Use of Manure as a Crop Fertilizer

In this section, we assess the extent to which animal manure is used as fertilizer, as well as the conditions under which it is used. We first estimate aggregate use—the total acres of planted cropland in the U.S., and the share receiving manure, by crop. We then provide greater detail, drawn from ARMS, for the eight major field crops that account for over 70 percent of the acreage receiving manure. We also explore manure disposal among producers of manure—specifically, hog, dairy, and poultry operations.[9]

Manure Use in the Aggregate

Manure was spread as fertilizer on about 15.8 million acres of U.S. cropland in 2006, just 5 percent of total planted acreage of 315.8 million acres (Table 1).[10] In principle, manure could be spread on far more cropland, mitigating the risks that arise from excessive concentrations of manure and replacing high-priced commercial fertilizers. But there are several barriers to wider use.

Over half (52 percent) of harvested crop acres were on farms with no livestock production at all.[11] Across crops, the share of harvested acreage on farms with no livestock varied from 80 percent for cotton and 70 percent for peanuts, to 51-62 percent for soybeans, corn, wheat, sorghum, and barley, to

[9]We use 2006 NASS survey data for estimates of planted acreage, in total and by commodity. All other data in this section are drawn from ARMS data.

[10]See box "Estimating the Amount of Cropland Receiving Manure" (p. 9), for details.

[11]Using 2006 ARMS Phase III data, which reports harvested acres.

Table 1
Manure applications by crop, 2006

Commodity receiving manure	PII year	Manure share (%)	2006 Acres (000)		Share of all manured acres
			Planted	Manured	
Major Crops					
Barley	2003	2.9	3,452	100	0.6
Corn	2005	11.6	78,327	9,086	57.6
Cotton	2003	2.6	15,274	397	2.5
Oats	2005	9.0	4,168	375	2.4
Peanuts	2004	4.2	1,243	52	0.3
Sorghum	2003	0.7	6,522	46	0.3
Soybeans	2006	1.3	75,562	982	6.2
Wheat	2004	0.7	57,344	401	2.5
Subtotal		**4.7**	**241,892**	**11,439**	
Hay and Grasses					
Hog, dairy, broiler				3,360	
Beef				791	
Subtotal		**6.9**	**60,087**	**4,151**	26.3
All other crops		**1.4**	**13,856**	**194**	1.2
Total		**5.0**	**315,835**	**15,784**	**100.0**

Sources: Planted acreage estimates are drawn from USDA/NASS Acreage report released in June, 2006, while manured acreage estimates for major crops are based on data drawn from ARMS Phase II surveys, 2003 through 2006. Further explanation of the estimation procedures, and detail on estimation of hay and grass acreage, can be found in Text Box: Estimating the Amount of Cropland Receiving Manure.

less than 30 percent for oats and hay. Farms that combine crop and livestock production are much more likely to spread manure on their cropland.

The high cost of transporting manure limits its use on farms without livestock, and also limits its application to the distant fields operated by farms with livestock. Finally, the variation in nutrient loadings in manure may limit applications to some crops.

Among commodities, corn (9.1 million acres) accounts for over half of all acreage spread with manure. Corn is the country's largest single crop, with 24.8 percent of all planted acres in 2006. But corn's share of manured acreage is more than twice as large as its share of all planted acreage, largely because corn is demanding of nitrogen and is grown for feed on many dairy and hog operations. The other major manure recipients are hay and grasses, which account for 4.2 million acres, and soybeans, with 0.98 million acres.[12] Six other field crops (barley, cotton, oats, peanuts, sorghum, and wheat) together account for a total of 1.4 million acres.[13]

