

7-1998

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Recommended Citation

Wang, Erda; Babcock, Bruce A.; and Hurley, Terrance M., "Crop Nutrient Needs Potentially Supplied by Livestock in Iowa, Illinois, and Indiana" (1998). *CARD Working Papers*. 220.

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Crop Nutrient Needs Potentially Supplied by Livestock in Iowa, Illinois, and Indiana

Abstract

Midwestern agriculture is moving toward large, specialized production units where harvested crops are shipped off the farm and livestock are raised on purchased feed. Many people are concerned that increased manure concentration from specialized livestock units poses an unacceptable environmental risk. The unequal distribution of livestock production across counties in Iowa, Illinois, and Indiana suggests that a disaggregated analysis of crop nutrient use and manure nutrient supply is needed to estimate the risk of excess nutrient losses to the environment. The authors analyze nutrient use and supply at the county level.

Disciplines

Agricultural and Resource Economics | Agricultural Economics | Economics

**Crop Nutrient Needs Potentially Supplied by Livestock
Manure in Iowa, Illinois, and Indiana**

Erda Wang, Bruce A. Babcock, and Terrance M. Hurley

CARD Working Paper 98-WP 194
July 1998

Center for Agricultural and Rural Development
Iowa State University

CROP NUTRIENT NEEDS POTENTIALLY SUPPLIED BY LIVESTOCK MANURE IN IOWA, ILLINOIS, AND INDIANA

Introduction

Traditional farming, where livestock are raised on home-grown feed and livestock manure is recycled as a replacement for crop fertilizer, is the type of production system that both populist farming activists and environmental advocates would like to maintain and enhance. But midwestern agriculture is moving towards large, specialized production units where harvested crops are shipped off the farm and livestock are raised on purchased feed. Many people are concerned that increased manure concentration from specialized livestock units poses an unacceptable environmental risk, in part, because the nutrient supply from manure is greater than the nutrient demand from crops.

The supply of nutrients available for crop production in a given region for a particular year includes purchased fertilizer nutrients, generated livestock nutrients, nutrients that become available from natural sources such as nitrogen from rainwater, and nutrients that are stored in the soil. Nutrients leave a region in the form of exported crops and livestock or when they are lost to the air and water. Increased livestock concentration in a region increases the proportion of crops used for feed locally and, in many cases, can result in the need to import feed into a region. The resulting increase in nutrient supply from livestock manure and the decrease in loss from crop exports worries environmental groups because it creates the possibility of increased nutrient contamination in the air and water.

On a statewide basis, slightly more than one-half of the corn and soybeans raised in Iowa is consumed within the state's borders. The rest is exported to other states and other countries. Only (approximately) 13 percent of the corn and 13 percent of soybeans produced in Illinois are fed locally to livestock and poultry. And approximately 23 percent of the corn and 25 percent of the soybeans produced in Indiana are used for

livestock and poultry production. These estimates suggest that there is a net loss of nutrients in these states. Not surprisingly, farmers in these states purchase large quantities of fertilizer.

But livestock production in Iowa, Illinois, and Indiana is not uniformly distributed across all counties. This unequal distribution suggests that a more disaggregated analysis of crop nutrient use and manure nutrient supply is needed to estimate the risk of excess nutrient losses to the environment. This report analyzes these factors at the county level, estimating the supply of nutrients available from livestock manure and poultry litter. The crops considered are corn, soybeans, wheat, and grain sorghum. The expected trend crop yields are used for the nutrient uptake calculations and animal production estimates and are based on the 1992 Census of Agriculture (USDOC 1992). Crop nutrient uptake estimates are based on information from Iowa State University Extension (ISU Extension 1996).

Methods and Assumptions

Estimation of county-level nutrient balances should account for the rate of nutrient uptake by crops, how livestock and poultry manure are managed, and differences in soil characteristics across counties (Killorn 1998). Detailed information about nutrient uptake and soil is available for all three states in this study. However, Iowa is the only state with detailed data about the types of manure handling systems in use. Thus, we are forced to apply the Iowa information to the other two states.

Nitrogen uptake is assumed to be 0.7 pounds per bushel for corn, zero for soybeans (Killorn 1998), 1.2 pounds per bushel for wheat, and 0.85 pounds per bushel for sorghum (Hoden 1998). Phosphorus (P_2O_5) uptake is assumed to be 0.375 pounds per bushel for corn, 0.8 pounds per bushel for soybeans, 0.6 pounds per bushel for wheat (ISU Extension 1996), and 0.385 pounds per bushel for sorghum (Hoden 1998). Multiplying these coefficients by expected crop yield and acreage in county results in total nutrient consumption by each crop. This consumption estimate is a baseline for crop nutrient demand.

