The Extent and Characteristics of Manure Use on U.S. Cropland under Rate Restrictions [*]

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We used recent national surveys of U.S. producers of eight major field crops to examine the extent and characteristics of manure use and the cost impacts of Federal, State, and local restrictions governing application rates on cornfields, which received by far the most manure. The decision to use manure and the acquisition method, animal source, application rate, and application method were influenced by the product mix, location, and size of crop farms. Farmers who managed livestock operations and did not specialize in crop production were far more likely to use manure than farmers who specialized in crop production. In addition, Tobit estimates indicate that the application rate for corn producers who used manure was higher for those who raised livestock, higher still for those whose application rates were influenced by restrictions, and declined with the number of planted corn acres. Corn producers influenced by restrictions applied more manure nutrients, less chemical nutrients, and more nutrients from both sources than producers who were not influenced by restrictions. Our analysis suggests that the restrictions did not increase the cost of fertilizing cornfields with chemical nutrients in 2005.

Introduction

Crop farmers who manage livestock operations, or cropland near livestock operations, may be able to reduce fertilizer expenditures and improve soil quality by using more animal manure and less chemical fertilizers. However, manure stockpiles and excessive application rates can damage water resources and pollute the atmosphere; and Federal, State, and local governments have responded by promulgating regulations and establishing environmental conservation programs. Recent regulatory initiatives require many large livestock operations to develop and implement nutrient management plans, which base application rates on agronomic standards and require many operators to spread manure over much larger land bases and transport the excess. The

objective of this study is to examine the extent and characteristics of manure use by U.S. crop farmers under application rate restrictions.

We describe the data in the next section and the extent and characteristics of manure use in the following section. We discuss our analysis of the corn production cost impacts of rate restrictions in the fourth section, focusing on the corn sector because manure use was most extensive, by a very large margin, on U.S. cornfields. We close with a very brief summary of the main findings in the last section.

Data

We used a large, representative and comprehensive database known as the Agricultural Resource Management Survey (ARMS). We relied mainly on field-level data; however, we also used farm-level data.[1] ARMS is the U.S. Department of Agriculture's primary annual source of information on the financial condition of farm businesses and households and farm production practices. Enumerator-assisted surveys of farmers, focusing on their farm business and household, are conducted annually in three phases. Phase I, a screening questionnaire used to improve survey efficiency, verifies that producers meet certain criteria. Phase II is a series of commodity surveys, conducted during the Fall of each year, aimed at physical and economic data on inputs, management practices, and production costs. Phase III, conducted in the following winter, focuses on farm income and expenditures, farm financial arrangements, and other characteristics of the farm business and farm household.

Phase II surveys focus on operations that produce specific crops; a specific field planted to the crop is chosen at random for questions concerning land use and production practices, including manure applications. In particular, operators are asked to report the number of acres on the field that received manure, the animal source, how it was obtained and applied and, among

other questions, whether the application rate was influenced by Federal, State, or local restrictions. Phase II respondents also receive Phase III surveys, so the information on production practices can be linked to farm financial information. Phase II covers one or two crops in most years, with recent surveys directed to barley (2003), corn (2005), cotton (2003), oats (2005), peanuts (2004), sorghum (2003), soybeans (2006), and wheat (2004), which allowed us to assess manure applications to those major field crops.

Extent and Characteristics of Manure Use by U.S. Crop Producers

We combined estimates of manure acreage shares and application rates for 2003-2006 with the most recent estimates of acres planted to these crops in 2006 (USDA 2008) to estimate the extent of manure use in 2006 (table 1). Assuming manure acreage shares and application rates remained constant during 2003-2005, an estimated 11.5 million acres received manure in 2006, which is slightly less than 5% of the 242 million acres planted to these crops. Almost 80% of the acres that received manure were corn acres and, because manure application rates were highest for corn (table 2), over 86% of the total amount of manure nitrogen, phosphorous and potassium applied to these crops was applied to corn acres. In decreasing acreage levels, soybean, wheat, cotton and oat fields accounted for over 18% of the acres that received manure, and barley, peanut and sorghum fields accounted for the remaining 1.7%.

Which Farmers Used Manure?

Management of a beef, dairy cattle, or hog operation was an important determinant of manure use for barley, corn, oat, soybean and wheat farmers, whereas proximity to a livestock (primarily poultry) operation was an important determinant of manure use for peanut and cotton farmers. Because manure produced by beef, dairy cattle, and hogs is expensive to transport, producers of the former crops who did not manage beef, dairy cattle, or hog operations were less likely to use

manure; those who did were more likely to use manure, and the manure they used was primarily from these animal sources. Over 80% of barley, corn, oat, soybean and wheat farmers and over 70% of sorghum farmers who used manure produced their own (figure 1), and the animal sources were primarily beef or dairy cattle, followed by hogs (figure 2). Poultry manure is not as costly to transport, and almost 52% of the peanut farmers and 60% of the cotton farmers who used manure purchased poultry manure from nearby operations. Peanuts and cotton are produced primarily in the southeast, where the majority of broilers are produced, and the majority of peanut (70%) and cotton (80%) farmers do not manage livestock operations.

Farmers who manage large crop operations generally specialize in crop production and do not manage livestock enterprises; therefore, manure is expensive relative to chemical fertilizers as a source of nutrients. Farmers who manage smaller crop operations are more diversified and more likely to raise livestock and have as a result cheaper access to manure nutrients. Therefore, smaller crop operations were more likely to use manure (figure 3).[2] It is also likely that the case that manure is less favored by large crop producers since it is more difficult (i.e. requiring more time and management resources) to apply than chemical fertilizers. We sorted producers of each of the eight crops into four acreage classes and calculated the percentages of producers in each of the size classes who used manure. Forty-three percent of corn farmers with planted acres in the smallest quartile used manure, compared to only 13% in the largest quartile. A similarly strong linkage between planted acres and manure use emerged for oat and barley producers. Peanut was the only crop without a clear relationship between planted acreage and manure use.

Manure Use Restrictions

Growing concerns about the environmental impacts of high concentrations of animals and animal waste have spurred local, State, and Federal actions to improve management. Current Clean

Water Act regulations require concentrated animal feeding operations (CAFOs), that discharge or propose to discharge animal waste to surface waters, to obtain a National Pollutant Discharge Elimination System (NPDES) permit and develop and implement a nutrient management plan. Such a plan sets a limit on the nutrient application rate.[3] Also, under the 2003 regulations, CAFOs that are not required to have an NPDES permit, but wish to claim the storm water exemption for runoff from fields, must develop and implement a nutrient management plan to demonstrate that due care is being taken to minimize polluted runoff from fields receiving manure. Some States have also implemented restrictions on the application of animal waste on cropland.

