four intervening size-of-feedlot categories--i.e., of feedlots with capacities between 1,000 and 16,000 head of cattle--changed little between 1973 and 1993.

The increased feedlot concentration in the nation's 13 major cattle feeding states also can be visualized in terms of absolute shifts in the numbers of cattle between the smallest and two largest size-of-feedlot categories. Between 1973 and 1993, the size-of-feedlot shift of cattle feeding was almost exclusively from feedlots with an "under 1,000 head capacity" to feedlots with 16,000 or more head in capacity. The absolute changes (not shown in the figure) were as follows:

* 4.3 million fewer head of cattle fed in feedlots with under a 1,000 head capacity;

* 1.0 million more head of cattle in feedlots with a 16,000-31,999 head capacity; and

* 3.2 million more head of cattle in feedlots with a 32,000 or more head capacity.

Accompanying differences in average feedlot sizes among states, of course, are differences in the percentages of fed cattle marketed from feedlots of different sizes. The size-of-feedlot category with 4,000 or more head accounts for 90% or more of total fed cattle marketings in 7 of the 13 major cattle feeding states: Texas, Arizona, Oklahoma, California, Washington, Kansas, and Idaho (Table 4). At the other extreme are the three midwestern states--Iowa, Illinois, and Minnesota--in which the under 1,000 head size-of-feedlot category accounts for over 70% of fed cattle marketed and feedlots with 2,000 or more head account for only 7-15% of marketings.[9]

Table 4. Size-of-feedlot distribution in the number of fed cattle marketed, 13 states covered by Livestock Marketing Information Center project, 1993.[a]

State	Percent of cattle, by size-of-feedlot (head): Less than 1,000	1,000 - 1,999	2,000 - 3,999	4,000 or more
Texas	0.6	0.4	1.3	97.7
Arizona	....	2.6[b]	....	97.4
Oklahoma	1.3	1.4	0.6	96.7
California	..... 0.9	.....	2.9	96.2
Washington	..... 1.8	.....	2.2	96.0
Kansas	2.4	1.7	3.2	92.7
Idaho	2.4	3.2	4.0	90.4
Colorado	1.7	3.0	6.8	88.5
Nebraska	16.5	5.8	11.1	66.6
South Dakota	24.8	14.6	23.5	37.1
Iowa	70.9	14.2	..... 14.9	.....
Illinois	74.1	13.3	..... 12.6	.....
Minnesota	76.9	15.9	..... 7.2	.....
13-state sub-total	12.7	4.0	5.7	77.6

[a] Source: LMIC, 1994, pp 1-7. Percentages shown between size-of-feedlot columns apply to the size-of-feedlot categories spanned by the respective sets of dots (...).

[b] The 2.6% covers all feedlots with a capacity up to 16,000 head.

South Dakota's size-of-feedlot distribution is more like that in the Midwest than in the other states--especially in regard to its having very few large feedlots. Nevertheless, in South Dakota--compared to Iowa, Illinois, and Minnesota--substantially fewer cattle come from feedlots with under 1,000 head (only 25% versus over 70% of total fed cattle marketed in the other three states) and substantially more come from feedlots with 2,000 or more head (61% versus 7-15% in the other three states).[10]

Changes between 1973 and 1993 in South Dakota's size-of-feedlot distribution are portrayed in Figure 6. The relative importance of the under 1,000 head category has decreased greatly, accounting for 67% of fed cattle marketings in 1973 and only 25% of marketings in 1993. The relative importance of each of the other four size-of-feedlot categories has increased over the past 21 years, with the percentage point differences between 1973 and 1993 being

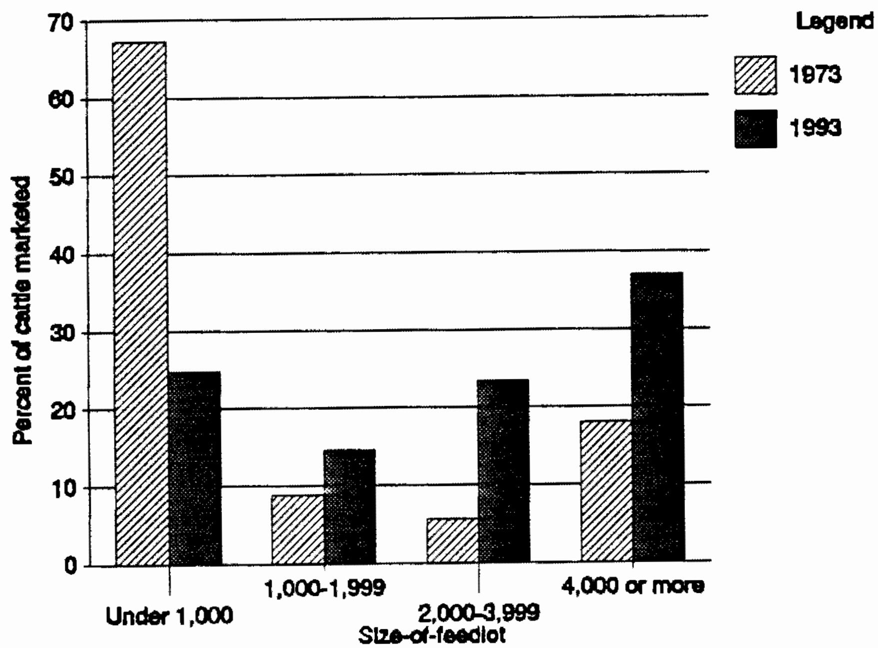
[9]Restrictions on corporate farming in Iowa, Minnesota, and South Dakota have been one factor limiting the development of large feedlots in these states (Krause, 1991, pp 43-44).

[10]The numbers of feedlots in the various size-of-feedlot categories for South Dakota are as follows: 3,900 feedlots with under 1,000 head; 52 with 1,000-1,999 head; 33 with 2,000-3,900 head; and 15 with 4,000 or more head (So Dak Agric Stat Serv, 1994, p 55).

greatest (18-19 percentage points) for the 2,000-3,999 and 4,000 or more head categories. In absolute numbers, 256 thousand less fed cattle were marketed from feedlots with under 1,000 head capacity in 1993 compared to 1973. Partially counterbalancing increases for the other size-of-feedlot categories are as follows (not shown in the figure):

* 1,000-1,999 head capacity, 21 thousand;
* 2,000-3,999 head capacity, 82 thousand; and
* 4,000 or more head capacity, 79 thousand.

Figure 6. Size-of-feedlot distributions in the number of fed cattle marketed, South Dakota, 1973 and 1993.

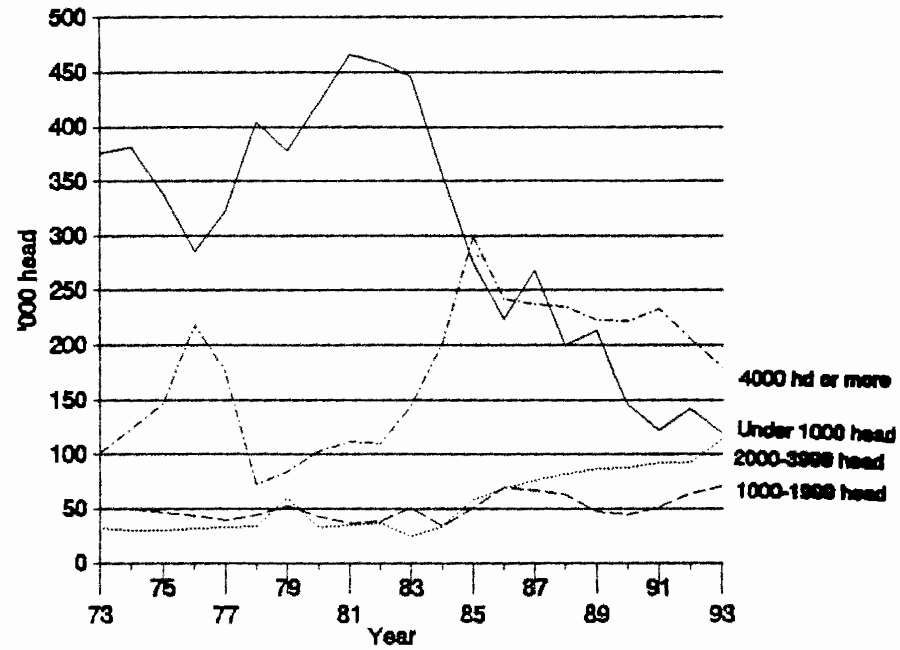


Source: Livestock Marketing Information Center, 1994, p 6.

Year-by-year changes since 1973 in fed cattle marketed in South Dakota for each of the four size-of-feedlot categories are shown individually in Figure 7 and collectively in Figure 8. Fed cattle numbers in South Dakota peaked at 685 thousand in 1985 and have decreased rather steadily since then to 485 thousand in 1993 (an annual average reduction of 25 thousand head). The number of fed cattle marketed from feedlots with under a 1,000 head capacity peaked in 1981 at 466 thousand; it has since dropped steadily at an annual average rate of nearly 29 thousand head.

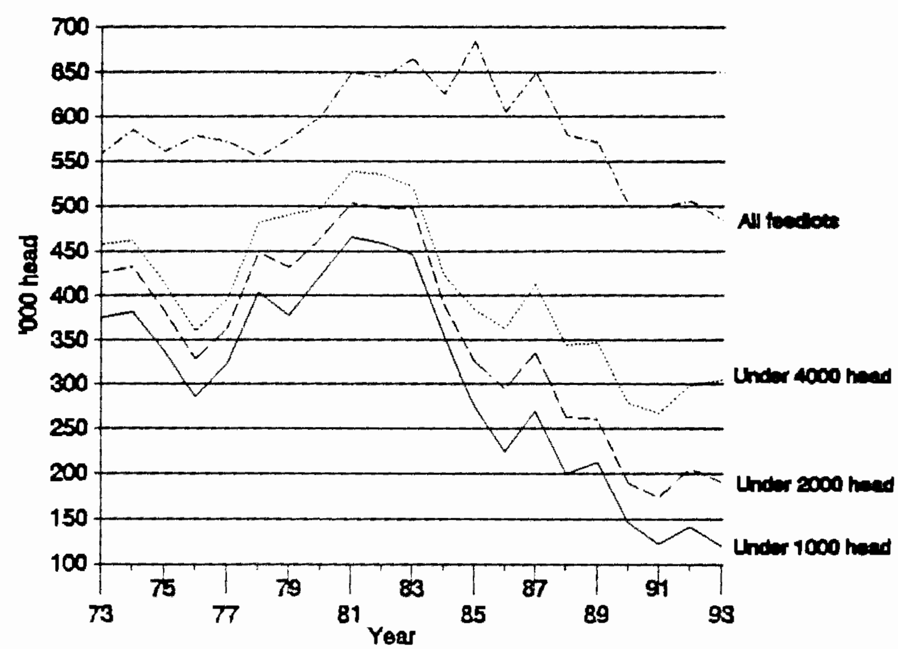
The number of fed cattle marketed from feedlots in South Dakota with 4,000 or more head has fluctuated widely, ranging from 73 thousand in 1978 to 300 thousand in 1985. The number of cattle marketed from this large category has trended down since 1985, with the number dropping below 200 thousand in 1993 for the first time in the last 10 years. This drop reflects a combination of fewer feedlots with more than a 4,000 head capacity [e.g., 15 in 1993 versus 21 in 1992, 18 in 1991, and 16 in 1990 (So Dak Agric Stat Serv, 1994, p 55)] and fewer cattle being marketed per large feedlot. Some growth in fed cattle marketings has been registered with the two intermediate size feedlot categories during the past two decades, with the growth most steady and greatest since 1983 for the 2,000-3,999 feedlot category.

Figure 7. Fed cattle marketed, by size-of-feedlot category, South Dakota, 1973-1993.



Source: Livestock Marketing Information Center, 1994, p 6.

Figure 8. Cumulative number of fed cattle marketed, by size-of-feedlot category, South Dakota, 1973-1993.

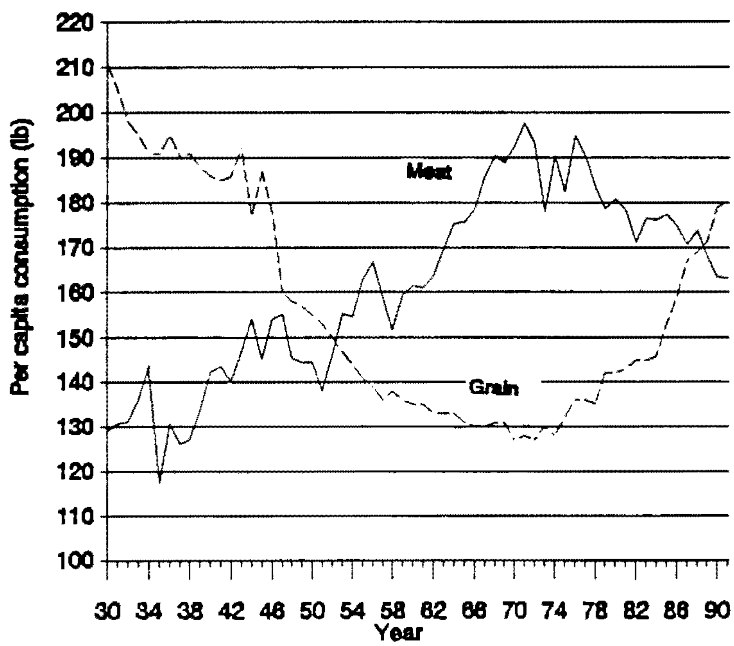


Source: Livestock Marketing Information Center, 1994, p 6.