Nutrient production coefficients from livestock manure are shown in Table 1. These are estimates and are based on typical livestock operations. Three coefficients are used. The first is an estimate of the total nutrients produced by the animal measured at the source. The second estimate assumes manure handling and storage systems using deep pits for hogs and layers, open feedlots for cattle, and scrape and store systems for dairy. These systems capture and preserve a moderate amount of the nutrient produced. The third estimate is for a lagoon-based system, in which only some of the nutrients produced are available for crop utilization.

Table 1. Nutrient production and retention by livestock and poultry enterprise and manure storage method

| Enterprise and Manure Storage | Nutrient Retention | | | | | |
|-------------------------------|--------------------|-------------------------------|----------|-------------------------------|------|-------------------------------|
| | Total | | Moderate | | Low | |
| | N | P ₂ O ₅ | N | P ₂ O ₅ | N | P ₂ O ₅ |
| | (Pounds) | | | | | |
| Finish Hogs | 10.7 | 4.2 | 8.0 | 4.0 | 3.2 | 1.7 |
| Beef Feedlot | 50.8 | 25.4 | 30.5 | 17.8 | 15.2 | 10.2 |
| Dairy Cow | 314.0 | 144.0 | 220.0 | 130.0 | 94.2 | 57.6 |
| | (Pounds per Bird) | | | | | |
| Layers | 3.0 | 3.7 | 2.1 | 3.5 | 0.75 | 1.5 |
| Broilers | 0.150 | 0.07 | 0.09 | 0.06 | 0.15 | 0.07 |
| Turkeys | 0.66 | 0.84 | 0.40 | 0.75 | 0.66 | 0.84 |

Note: Moderate storage nutrient retention assumes deep pit storage for hogs and layers, open feedlots for cattle, scrape and pit storage for dairy, and litter for broilers. Low storage nutrient retention assumes lagoons for hogs, feedlots for cattle, dairy and layers, and litter for broilers. Finish hog means farrow to finish and assumes 15.9 pigs per sow per year. Feedlots hold cattle on feed 210 days (Lorimor 1994; Sell 1998).

Individual operations may use a combination of manure handling systems. Each state and each particular county certainly exhibits a combination of systems. Thus, the actual percentage of nutrients recycled in a county or region will likely represent a composite of the systems. Farm-specific nutrient management plans based on cropping patterns, yield potential, and manure handling systems will more accurately reflect the actual nutrient balance in a region.

Results and Discussion

Figures 1 through 4 show county-level acreages for corn, soybeans, wheat, and sorghum in the three-state region in 1992. Figures 5 through 8 present 1992 trend yields. Figures 9 through 12 present 1992 county-level livestock production levels for hogs, milk cows,

cattle, and poultry. Figures 13 through 16 indicate percentage of crop uptake of nitrogen and phosphorus supplied by livestock and poultry manure under different manure nutrient retention rates in each county of the three states. Aggregation of the county data to the state level shows that corn, soybean, wheat, and sorghum production in Iowa require 1.119 billion pounds of nitrogen and 868 million pounds of phosphorus annually. Crop production in Illinois uses 1.070 billion pounds of nitrogen and 871 million pounds of phosphorus. And in Indiana, crop production requires 558 million pounds of nitrogen and 443 million pounds of phosphorus per year.

Under the assumption of no storage loss of manure nutrients, a total of 506 million pounds, 205 million pounds, and 222 million pounds of nitrogen, and approximately 100 million pounds, 98 million pounds, and 147 million pounds of phosphorus can be produced from livestock and poultry manure in Iowa, Illinois, and Indiana. These results indicate that with low nutrient losses manure nutrients produced by livestock and poultry can supply 45 percent of crop uptake nitrogen in Iowa, 19 percent in Illinois, and 40 percent in Indiana. With moderate nutrient retention (moderate storage loss), manure can provide 32 percent of crop uptake nitrogen in Iowa, 14 percent in Illinois, and 28 percent in Indiana. And under the scenario of low nutrient retention (high storage loss), manure can still provide 13 percent of crop uptake nitrogen in Iowa, 6 percent in Illinois, and 13 percent in Indiana. In addition, with total nutrient retention, manure can provide 28 percent of crop uptake phosphorus in Iowa, 11 percent in Illinois, and 33 percent in Indiana. With a moderate nutrient retention, manure is able to supply 25 percent of crop uptake phosphorus in Iowa, 10 percent in Illinois, and 31 percent in Indiana. With the assumption of low nutrient retention, manure can provide 12 percent of phosphorus in Iowa, 5 percent in Illinois, and 15 percent in Indiana (see Table 2).