The following question is included in the Phase II questionnaires: "Were the manure application rates to this field influenced by Federal, State, or local restrictions?" If a respondent answered "yes" we labeled the respondent restricted, and if the respondent did not answer the question or answered "no" we labeled the respondent unrestricted. That is, the only way we were able to determine whether a respondent was restricted was if the respondent reported being restricted. In addition, the respondents were not asked to describe the restrictions. However, the respondents were asked whether the basis of the application rate restrictions were the nitrogen and/or phosphorous requirements of the crop.

Returning to our discussion of the survey data, the majority of crop farmers who used manure and reported that their application rates were influenced by manure use restrictions managed livestock operations. Restrictions influenced manure application rates on 29% of the corn acres receiving manure, 26% of the soybean acres, 19% of sorghum acres, and between 7-11% for the other crops (figure 4).[4] Among producers whose application rates were influenced by restrictions, nitrogen requirements were cited as a limiting factor by 80% of corn producers, 70%

of soybean producers, and 90% of cotton producers. Phosphorus requirements played a major role for corn, oat, soybean and sorghum producers. However, restrictions influenced manure use much more on planted corn and soybean acres than for the other crops (figure 5).

Substitution Between Manure and Chemical Nitrogen

Very few farmers rely exclusively on manure as a source of fertilizer because the manure type most readily available may not have the right combination of nutrients and because some fields may be at a considerable distance from manure storage facilities. Therefore, increased use of manure may allow farmers to reduce, rather than eliminate, chemical fertilizer applications. For example, 25% of corn farmers used manure and chemical fertilizer, and 75% used chemical fertilizer only. None of the corn farmers surveyed reported using only manure.

Three of the ARMS Phase II crop surveys asked farmers whether their use of manure allowed them to reduce their use of chemical nitrogen on the field. The three crops were corn, oats, and soybeans, which together accounted for 86% of the acres planted to the eight field crops that received manure (table 1). The three crops have substantially different agronomic requirements for nutrients; corn has one of the highest nitrogen requirements of all crops, while soybean has one of the lowest nitrogen requirements (table 2).

Manure clearly substitutes for chemical fertilizers as a source of nitrogen in corn production. Sixty-one percent of corn farmers who used manure reported reducing chemical nitrogen applications an average 58% (figure 6). Moreover, substitution had a clear economic value. On average, corn producers who used no manure spent $47.50 (± $2.01) per acre on chemical fertilizers in 2005, while those who used manure spent $29.90 (± $4.43) an acre on chemical fertilizers.[5]

Substitution appears to have been weaker for oats and soybeans; 35% of oat producers and 29% of soybean producers reported that manure applications allowed them to reduce chemical nitrogen applications, although those that did reduce applications, cut their chemical nitrogen applications substantially, by 76% (oats) and 85% (soybeans). Note however that respondents who did not reduce chemical nitrogen applications were not necessarily applying manure and chemical nitrogen to their field; they may not have intended to apply any chemical fertilizers, and so had no applications to reduce.

It is important to note that farmers who applied both manure and chemical fertilizer applied far more nutrients to their fields than farmers who applied only chemical fertilizer. This suggests that the former group of farmers may have been able to reduce their use of chemical fertilizers much more than they did. For example, assuming corn, oat, wheat, cotton and sorghum farmers who did not use manure applied the appropriate mix of chemical nutrients, producers of these crops who used manure appear to have been able to eliminate their use of chemical fertilizers completely.

Methods of Manure Application

Farmers can apply manure in several ways, and ARMS Phase II surveys specify four: broadcast, or spread on top of the soil; broadcast and incorporated into the soil; injected into the soil during application; or sprayed onto the soil using an irrigation system. Broadcasting can reduce the cost of using manure, but it may also encourage nutrient run-off and lead to odor problems.

Most farmers either broadcast their manure, or broadcast with incorporation, and the incidence of each method varied by crop. Farmers were far more likely to broadcast without incorporation on corn, soybeans, or oats, while manure was usually broadcast with incorporation on cotton, sorghum, peanut, and wheat fields. Injection and irrigation systems are significant new

capital investments, and relatively few farmers in any commodity used them, although the former method covered significant shares of corn and soybean acreage. Only about 10% of corn producers who applied manure injected or knifed it into the soil; however, the method was used on 18% of the corn acres that received manure. Similarly, 25% of the corn producers who applied manure chose to broadcast with incorporation, but the method was used on 36% of the corn acres that received manure.

Corn Production Cost Impacts of Manure Use Restrictions

We used the 2005 surveys of corn producers to examine the determinants of the manure application rate (hereafter the application rate) and the cost impacts of Federal, State, and local restrictions. We merged the Phase II and Phase III datasets because the latter contains information about livestock operations and farmer demographics. There are 2019 usable observations in the Phase II data, 461 of the respondents used manure, and 100 of those respondents reported that their application rate was influenced by restrictions. However, when the Phase II and Phase III datasets are merged there only 1180 usable observations, with 167 of the respondents using manure and 35 of those influenced by restrictions. There are less observations to work with when the datasets are merged; however, the merge was necessary to account for the impact of livestock production on the application rate. Generally, not all respondents who are willing to fill out the Phase II questionnaire are also willing to fill out the Phase III questionnaire, and the dropoff is generally around 30%. Unfortunately, the dropoff in 2005 was almost 42%.

Because the application rate must be greater than or equal to zero we estimated a tobit model (Greene, pp. 691-706). Implicit assumptions are that the latent variable depends linearly on a set of independent variables and a zero-mean, constant-variance, normally distributed error term.

Because farms are not surveyed randomly under the ARMS, the observations must be weighted so that coefficient estimates and weighted statistics can be calibrated to a representative unit. Our estimates are weighted to represent the average acre planted to corn in the United States in 2005. We used a delete-a-group jackknife methodology to estimate the standard errors of the estimated coefficients, because the multi-phase sample design and the weight-estimation procedures make it difficult to apply classical variance formulas. (Dubman).