Rationale for concentration

The central factors underlying the increased number of cattle fed since the 1930s in the U.S. (**national concentration**) have been increases in the aggregate demand for meat and meat-related products by Americans and technological developments conducive to expanded beef cattle production. The increased aggregate demand has arisen because of population increases in the country and consumers substituting meat for grains in their diets, especially through the 1970s. The increase in per capita consumption of red meat between the 1930s and mid-1970s is rather striking; some decreases have since occurred (Figure 9). However, the decrease has been more than counterbalanced by increases in per capita poultry consumption. For example, per capita poultry consumption (carcass weight) has doubled from 48 lb in 1975 to 96 lb in 1992. As a result, total per capita red meat and poultry consumption (carcass weight) increased from 229 lb in 1975 to 262 lb in 1992 (Duewer et al., 1993, p 3).

Figure 9. Per capita red meat and grain consumption, U.S., 1930-1991.



Source: Agricultural statistics, 1957. U.S. Dept of Agric. Washington, D.C.: U.S. Government Printing Office, pp 60-61 and 434-435 (also the following annual volumes: 1950, p 68; 1961, p 52; 1965, pp 53 and 362; 1980, pp 49 and 352; 1992, pp 49 and 293).

*Data for the following meats and grains are covered in this figure:
(1) meat -- beef, veal, lamb and mutton, and pork (excluding lard) and
(2) grains -- wheat flour, rice (milled), corn flour and meal, and oat food products.

The increased per capita consumption of red meat and poultry and decreased per capita consumption of grains have been associated with (1) the substantial increases in per capita disposable incomes earned by Americans and (2) the fact that--in the ranges of income experienced by most Americans during the 1930s to 1970s--meats and poultry were "superior" consumer goods with positive income elasticities of demand, whereas most grains were "inferior" with negative income elasticities of demand. Since the 1970s, however, grains have again become "superior"--presumably because of their being perceived to be more conducive to good health than red meat.[11]

The shift of **regional concentration** of fed cattle from the Midwest and Southwest to the Central and Southern Plains has been prompted by a number of interrelated "push" and "pull" factors.[12] Interrelated "push" factors underlying the shift of cattle from the Midwest include (1) higher feedgrain prices in the 1970s, precipitated by rather major world food shortages, and government price supports for grain which provided economic incentives to reinforce the natural comparative advantage of the Midwest in cash grain production; (2) active development and use of (a) new crop production and handling technologies and (b) larger tractors and farm machinery that enabled reductions in per unit crop production costs; and (3) a rather major reduction in the number of family farms on which small feedlots had been rather commonly maintained in the Midwest. Thus, many traditional Midwestern crop-livestock farmers dropped their cattle operations in the 1970s and early 1980s to concentrate exclusively on relatively more profitable crop production. The cropping systems most commonly emerging were (1) monoculture corn and (2) corn-soybean rotations (Grigg, 1974, p 178; Power and Follett, 1987).

"Push" factors underlying the shift of cattle from the Southwest were quite different from those in the Midwest. Most fundamental, perhaps, was the rapid increase of the human population in California and Arizona. Accompanying the increased population density was (1) a bidding up of land and water prices that made local production of feeder calves and feed supplies less economically viable and (2) increased concern over the soil, water, and air pollution potential from large-scale feedlots. In the face of rising costs to transport feeder calves and feed supplies over increased distances and meet increasingly stringent environmental regulations, many feeders in the Southwest dropped out of business.

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[11]The sources of growth in domestic per capita grain consumption from 1974 to 1991 have been as follows: wheat from 110 lb to 136 lb; oats from 3 lb to 13 lb; rice from 8 lb to 17 lb; and corn from 8 lb to 14 lb.

[12]The ideas and facts presented in this section are drawn mainly from Krause (1991), and also from Dietrich et al. (1985); Johnson et al. (1989); and Madsen and Gee (1986). However, none of these authors used a "push-pull" terminology to describe the rationale for regional shifts in fed cattle production.

"Pull" factors which brought additional cattle to the Central and Southern Plains include the following:

* Dryer climate, with less need for (1) investment in feedlot paving to keep cattle out of the mud and (2) immediate and continuing attention to manure disposal;

* Warmer climate, especially in the south, which is conducive to (1) more efficient feed-to-meat conversion (Pritchard and Preston, 1992) and (2) year-round feeding, with less need for expensive shelter to protect cattle from harsh winters;

* Development and use of new irrigation technology and new hybrid sorghum and milo varieties especially well-suited to the Central and Southern Plains;

* Greater financing opportunities and lesser environmental concerns in the Plains than in either the Midwest or Southwest;[13] and

* Rail and truck rate deregulation, development and use of larger rail cars and unit-trains, and the raising of highway weight limits for road trailers during the 1970s--which reduced transportation costs for hauling cattle feed supplies to feedlots in the Plains.

The increased population of fed cattle per acre of farmland **(farmland concentration)** has been associated with greatly increased numbers of cattle being fed far from the farmland on which their feed is raised. This separation of cattle from farmland has been caused by both technological and institutional factors.

A capacity to effectively manufacture fertilizer from atmospheric nitrogen began to develop in the U.S. in the period prior to World War II. During the war, numerous plants were constructed to manufacture nitrogen for use in munitions. At the war's end, these manufacturing plants became available for manufacture of synthetic nitrogen fertilizers at relatively low prices. Cost-efficiencies also were realized in producing phosphorus fertilizers from rock phosphates.

These circumstances--combined with major efforts to develop and use high yielding, fertilizer-responsive varieties--led to a major increase in synthetic fertilizer use in (and the productivity of) U.S. agriculture during the period of the 1940s to 1980s. In this "new" technological and institutional environment, crops could be raised profitably with little or no reliance on animal manure.[14] Further, government commodity programs and subsidies tended

[13]In general, the Plains states have fewer lakes and deeper aquifers than many of the states in the Midwest and Southwest. This physical difference may explain, at least in part, why environmental concerns from agriculture tend to be less in the Plains states.

[14]Hallberg (1987, p 6) reports that the two primary sources of nitrogen (N) in Iowa's Big Spring Basin are manure and fertilizer. Since 1958, N from manure sources increased 0.3 times, while N from fertilizer increased 2.5-3.0 times. Increased total corn acreages and fertilization application rates underlie the shift from fertilizer being only a minor source to being the single largest source of N.

to reduce commodity farm price and income risks, thereby allowing cattle feeding to be separated from feed grain production without producers incurring the otherwise normal added risks of enterprise specialization (after Batie, 1993; Caneff, 1993, p 16; Logan, 1990, p 588; Koepf, 1985, p 41; Papendick et al., 1987, p 19; Parr and Hornick, 1992, p 185; OTA, 1990, pp 32-34; Pesek, 1989).

The primary driving force behind greater **individual feedlot concentration** is economies-of-size in cattle feeding and marketing. Such economies arise primarily from the spreading of fixed feedlot investments (e.g., feeding equipment, feedmills, pens and other livestock handling facilities, pollution control facilities)[15] and production and marketing management across the larger number of cattle in larger feedlots.

Compared to family farm feedlot operations, managers of large feedlots can specialize in the daily management and supervision of cattle--thereby helping to insure immediate identification of cattle that are sick or otherwise require special attention. They also can more realistically gain and exercise competence in determining the most economic options for buying feeder cattle and feed supplies, securing debt financing, and selling finished cattle. With large-scale feedlots, quantity discounts in purchasing inputs often can be realized. Physical input, credit, and selling transaction costs can be spread over larger numbers of cattle. Further, supplies of cattle in "large" feedlots may be adequate for managers to access potential advantages of the futures market and contractual arrangements with meat processors.

Two additional factors favoring large-scale cattle feeding were (1) development of biological products (e.g., feed additives, growth stimulants, pest control, new and improved animal medicines) that began to be available in the 1950s to help counteract potential health problems otherwise inherent in feeding large numbers of cattle confined in small spaces and (2) federal tax regulations that, until 1986, provided significant tax cost-savings (e.g., investment credits, current expensing) favoring investments in large feedlots and large batches of cattle (after Dietrich et al., 1985; Krause, 1991; Madsen and Gee, 1986).

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[15]Reimund et al. (1981) concluded that federal and state animal waste run-off abatement programs were increasing the comparative advantage of large feedlots over small ones.

Limitations of concentration

While the prior discussion shows a strong and somewhat persuasive rationale for livestock concentration in the U.S., not all the truth is represented in that discussion. Economies-of-size are not infinite in any production or manufacturing situation. There comes a point at which management no longer can effectively and efficiently supervise and coordinate all the expanded activities and personnel in a continuously growing enterprise. Depending on the level of managerial expertise and the complexity/limitations of technological, managerial, institutional, and economic circumstances involved in a production and marketing enterprise, diseconomies-of-size may enter--in some instances, at only a relatively modest size-of-enterprise and, in others, at a much larger size-of-enterprise. While not all possible economies- and diseconomies-of-size in cattle feeding have been tested in the "real-world," available research shows that the threshold-level for "most economically-efficient" feedlots varies greatly by producer and by state (after Gustafson and Van Arsdall, 1970; Hopkin, 1957; Madsen and Gee, 1986).[16]

Other potential limitations of geographically concentrated livestock production include (1) a possible intensification of health problems with cattle living in very close proximity with each other (CAST, 1981; Clancy, 1986; Jacobson, 1992; Mickley and Fox, 1987); (2) a loss of soil fertility enhancement and insect-disease-weed control, when legume- and grass-based rotations and animal manure applications to farmland traditionally inherent in integrated crop-livestock farms are no longer followed, because of the physical separation of crop production from livestock production (Pesek, 1989, p 55); and (3) a breakdown in natural nutrient recycling that, among other things, can result in intensified problems of soil and water pollution and/or changes in soil quality. Since the first two topics are not of central interest in this report, I discuss only the third.

The basic nutrient cycling system in traditional polyculture crop-livestock systems is portrayed in Figure 10. Crops are fed to livestock; the livestock produce manure which is used to augment the fertility of farmland;[17] and the farmland in turn is used to produce crops. While this figure portrays a completely closed cycle, in practice there probably were some leakages in most situations historically; some farm products were sold off-farm and some elements in

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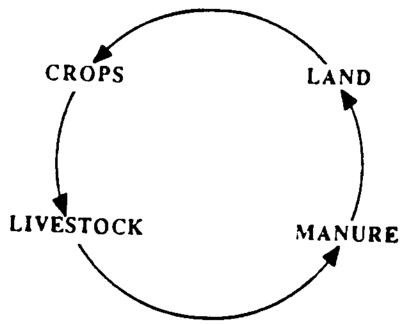
[16]In these studies of economies-of-size in cattle feeding, only private costs were examined. If ecological and rural community externality costs (with uncertainties being assigned a cost rather than simply being disregarded) were also included in analysis, the threshold-level for "most economically-efficient" feedlots would almost assuredly be at a smaller scale than when only private costs are taken into consideration.

[17]Mott (1974, p 327) reports that 75% of the nitrogen and 90% of the minerals in the feed consumed by grazing, lactating cows is returned to the soil. Klausner (1989, p 79) indicates that 70-80% of the nitrogen, 60-85% of the phosphorus, and 80-90% of the potassium fed to different species of animals is excreted in their manure. Ensminger (1987, pp 400-401) indicates that about 75% of the nitrogen, 80% of the phosphorus, and 85% of the potassium contained in animal feeds is returned as manure; in addition, about 40% of the organic matter in feeds is excreted as manure.

manure were lost to the atmosphere and water. Nevertheless, this figure captures the essence of fundamental crop-livestock interactions in traditional, natural farming systems.

Figure 10. Nutrient cycling in well-managed traditional polyculture crop-livestock systems: An overview.



Source: Walter et al., 1987, p 258.

With the development of "modern" agriculture, the basic nutrient cycling system has been interrupted (Figure 11). To obtain higher production, synthetic inorganic chemical fertilizers[18] are imported from outside the system to augment and, in many cases--especially in monoculture cropping systems--to completely replace animal manures. In those many instances in which livestock production has become separated from crop production, manure often is a bulky waste product which cannot be economically transported for application to distant farmland. In the extreme, manure must be treated and disposed. Further, feed supplies often must be transported from specialized crop farms to specialized livestock feeding facilities (after Batie, 1993, p 78; Caneff, 1993, p 16; OTA, 1990, pp 32-34; Power and Follett, 1987; Walter et al., 1987, p 257).