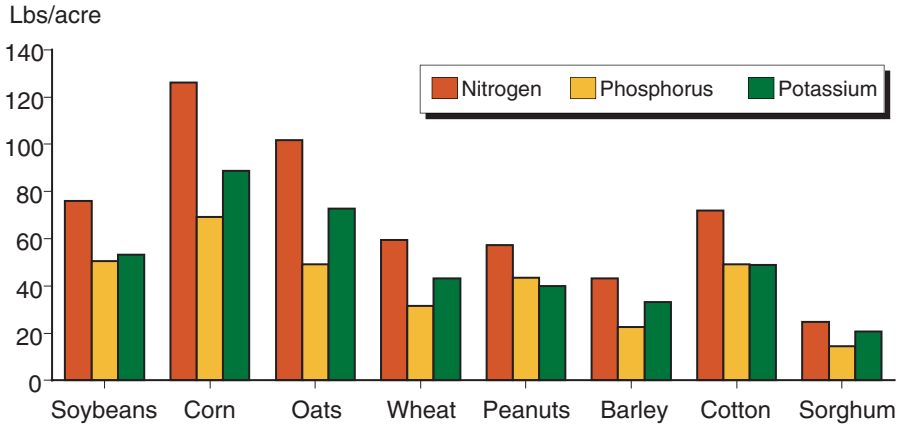
Manure is a more important nutrient source for some crops than for others. Nearly 12 percent of the acreage planted to corn received manure, as did 9 percent of oats and 7 percent of hay (Table 1). But other crops are much less intensive users—just over 4 percent of peanut acreage received manure, compared to 2.6 percent of cotton, 1.3 percent of soybeans, and less than 1 percent of sorghum and wheat.

While corn accounts for 79 percent of manured acreage among the eight major field crops, it accounts for 87 percent of the manure nitrogen applied (Figure 2). Nutrient application rates are higher for corn, wheat, and cotton than for other crops, with corn receiving 140 pounds of manure nitrogen per acre, on average, as well as 69 pounds of potassium and 91 pounds of phosphorus (Figure 1).[14]

The share of acreage receiving manure has likely risen since 2006, and it may continue to rise. Changes in crop prices led to a sharp increase of planted corn acreage after 2006. In addition, commercial fertilizer prices rose sharply in 2006-08, which should have led to some substitution of manure

Figure 1

Manure nutrient application rates, by crop



Source: ARMS Phase II, 2003-2006.

[12]Soybeans account for 24 percent of harvested acres but less than 7 percent of acres receiving manure, likely due to the crop's low nitrogen requirements.

[13]Manure that is applied to corn in one year may provide nutrients for another crop—such as soybeans—planted on the land in a following year. Our data are based only on the crop planted in the year the manure was applied.

[14]Application rates vary considerably across farms, due to differences in crop rotation, commercial fertilizer use, and soil characteristics. The differences in mean values reported in Figure 1 are not statistically significant.

Estimating the Amount of Cropland Receiving Manure

In Table 1, we estimate the total number of cropland acres receiving manure in 2006. Since no one source provides an estimate of the total number of acres receiving manure in the U.S. in any given year, we relied on several different sources.

ARMS Phase II data provide estimates of planted acreage, and acreage receiving manure, for barley, corn, cotton, oats, peanuts, sorghum, soybeans, and wheat. Phase II data have two major weaknesses. First, the eight major field crops are surveyed in different years. We need to make some adjustments to estimate manured acreage for each crop in 2006. Second, the eight crops accounted for 77 percent of total planted acreage in 2006, and we must estimate manured acreage for the remaining cropland.

For the major field crops, we assume that each crop's ratio of manured to planted acreage remained constant over time. For example, 11.6 percent of corn acreage in the 2005 ARMS Phase II survey received manure, so we assume that 11.6 percent of 2006 acreage received manure. Similarly, 2.6 percent of cotton acreage in the 2003 survey received manure, so we assume that 2.6 percent of 2006 acreage received manure. Estimated 2006 manured acreage is the product of USDA/NASS estimates of 2006 planted acreage and each crop's manured acreage share (USDA, NASS, 2006).

The eight crops listed in the top panel of Table 1 accounted for 77 percent of total planted acreage in 2006. The major omitted crop is hay, with 60.1 million planted acres, according to NASS. Other omitted crops accounted for 94 percent of the remaining 13.9 million acres: Rice (2.9), sunflowers (1.9), edible beans (1.5), rye (1.4), sugarbeets (1.4), canola (1.0), sugarcane (0.9), flaxseed (0.7) millet (0.6), and tobacco (0.3).

We have no ARMS Phase II surveys of hay and grasses, but ARMS Phase III surveys covered hog, dairy, and broiler producers in 2004, 2005, and 2006, respectively. Each questionnaire contained questions on the application of manure from those operations to hay and grasses.

Respondents to the dairy survey were asked directly for the amount of hay acreage spread with manure—1.93 million acres. Broiler and hog producers were asked to list the major crop receiving manure, the amount of major crop acreage that received manure, and the total acreage that received manure. For broiler growers, those who listed hay and grasses as the primary crop, spread manure on 685,000 acres of hay and grasses. But those who listed another primary crop spread manure on 63,000 acres in addition to the primary crop. If all of those acres were hay and grassland, then total hay and grassland acreage receiving manure could have been as high as 748,000 acres.