Table 2. Percentage of crop nutrients provided by livestock and poultry manure under different manure storage losses

| | Iowa | | Illinois | | Indiana | |
|-----------------------|-----------|-------------------------------|----------|-------------------------------|---------|-------------------------------|
| | N | P ₂ O ₅ | N | P ₂ O ₅ | N | P ₂ O ₅ |
| | (Percent) | | | | | |
| No Storage Loss | 45 | 28 | 19 | 11 | 40 | 33 |
| Moderate Storage Loss | 32 | 25 | 14 | 10 | 28 | 31 |
| High Storage Loss | 13 | 12 | 6 | 5 | 13 | 15 |

If moderate nutrient retention can properly reflect a common practice for manure management in each state, then these results indicate that hog manure could be a major contributor of crop nutrients among different manure sources. Total manure contributed 32 percent of crop uptake nitrogen in Iowa, of which swine manure accounts for 19 percent, feed cattle manure 6 percent, dairy manure 5 percent, and poultry manure 2 percent (see Table 3).

Table 3. Percentage of crop uptake nutrients provided by different type of livestock manure under moderate storage loss

| | Iowa | | Illinois | | Indiana | |
|-------------|-----------|-------------------------------|----------|-------------------------------|---------|-------------------------------|
| | N | P ₂ O ₅ | N | P ₂ O ₅ | N | P ₂ O ₅ |
| | (Percent) | | | | | |
| Hog | 19 | 12 | 8 | 5 | 13 | 8 |
| Beef Cattle | 6 | 4 | 2 | 1 | 1 | 2 |
| Dairy | 5 | 4 | 3 | 2 | 6 | 4 |
| Poultry | 2 | 5 | 1 | 2 | 8 | 17 |
| Total | 32 | 25 | 14 | 10 | 28 | 31 |

These results imply that hog manure accounts for 59 percent of manure in Iowa, while beef cattle manure, dairy manure, and poultry manure accounted for 19 percent, 16 percent, and 6 percent, (see Table 4). Correspondingly, a total of 14 percent of crop uptake nitrogen is provided by livestock and poultry manure in Illinois: 8 percent is contributed by hog manure, 2 percent by beef cattle manure, 3 percent by dairy manure, and 1 percent by poultry manure. In Indiana, a total of 28 percent crop uptake nitrogen is contributed by livestock and poultry manure: 13 percent by hog manure, 1 percent by beef cattle manure, 6 percent by dairy manure, and 8 percent by poultry manure.

Table 4. Percentage of crop nutrients contributed by different types of animal manure under the assumption of moderate storage loss

| | Iowa | | Illinois | | Indiana | |
|-------------|-----------|-------------------------------|----------|-------------------------------|---------|-------------------------------|
| | N | P ₂ O ₅ | N | P ₂ O ₅ | N | P ₂ O ₅ |
| | (Percent) | | | | | |
| Hog | 59 | 47 | 58 | 50 | 46 | 26 |
| Beef Cattle | 19 | 21 | 14 | 10 | 4 | 6 |
| Dairy | 16 | 14 | 21 | 20 | 21 | 13 |
| Poultry | 6 | 18 | 7 | 20 | 29 | 55 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

Similar patterns can be observed for phosphorus production in each state. In the aggregate, 25 percent of crop uptake phosphorus is provided by livestock and poultry

manure in Iowa, hog manure accounts for 12 percent, beef cattle for 4 percent, dairy manure for 4 percent, and poultry manure for 5 percent. This means that hog manure supplies 48 percent of the total crop uptake phosphorus, and the rest is contributed by poultry, feed cattle, and dairy manure. A total of 10 percent crop uptake phosphorus is provided by livestock and poultry manure in Illinois: 5 percent by swine manure, 1 percent by beef cattle, 2 percent by dairy, and 2 percent by poultry manure. In Indiana, a total 31 percent of crop uptake phosphorus is supplied by livestock and poultry manure production: 17 percent by poultry manure, 8 percent by hog manure, 2 percent by beef cattle manure, and 4 percent by dairy (see Table 3).

This analysis shows that livestock and poultry manure could be a significant contributor to the crop nutrient requirement in each of the three states. But, relatively speaking, manure provides more nitrogen for crop production needs than it does phosphorus, as the soil quality is not taken into consideration. For example, under low storage nutrient loss in Iowa, manure can provide 45 percent of nitrogen and 28 percent of phosphorus. A similar phenomenon is observed in Illinois and Indiana.

Under moderate nutrient storage loss, there are 12 counties in Iowa where livestock and poultry manure can offer more than 50 percent of crop uptake nitrogen. Of those 12 counties, two (Adams and Dubuque) produce more than 100 percent of crop-required nitrogen. There are 35 of 99 counties in Iowa where manure can supply less than 20 percent of crop-required nitrogen. In Illinois, there are only four counties that can generate more than 50 percent of crop required nitrogen, and 82 of 102 counties generate less than 20 percent of crop-required nitrogen from manure. In Indiana 12 counties can provide more than 50 percent of crop-required nitrogen and of those 12 big manure producers, four counties (Decatur, Dubois, Elkhart, and Martin) produce more than 100 percent of their crop-required nitrogen (Figure 13).