Additional details on nutrient cycling in crop-livestock systems are portrayed in Figure 12. Among other things, the figure shows how (1) livestock manure and crop residues contribute to both the build-up of soil organic matter and the generation of soil nutrients useful in crop production; (2) atmospheric nitrogen fixed by legumes serves comparable roles to livestock manure and crop residues in augmenting soil fertility; (3) atmospheric nitrogen converted into nitrogenous fertilizer contributes soil nutrients useful in crop production; and (4) nutrients can be lost to the system through denitrification and "leaching," with the latter term apparently embracing both run-off and leaching of residual nutrients in livestock waste.[19]

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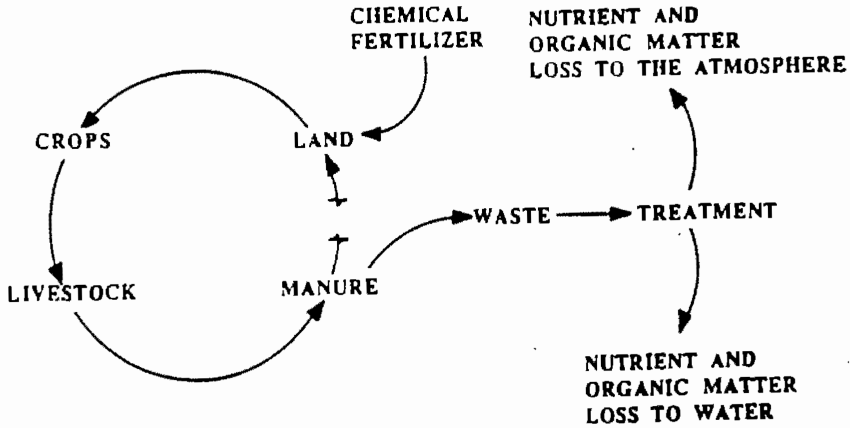
[18]In this report, terms used to characterize two soil fertility augmenting sources are "synthetic inorganic chemical fertilizers" and "organic" livestock manure. However, these terms are not entirely satisfactory. Both sources, in fact, contain chemicals. Further, urea is an"organic" compound chemically, but it is prohibited by "organic" certifying authorities.

[19]The loss of nutrients from volatilization of ammonia is not portrayed in Figure 12.

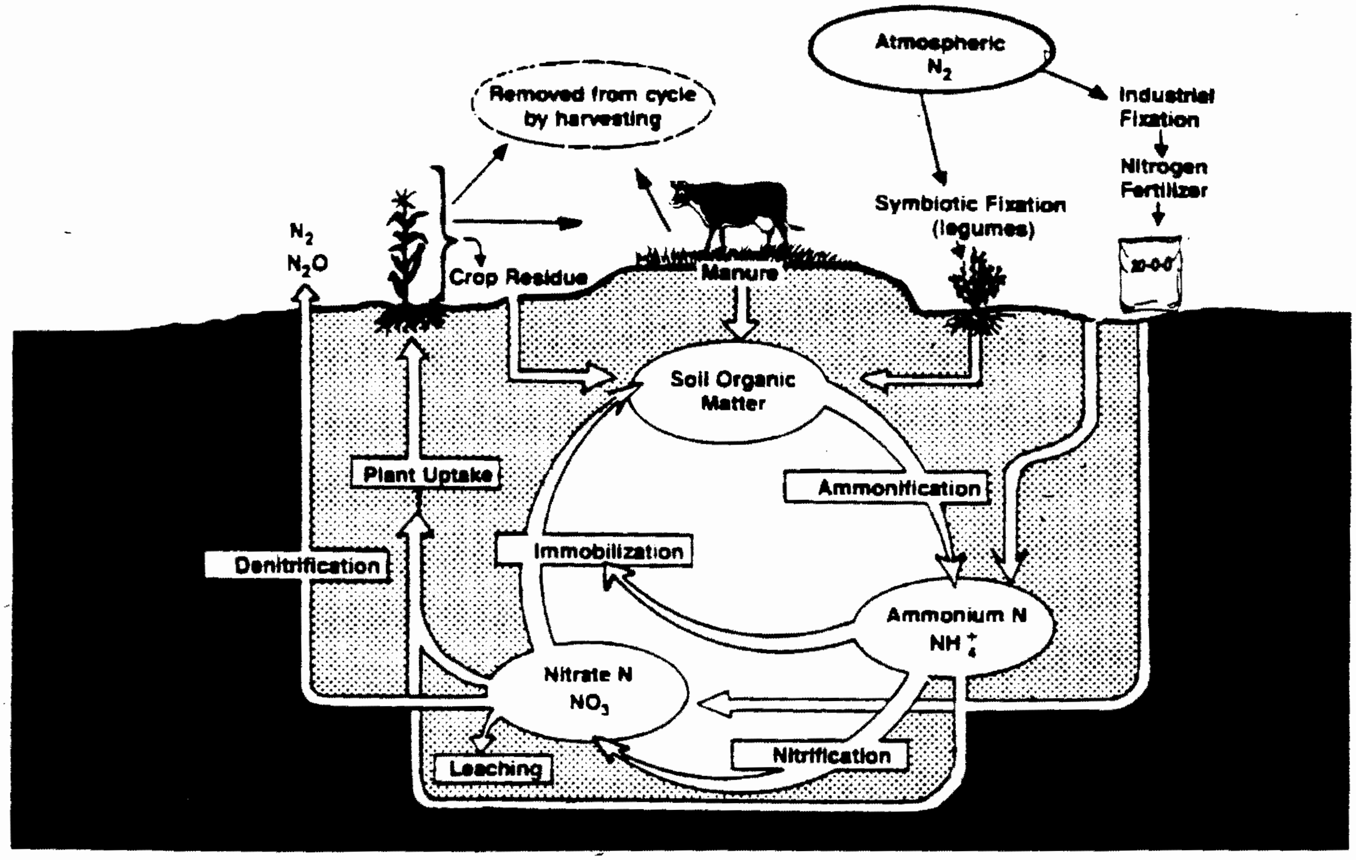
Figure 11. Nutrient cycling with "modern" crop-livestock systems: An overview.*



Source: Walter et al., 1987, p 258.

*Depending on the quality of livestock waste and farmland management practices, nutrient and organic matter loss to the atmosphere and water may or may not be great.

Figure 12. Nutrient cycling with "modern" crop-livestock systems.



Source: Leopold Letter, Vol 6, No 1, Spring 1994, p 4 (adapted from L.G. Bundy, Soil and applied nitrogen, A2519, CES, UW-Extension, 1985).

With concentrated livestock production, environmental concerns can arise in connection with waste run-off from feedlots (termed "point pollution") and nutrients leaching into soil and water from manure in excess of the nutrients required by crops (termed "non-point pollution").[20] Other things the same, possibilities for both types of pollution are greater if cattle are fed in large feedlots.[21] Point pollution may increase because of the large amounts of feedlot waste available as potential run-off into ground and surface water sources in the immediate vicinity of large feedlots. Non-point pollution may increase because the economic disincentives for transporting manure long distances from its point of origin may result in excessively heavy manure applications on farmland close to large feedlots.

While studies on possible water contamination arising from disposal of animal wastes have not been widespread, some recent research results show a linkage between livestock waste disposal and instances of soil/water pollution. Some illustrations follow:

* Chesters and Schierow (1985) and Myers et al. (1985) indicate that agriculture is the largest single non-point source of water pollutants, including sediments, salts, fertilizers, pesticides, and manures;

* The National Research Council--in its recent study "Soil and Water Quality, An Agenda for Agriculture"--reports that the concentration of cattle in large confinement feeding operations and the increasing regional concentration of dairy, poultry, and other animal production systems are giving rise to more manure being produced than can be used efficiently on nearby croplands (Batie, 1993, p 407);

* Brown et al. (1989), Pinkowski et al. (1985), and Walter et al. (1987) have undertaken studies documenting substantial nutrient loadings in groundwater from livestock and poultry manure;

* Benbrook (1991, pp 39, 49), citing the increasing problem of waste management as feedlots continue to become larger and larger, indicates that (1) surface and ground water monitoring studies are showing, with increasing frequency, that "elevated levels of nitrates in rural wells tend to be clustered in areas with high concentrations of livestock per acre" and (2) "animal agriculture contributes an estimated 25% to 30% of all groundwater pollution;"

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[20]A possible hybrid "point-non-point pollution" situation can arise if manure accumulates around livestock watering locations and/or intermittent-use stock pens in grazing areas.

[21]One factor that may not be same is quality of livestock waste management. Twenty thousand cattle in one well designed and managed feedlot may give rise to fewer pollution problems than those same 20,000 cattle in 50 poorly designed and managed feedlots with 400 cattle each.

As noted above, in South Dakota, livestock feeding operations that consist of more than 1,000 animal units are required to obtain approval from the Department of Environment and Natural Resources for livestock waste management systems (Johnson and Ullery, 1993, p 9).

* Keeney (1986) and Ritter and Chirnside (1987) indicate that application of excessively high manure rates--relative to crop needs--has been a cause for high nitrate aquifers in several areas including Wisconsin, California, and Delaware;

* Logan (1990, p 604) indicates that the trends toward large-scale, regionally concentrated confinement cattle feeding are leading to regional concentrations of manure, with little economic incentive for a redistribution of the manure to areas where livestock feeds are produced; and

* Pesek (1989, p 152) reports that in Lancaster County, PA--where farms have a high ratio of livestock per acre of cropland--manure applications average over 40 tons per acre per year, supplying far more than the nutrient-needs of the crops grown in the region.

Point pollution is represented by run-off from feedlots to surface and ground water sources nearby the feedlots. Such run-off may contain high concentrations of nutrients (e.g., phosphorus), salts, pathogens, and oxygen-demanding organic matter. When feedlot run-off enters streams or lakes, the excess organic matter and nutrients can cause oxygen depletion in shallower areas and eutrophication (a process by which a body of water becomes rich in dissolved nutrients such as phosphates and often becomes seasonally deficient in dissolved oxygen) in deeper areas, which can lead to fish kills, algae blooms, and contamination of the water as a drinking source for animals and humans (after Batie, 1993, p 399; Logan, 1990, p 604; Paine, 1973; Pesek, 1989, p 144; Sweeten, 1990, p 2).

When nutrients in animal manure applied to farmland exceed the nutrient requirements of crops, the excess nutrients (nitrogen most commonly, but phosphorus also) often leach through the soil and may reach groundwater supplies. Such non-point pollution leaching can give rise to a variety of health and growth problems for plants, animals, and humans.

Plant growth can be retarded by excessive manure applications to farmland because of the following possible chain of events: build-up of salts (e.g., sodium chloride) in soil, breakdown of soil structure, and reduced soil aeration and water infiltration. Ammonia may build up which can damage emerging seedlings. High soil phosphorus levels can interfere with plant nutrition by inhibiting uptake of metallic trace elements such as iron, zinc, and copper. When manure or plant residues are added to land, oxygen levels can drop and carbon dioxide levels can increase rather drastically, thereby inhibiting plant growth. Because of the heavy equipment often involved in manure distribution, problems of soil compaction can be accentuated by the heavy manuring of fields (after Batie, 1993, pp 399, 406; Gebhart and Makovy, 1994, p 5; Johnson and Ullery, 1993, p 4; Kaffka, 1992, p 47; MWPS, 1985, p 10.1; Mathers and Stewart, 1984, pp 1022, 1025).

Human and animal health also can be adversely affected by the presence of pathogenic organisms (e.g., fecal bacteria, viruses), nitrate, and ammonia in drinking water contaminated by excessive applications of livestock manure. In the extreme, problems of infant cyanosis (blue babies) and chemical diarrhea can arise. Elevated nitrogen concentrations in forage from excessive manure applications can sometimes threaten grazing animals' health through metabolic disorders such as grass tetany and fat necrosis. In addition, human welfare can be adversely affected by the presence of odors accompanying the transportation and heavy application of manure to farmland.

Further, the existence of excessive applications of livestock manure to farmland represents poor stewardship of a natural resource. Instead of manure serving a constructive purpose in plant production through its positive impact on soil fertility and its replacement of synthetic chemical fertilizers that otherwise would have to be purchased, it is wasted (after Batie, 1993, pp 78 and 403; Ensminger, 1987, p 893; Gilbertson et al., 1979, p 2; MWPS, 1985, p 10.1; OTA, 1990, pp 134-135).

LIVESTOCK MANURE: A NATURAL RESOURCE OR A WASTE PRODUCT?

Value of manure produced

A half century ago, animal manures were considered a valuable resource in providing fertility to U.S. soils. The following quote from the 1938 Yearbook of Agriculture (USDA, 1938, p 445) captures this notion:

> One billion tons of manure, the annual product of livestock on American farms, is capable of producing $3,000,000,000 worth of increase in crops. The potential value of this agricultural resource is three times that of the nation's wheat crop and equivalent to $440 for each of the country's 6,800,000 farm operators. The crop nutrients it contains would cost more than six times as much as was expended for commercial fertilizers in 1936. Its organic matter content is double the amount of soil humus annually destroyed in growing the nation's grain and cotton crops.

Beginning with the intensification of agriculture after World War II, however, manure has increasingly come to be viewed as a waste product for disposal rather than a natural resource to be used with care (Wadman et al., 1987). A principal underlying reason is the striking increase in the geographic density of the U.S. cattle population described earlier in this report.

The amount of manure produced in concentrated areas of livestock production often far exceeds the fertility needs of nearby farmland. Hauling manure to more distant farmland is often uneconomic because of high transportation costs arising from the very bulky nature of manure. The unfavorable economics of transporting manure have been reinforced by the development of relatively inexpensive sources of synthetic fertilizers--also noted above. Thus, many modern-day livestock producers have found manure disposal to be more a problem than an opportunity (after Batie, 1993, pp 399-400; Kaffka, 1992, p 47; King, 1990, p 94; Logan, 1990, p 588).