Following the same rationale, we estimate that hog producers spread manure on 244,000-516,000 acres of hay and grassland. Those who listed hay and grasses as the primary crop spread manure on 244,000 acres. Those who listed another primary crop spread manure on 2.21 million acres of the primary crop (90 percent was corn) and 272,000 acres of secondary crops. If all of those secondary acres were hay and grasses, then manured hay and grass acreage could have been as high as 516,000 acres.

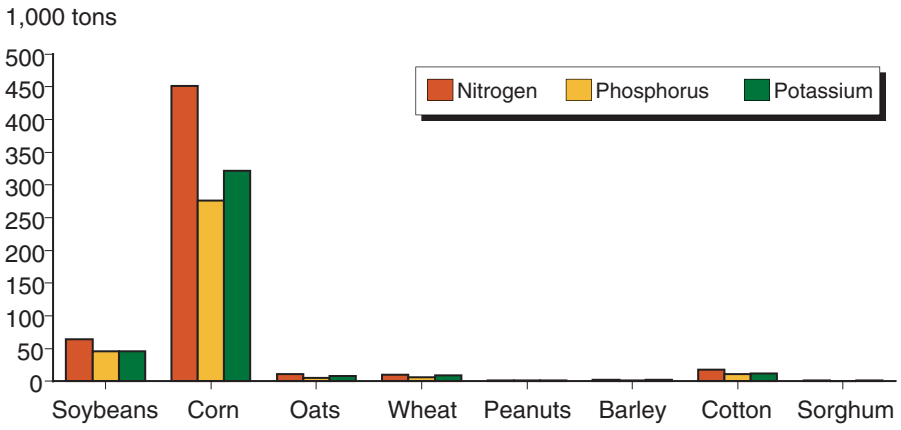
Taken together, hog, broiler, and dairy producers spread manure on between 2.86 and 3.20 million acres of hay and grassland. However, the ARMS commodity versions cover only producers in States amounting to 90 percent of production. Assuming that producers in other States act like producers in major States, we should increase our estimates by 11 percent, to a range of 3.17-3.55 million acres. We report the midpoint, 3.36 million acres, in Table 1.

Beef manure, primarily from feedlots, can also be spread on hay and grasses, but we have no ARMS surveys of feedlot manure management practices. We can, however, use the Phase II surveys to estimate the number of acres of the eight major field crops that received manure from animals of different types—beef cattle, dairy cattle, horses, hogs, sheep, and poultry. We estimate that the amount of hay and grass acreage receiving dairy, hog, or poultry manure was 24.8 percent of the major crop acreage receiving that manure. If we assume that beef manure was spread in the same proportion, then we can estimate that 791,000 acres of hay and grasses received beef cattle manure in 2006 (Table 1). Adding the beef estimate to the stronger estimates for dairy, hogs, and broilers, we can raise our estimate of hay/grass acreage receiving manure to 4.15 million acres from 3.36 million acres.

Finally, we need to estimate the number of acres of other field crops receiving manure. Other field crops accounted for 13.9 million planted acres in total. We assumed that acreage planted to those crops received manure in the same proportions as the major field crops, with corn excluded. Under that assumption, 1.4 percent of the acreage planted to those crops, or 194,000 acres, received manure in 2006. We exclude corn because it is grown in close proximity to livestock operations and because of its high nitrogen requirements; including corn in the calculation would raise the estimate to 765,000 acres. In total, we estimate that 15.784 million acres received manure in 2006.

Figure 2

Total tons of manure nutrients applied, by crop



Source: ARMS Phase II, 2003-2006.

for commercial fertilizers. Corn uses more nutrients and relies on animal manure to a greater extent than other crops. Finally, large livestock producers are coming under increasing regulatory pressure to remove manure that is in excess of agronomic needs from their operations, and removal is usually to other cropland off the operation.

Which Farmers Use Manure?

Geography, commodity choices, and agronomic requirements create strong links between various crops and specific livestock species (Table 2). For example, dairy manure is used by more than half of the corn, oats, and barley operations who use manure (Figure 3). Beef manure was used by more than half of the sorghum and wheat operations that used manure, while poultry litter was used by more than half of the peanut and cotton operations that used manure. Only soybeans received manure from a wide variety of species. The linkages tend to follow from the proximity of specific crops to areas of livestock production.