The dependent variable is the sum of manure nitrogen, phosphorous, and potassium applied per treated acre. The application rate depends on the number of pounds of raw manure applied, whether it was liquid or dry when it was applied, and the animal source.[6] In the estimation results we report the independent variables include an intercept, planted corn acres, and dummy variables indicating whether: the corn producer managed a livestock operation; the application rate was influenced by Federal, State, or local restrictions; and soybeans were planted on the majority of the field during the Spring of 2004 (table 3). The presence of a livestock operation (figure 1) and the number of planted corn acres (figure 3) affected the likelihood of manure use, and we expected the application rate to be higher for operators with livestock and to decline with the number of planted acres. We included the restrictions dummy to examine the impact of restrictions on the application rate without having clear expectations regarding the sign of the coefficient estimate. We also included the soybean dummy because planting soybeans before corn reduces the amount of manure and chemicals that must be added to the soil to obtain the optimal level of nitrogen. That is, we expected its coefficient estimate to be negative.

In preliminary estimations we also included the price (dollars per pound) of chemical nutrients, the operator's age and educational attainment, and levels of government payments and off-farm income.[7] Because manure use may increase with the price of chemical fertilizers, the

impact of the latter was examined but ultimately found to have no statistically significant impact on the application rate.[8] However, we did not account for quality differences associated with liquid versus dry fertilizers, application methods, nor speeds-of-release, which were as a result embodied in the price. The age and level of off-farm income of crop farmers have been shown to be negatively correlated with manure use in Iowa and Missouri (Núñez and McCann). That is, younger crop farmers and farmers with less off-farm income were more likely to use manure. These variables, however, did not have a statistically significant impact on the application rate in our data.

The coefficient estimates are all statistically significant at the 0.05 level, with the exception of the coefficient estimate on the soybean dummy; however, its *p*-value is only slightly over 0.05 (table 3). The signs of the coefficient estimates on planted acres and the livestock and soybean dummies agree with *a priori* expectations. The application rate declined with the number of planted corn acres, was higher for corn producers who managed livestock operations, and was lower for corn producers who planted soybeans on the majority of the field in the Spring of 2004. The coefficient estimate on the restrictions dummy is highly statistically significant, and its sign indicates that restricted producers applied more manure per treated acre than producers whose application rates were not influenced by restrictions (figure 7).[9] Note further that the extra amount of manure applied by restricted producers was much larger for those who managed livestock operations and increased as the number of planted corn acres declined (figure 7). At average acreage levels for corn producers who applied manure, the coefficient estimates indicate that restricted and unrestricted producers who managed livestock operations applied, respectively, 447 and 228 pounds of manure nutrients per treated acre; restricted and unrestricted producers who did not manage livestock operations applied 285 and 162 pounds of manure

nutrients per treated acre. That is, restricted producers applied almost twice as much manure as unrestricted producers.

Descriptive statistics for restricted and unrestricted corn producers who applied manure are reported in table 4. Note first that none of the weighted means are statistically different at the 5% level but that the magnitudes of the differences are quite large for some variables. As shown in the table, restricted producers managed larger livestock operations, harvested more corn acres, and applied manure to a larger percentage of their cornfields than unrestricted producers. Restricted producers were also more likely than unrestricted producers to observe nutrient management plans – prepared in accordance with Federal, State, or district standards – specifying practices for applying chemical fertilizers and manure. The value of corn production and yield per harvested were similar; however, net income from all farming enterprises per operated acre (not just corn acres, but all operated acres) was larger for restricted producers. Restricted producers applied more manure nutrients, less chemical nutrients, and slightly more nutrients from both sources than unrestricted producers. Because they applied fewer chemical nutrients, chemical fertilizer costs per treated acre were, on average, over $7 higher for unrestricted producers. This suggests that the application rate restrictions did not increase the cost of fertilizing cornfields with chemical nutrients in 2005.

Conclusions

We used recent national surveys of U.S. producers of eight major field crops to examine the extent and characteristics of manure use and the cost impacts of Federal, State, and local restrictions governing application rates on cornfields, which received by far the most manure. The decision to use manure and the acquisition method, animal source, application rate, and application method were influenced by the product mix, location, and size of crop farms.

Farmers who managed livestock operations and did not specialize in crop production were far more likely to use manure than farmers who specialized in crop production. In addition, tobit estimates indicate that the application rate for corn producers who used manure was higher for those who raised livestock, higher still for those whose application rates were influenced by restrictions, and declined with the number of planted corn acres. Corn producers influenced by restrictions applied more manure nutrients, less chemical nutrients, and more nutrients from both sources than producers who were not influenced by restrictions. Our analysis suggests that the restrictions did not increase the cost of fertilizing cornfields with chemical nutrients in 2005.

[1] The field-level ARMS data are commonly referred to as the Phase II data, and the farm-level ARMS data are referred to as the Phase III data.

[2] For example, the mean 2006 corn acreage among farms with corn but no livestock was 272 acres, which is substantially higher than the 203 acres planted by farms with corn and livestock.

[3] Application limits vary by farm because they are based on estimates of the agronomic uptake of nutrients, which depends on the crop, soil type, and climate.

[4] 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. However, about 7% of the corn farms that are affected by restrictions, and 27% of the soybean operations, produced no livestock. These farms were likely influenced by state and local restrictions.

[5] The ± symbol precedes 95% confidence levels for means throughout. As shown, these weighted mean fertilizer expenditures are statistically different at the 5% level.

[6] The equations used to estimate pounds of manure nutrients are not included for brevity but are available from Livingston upon request at mlivingston@ers.usda.gov.

[7] Chemical fertilizer price (dollars per pound of nutrients) estimates were based on Phase II data and included the cost of custom applications. Because many respondents did not report fertilizer costs, we imputed price estimates using weighted, state-level prices based on regional price (USDA 2006) and state-level fertilizer use (Association of American Plant Food Control Officials and The Fertilizer Institute) estimates. If a fertilizer cost was not reported, the observation was imputed using the price corresponding to the respondent's state.

[8] Assuming the total nutrient application rate (pounds of manure plus chemical nutrients per treated acre) and the chemical fertilizer price were not simultaneously determined – an heroic

assumption perhaps, given that over 45% of chemical nutrients applied to U.S. cropland was applied to cornfields in 2005 – the chemical fertilizer price did have a statistically significant and negative impact on the total nutrient application rate.

[9] For brevity we refer to the subset of corn producers who used manure and whose application rates were and were not influenced by Federal, State, or local restrictions as restricted and unrestricted producers, respectively.