In some instances, however, particularly during periods of rapidly rising energy prices (synthetic fertilizer manufacture is very energy-intensive), some livestock producers have re-examined their views toward manure and have found ways to capitalize in its use to enhance the fertility of their farmland. [22] Further, some producers have expanded their manure use to (1) reduce out-of-pocket crop production costs and (2) act on a perception that chemical residues from organic manure sources are less troublesome to soil and water resources than residues from inorganic fertilizer sources (after Honeyman, 1991, p 65; Nelson and Shapiro, 1989, p 2; Stonehouse and Narayanan, 1984, p 201; Sutton et al., 1985, p 1; USDA, 1980).

Within this context, I now explore the potential economic value of manure currently produced in the U.S. and in South Dakota.[23] Accurately measuring the amounts of manure produced by the nation's population of domesticated animals is, of course, a challenging proposition. Nevertheless, several scholars/institutions have attempted to do so.

The U.S. Congress Office of Technology Assessment (OTA) recently estimated that the total amount of manure (dry weight) voided annually by livestock and poultry in the U.S. is 158 million tons (OTA, 1990, p 93).[24] Comparable estimates (million tons)[25] from other sources are as follows:

* 174 -- Follett et al. (1987, p 32);
* 158 -- Cross and Byers (1990);
* 137 -- Batie (1993, p 401); and
* 112 -- Van Dyne and Gilbertson (1978, p 6).

Of OTA's estimated total annual manure production of 158 million tons, 61% is from beef cattle, 18% from dairy cattle, 10% from hogs and pigs, 10% from poultry, and 1% from sheep (Table 5). A comparable breakdown by Van Dyne and Gilbertson (1978, p 6) for various livestock species in the U.S. is as follows: 56% from beef cattle, 23% from dairy cattle, 12% from hogs and pigs, 6% from poultry, and 3% from sheep. Of the total manure produced, Follett et al. (1987, p 32) estimate that 61% is excreted by animals directly onto pasture, rangeland, and cropland and 39% is collected from animals in confinement and mechanically applied to farmland.

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[22]Added quantities of livestock manure are also being processed and sold for garden and yard use.

[23]Manure from animals represents about 22% of all organic wastes produced in the U.S. By comparison, crop residues represent an estimated 54% of all organic wastes produced in the U.S. (Follett et al., 1987, p 31).

[24]Cromwell (1994, p 9) indicates that 158 million tons of manure, if loaded into boxcars, would stretch around the world 4.5 times!

[25]The conversion factor for converting metric tons to "British" tons is 1/0.907.

Table 5. Estimated U.S. livestock and poultry manure voided.

Species	Dry weight of manure voided: Million tons per year	Percent
Cattle		
Beef		
Beef cows and heifers	44.92	28.3
Stock on pasture	39.87	25.2
Cattle on feed	11.81	7.5
Beef sub-total	(96.60)	(61.0)
Dairy cows and heifers	29.09	18.3
Cattle sub-total	(125.69)	(79.3)
Hogs and pigs	15.54	9.8
Poultry (broilers, layers, turkeys)	15.46	9.8
Sheep	1.76	1.1
ALL SPECIES TOTAL	158.45	100.0

Source: Based on data reported in OTA (1990, p 93) that had been provided by J.M. Sweeten, "Improving livestock management practices to reduce nutrient contamination of groundwater," OTA commissioned paper, 1989.

Cross and Byers (1990) and Van Dyne and Gilbertson (1978, p 6) estimated the following amounts of nitrogen, phosphorus, and potassium in livestock and poultry manure produced in the U.S. (million tons), respectively :

* 6.50 and 4.08 -- nitrogen;
* 1.98 and 0.99 -- phosphorus; and
* 4.08 and 2.43 -- potassium.

Using 1993 synthetic chemical fertilizer prices per pound of 13.0 cents for nitrogen,[26] 21.1 cents for phosphorus, and 12.2 cents for potassium (USDA, 1993a, p 14), I determined that the total current economic value of these two estimated amounts of nitrogen, phosphorus, and potassium from manure produced annually in the U.S. is in the range of $2.07-3.53 billion.[27]

[26]A conservative approach was used in pricing the nitrogen in manure. The price of 13.0 cents per pound for nitrogen used in this calculation is that for anhydrous ammonia. In comparison, the price of nitrogen from ammonium nitrate in 1992 was 26.9 cents per pound (USDA, 1993b, p 375).

[27]Ensminger (1987, p 402); Klausner (1989, p 84); and MWPS (1985, p 10) indicate that the economic value of manure fertilizer can be reflected by applying commercial fertilizer prices against the amounts of available nitrogen, phosphorus, and potassium in the manure fertilizer. To the extent that livestock manure contains nutrients conducive to plant growth other than nitrogen, phosphorus, and potassium and has non-nutrient related beneficial impacts on soil fertility (see the next section), the full benefits of livestock manure are not captured by this value-of-manure evaluation approach.

Not all the manure initially voided by animals is necessarily available as a potential source to enhance the fertility of farmland. Van Dyne and Gilbertson (1978, p 5) estimate that 89% of the manure initially voided by livestock remains for use after losses from storage and various waste handling systems. If this loss-factor is applied to the $2.80 billion mid-point in the above range of total manure production values, the estimated potential annual value of the manure produced by livestock and poultry as a fertilizer for farmland in the U.S. would be $2.5 billion.

Johnson and Ullery (1993, p 1) report that livestock in South Dakota produce an estimated 26 million tons of manure annually, which contains approximately 240 thousand tons of actual nitrogen, 159 thousand tons of phosphate (P_2O_5), and 257 thousand tons of potash (K_2O). With the above 1993 prices and storage and handling waste factor, the estimated current annual economic value of manure as a fertilizer for farmland in South Dakota is $172 million. As a point of comparison, this figure represents 4.9% of total cash receipts from marketings and government payments to farmers and ranchers in South Dakota in 1992 (So Dak Agric Stat Serv, 1994, p 67).

Whether the estimated potential values of livestock and poultry manure of $2.5 billion nationally and $172 million in South Dakota are realized in practice depends on (1) the degree to which livestock manure and synthetic chemical fertilizers are indeed substitutes for one another and (2) the extent of managerial effort by livestock manure producers and users to realize the substitution possibilities.

Livestock manure as a substitute for commercial synthetic fertilizer

In this section, I examine broadly the possibilities and limitations for livestock manure as a substitute for synthetic chemical fertilizer. Since this is not a paper on extension manure management and agronomy, I leave the treatment of manure storage, handling, and application management to others (Gerwing et al., 1988; Johnson and Ullery, 1993; Killorn, 1985; MWPS, 1985; Nelson and Shapiro, 1989; Schmitt, 1988; Sutton et al., 1985; Sweeten, 1990).

Possibilities. Livestock manure contains nitrogen (N), phosphorus (P), and potassium (K) which can be used as substitutes for the N-P-K in synthetic chemical fertilizer. These macro-nutrients in manure, when managed efficiently, are believed by many to result in crop yields essentially equivalent to those from similar amounts of nutrients in commercial synthetic inorganic fertilizers (after Batie, 1993, p 77; Chase et al., 1991, pp 461-462; Holt and Zentner, 1985; pp 601-602; Killorn, 1985, p 2; OTA, 1990, p 92; Roka et al., 1993, p 169; Walter et al., 1987, p 257).

In addition to N-P-K that is present in both livestock manure and synthetic chemical fertilizer, livestock manure contains certain other macro-elements (e.g., calcium) and micro-elements (e.g., boron, cobalt, copper, manganese, molybdenum, zinc)[28] which can meet

[28]Some synthetic inorganic fertilizers are manufactured so as to contain certain micronutrients.

important nutrient needs of crops. Further, applying manure to farmland leads to a build-up of organic matter in soil and the release of nitrates.

Accompanying organic matter build-up and associated processes are (1) improvements in soil tilth, aeration, biological diversity and activity, water intake rate, water holding capacity, and solar heat absorption capacity; (2) greater soil moisture retention and less water run-off, with an associated reduction in leaching of potential surplus nutrients into ground and surface water supplies; (3) improvements in the aggregate stability of soils which enhances soil's resistance to water and wind erosion, compaction, and crusting; (4) improved chemical properties of soil, e.g., provision of a greater cation exchange capacity to retain nutrient cations, facilitating the availability of micronutrients, and buffering soil pH against rapid changes; and (5) increases in the solvency action of water on soil minerals. Applying livestock manure to farmland also is a means for bringing to the soil, as innoculants, beneficial bacteria from animals' digestive systems (after Baker et al., 1990, p 39; Batie, 1993, pp 77, 400; Beaumont, 1974; Elson, 1941; Ensminger, 1987, p 399; Hornick and Parr, 1987, p 64; Jacobson, 1992, p 2; Koepf, 1993, p 13; Mathers and Stewart, 1984, pp 1022-25; Roka et al, 1993, p 169; Rost and Kramer, 1957; Wallingford et al., 1975).[29]

Koepf (1985, p 36-41), in reviewing results of more than 10 long-term investigations of animal manure applied to farmland in various parts of Western Europe and a smaller number of studies in the U.S., draws a conclusion that the positive effects of livestock manures on soil fertility are longer-lasting than those from plant residues combined with synthetic chemical fertilizers. He uses the term "accumulated or medium-term" fertility to describe the combined carry-over effects of mutually interdependent plant and animal production. While not completely understood, he (p 36) offers the following explanation for "accumulated or medium-term" fertility.

> It builds up in steps that cannot really be measured by yearly soil parameters, but rather (it) shows changes in 5 to 10 year intervals. Similar periods of time are needed to exhaust it... I believe that medium-term fertility results from three overlapping factors: (1) the volume of nutrients in organic components that (is) circulating through the soil, plant, and animal compartments; (2) the long lasting carry-over effect of animal, mainly cattle, manures; and (3) organic soil components with relatively short half-lives.

These findings are consistent with Araji and Stodick (1990, p 119), Batie (1993, p 79), and OTA (1990, p 92) who report that, when manure is applied to the same field year after year, less manure is required in each succeeding year to maintain the same amount of nitrogen available to the crop.

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[29]Batie (1993, p 400) indicates that "continuous and judicious use of manure improves the physical and chemical properties of nearly all soils, particularly those that are shallow, coarse textured, or low in organic matter..."

In principle, arguments can be made for inorganic N from synthetic inorganic chemical fertilizers to be subject to either greater or lesser leaching losses when compared to N mineralized from organic manure. Since inorganic fertilizer N commonly exists in a soluble, useable (but also leachable) form, the leaching of possible surplus N from inorganic fertilizer can be kept to a minimum if the amounts and timing of applications are well-coordinated with peak nutrient needs of a crop. However, to the extent that inorganic fertilizer applications exceed the nutrient needs of crops and/or unexpected heavy precipitation follows such applications, nitrate leaching problems with inorganic sources can become substantial.

Compared with inorganic sources, nitrogen from organic sources is released more slowly. To the extent that crop N nutrient needs are distributed throughout the growing season rather than concentrated at only a few times, crop N needs may be more closely synchronized with the availability of N from organic manure sources than from inorganic sources. From this standpoint, then, the potential for leaching of nitrates can be less with organic sources. However, if N is released when crops are not actively absorbing it, nitrate leaching can become a problem with manure fertilization. Alternatively, if inadequate organic N is available at peak times of N need by crops, crop performance can be impaired (after Magdoff, 1991, pp 4-5; Papendick et al., 1987, pp 21-22; Pesek, 1989, p 144; OTA, 1990, p 92).

Magdoff (1991, pp 4-5) indicates that relatively few experiments have been designed to compare empirically the leaching potential of N from organic and synthetic sources when optimal amounts of available N are supplied from both sources. Some such experiments show greater leaching potential with synthetic sources (Comfort et al., 1987; Kaffka, 1993, p 4), some show greater leaching potential with organic sources (Roth and Fox, 1990), and others show inconclusive results (Sutton et al., 1986; Xie and MacKenzie, 1986). Notwithstanding this diversity in experimental findings on the relative leachability of N from organic versus inorganic sources, the view most often expressed in the literature on sustainable agriculture is for a lesser leaching potential of N from organic sources (Nelson and Shapiro, 1989, p 2; USDA, 1980).

Thus, from the standpoint of nitrate leaching, the use of livestock manure can be advantageous relative to synthetic inorganic chemical fertilizers, but it need not necessarily be. I now focus on other more clearly limiting aspects of reliance on livestock manure to meet soil fertility needs.

Limitations. Many of the potential limitations in substituting livestock manure for synthetic inorganic chemical fertilizers revolve around uncertainties on the amounts of various nutrients in livestock manure that ultimately will become available for use by crops and soil. These uncertainties revolve around variations in (1) the amounts produced and nutrient composition of manure at the time it is voided by livestock; (2) management practices for storing, handling, and applying manure to farmland; and (3) soil and climatic conditions at the time when manure is applied to farmland.[30]

Other things the same, producers who use inputs--whose batch-to-batch composition is consistently uniform--are facilitated in making wise decisions on the use of such inputs. Since many factors impact the quantities of nutrients from a given quantity of manure that ultimately become available for use by crops and soil, I briefly explore some of them.