Table 2

Acreage receiving manure, by crop and species, 2006

Crop	Acres applied (000), by source of manure					
	Dairy cows	Beef cattle	Swine	Poultry	Other	**All**
Barley	54	36	4	4	2	**100**
Corn	5,612	1,617	1,161	472	224	**9,086**
Cotton	67	101	0	228	1	**397**
Oats	218	139	8	3	7	**375**
Peanuts	0	8	0	44	0	**52**
Sorghum	1	37	7	1	0	**46**
Soybeans	354	327	139	132	30	**982**
Wheat	107	250	26	12	6	**401**
All	**6,413**	**2,515**	**1,345**	**896**	**270**	**11,439**

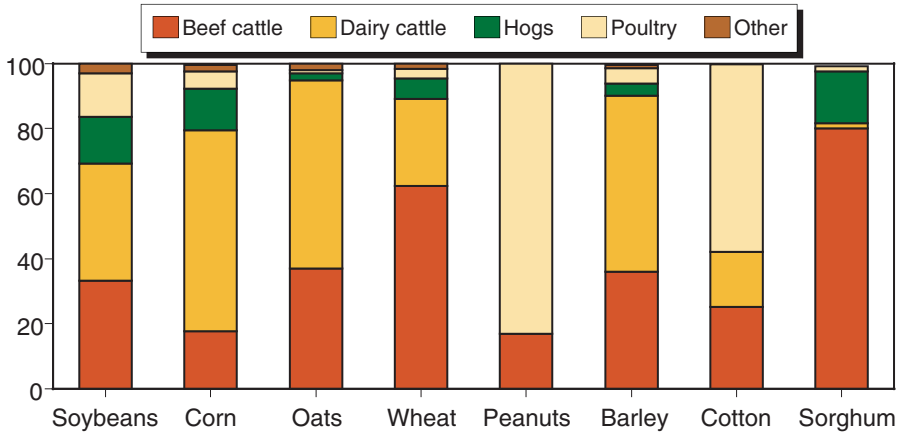
Note: other sources include equine, sheep, and biosolids.

Source: ARMS Phase II surveys for the specific crops, 2003 through 2006, adjusted to a 2006 planted acreage base using the June 2006 USDA/NASS Acreage report.

Figure 3

Animal source of manure, by crop

Percent of manure applied



Source: ARMS Phase II, 2003-2006.

Most crop enterprises cover a wide range of planted acreages, from 10 acres up to several thousand planted to a single crop. Smaller enterprises are more likely to use manure in most crop categories (Figure 4). We sorted producers of each of the eight field crops into four size classes, depending on their planted acreage of the commodity, and calculated the proportion of producers in each size class who use manure.[15] Among corn farms, 43 percent of operations in the smallest quartile used manure, compared to only 14 percent in the largest quartile. The pattern—of a higher incidence of manure use among smaller crop enterprises—holds for most other crops as well. Only in peanuts is there no clear relation between planted acreage and manure use.

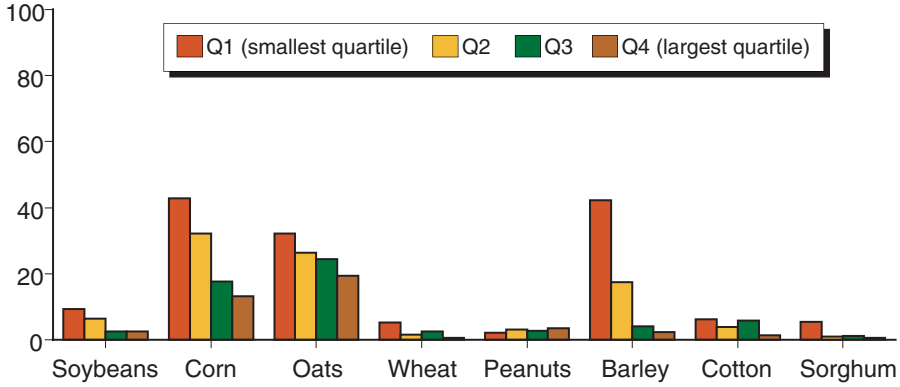
The pattern likely reflects the overall mix of commodities produced by the farm—that is, large field crop operations are more likely to specialize in field crop production, with no livestock enterprises, and as a result find manure fertilizer to be more costly for them, when transport costs are considered. In ARMS Phase III data, which provides information on all commodities produced by the farm, farms with no livestock tend to have higher planted crop acreages than farms with livestock. For example, the mean 2006 corn

[15]Specifically, the classes are quartiles, with Q1 representing the smallest 25 percent of crop acreages, Q4 representing the largest 25 percent, and Q2 and Q3 capturing the 26th-50th and 51st-75th percentiles, respectively..