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Table 1. Manure acreage shares, planted acres, acres receiving manure and tons of manure nutrients applied in 2006

crop	manure share	planted acres	acre receiving manure	tons of manure nutrients applied		
		thousands		nitrogen	phosphorous	potassium
barley	2.9%	3,452	99	2,035	1,052	1,725
corn	11.6%	78,327	9,117	639,317	315,873	413,688
cotton	2.6%	15,274	402	18,717	12,542	12,259
oats	9.0%	4,168	374	16,982	7,785	14,052
peanuts	4.2%	1,243	53	1,524	1,076	1,193
sorghum	0.7%	6,522	46	2,281	1,588	1,398
soybeans	1.3%	75,562	958	25,860	14,673	20,887
wheat	0.7%	57,344	409	24,946	13,739	23,125
total	4.7%	241,892	11,458	731,661	368,327	488,329

Notes: The manure shares are weighted sums of acres receiving manure divided by weighted sums of planted acres during the reference year of the most recent survey for each crop. 2006 planted acres are from USDA (2008). Acres receiving manure are the products of the manure shares and the 2006 planted acreage estimates. Tons of manure applied are given by the product of 1000, acres receiving manure, and the manure-nutrient application rates (see table 2) divided by 2000. The application rates are weighted pounds of nutrients divided by weighted sums of nutrient-treated acres during the reference year for each crop.
Source: ARMS data for the years in which producers of these crops were most recently surveyed (see text).

Table 2. Animal manure, chemical-fertilizer, and total-nutrient application rates for farmers who applied both and farmers who applied only chemical fertilizers by crop

variable	corn	soybeans	oats	wheat	peanuts	barley	cotton	sorghum
farmers who applied chemical fertilizer and manure								
manure nitrogen	140	54	91	122	58	41	93	98
manure phosphorous	69	31	42	67	41	21	62	68
manure potassium	91	44	75	113	45	35	61	60
chemical nitrogen	100	16	31	73	45	56	97	109
chemical phosphorous	41	48	35	36	22	28	51	36
chemical potassium	58	83	59	50	109	41	81	
total nitrogen	258	72	125	204	101	128	191	210
total phosphorous	102	88	76	92	61	55	81	79
total potassium	133	160	133	132	119	51	87	43
farmers who applied only chemical fertilizer								
chemical nitrogen	143	16	59	70	33	60	92	81
chemical phosphorous	60	46	35	36	50	29	49	32
chemical potassium	87	81	48	37	74	19	79	27

Notes: These are weighted mean application rates: weighted sums of applied nutrients (in pounds) divided by weighted sums of treated acres. We used the most recent ARMS data for each crop (see text). For all of the crops except sorghum, total nutrient application rates are weighted sums of applied chemical- plus manure-nutrients divided by the weighted sum of the lesser of chemical-fertilizer treated acres or manure treated acres. We used the weighted sum of the average of chemical-fertilizer and manure treated acres for sorghum.

Table 3. Tobit estimate of the determinants of the manure nutrient application rate

Dependent variable	pounds of manure nutrients per treated acre		
Observations	1,180		
Standard error of the estimate	420.41		
Log likelihood	-1,286,062		
AIC	2,572,137		
Schwartz criterion	2,572,208		
coefficient	estimate	standard error	p value
intercept	-562.66	64.97	1.13E-06
planted corn acres in the surveyed field	-2.06	0.67	0.03
=1 if livestock operation on farm	411.00	57.03	1.14E-05
=1 if application rate influenced by federal, state, or local restrictions	678.60	100.15	2.40E-05
=1 if soybeans were planted on the majority of the field in the Spring of 2004	-174.26	64.19	0.05

Notes: These are weighted coefficient estimates. Standard errors were estimated using a delete-a-group jackknife methodology (Dubman). The p-values were calculated using a *t* distribution with 14 degrees of freedom.

Source: 2005 ARMS survey of corn producers

Table 4. Descriptive statistics for restricted and unrestricted corn producers who applied manure

	application rate influenced by restrictions			application rate not influenced by restrictions		
	weighted mean	± 95%	respondents	weighted mean	± 95%	respondents
value of all livestock production per farm[a]	$628,017	$444,532	32	$314,741	$208,280	112
harvested corn acres per farm[a]	414	220	35	197	54	132
percent of acres treated with manure[b]	87%	27%	35	70%	14%	132
comprehensive nutrient management plan[b]	37%	22%	35	13%	7%	132
manure-only nutrient management plan[b]	22%	10%	35	10%	8%	132
value of corn production per harvested acre[a]	$297	$46	35	$262	$29	132
net income per operated acre[a]	$144	$188	35	$99	$52	132
yield per harvested corn acre (bushels)[a]	164	12	35	157	11	132
lbs manure nutrients per treated corn acre[b]	301	111	33	229	53	132
lbs chemical nutrients per treated corn acre[b]	109	37	35	169	29	132
lbs nutrients (all sources) per treated corn acre[b]	411	88	35	398	58	132
chemical fertilizer cost per treated corn acre[b]	$28.31	$15.29	35	$35.93	$11.80	132

Notes: Standard errors were estimated using a delete-a-group jackknife methodology (Dubman). The p-values were calculated using a *t* distribution with 14 degrees of freedom. The column labeled respondents indicates the number of observations used to estimate the weighted mean. The mean value of livestock production was computed only for operations with livestock.

[a] The 2005 ARMS Phase III, farm-level data and weights were used to compute the means and 95% confidence levels.

[b] The 2005 ARMS Phase II, field-level data and weights were used to compute the means 95% confidence levels.