While the N-P-K content of inorganic chemical fertilizers can be monitored closely and assured in synthetic manufacturing processes, the same is not true of manure produced by livestock. In fact, different types of livestock managed in different ways may produce manure which differs considerably in its nutrient content. Illustrative factors impacting the amounts and nutrient content of manure produced by livestock are species and age of livestock, rate of feeding of livestock, composition of livestock rations, and bedding and other practices. For example, livestock on intensive feeding programs can be expected to void more nutrient-dense manure. Those on high roughage rations usually void larger amounts of manure--relative to total dry matter intake--than those on high concentrate rations. The nutrient content of manure produced, and sometimes also the rate of decomposition of organic matter in manure, depends on amounts of inorganic salts and feed additives in rations. In addition, amounts of bedding used, feed spilled, and water added to or lost from manure impact the nature and density of nutrients of manure produced by livestock in confinement conditions.

Once produced, manure is vulnerable to nutrient loss--especially in regard to its nitrogen component.[31] For example, manure N can be lost through volatilization of inorganic N (ammonia), denitrification of nitrate into N_2 and N_20 gas, and nitrification of organic and inorganic forms of N in the soil. The latter results in generation of nitrates which can become subject to loss through run-off and leaching.

Nitrogen losses are impacted strongly by management practices in storing, handling, and applying manure to farmland and by soil and climatic conditions at the time when manure is applied to farmland. The following **manure management practices** impact the vulnerability of manure to nutrient losses:

* Form in which manure is collected and spread, namely, whether the manure is in solid raw, solid composted, slurry, or liquid form;

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[30]This section draws most heavily from Kaffka (1992, pp 47-54), and also from Gebhart and Makovy (1994, p 5); Honeyman (1991, p 65-66); Kaffka (1993, p 4); Klausner (1989, p 79); MWPS (1985, pp 10.1-10.2); McGrath (1993, p 97); Nelson and Shapiro (1989, pp 2-4); Rynk (1989, 170-171); Stonehouse and Narayanan (1984, p 201); Sutton et al. (1985, p 1); and Van Dyne and Gilbertson (1978, pp 1-2).

[31]MWPS (1985, p 10.1) indicates that "phosphorus and potassium losses (from animal wastes) are negligible except for open lots or lagoons. About 20-40% of the phosphorus and 30-50% of the potassium can be lost by run-off and leaching in open lots. However, much of the P and K can be recovered by run-off control systems such as settling basins and holding ponds."

* Method and duration of manure storage, including whether cattle are kept in roofed or open areas and, if manure is stored as a liquid, whether it is stored aerobically or anaerobically above or below ground or in a lagoon;

* Method of application, namely, whether manure is knifed (i.e., injected into the ground), applied with irrigation water, or applied on the ground surface and, if the latter, whether and when--relative to application--manure is incorporated and whether the land surface is bare ground or a growing crop (e.g., grassland);

* Season of year when manure is applied, including the timing of manure application relative to when crops need nutrient supplies; and

* Rate of manure application.

Uncertainties on the nutrient content of manure linked to varying practices for storing, handling, and applying manure to farmland are compounded by the fact that rates of manure application to farmland generally cannot be controlled as accurately as rates of synthetic commercial fertilizer application. The lack of control arises from the existence of less finely-calibrated machinery for applying to farmland manure versus commercial fertilizer.

Soil and climatic conditions at the time when manure is applied to farmland also affect nutrient losses and, hence, impact the amount of nutrients from manure that ultimately become available for use by crops and the soil. For example, nutrient losses often differ for manure applied to soil which is (1) well-drained versus poorly drained, (2) saturated versus dry at the time of application, and (3) coarse- versus fine-textured. Nitrification of N in the soil that results in generation of nitrates depends on availability of readily decomposable organic matter, level of soil pH (optimum at around pH 8.5), soil water content (nitrification decreases with increasing moisture tension), soil temperature (optimum at 22 degrees C), soil management (tillage), and soil oxygen content. Critical environmental conditions that impact not only nitrification but other manure nutrient losses are precipitation, temperature, windspeed, and humidity. Run-off and leaching of excess nutrients take place when precipitation exceeds evapotranspiration and soil water holding capacity.[32]

Compounding uncertainties on the amounts of nutrients in livestock manure potentially available to crops is the fact that neither the proportion of available nutrients that actually becomes used by crops nor the time when nutrients become available to crops is totally predictable. In general, it is known that only part (50-70%) of manure N is available during the first year following application (organic N must be mineralized before it can be used by plants),

[32]Nutrients in manure applied on frozen soil are vulnerable to major losses, since the nutrients cannot enter the soil and become available for plant take-up at the time of application (Vermont RCWP Coord Com, 1991, pp 193-197).

whereas at least 80% of manure P and K are quite readily available. Manure micronutrients generally are intermediate between N and P/K in the timing of their availability.[33]

Thus, the overall conclusion from this discussion on manure nutrient uncertainties is that producers who use livestock manure to meet soil fertility needs can expect to meet actual crop and soil nutrient requirements with less precision than those who use synthetic inorganic chemical fertilizers. While prudent manure management can overcome some degree of the imprecision (recall the list of references at the beginning of this section), other elements of the imprecision are essentially beyond the control of crop and livestock producers.

An additional potential limitation of relying on livestock manure rather than synthetic fertilizers to meet soil fertility needs is that the balance of N-P-K nutrients in livestock manure may not coincide with the balance of N-P-K nutrient requirements by crops. If so, synthetic sources of nutrients may be required to supplement livestock manure. Whether a general pattern exists in the nature of imbalance between manure nutrient availabilities and crop nutrient needs, however, appears open to question. Stonehouse & Narayanan (1984, p 209) indicate that "the optimal manure-handling system that meets all of the nitrogen requirements for a pre-specified set of crops supplies only 95% of the phosphorus needs and only about 70% of the potassium needs." On the other hand, Klausner (1989, p 86) indicates that "when manure is applied to meet the N requirement of a crop, P and K will usually be applied in excess" and Batie (1993, p 406) indicates "when manure is applied at rates sufficient to supply adequate nitrogen for most cropping conditions, excess amounts of phosphorus and potassium are added."[34]

[33]Kaffka (1992, p 47) also indicates that "the inorganic N content of manure varies as a percentage of the total amount of N present and, for a large supply of manure, it is difficult to know this percentage with certainty."

[34]Additional potential limitations of manure as a substitute for synthetic chemical fertilizer are (a) those indicated in the last two paragraphs in the "limitations of (livestock) concentration" section, (b) the possibility that the availability of N from organic manure sources may not be fully synchronized with crop N needs, (c) the possibility of manure hauling and spreading being rather time-consuming and costly, and (d) manure spreading sometimes contributing to the scattering of weed seeds and/or disease sources over cropland.

SOUTH DAKOTA CASE STUDY: METHODOLOGY

Feedlots-farms-ranches studied

The remainder of this report is based on analysis of a subset of the 102 cattle feeders who responded to a 1991-92 mail survey sent to (1) all of the state's cattle feeders with a feedlot capacity of 500 head or more and (2) an approximate 12% random sample of feedlots with less than 500 head (Taylor and Feuz, 1994).[35] Of those 102 respondents, 78 provided information on each of the key variables covered in this case study of feedlot-farm-ranch manure production and disposition.

The feedlot design capacity for the 78 cattle feeders covered in this report ranges from 11 to 6,665 head and averages 890 head. These feedlots average nearly 12 times the average feedlot-size in South Dakota of 75 head (USDC, 1989a, p 28). The design capacity for 73% of the 78 feedlots is less than 1,000 head (Table 6). At the other extreme, 4% of the feedlots in this study are designed for 4,000 head or more. Of 3,900 feedlots in the state with a capacity of less than 1,000 head, 1.5% are represented in the 78 feedlots covered in this report. Of the state's 100 feedlots with a capacity of 1,000 head or more, however, 21% are covered in this report.

Table 6. Design capacity of selected feedlots studied.

Design capacity: Size-of-feedlot category (head of cattle)	Feedlots studied		Total feedlots in S.D. in 1993		Feedlots studied as a percent of total feedlots in S.D. in 1992
	Number	Percent	Number[a]	Percent	
Less than 1,000	57	73.1	3,900	97.50	1.5
1,000 - 1,999	11	14.1	52	1.30	21.2
2,000 - 3,999	7	9.0	33	0.82	21.2
4,000 or more	3	3.8	15	0.38	20.0
Total	78	100.0	4,000	100.00	2.0

a/ Source: SD Ag Stat Serv, 1994, p 55.

The average cropland area reported by the 78 cattle feeders is 1,475 acres, which is 2.4 times the average of 605 acres for farms and ranches throughout the state (USDC, 1989a, p 7). Taking into consideration this information along with the above comparative information on average feedlot sizes, we see that the average concentration of fed cattle per acre of cropland

[35]In addition to the survey results for the 98 "randomly-selected" feedlots reported in Taylor and Feuz (1994), survey data were obtained from 4 purposively selected feedlot managers believed to be following "organic" beef production practices.

for the feedlots covered in this study[36] is roughly five times that for feedlots on the average in the state.[37] Of the 78 feedlots covered in this report, 75 are located east of the Missouri River.

Thus, we can conclude that these 78 feedlots-farms-ranches are much above-average for the state in both feedlot design capacity and density of fed cattle per acre of cropland. Further, they are heavily concentrated in the eastern part of the state. Since eastern South Dakota has been determined to be included in one of four areas nationally in which livestock--and, hence, potential problems of animal waste disposal--are heavily concentrated (Gilbertson et al., 1979; Logan, 1990), these study-characteristics are especially significant.[38]

In addition to fed cattle, 51 (65%) of the 78 feedlot operators have other livestock and poultry enterprises. Of these 51 operators, 26 have one other livestock enterprise, 14-two other enterprises, 9-three other enterprises, and 2-four other enterprises.

The most common other livestock enterprise involves beef cows. Forty-five (58%) of the 78 cattle feeders maintain beef cow herds ranging in size from 11 to 550 head and averaging 135 cows each. These beef cow enterprises average about 1.7 times the state-wide average herd-size of about 80 cows (USDC, 1989a, p 29). Other livestock enterprises maintained by the feedlot operators in this study are as follows:

* Slaughter hogs: 15 operators (19%) selling an average of 750 head/yr each;
* Brood sows: 11 operators (14%) with an average of 75 sows each;
* Dairy cows: 9 operators (12%) with an average of 90 cows each;
* Stocker cattle: 8 operators (10%) selling an average of 120 stockers/yr each;[39]
* Sheep: 3 operators (4%) with an average of 210 ewes each;
* Slaughter lambs: 3 operators (4%) selling an average of 135 lambs/yr each;
* Broilers: 2 operators (3%) selling an average of 4,250 broilers/yr each; and
* Layers: 2 operators (3%) with an average of 270 hens each.

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[36]On the selected feedlots-farms-ranches studied, there is a feedlot design capacity of about 600 head per 1,000 acres of cropland.

[37]To the extent that the average acreage of cropland operated by the state's cattle feeders may differ from that for all farmers and ranchers in the state, there is an error in this statement. Information on the average cropland acreage for the state's cattle feeders is not available. Therefore, one cannot ascertain the validity of the presupposition that the average cropland acreages for (a) all cattle feeders and (b) all farmers and ranchers in the state are the same.

[38]In their manual for evaluating agronomic and environmental effects of animal waste utilization on cropland and pasture land in the U.S., Gilbertson et al. (1979) conclude that the three areas of greatest livestock concentration nationally are (1) New York, Pennsylvania, and Vermont; (2) Wisconsin, Iowa, southern Minnesota, northern Illinois, eastern South Dakota, and eastern Nebraska; and (3) southern California and New Mexico. The growing number of large poultry operations in the Delmarva peninsula and the southeast represent a fourth current geographic area of animal concentration (Logan, 1990, p 588). In addition to relatively dense cattle populations, environmentally sensitive surficial aquifers and glacial lakes are rather common in eastern South Dakota.

[39]Not included in the 120 average is one producer who indicates that he sells 5,000 stockers each year.

In estimating the amount of manure produced on the 78 feedlots-farms-ranches, attention was given to the manure produced by both fed cattle and the animals represented in these other livestock enterprises.

Livestock manure available for application to farmland

The objective in this phase of analysis was to determine the amount of manure produced by the various species and types of livestock and poultry found on the 78 feedlots-farms-ranches that could be assumed to be available for application to the farmland associated with the respective operations. To accomplish this objective, literature reviews were undertaken to determine (1) the amounts of manure estimated by various scholars to be initially voided by each category of livestock and (2) the percentages of dry matter in raw manure produced by different species of livestock. Based on the estimates provided by these scholars, I used my judgment to determine the amount of manure production and percentage dry matter in manure assumed for each category of livestock found on the 78 feedlots-farms-ranches in the study. These assumed amounts of manure production were adjusted down to account for losses during the process of manure being stored and handled prior to field application. Finally, decisions were made on the proportion of total manure produced by each species and type of livestock that was assumed to be scraped, collected, and spread on cropland versus the proportion that was assumed to drop directly from grazing animals onto pasture land.