Figure 4

Farmers who applied manure, by crop and size

Percent of farmers



Source: ARMS Phase II, 2003-2006.

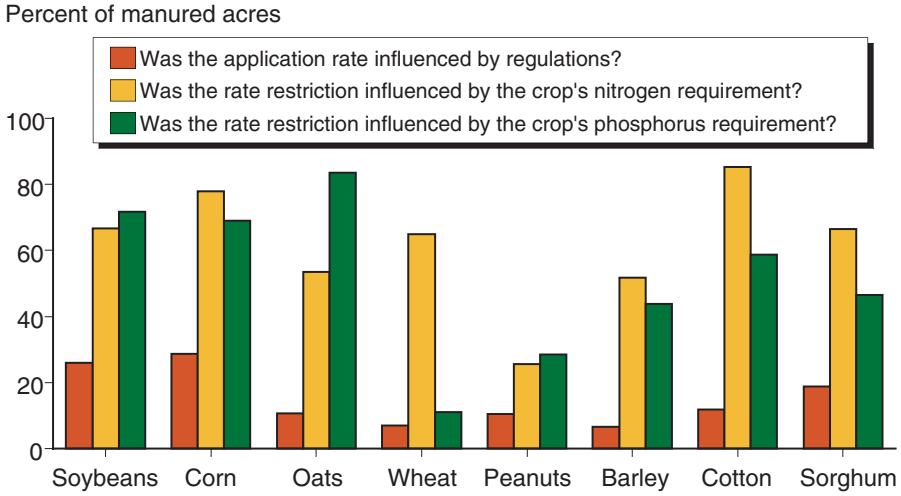
acreage among farms with corn but no livestock was 272 acres, substantially higher than the 203 acres planted by farms with corn and livestock.

Regulations can impact manure use as well. Regulations influenced manure application rates on 29 percent of the corn acres receiving manure, along with 26 percent of the soybean acres, 19 percent of sorghum acres, and 7-11 percent of the other crops (Figure 5).[18] Regulations may be based on the crop's nitrogen or phosphorus requirements. Among producers whose application rates were influenced by regulations, nitrogen requirements were cited as a limiting factor by 80 percent of corn producers, 70 percent of soybean producers, and 90 percent of cotton producers. Phosphorus requirements played a major role for corn, oats, soybean, and sorghum producers. However, regulations influenced manure use much more on planted corn and soybean acres than for other crops (Figure 6).

[18]About 7 percent of the corn farms that are affected by restrictions, and 27 percent of the soybean operations, produce no livestock. Farms that produce only crops, and that use manure obtained from livestock operations, are not required to obtain permits for the discharge of manure nutrients under the Federal Clean Water Act. These farms are likely influenced by State and local restrictions.

Figure 5

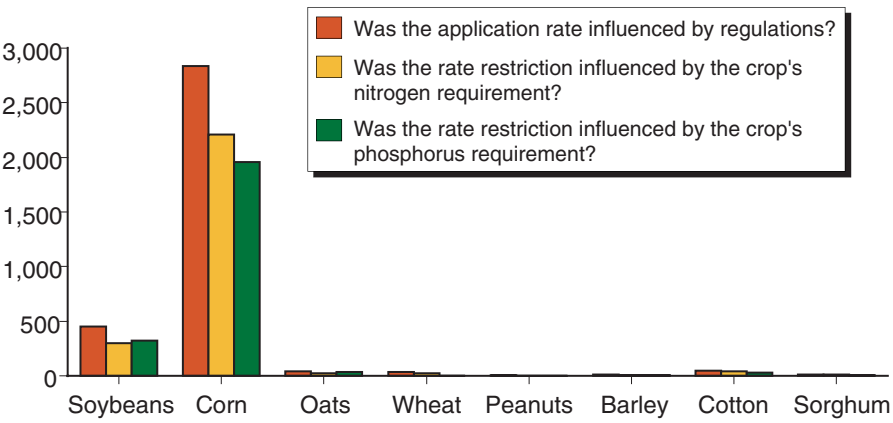
Manure applications influenced by national, State, or local regulations



Source: ARMS Phase II, 2003-2006.