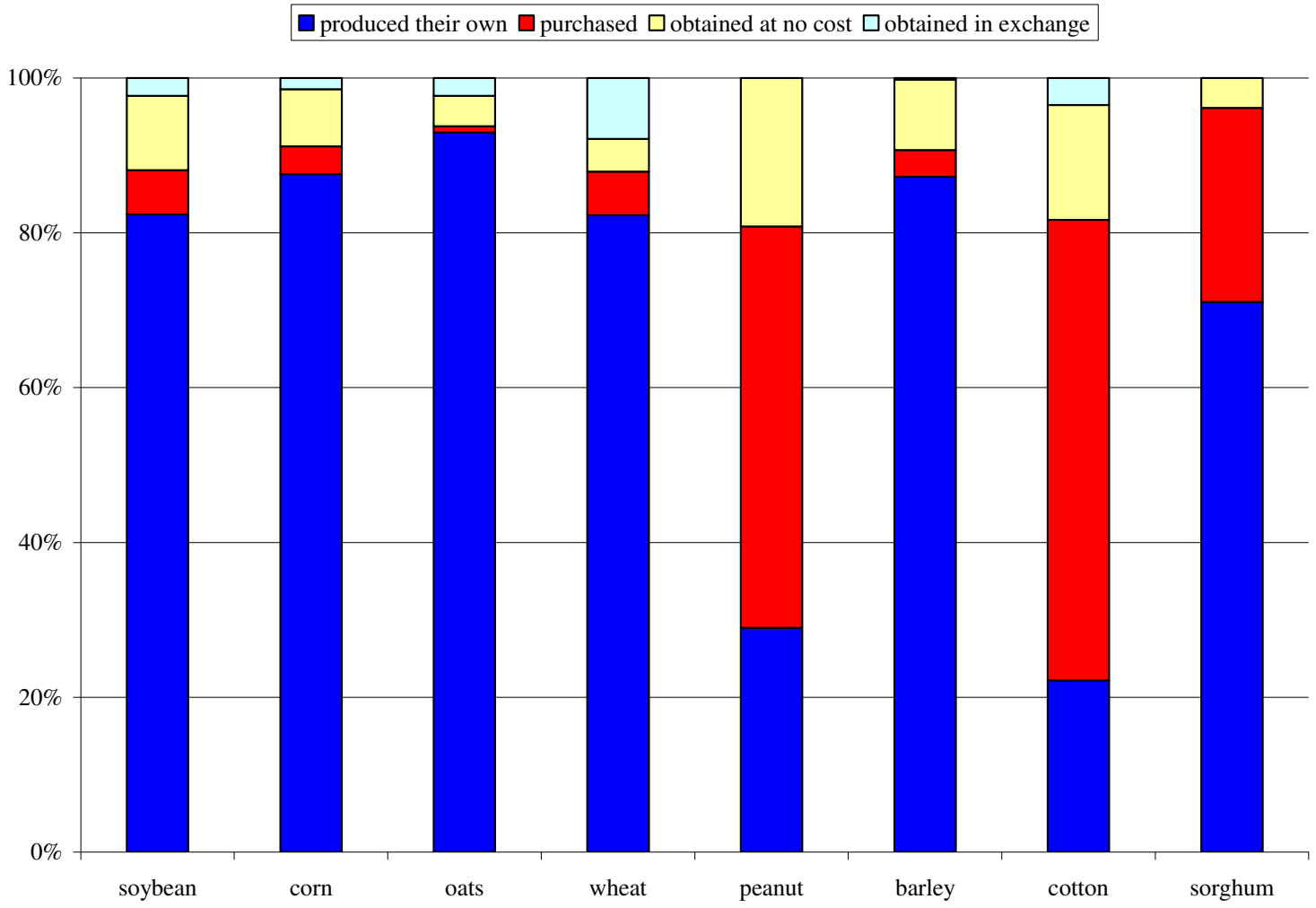

Figure 1. Method of manure acquisition by crop

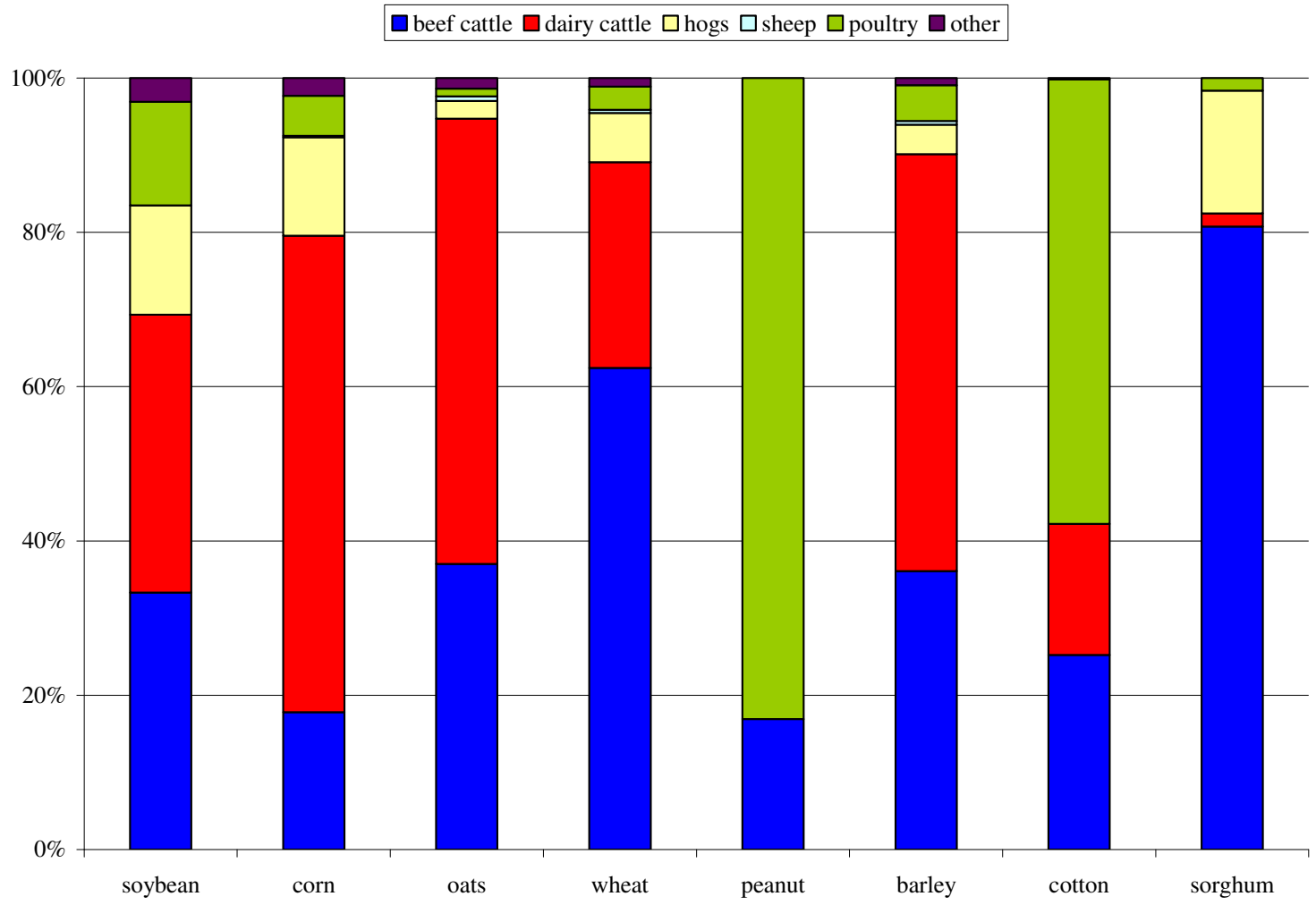

Figure 2. Animal source of manure by crop

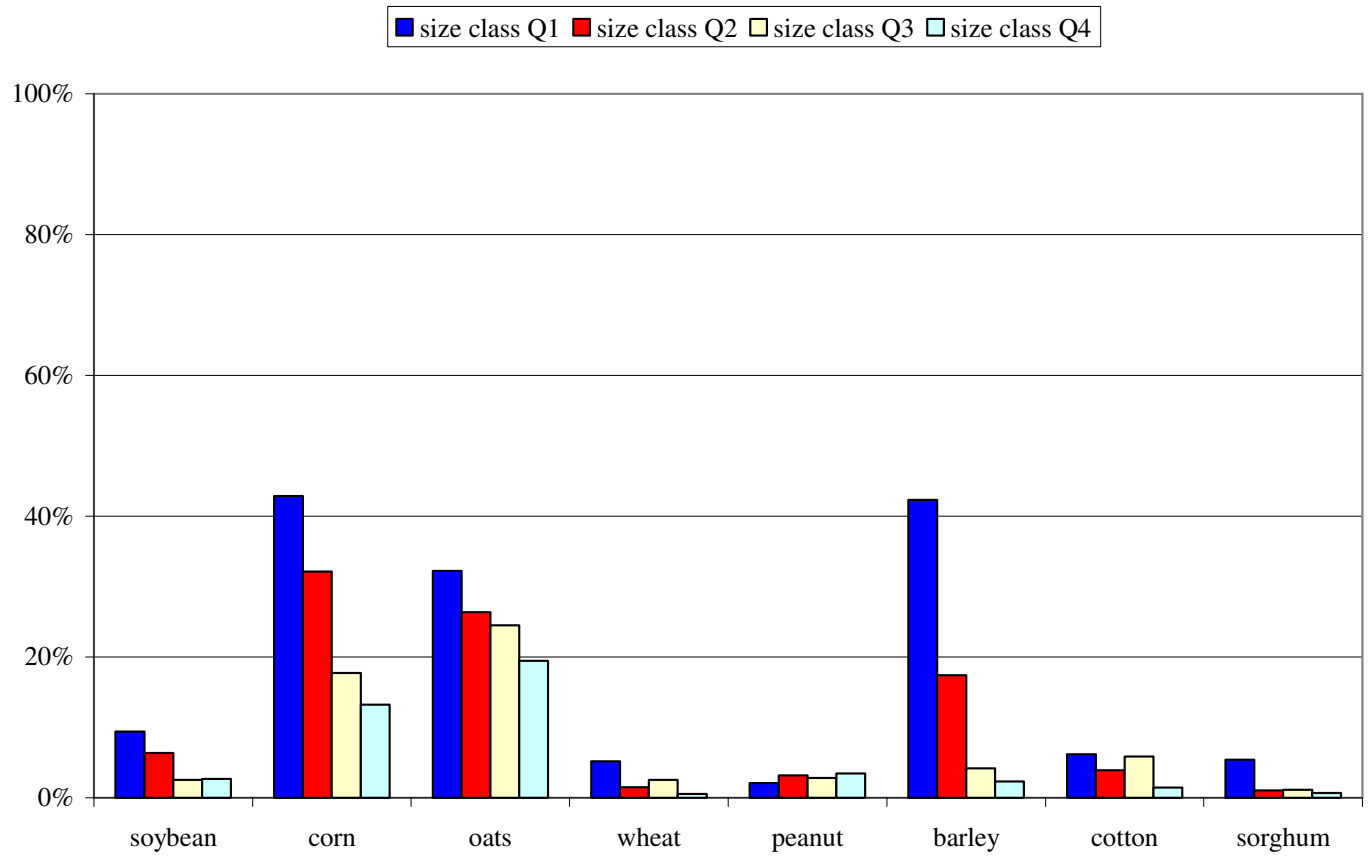

Figure 3. Percentages of crop farmers who used manure by planted acreage category: farmers in size class Q1 planted less than the first quartile of survey respondents' planted acres; Q2, planted acres in between the first and second quartiles; Q3, planted acres in between the second and third quartiles; and Q4, planted acres greater than the third quartile