In the following paragraphs, I explain the findings from the literature reviews and the procedures followed in estimating the amounts of manure produced by each species and type of livestock assumed to be available for spreading on cropland and for dropping directly on pasture land.

Since the vast majority of the surveyed feedlot operators (87% of them) apply manure to their farmland in a solid raw form (Taylor and Feuz, 1994, p 41), I extracted from various references data on rates of manure production for only solid raw waste systems.[40] The manner in which estimated rates of solid raw manure production was shown for different species and types of livestock often varied among references. These differences involved whether rates of production were expressed in terms of (1) "raw" or "dry" manure; (2) initially voided manure or manure that was assumed to be available for application to farmland; (3) the manure for one standard body weight, or a variety of body weights, for different species of livestock; and (4) a time reference point of per-day or per-production period. To convert the amounts of manure reported in various references to a standardized basis, these four issues were dealt with as follows.

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[40]In limiting consideration in this study to solid raw manure, it was assumed that the nutrient content available to crops and the soil in slurry, liquid, and composted manure is the same as if the manure had been applied in solid raw form.

The results of the review of literature on percentages of dry matter in manure associated. with solid handling systems are shown in Table 7. Based on this information, I determined that in this study we would assume manure from various livestock species--at the time of application to farmland--to contain the following percentages of dry matter:

* Poultry, 55%;
* Beef cattle and sheep, 30%; and
* Dairy cattle and hogs, 18%.

Table 7. Percent dry matter in manure from solid handling systems reported in the literature, by livestock species.

Literature source	Percent dry matter in manure				
	Beef	Dairy	Swine	Sheep	Poultry
Ensminger (1987, p 400)	21	n/a	25	35	46
Killorn (1985, p 1)	12	13	9	n/a	n/a
Watts (1991, p 3)	12	n/a	n/a	n/a	n/a
MWPS (1985, p 10.4); Nelson and Shapiro (1989, p 5); Sutton, et al. (1985, p 4)	51[a]	20	18	28	60

[a]The 51% reported in the table is for beef cattle in "open dirt lots." For cattle in "open concrete lots," the percent dry matter is 15%.

Of the manure initially voided by animals, 89% was assumed to be available for application to farmland. This assumption was based on the estimated manure storage and handling loss reported in the "classic study" by Van Dyne and Gilbertson (1978, p 5) on U.S. livestock and poultry manure production.

The amounts of manure produced by different types of beef cattle and sheep were reported by various scholars to be directly proportional to body-weight within each species-type. The reference points for calculating rates of manure production for various categories of beef cattle and sheep were 1,100 lb beef brood cows and 180 lb breeding ewes, respectively. For hogs and poultry, on the other hand, reported rates of manure production per pound of body-weight differed for breeding versus finishing animals. Thus, rates of manure production for different categories of hogs and poultry were based directly on amounts reported in the literature review, rather than calculated relative to species' baseline body-weights.

Assumed body-weights and days in herd per production period for the various categories of livestock and poultry were based on Taylor, et al. (1990, p 40); Lamp, et al. (1989, pp 55, 58-59); and the judgment of concerned SDSU scientists. For growing and finishing livestock and poultry, rates of manure production were determined in relation to the average body-weights of animals from beginning to end of their respective feeding periods.

The results of the literature review on amounts of manure production (i.e., manure and urine initially voided) by different species and types of livestock and poultry are presented in Annex A. Data on the two above-mentioned livestock management features and the manure production for various species and types of livestock and poultry assumed in this study--based on the tables comprising Annex A--are shown in Table 8. Assumed body-weights for the respective animals are shown in Column 1, and the days that each category of livestock were assumed to be in the herd/flock are shown in Column 2. Amounts of manure assumed to be available for application to farmland are shown on a pound-per-day basis in Column 3 and on a ton-per-production period basis in Column 4.[41] The manure available for application to farmland from cattle finished for 270 days amounts to 5.8 tons per head; for beef brood cows, it amounts to 11.1 tons per head per year.

Table 8. Amounts of manure produced by various species and types of livestock and poultry assumed in the study.

Category of livestock	Livestock management assumptions: Body-weight (lb)	Livestock management assumptions: Days in herd/flock	Manure available for application: Lb/day	Manure available for application: Tons for days in herd/flock	Estimated production of initially voided manure (lb)
Beef cattle					
Brood cow	1,100	365	61	11.13	25,015
Service bull	1,700	365	94	17.16	n/a
Stockers	615	200	34	3.40	n/a
Finishing cattle[a]	775	270[a]	43	5.81	n/a
Dairy cow	1,300	365	93	16.97	38,140
Hogs					
Brood sow	350	365	11	2.01	4,510
Market hog	135	150	11	0.83	1,855
Sheep					
Ewe	180	365	6.3	1.15	2,585
Market lamb	70	140	2.5	0.18	n/a
Poultry					
Layer	7	365	0.30	0.055	123
Broiler	7	45	0.40	0.009	20.2

[a]For illustrative purposes, I show a 270-day feeding period for finishing cattle. However, in this study, I used each respondent's reported feedlot design capacity and quarterly feedlot utilization rates to determine the estimated total "cattle-feeding days" per year for the respondent. For each "cattle feeding-day" in the feedlot, the 43 lb/day manure production rate was applied.

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[41]The data in Column 5 are based on the tons of manure shown in Column 4, with an 11% adjustment for storage and handling losses. These data on the assumed pounds of raw manure initially voided can be compared directly to the levels of raw manure production reported in various literature sources shown in Annex A.

In reviewing a draft manuscript of this report, John Wagner (SDSU beef extension ruminant nutritionist, November 2, 1994) raised a question about the amounts of manure production assumed in this study. Multiplying the percentages of indigestible content of various feedstuffs by the daily amounts of those feedstuffs consumed by various species and types of livestock results in much smaller amounts of waste product than the amounts of manure assumed in this study. One point of difference, however, is that most of the literature on manure production reviewed involved both manure and urine production, whereas Wagner's considerations do not include attention to urine.

The total amounts of manure produced by various species and types of livestock and poultry on each of the 78 feedlots-farms-ranches were calculated by multiplying the data in Column 4 of Table 8 by the respective numbers of each type of livestock found in the respective farm operations.

The final step in this phase of analysis was to determine the amounts of total manure produced by each feedlot-farm-ranch that would be assumed to (1) drop directly from grazing animals onto pasture land versus (2) be available for scraping, collecting, and spreading on cropland. For fed cattle, the estimated percentage of non-spread manure was based on responses to a question in the mail survey in which producers were asked to indicate the percentage of total manure from their fed cattle that they estimated dropped directly on grazing land. Thus, data on the proportions of total manure produced by fed cattle assumed to be dropped directly on pasture land versus spread on cropland were respondent-specific. The percentages of manure produced that were assumed to drop directly on pasture land for other species and types of livestock and poultry were common among respondents. These assumed percentages were as follows (after OTA, 1990, p 136):

* Brood cows, service bulls, and stockers, 80%;
* Ewes, 80%;
* Dairy cows, 50%;
* Brood sows and market hogs, zero;
* Market lambs, zero; and
* Layers and broilers, zero.

These percentages, multiplied by the total quantities of manure produced by each species of livestock for each feedlot-farm-ranch, represented the tons of manure assumed to drop directly from grazing livestock onto pasture land for each feedlot-farm-ranch.[42] These amounts were subtracted from the total manure produced by each species and type of livestock on each feedlot-farm-ranch to determine the tons of manure assumed to be available for spreading on cropland.

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[42]Petersen et al. (1956, p 440) and King (1990, p 92) draw attention to the incomparability of manure dropping as excreta on pasture land and manure being spread mechanically on farmland. Because manure excreta may drop on only a small proportion of a pasture's surface area during any individual grazing period, they conclude that an assumption that manure-droppings are uniformly distributed over pasture surfaces is a major abstraction from reality. While I agree with their argument in the short-term, it does not seem to me to hold up in the long-term. Except for some acknowledged concentration of manure near watering holes and other areas where cattle may naturally gather, the probability is high that individual manure excretions will drop at different places within a pasture over time and thus, in the longer-term, the overall evenness of distribution of manure dropped as excreta on pasture land may not differ that much from manure spread mechanically on farmland.

Nutrient content of livestock manure

Since data in some references for phosphorus were reported in terms of P_2O_5, rather than elemental P, and in some references for potassium in terms of K_2O, rather than elemental K, the following approach was used to convert oxidized nutrient forms to elemental nutrient forms:

* Percentage P_2O_5 was multiplied by 0.44 to obtain percentage elemental P; and

* Percentage K_2O was multiplied by 0.83 to obtain percentage elemental K.

These oxidized-to-elemental form constants were taken from MWPS (1985, p 10.3).

The results of the literature review on percentages of nitrogen (N), phosphorus (P), and potassium (K) in raw solid manure applied to fields produced by different species of livestock and poultry are presented in Annex B. Based on these data, I decided to assume the percentages of N, P, and K in the manure produced by various livestock species shown in Table 9. Beef cattle manure--with 0.72% N, 0.23% P, and 0.65% K--generally is less nutrient-dense than poultry and sheep manure, but more nutrient-dense than either dairy cattle or hog manure.

Table 9. Assumed nitrogen (N), phosphorus (P), and potassium (K) content in manure produced by various livestock species.

	Percent of raw solid manure applied to fields		
Livestock species	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Beef cattle	0.724	0.227	0.650
Dairy cattle	0.485	0.098	0.427
Hogs	0.422	0.142	0.340
Sheep	0.992	0.197	0.967
Poultry	1.736	0.696	0.833

Nutrient application intensities from livestock manure on farmland

Nutrient application intensities from livestock manure on farmland were estimated separately for manure spread on cropland and for manure dropped by grazing animals directly on pasture land. The acreages of cropland on which manure was assumed to be spread and the acres of grazing land on which manure was assumed to be dropped for each feedlot-farm-ranch were determined as follows.

By means of a question in the 1991-92 feedlot operator survey (Taylor and Feuz, 1994, p 23), we determined that the vast majority of producers applied their spread manure on cropland rather than on pasture land. Producers indicated the percentages of their total cropland on which they typically applied barnyard manure. On average, manure was reported to be spread on about 70% of total cropland acres. To simplify, in this study I assumed that all spread manure was applied to cropland. Thus, the acres on which various producers were assumed to spread manure were determined by multiplying their reported percentages of cropland receiving spread manure applications by their respective total cropland acreages.

Manure from grazing animals was assumed to be dropped exclusively on pasture land. This simplified assumption emerged after consideration to the following opposing sources of possible misestimation. To the extent that livestock on the feedlots-farms-ranches in the study graze periodically on crop residues, assuming that grazing animal manure falls exclusively on pasture land gives rise to an over-estimation of actual manure application rates to pasture land. However, to the extent that producers spread some manure on pasture land--rather than exclusively on cropland, as assumed above--the assumptions in the study result in an under-estimation of manure application rates on pasture land.

Amounts of N and P from (1) manure spread on cropland and (2) manure dropping on pasture land were determined by taking the sum of the following cross-products for the respective types of manure on each feedlot-farm-ranch:

* Total tons of manure available for application from each species-type; and

* Percentages of N and P for each species-type.[43]

These feedlot-farm-ranch totals were then converted to pounds and divided by the respective cropland and pasture land acreages to determine the pounds of N and P applied per acre of cropland and pasture land for each farm operation.

Determinants of livestock manure nutrient application intensities

The following 17 factors were hypothesized to affect the amounts of nitrogen and phosphorus from livestock manure that producers spread on their cropland:

* Cropland acres: an inverse relationship between manure nitrogen and phosphorus application intensity and cropland acres was hypothesized, since--other things the same--manure can be expected to be spread more thinly if cropland acreages are large;

* Percent of cropland acres receiving spread manure applications: an inverse relationship for the same reason as stated for cropland acres;

* Feedlot design capacity: a direct relationship, since amounts of manure produced can be expected to be greater for feedlots with larger design capacities;

[43]Since adverse environmental implications from possibly excessive livestock manure applications are more likely to involve nitrogen and phosphorus than potassium, manure nutrient application intensities were computed only for nitrogen and phosphorus.

* Percent of total dry matter intake from grain (during three different stages of feeding): an inverse relationship, since the proportion of non-digested feed can be expected to be less for cattle receiving diets with high grain-to-roughage ratios;

* Number of breeding animals on the farm-ranch (for each of beef cows, dairy cows, sows, and ewes): a direct relationship, since the amount of manure produced can be expected to be positively related to the numbers of animals on a farm-ranch;

* Targeted finishing weights (for each of steers and heifers): a direct relationship, since manure production can be expected to be positively related to body-size;

* Beef cattle manure as a percent of total livestock manure: a direct relationship, since farms-ranches were selected for inclusion in this study only if they were known a priori to have beef cattle;

* Finishing cattle manure as a percent of total beef cattle manure: a direct relationship, since farms-ranches were selected for inclusion in this study only if they were known a priori to have finishing cattle;

* Percent of cattle finishing labor provided by family members: an inverse relationship, since farmers who hire at least some labor were expected to have a larger supply of labor available to scrape, collect, and spread manure which is more labor-demanding than to spread synthetic chemical fertilizer;

* Age of operator: no clear expected relationship; and

* "Organic" versus "mainstream" self-perception: a direct relationship, since farmers who tend to perceive themselves as following "organic" production methods may be more aware of the value of manure in enhancing soil fertility.