Figure 6

Manure applications influenced by national, State, or local regulations



Source: ARMS Phase II, 2003-2006.

Manure Transport Among Farms

Most operators apply the manure produced on the farm to the farm's cropland (Figure 7). Among farmers who use manure, more than 80 percent of barley, corn, oats, soybean, and wheat producers, and 71 percent of sorghum producers, apply manure produced on-farm. The exceptions occur in peanuts and cotton, where most manure is acquired from other farms—recall that peanut and cotton farms tend to rely on poultry litter, which is dry and hence less costly to transport and is produced on farms that often have no crop enterprises.

Many farmers acquire manure for no explicit cost (they may pay to transport it). Some pay for the manure, and, in some places, livestock producers pay farmers to accept manure. Peanut and cotton operations purchase most of the manure that they acquire off-farm, as do most sorghum producers, but corn and soybean producers, who, because of their size, still account for most of the manure that is acquired, are more likely to obtain manure for no cost than to pay for it (Figure 7).

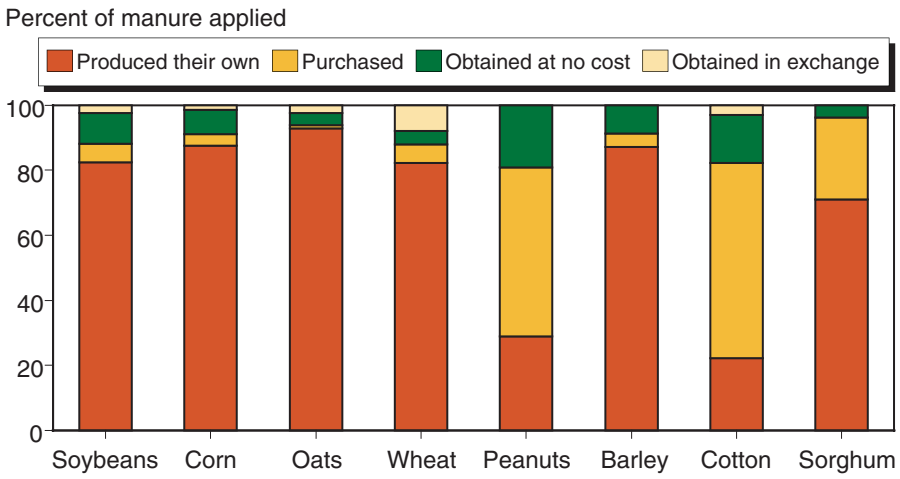
We used ARMS Phase III dairy, hog, and broiler surveys to look at manure removal from livestock operations (Table 3). Only 5 percent of dairy farms remove any manure from the farm, but 19 percent of all manure is removed. This is because larger farms are far more likely to remove manure, and farms in the largest class (2,000 animal units, about 1,500 cows) remove nearly half of their manure.

A similar pattern holds among hog operations. Only 16 percent of farms remove manure, but 26 percent of all manure is removed, and the share that is removed increases in larger operations. The largest operations (at least 1,000 animal units, or 6,000-7,000 market hogs removed in a year) remove one-third of all the manure generated on the farm.

Broiler operations are different, because many have no cropland and because broiler litter is less costly to transport. Sixty-one percent of broiler litter is

Figure 7

Manure acquisition method, by crop



Source: ARMS Phase II, 2003-2006.

Table 3
Manure removal on dairy, hog, and broiler operations, by size of farm

Commodity and size class	Percent with no cropland	Manure removed (percent)
Dairy		
Farms	5	5
Weighted by production	12	19
By size class (AU)		
<300	3	3
300-649	12	12
650-999	12	23
1,000-1,999	22	37
2,000 or more	26	49
Hogs (market)		
Farms	10	16
Weighted by production	19	26
By size class (AU)		
<300	7	13
300-649	10	20
650-999	14	29
1,000 or more	27	33
Broilers		
Farms	32	58
Weighted by production	29	61
By size class (AU)		
<300	33	56
300-649	30	63
650-999	28	63
1,000 or more	9	68

Notes: One animal unit equals 1,000 pounds (liveweight) of livestock or poultry in inventory. Average liveweight of animals in inventory was assumed to be 1,350 pounds for cows and bulls; 375 pounds for breeding swine; for slaughter swine, one-half of the difference between market weight and weight when entering the farm's inventory; and half of the average weight at removal for broilers.