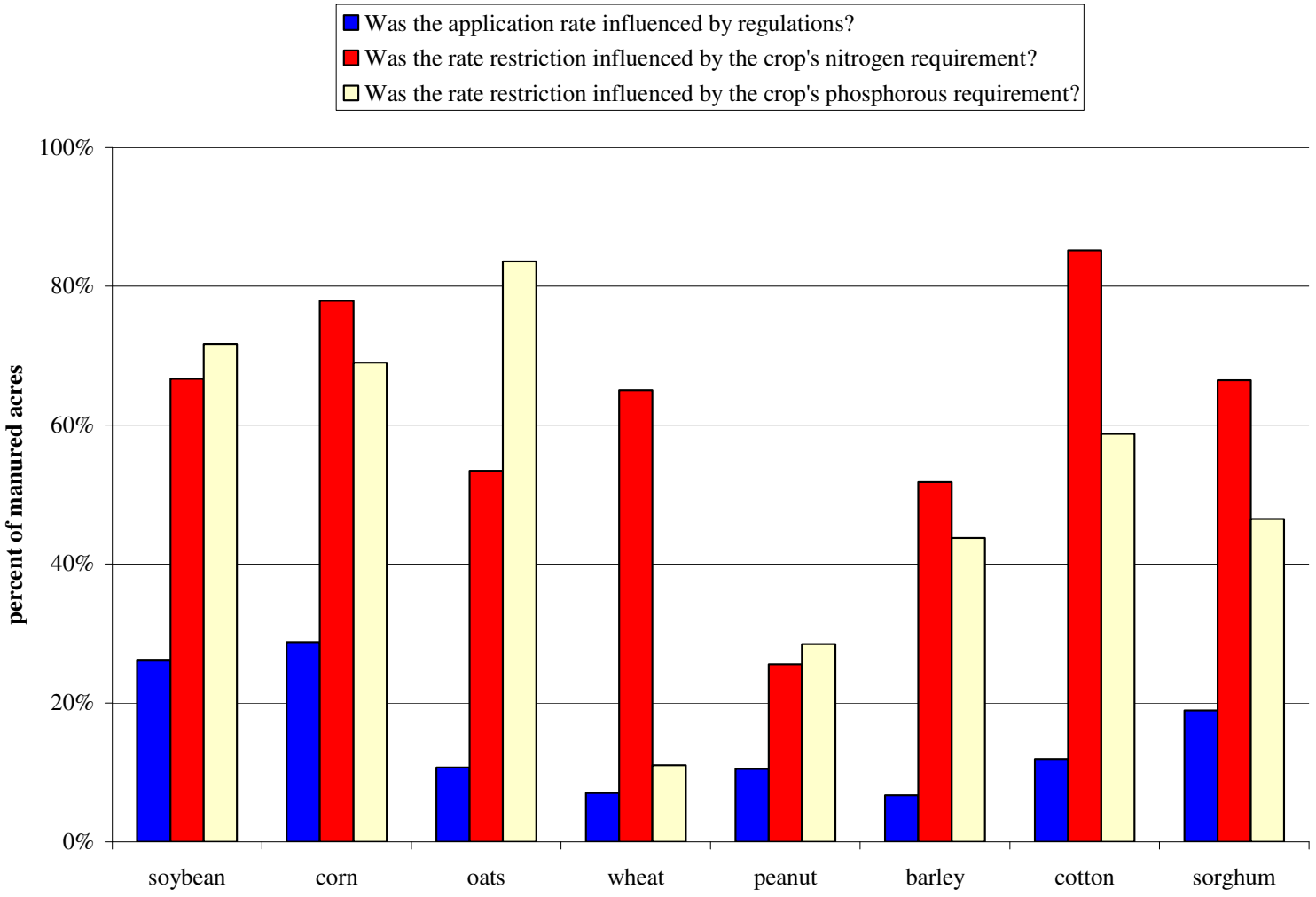

Figure 4. Manure applications influenced by national, state or location regulations: percent of manured acres

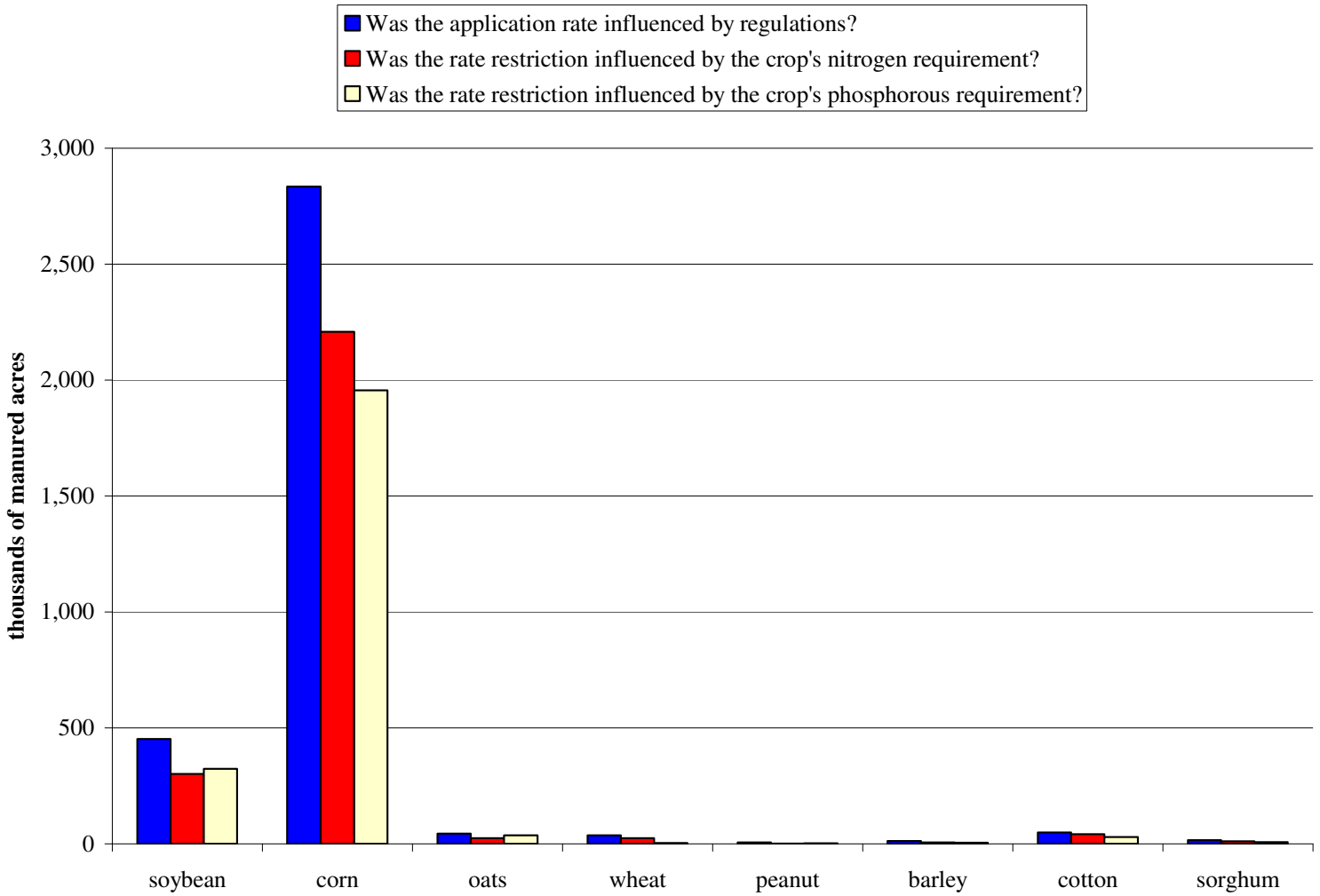

Figure 5. Manure applications influenced by national, state or location regulations: thousands of manured acres