These relationships were tested, one-at-a-time, through Chi Square analysis and simultaneously through multiple regression analysis. In both cases, the unit of analysis was a feedlot-farm-ranch and the "dependent variable" was pounds of nitrogen applied per acre of cropland **(N/A)**. The analyses also were repeated for phosphorus **(P/A)**.

In the Chi-Square analysis (SAS, 1988, p 530), the 78 feedlots-farms-ranches were ordered according to a 7-part frequency distribution of the variable **N/A**,[44] with parts of the frequency distribution defined as follows (lb):

* Less than 10.0;
* 10.0 - 19.9;
* 20.0 - 34.9;
* 35.0 - 64.9;
* 65.0-99.9;
* 100.0 - 139.9; and
* 140.0 or more.

[44]Since results for the Chi-Square tests involving **P/A** were essentially the same as those for **N/A**, only the latter are presented in this report.

Frequency distributions were also established for each of the 17 factors examined in relation to **N/A.** The Chi-Square test of relationship for each pair of variables involved a determination of the statistical significance of any patterns in the categorical counts for the variables. If the mean values for the various categories of a particular factor--which was statistically significant in its relationship with **N/A**[45]--were monotonically increasing or decreasing, the relationship between that factor and **N/A** was described as direct or inverse, respectively. Otherwise, the relationship was described as significant, but with only a general or no consistent pattern.

In the multiple regression analysis, the SAS (1988, Chpt 28) REG-MAXR procedure was followed. With this software package, the factor-variables were forward-selected to fit the best 1-variable model, best 2-variable model, ..., and best 17-variable model. Variables were switched at each step so that R^2 was maximized. Once the complete model was estimated, the statistical properties at each successive step were examined. In determining the subset of factor-variables to include in a second-phase reduced model regression, joint consideration was given--at each step in the MAXR procedure--to the R^2 change and the number of statistically significant factor-variables and the signs of each. The reduced model was run with the subset of selected factor-variables regressed against **N/A** following the "default model" regression procedure. The same procedure was used for the **P/A** regression. This approach permitted estimation of revised parameters and the adjusted R^2 for the reduced models.[46]

[45]If a particular Chi-Square test involved more than 25% of cells with expected counts of less than five, the results of the testing were "automatically" considered as statistically insignificant.

[46]Adjusted R^2's are not computed with the MAXR procedure.

SOUTH DAKOTA CASE STUDY: ESTIMATED LIVESTOCK MANURE NUTRIENT APPLICATION INTENSITIES

Manure spread on cropland

Total tons spread per acre. To obtain an initial general notion of spread manure application intensities, I determined the total tons of livestock manure from all species spread per acre of cropland per year on each of the 78 feedlots-farms-ranches. These estimated average manure application intensities ranged from 0.4 to 28.1 tons/acre and averaged 6.1 tons/acre. Ten percent of producers spread an estimated average of less than 1.0 ton/acre (Table 10). At the other extreme, 8% of producers apply an estimated 15.0 tons or more per acre of cropland.[47]

Table 10. Total tons of livestock manure spread per acre of cropland: 78 feedlots-farms-ranches.

Application rate (ton/A)	Percent of producers
Less than 1.0	10.3
1.0 - 1.99	20.5
2.0 - 3.99	15.4
4.0 - 5.99	16.7
6.0 - 9.99	17.9
10.0 - 14.99	11.5
15 or more	7.7

The sources of the total manure produced on the 78 feedlots-farms-ranches are displayed in Table 11. Over 92 percent of total manure is produced by finishing cattle, including stockers. Beef cow herds account for just over 3% of total manure and hogs for just under 3%.

Table 11. Sources of manure produced: 78 feedlots-farms-ranches.

Category of livestock	Tons	Percentage
Finished cattle, including stockers	386,384	92.23
Beef cow-calf herd, including bull	14,202	3.39
Hogs	11,005	2.63
Dairy cows	7,001	1.67
Sheep	217	0.05
Poultry	106	0.03
Total	418,915	100.00

[47]Total spread manure application rates on cropland for three (3.8%) of the 78 feedlots-farms-ranches exceed 20 tons/acre.

Nitrogen and phosphorus application rates per acre. Levels of manure nitrogen applied per acre of cropland range among producers from 6 to 507 lb/acre and average 98 lb/acre. The most common range of manure N application rates is 35-65 lb/acre, with nearly one-fourth of producers making applications within this range (Table 12). At the low end of the manure N continuum, 9% of producers apply less than 10 lb/acre and another 9% apply 10-20 lb/acre. At the high end, 14% apply 140-225 lb/acre and 10% apply 225 lb/acre or more.

Table 12. Levels of nitrogen and phosphorus from livestock manure spread on cropland: 78 feedlots-farms-ranches.

Nitrogen (N)		Phosphorus (P)	
Application rate (lb/A)	Percent of producers	Application rate (lb/A)	Percent of producers
Less than 10.0	9.0	Less than 4.0	10.3
10.0 - 19.9	9.0	4.0 - 5.9	5.1
20.0 - 34.9	11.5	6.0 - 9.9	12.8
35.0 - 64.9	24.3	10.0 - 19.9	25.6
65.0 - 99.9	12.8	20.0 - 29.9	12.8
100.0 - 139.9	9.0	30.0 - 44.9	10.3
140.0 - 224.9	14.1	45.0 - 64.9	12.8
225 or more	10.3	65.0 or more	10.3
	100.0		100.0

Levels of manure phosphorus estimated to be applied per acre of cropland range among producers from 2 to 159 lb/acre and average 31 lb/acre. At the two ends of the manure P continuum, 10% of producers apply less than 4.0 lb/acre and 10% apply 65 lb/acre or more.

In two literature sources, comparable information on total tons per acre of spread manure and rates of manure N and P applied per acre are reported.

1. Mathers and Stewart (1984, p 1025) report that:

> Results from a 14-year study utilizing beef feedlot manure show that annual applications of 22 Mg manure/ha (9.8 tons/acre) ... will supply fertilizer needs of irrigated corn... Manure applications of 67 Mg/ha (29.9 tons/acre) or more may cause salt or high ammonia damage to emerging seedlings and N losses by nitrate leaching below the root zone.

2. Ensminger (1987, p 403) reports that:

> Based on earlier studies in the Midwest, before the rise of commercial fertilizers, it would appear that one can apply from 5 to 20 tons of manure/acre, year after year, with benefit. Heavier applications can be made, but probably should not be repeated every year. With higher rates than 20 tons per year, there may be excess salt and nitrate buildup... Without doubt the maximum rate at which manure can be applied to the land will vary widely according to soil type,

rainfall, and temperature. State regulations differ in limiting the rate of manure application. Missouri draws the line at 30 tons/acre on pasture and 40 tons/acre on cropland. Indiana limits manure application according to the amount of nitrogen applied, with the maximum limit set at 225 lb/acre per year.

The average application of 6.1 tons/acre for the feedlots-farms-ranches in this study is far less than any "danger-level" cited in either of these studies. Even the maximum rate of 28 tons/acre in this South Dakota study falls far short of the 40 tons/cropland-acre maximum permitted in Missouri. However, the maximum permitted application rate for manure nitrogen in Indiana of 225 lb/acre is exceeded by 10% of the feedlots-farms-ranches in this study.

Based on these acknowledged rather "soft" reference points, it would appear that the intensity of manure applications for the vast majority of the feedlots-farms-ranches covered in this study is not likely to be in an environmental danger-zone. This finding is particularly significant in view of (1) the design capacity of the feedlots covered in this study being 12 times the average for all feedlots in South Dakota, (2) the average concentration of fed cattle per acre of cropland for the feedlots covered in this study being five times that for all feedlots in the state, and (3) eastern South Dakota (in which 75 of the 78 feedlots in this study are located) being included in one of four production areas nationally in which there exist possible excessive animal wastes because of heavily-concentrated livestock production.

Manure dropped on pasture land

Levels of manure nitrogen dropped by grazing cattle per acre of pasture land range among producers from zero to 117 lb/acre and average 33 lb/acre. Thirty-two percent of the 78 feedlots-farms-ranches have no livestock that graze on pasture land (Table 13). The most common grazing manure N dropping-rate ranges are 20-40 and 40-60 lb/acre, with 22% and 16% of producers having cattle that drop manure N within these respective ranges of intensity. At the high end of the continuum, the manure N dropping-rate for 10% of producers is 80 lb/acre or more. OTA (1990, p 136) indicates that rates of manure N dropped on pasture land in the U.S. commonly range from 1 lb/acre on sparse rangeland to 500 lb/acre on intensively grazed pastures. Relative to this range, the estimated pasture manure N dropping-rates for South Dakota feedlots-farms-ranches would seem to be rather modest.

Table 13. Levels of nitrogen and phosphorus from livestock manure that drop on pasture land: 78 feedlots-farms-ranches.

Nitrogen (N)		Phosphorus (P)	
Application rate (lb/A)	Percent of producers	Application rate (lb/A)	Percent of producers
Zero	31.8	Zero	31.8
0.1 - 19.9	9.5	0.1 - 4.9	6.3
20.0 - 39.9	22.2	5.0 - 9.9	15.9
40.0 - 59.9	15.9	10.0 - 14.9	15.9
60.0 - 79.9	11.1	15.0 - 19.9	12.7
80 or more	9.5	20.0 - 24.9	9.5
	100.0	25 or more	7.9
			100.0

Levels of manure phosphorus dropped per acre of pasture land range among producers from zero to 36 lb/acre and average 10 lb/acre. The most common grazing manure P dropping-rate ranges are 5-10 and 10-15 lb/acre, with 16% of producers having cattle that drop manure P within each of these ranges of intensity. At the high end of the continuum, the manure P dropping-rate for 8% of producers is 25 lb/acre or more.

It is conceivable that a patterned relationship exists in individual producers' manure N/P application intensities on cropland versus on pasture land. For example, given producers with given numbers of livestock--each of whom thereby has a given manure production capacity--may be considering whether to apply their manure on either cropland or pasture land. To the extent that their manure application intensities on cropland are high, their application intensities on pasture land would be low and, thus, their manure application intensities on cropland and on pasture land would be expected to show a patterned inverse relationship. It is also possible, however, that producers with a special consciousness of diminishing returns in manure-use may follow management strategies to achieve a more even balance in their applications of manure between cropland and pasture land. If so, patterned differences among producers in manure application intensities on cropland versus on pasture land would be rather unlikely.

To determine whether there seems to be a patterned relationship between individual producers' manure applications on cropland and on pasture land, I (1) organized the 78 feedlots-farms-ranches according to a frequency distribution of spread manure N applications to cropland and (2) then computed the mean amount of manure N represented in droppings on pasture land for each spread manure frequency category. A similar procedure was followed with phosphorus. Chi-Square tests were undertaken to determine if relationships between spread manure application intensities on cropland and manure-dropping intensities on pasture land were statistically significant. Results of analysis show no statistically significant patterned relationship in the amounts of manure that producers spread on cropland and those that cattle drop on pasture land (Table 14). Thus, it can be concluded that the "diminishing returns" hypothesis mentioned above applies or, for some other reason, a systematic trade-off in manure being applied to cropland versus to pasture land does not seem to apply for the feedlots-farms-ranches under study.

Table 14. Mean levels of nitrogen and phosphorus from livestock manure that drop on pasture land for 78 feedlots-farms-ranches, by levels of nitrogen and phosphorus from livestock manure spread on cropland.[a]

Nitrogen (lb N/A)		Phosphorus (lb P/A)	
Amount applied to cropland	Mean amount that drops on pasture land	Amount applied to cropland	Mean amount that drops on pasture land
Less than 10.0	17.3	Less than 4.0	8.4
10.0 - 19.9	54.0	4.0 - 5.9	13.3
20.0 - 34.9	24.5	6.0 - 9.9	6.9
35.0 - 64.9	30.8	10.0 - 19.9	10.3
65.0 - 99.9	49.4	20.0 - 29.9	15.4
100.0 - 139.9	32.2	30.0 - 44.9	8.8
140 or more	26.5	45 or more	8.6

[a]Chi-Square tests of the frequency distributions for (a) amounts of manure spread on cropland and (b) amounts of manure dropping on pasture land were not statistically significant for either nitrogen or phosphorus.

Factors associated with nitrogen and phosphorus application rates from livestock manure spread on cropland

The mean values for each of the 17 factors hypothesized to be related to the amounts of spread manure N applied to cropland are shown in Annex C. The only factor shown through Chi-Square analysis to be statistically significant in its relation with manure N/acre is feedlot design capacity ($P < 0.01$). The relationship is direct, thereby confirming the hypothesized pattern of heavier spread manure applications on cropland for larger feedlots.

The results of the reduced model multiple regression analysis are displayed in Table 15. Both of these regressions include 7 of the originally considered 17 factors; both overall regressions are statistically significant ($P < 0.01$). The seven variables included in both regressions account for 66% of the variation in the N/A and P/A nutrient application intensity variables.