Source: ARMS Phase III data, reported in MacDonald and McBride (2009)

removed from the operation. Even the smallest classes remove most, but the largest remove close to 70 percent.

Manure markets tend to be highly localized. In some areas, manure carries enough value as fertilizer that crop producers are willing to pay to receive it; in other areas, livestock producers must pay other farmers to take the manure. About 20 percent of the dairy and hog manure that is removed from farms is sold, as is 36 percent of broiler litter.[17] About 60 percent of the hog and broiler manure that is removed from farms is given away for no exchange of money. Prices for manure are determined by the quantities produced in an area relative to the amount of nearby cropland, the mix of crops grown, and the cost of transporting manure. With production shifting to large livestock operations, which are coming under increasing pressure to reduce nutrient applications to their own land, we can expect to see increased manure removals.

[17]See table 4, where about 20 percent of removed dairy and hog manure is sold, and about 36 percent of removed broiler litter is sold.

Table 4
Manure removal transactions from livestock operations

	Dairy	Hogs	Broiler
	Percent of total production		
Manure removed from operation	19	26	61
Sold by operation	4	5	22
Operation paid to haul it away	7	3	3
Operation gave it away	8	18	36
Prices	*$ per cwt of production*		
Revenue from manure sales	0.28	0.22	0.20
Expenses to haul manure away	0.39	0.34	0.31

Source: Authors' calculations, based on data from the Agricultural Resource Management Survey, Phase III, version 4, 2004 (hogs), 2005 (dairy), and 2006 (broilers).

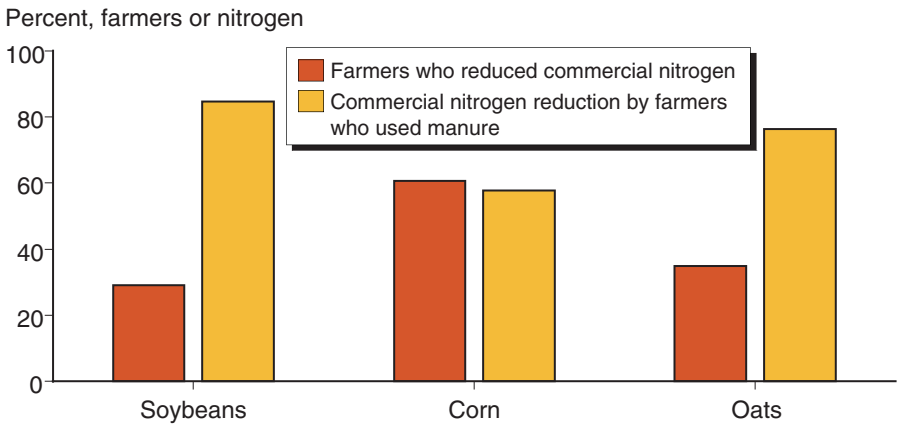
Substitution Between Manure and Commercial Nitrogen Applications

Very few farms rely exclusively on manure as a source of fertilizer because manure may not have the right combination of nutrients for the crop and because some fields may be at a considerable distance from manure storage facilities. Increased use of manure may allow farmers to reduce, rather than eliminate, their commercial fertilizer applications.

Three ARMS Phase II surveys (corn, oats, and soybeans) asked farmers whether their use of manure allowed them to reduce commercial nitrogen applications. The three crops accounted for 91 percent of manured acreage among the eight major field crops, and they each have different agronomic requirements for nutrients; corn has among the highest nitrogen requirements while soybeans have among the lowest.

Manure clearly substitutes for commercial fertilizers in corn production—61 percent of corn farmers reported that they reduced commercial nitrogen applications on their fields that received manure, and those operators cut their commercial nitrogen applications by 58 percent, on average (Figure 8). Farmers who applied commercial and manure fertilizers in 2005 had

Figure 8
Substitution between manure and commercial nitrogen



Source: ARMS Phase II, 2003-2006.

commercial fertilizer costs that were $17.60 an acre (37 percent) lower than farmers who used only commercial fertilizers on corn.