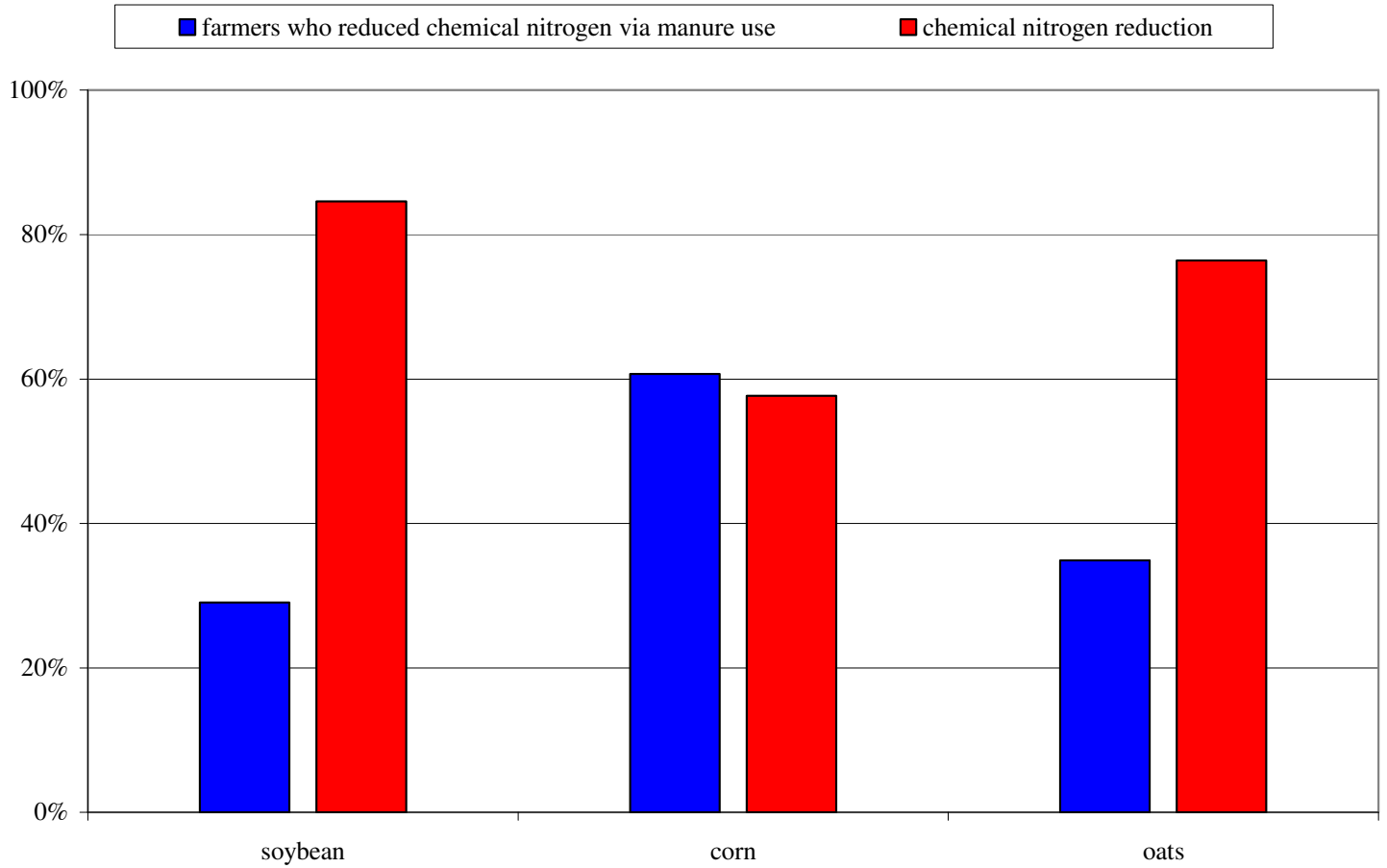

Figure 6. Substitution of manure and chemical nitrogen

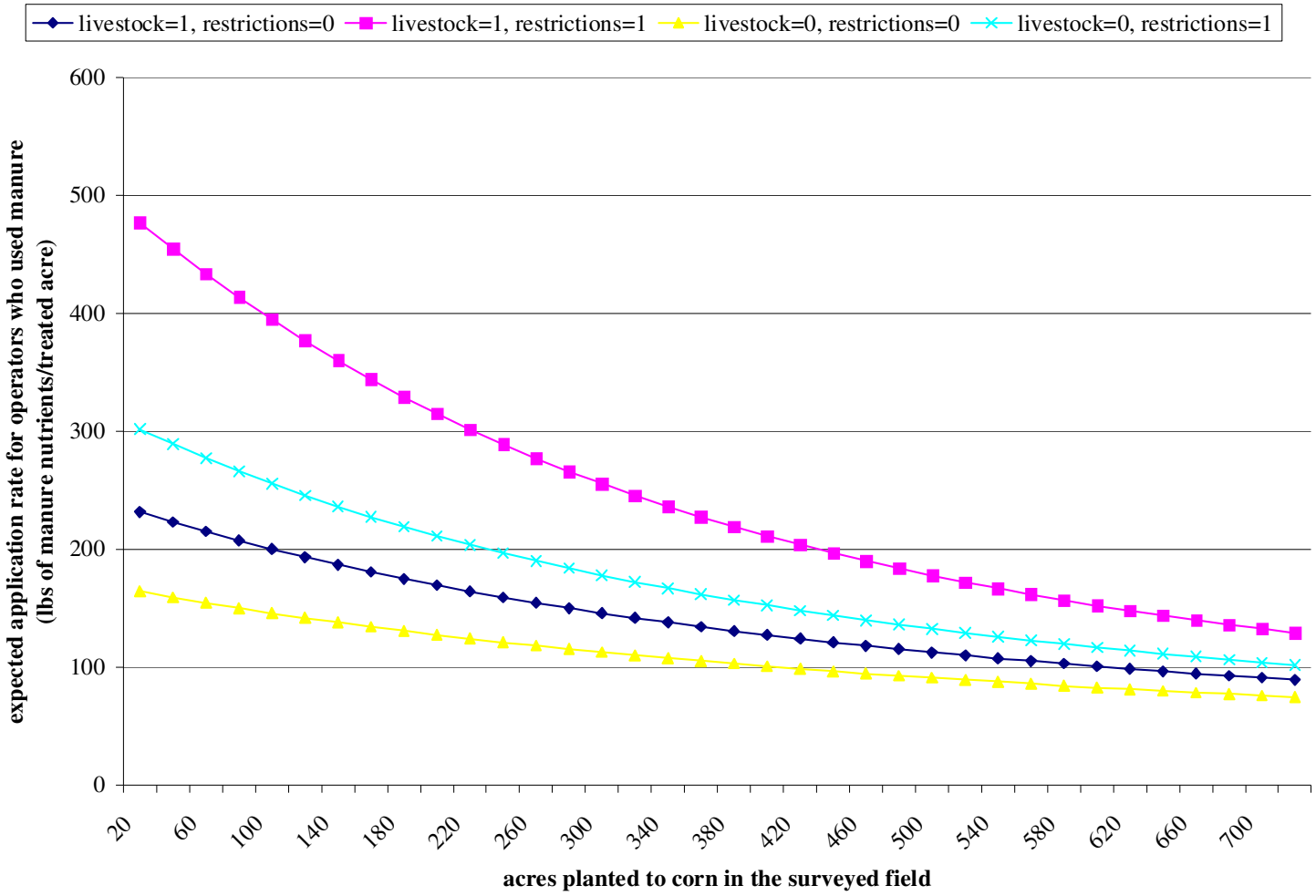

Figure 7. Expected application rates for corn producers who used manure and planted soybean on the majority of the field last year, did (livestock=1) or did not (livestock=0) manage livestock operations, and whose application rates were (restrictions=1) or were not (restrictions=0) influenced by Federal, State, or local restrictions, by planted corn acres