With the assumption of moderate storage loss, there are nine counties in Iowa where manure can provide more than 50 percent of crop-required phosphorus. Of these nine counties, two (Allamakee and Grundy) produce more than 100 percent of their crop-required phosphorus. Similarly, there are 11 counties in Indiana where manure production provides more than 50 percent of crop-required phosphorus, and 19 counties produce more than 20 but less than 50 percent of their crop-required phosphorus (see

Figure 16). Finally, under the same assumption, there are only three counties (Stephenson, Clinton, and Jo Daviess) in Illinois where manure production can provide more than 50 percent of their crop-required phosphorus and 95 counties where manure provides less than 20 percent of total their crop-required phosphorus.

Two things are important about the state-level manure supply and demand information presented here. The first is that the percentages can only give an overall picture of manure production capacity in each state, and they do not reveal any county-specific information. However, due to the nonhomogeneous intensity of livestock and poultry production prevailing among the counties in each state, the amount of manure nutrients produced in some counties is much higher than that produced in others. As a result, those counties with a lower concentration of livestock production (Figures 9-12) cannot rely on manure as a major source for their crop nutrients. In addition, because it is costly to transport manure nutrients very far, it is not economical to move nutrients from one county to another.

Another aspect to be considered is that in some counties the quantity of nitrogen created in livestock production is far greater than is required for crop production, even without accounting for the nitrogen in the soil. For instance, under the condition of moderate storage loss, livestock and poultry production in Decatur County, Indiana, produces more than two times the nitrogen needed by its crops, and hog production alone contributes more than its entire crop uptake nitrogen. The county also produces 232 percent of its crop-required phosphorus. In addition, Martin, Elkhart, and Dubois Counties in Indiana each produces more than 100 percent of crop-required nitrogen and phosphorus. It is clear that counties such as these need to pay more attention to the issue of manure handling than other counties where such surpluses do not exist.

More accurate nutrient balances than those reported here can be estimated. First, this report did not consider the present nutrient status of soils. Where past phosphorus applications have resulted in high soil levels of phosphorous, crops do not need manure applications with sizeable phosphorus content. For example, soil in many parts of Iowa contains enough phosphorus to maintain crop yields for an extended period, i.e., more than 10 years, without further applications (Killorn 1998). Therefore, phosphorus originating from livestock and poultry manure will be completely useless for crop

production and subject to environmental loss. In areas where this is the case, the results of this report overestimate the crop's demand for nutrients supplied by manure. Additionally, our estimates do not account for nitrogen fixation from soybeans, which also reduces the demand for nutrients supplied by manure.

Finally, our estimated results are primarily shaped by the manure nutrient storage loss assumptions. The coefficients listed in Table 1 show that nitrogen and phosphorus nutrients will be diminished by 70 percent and 60 percent for the finishing hog manure as the manure management system is switched from no storage loss to high storage loss, and a similar range of nutrient losses is also experienced for the other types of manure. Furthermore, most of our conclusions are based on moderate nutrient loss, which may not be consistent with a particular county's situation. Thus, the capacity of livestock manure to provide crop-required nutrients could be significantly increased as manure handling systems are improved.

Conclusions

Manure nutrients from livestock and poultry production can contribute a significant proportion of nutrients used by crops in Iowa, Illinois, and Indiana. Under the condition of moderate manure storage loss, manure could provide 32 percent, 14 percent, and 28 percent of crop-uptake nitrogen, and 25 percent, 10 percent, and 31 percent of crop-absorbed phosphorus in Iowa, Illinois, and Indiana. With no manure storage loss, the capacity of manure to deliver crop nutrients can be much higher.

Relatively speaking, manure provides more nitrogen than phosphorous for crop production in each of the three states. Needless to say, this result is very sensitive to crop pattern variations. According to the assumptions used in this report, i.e., no nitrogen is required for soybean production, it is legitimate to conclude that the more soybeans grown, the greater the nitrogen surplus. But the balance for phosphorus use is relatively less sensitive to cropping pattern changes since phosphorus is needed for every type of crop production. The point is that the ultimate nutrient balance is determined by the type of crop pattern selected for livestock and poultry production areas. There is no question that manure could become a reliable source of crop-required nitrogen and phosphorus for local crop production if it can be shipped across county boundaries. The potential is

that Iowa farmers could significantly reduce their purchasing of commercial nitrogen and phosphorus fertilizer through more effective use of animal manure.

Due to the nonhomogeneous distribution of the livestock industry within each state, the overall state-level crop nutrient balance information in this report can be misleading. Real manure management issues must be addressed and analyzed at a more disaggregate level. Therefore, the attached county level manure production information should be useful for those who deal with issues of regional manure management.

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