Substitution is weaker for oats and soybeans; 35 percent of oats and 29 percent of soybean producers who applied manure said that manure applications allowed them to reduce commercial nitrogen applications, although those farmers that did so cut their commercial nitrogen applications substantially—by 76 percent (oats) and 85 percent (soybeans). Those respondents who did not reduce commercial nitrogen applications were not necessarily applying manure and commercial nitrogen to their field; they may have not intended to apply any commercial fertilizers, and so had no applications to reduce.

Methods of Manure Application

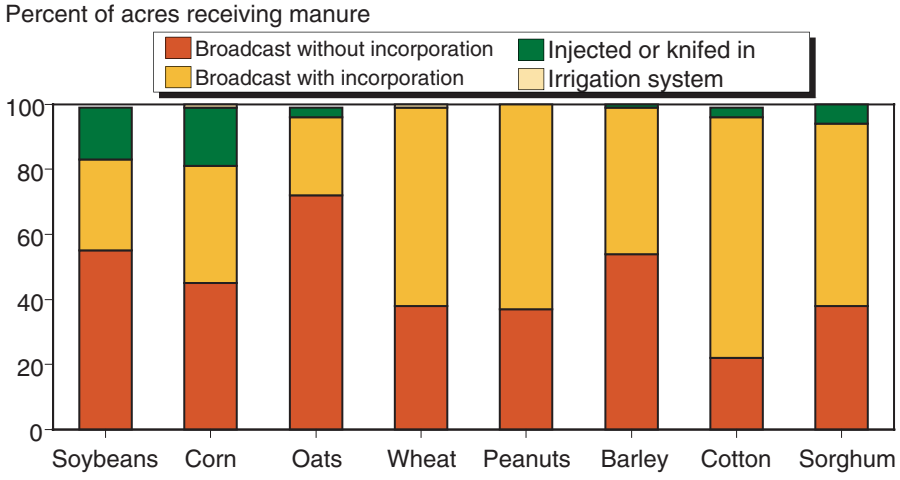
Farmers can apply manure in several ways. ARMS Phase II surveys specify four. It can be broadcast, or spread on top of the soil. It can be broadcast and then incorporated into the soil by tillage shortly after the initial application. It can be injected into the soil during application. Finally, it can be sprayed onto the soil through an irrigation system. Broadcasting may save on some costs, but it may also encourage run-off of nutrients and may lead to more odor problems.

Most farmers either broadcast their manure, or broadcast with incorporation, and the incidence of each method varies with the crop (Figure 9). Farmers are far more likely to broadcast without incorporation on corn, soybeans, and oats, while manure is usually broadcast with incorporation on cotton, sorghum, peanut, and wheat fields.

Injection and irrigation systems require significant new capital investments, and relatively few farmers in any commodity use them, although the former method does cover significant shares of corn and soybean acreage (Figure 10). Only about 10 percent of corn operators who apply manure report that they inject or knife manure into the soil, but the method covers 18 percent of manured corn acres. Similarly, 25 percent of corn operations that use manure choose to broadcast with incorporation, and those operations cover 36 percent of manured corn acres.

Figure 9

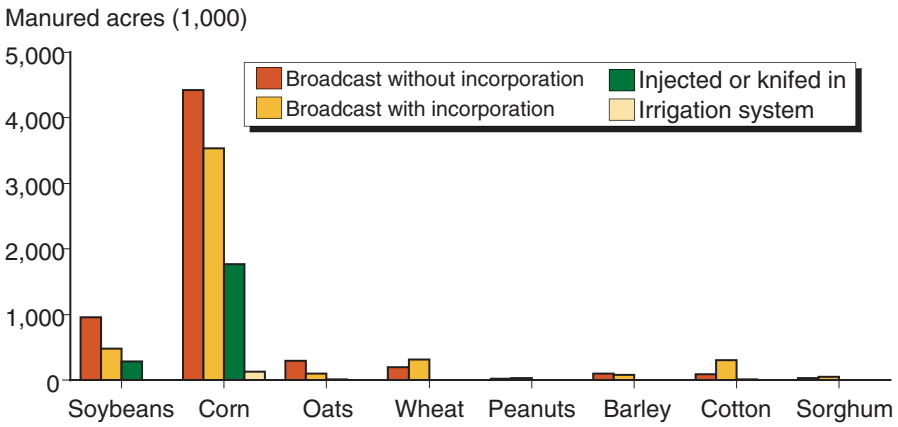
Method of manure application, by crop



Source: ARMS Phase II, 2003-2006.

Figure 10

Manure application method, by crop



Source: ARMS Phase II, 2003-2006.