Table 15. Factors associated with nitrogen (N) and phosphorus (P) application rates for livestock manure spread on cropland: 78 feedlots-farms-ranches.[a]

	N (lb/A)	P (lb/A)
Regression parameters		
F-ratio of the regression	22.1***	22.3***
Adjusted R^2 (%)	65.7	65.9
Regression coefficients		
Acres of cropland	-0.041***	-0.013***
Percent of cropland acres receiving spread manure applications	-1.549***	-0.487***
Feedlot design capacity (head)	0.084***	0.026***
Percent of total dry matter intake from grain:		
Backgrounding (500 - 750 lb)	0.442[ns]	0.146[ns]
Early finishing (750 - 950 lb)	1.347**	0.413**
Late finishing (> 950 lb)	-1.121**	-0.338**
Number of beef cows on farm	0.103*	0.032*

[a]The levels of significance for the overall regression and the various regression coefficients are denoted as follows: *** = 0.01, ** = 0.05, * = 0.10, and [ns] = not significant ($P < 0.10$).

The estimated parameters for six of the seven variables included in the reduced model regressions differ significantly from zero.[48] They are as follows:

* Feedlot design capacity ($P < 0.01$), which is directly related to manure nutrient application intensity--as originally hypothesized--with 0.8 lb/acre more manure N and 0.3 lb/acre more manure P for every additional 10 head of design capacity;

* Cropland acres ($P < 0.01$), which is inversely related to manure nutrient application intensity--as originally hypothesized--with 0.4 lb/acre more manure N and 0.1 lb/acre more manure P for every additional 10 acres of cropland;

[48]The one exception is percent of total dry matter intake from grain during the backgrounding feeding period. The relatively small range of values among producers for this variable (see Annex C) may possibly explain why the variable's estimated parameter fails to differ significantly from zero.

* Percent of cropland receiving spread manure applications ($P < 0.01$), which is inversely related to manure nutrient application intensity--as originally hypothesized--with 1.5 lb/acre more manure and 0.5 lb/acre more manure P for every additional 1% of cropland receiving spread manure applications;

* Percent of total dry matter intake from grain during the early finishing period ($P < 0.05$), which is directly related to manure nutrient application intensity--contrary to the original hypothesis--with 1.3 lb/acre more manure N and 0.4 lb/acre more manure P for every additional 1% of total dry matter intake from grain;

* Percent of total dry matter intake from grain during the late finishing period ($P < 0.05$), which is inversely related to manure nutrient application intensity--as originally hypothesized--with 1.1 lb/acre less manure N and 0.3 lb/acre less manure P for every additional 1% of total dry matter intake from grain; and

* Number of beef cows on the farm-ranch ($P < 0.10$), which is directly related to manure nutrient application intensity--as originally hypothesized--with 1.0 lb/acre more manure N and 0.3 lb/acre more manure P for every additional 10 beef cows in the herd.

Taken collectively, the results of the Chi-Square and multiple regression analysis show that, of the 17 originally considered variables, feedlot design capacity is most closely associated with spread manure nutrient application intensities on cropland. The multiple regression analysis shows the additional five variables just described to be significantly related to spread manure nutrient application intensities. Neither type of statistical analysis, however, shows any of the other 11 variables to be stable in their relationship with spread manure nutrient application intensities:

* Percent of total dry matter intake from grain during the backgrounding period;

* Numbers of dairy cows, sows, and ewes maintained by producers;

* Targeted finishing weights for steers and heifers;

* Beef cattle manure as a percent of total livestock manure;

* Finishing cattle manure as a percent of total beef cattle manure;

* Percent of cattle finishing labor provided by family members;

* Age of operator; and

* Producers' self perception of following "organic," "transition," or "mainstream" production practices.

Readers are encouraged to return to the first section of the report for a summary of the findings and conclusions from the study.

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ANNEX A

REPORTED SOLID RAW MANURE PRODUCTION: BY SPECIES AND TYPE OF LIVESTOCK AND POULTRY

Note: The data shown in these tables are amounts of raw manure estimated to be initially voided by animals. The amounts reported in the referenced publications were adjusted to a common basis for the animals described in the respective table titles of the annex. The nature of the standardizing-adjustments is described in the text.

Table A1. Annual raw manure production, 1,100 lb. beef cow.

Estimated production (lb.)	Reference citation
35,425	Ensminger (1987, Table 10.3, p 400)
26,400	Ensminger (1987, Table 10.4, p 400)
25,300	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
24,200	Killorn (1985, p 1)
24,090	Watts (1991, p 3)
7,195	Van Dyne and Gilbertson (1978, p 3)

Table A2. Annual raw manure production, 1,300 lb. dairy cow.

Estimated production (lb.)	Reference citation
39,000	CTIC (1992, p 3); Killorn (1985, p 1); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
31,200	Ensminger (1987, p 400)
26,390	Van Dyne and Gilbertson (1978, p 3)

Table A3. Annual raw manure production, 350 lb. brood sow average body-weight.

Estimated production (lb.)	Reference citation
11,200	Ensminger (1987, p 400)
4,550	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
3,285	Killorn (1985, p 1)

Table A4. Raw manure production, market hog, 135 lb. average body-weight during 150 day feeding period.

Estimated production (lb.)	Reference citation
2,000	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
1,775	Ensminger (1987, p 400)
1,410	Van Dyne and Gilbertson (1978, p 3)
1,350	Killorn (1985, p 1)

Table A5. Annual raw manure production, 180 lb. ewe.

Estimated production (lb.)	Reference citation
2,700	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
2,160	Ensminger (1987, p 400)
785	Van Dyne and Gilbertson (1978, p 3)

Table A6. Annual raw manure production, 7 lb. layer.

Estimated production (lb.)	Reference citation
140	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
63	Ensminger (1987, p 400)
45	Van Dyne and Gilbertson (1978, p 3)

Table A7. Raw manure production, broiler, 7 lb. average body-weight during 45 day feeding period.

Estimated production (lb.)	Reference citation
22.4	CTIC (1992, p 3); MWPS (1985, p 10.5); Nelson and Shapiro (1989, p 4); Sutton, et al. (1985, p 4)
7.8	Ensminger (1987, p 400)
3.6	Van Dyne and Gilbertson (1978, p 3)

ANNEX B

REPORTED NITROGEN (N), PHOSPHORUS (P), AND POTASSIUM (K) CONTENT IN MANURE PRODUCED BY VARIOUS LIVESTOCK SPECIES

Table B1. Beef cattle manure.

Literature source	Geographic area	Percent of raw solid manure applied to fields		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Baker and Raun (1989, p 123)	No specific indication	1.050	0.368	1.040
Cooke (1982, p 97)	USA	0.700	0.200	0.400
Ensminger (1987, p 400)	No specific indication	0.560	0.100	0.500
Gerwing, et al. (1988, p 20)	South Dakota	0.250	0.066	0.291
Killorn (1985, p 1)	Iowa	0.250	0.110	0.415
MWPS (1985, p 10.4)	Midwest	1.050	0.368	1.040
McGary (1989, p AC-8)	Pennsyl-vania	0.736	0.163	0.532
Nelson & Shapiro (1989, p 5)	Nebraska	1.050	0.368	1.040
Schmitt (1988, p 2)	Minnesota	0.700	0.198	0.457
Sutton, et al. (1985, p 4)	Minnesota	1.050	0.368	1.040
Watt (1991, p 3)	Australia	0.567	0.185	0.400

Table B2. Dairy cattle manure.

Literature source	Geographic area	Percent of raw solid manure applied to fields		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Baker and Raun (1989, p 123)	No specific indication	0.450	0.088	0.415
Cooke (1982, p 97)	USA	0.600	0.100	0.500
Ensminger (1987, p 400)	No specific indication	0.560	0.100	0.500
Gerwing, et al. (1988, p 21)	South Dakota	0.250	0.066	0.291
Killorn (1985, p 1)	Iowa	0.550	0.132	0.457
MWPS (1985, p 10.4)	Midwest	0.450	0.088	0.415
McGary (1989, p AC-8)	Pennsyl-vania	0.541	0.121	0.408
Nelson & Shapiro (1989, p 5)	Nebraska	0.450	0.088	0.415
Schmitt (1988, p 2)	Minnesota	0.550	0.110	0.457
Sutton, et al. (1985, p 4)	Minnesota	0.450	0.088	0.415

Table B3. Hog manure.

Literature source	Geographic area	Percent of raw solid manure applied to fields		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Baker and Raun (1989, p 123)	No specific indication	0.450	0.176	0.311
Cooke (1982, p 97)	USA	0.500	0.100	0.400
Ensminger (1987, p 400)	No specific indication	0.500	0.140	0.379
Gerwing, et al. (1988, p 20)	South Dakota	0.250	0.066	0.291
Killorn (1985, p 1)	Iowa	0.250	0.110	0.415
MWPS (1985, p 10.4)	Midwest	0.450	0.176	0.311
Nelson & Shapiro (1989, p 5)	Nebraska	0.450	0.176	0.311
Schmitt (1988, p 2)	Minnesota	0.500	0.154	0.332
Sutton, et al. (1985, p 4)	Minnesota	0.450	0.176	0.311

Table B4. Sheep manure.

Literature source	Geographic area	Percent raw solid manure applied to fields		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Cooke (1982, p 97)	USA	1.400	0.200	1.000
Ensminger (1987, p 400)	No specific indication	1.400	0.210	1.000
Gerwing, et al. (1988, p 20)	South Dakota	0.750	0.110	0.623
MWPS (1985, p 10.4)	Midwest	0.800	0.220	1.060
Nelson & Shapiro (1989, p 5)	Nebraska	0.800	0.220	1.060
Sutton, et al. (1985, p 4)	Minnesota	0.800	0.220	1.060

Table B5. Poultry manure.

Literature source	Geographic area	Percent of raw solid manure applied to fields		
		Nitrogen (N)	Phosphorus (P)	Potassium (K)
Cooke (1982, p 97)	USA	1.65	0.500	0.500
Ensminger (1987, p 400)	No specific indication	1.56	0.402	0.350
Gerwing, et al. (1988, p 20)	South Dakota	1.25	0.550	0.415
MWPS (1985, p 10.4)	Midwest	2.23	1.023	1.411
Nelson & Shapiro (1989, p 5)	Nebraska	2.23	1.023	1.411
Schmitt (1988, p 2)	Minnesota	1.00	0.352	0.332
Sutton, et al. (1985, p 4)	Minnesota	2.23	1.023	1.411

Annex C. Means for factors potentially associated with nitrogen application rates from livestock manure spread on cropland[a]

Pounds of nitrogen (N) applied per acre of cropland	Means						Number of breeding animals on farm			
				Percent of total dry matter intake from grain						
	Acres of cropland	Percent of cropland acres receiving spread manure applications	Feedlot design capacity (head)	Backgrounding (500 - 750 lb)	Early finishing (750 - 950 lb)	Late finishing (> 9950 lb)	Beef cows	Dairy cows	Sows	Ewes
Frequency distribution										
Less than 10.0	1,235	87.9	200	35.3	55.7	74.5	14	1	26	0
10.0 - 19.9	1,040	92.9	170	41.7	56.4	71.7	20	24	10	0
20.0 - 34.9	1,915	83.4	435	37.5	57.0	80.5	131	1	0	0
35.0 - 64.9	1,065	69.8	480	35.6	54.5	68.5	61	8	6	0
65.0 - 99.9	2,175	68.0	1,015	36.8	63.2	73.8	159	29	12	24
100.0 - 139.9	1,185	68.7	1,055	37.7	70.0	79.3	55	0	29	0
140 or more	1,660	54.2	1,905	40.0	63.9	76.2	77	11	8	21
All feedlots										
97.7	1,475	70.9	890	37.8	59.9	74.3	77	11	11	8

[a]For ease of interpretation, data for the final variable in the table are shown as percentages of each type of producer rather than as the mean self-perception code (with "mainstream" = 1, "transition" = 2, "organic" = 3).

Annex C continues

Pounds of nitrogen (N) applied per acre of cropland	Means						Percentages of producers perceiving themselves to be:		
					Feedlot manager personal characteristics				
	Targeted finishing weights (lb)		Beef cattle manure as a percent of total livestock manure	Finishing cattle manure as a percent of total beef cattle manure	Percent of finishing cattle labor provided by family members	Age of operator (years)	"Main-stream"	"Trans-ition"	"Organic"
	Steers	Heifers							
Frequency distribution									
Less than 10.0	1,240	1,110	85.3	84.1	87.0	56.4	71.4	14.3	14.3
10.0 - 19.9	1,195	1,145	75.7	78.3	73.9	53.3	100.0	0.0	0.0
20.0 - 34.9	1,225	1,110	89.4	83.6	97.8	45.3	88.9	11.1	0.0
35.0 - 64.9	1,245	1,130	81.9	84.5	88.4	45.5	94.7	5.3	0.0
65.0 - 99.9	1,185	1,095	90.9	81.4	77.5	47.9	90.0	0.0	10.0
100.0 - 139.9	1,220	1,100	99.4	93.0	82.9	42.1	85.7	0.0	14.3
140 or more	1,225	1,120	93.3	84.6	72.9	47.4	94.7	5.3	0.0
All feedlots									
97.7	1,225	1,115	88.0	84.2	82.4	47.6	90.9	5.2	3.9