ESTIMATED NUTRIENT MOVEMENT WITH ALTERNATIVE POULTRY LITTER APPLICATION RATES ON VARIOUS SOILS, USING DIFFERENT MANAGEMENT SYSTEMS

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The Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri has devoted significant effort over the past few years examining the interface between production agriculture and the environment at the farm and watershed scales. During the last two years the state of Missouri through an advisory panel, has determined that one area of major interest is the environmental performance of broiler producers. The Missouri Poultry Federation has cooperated in this effort to quantify the environmental and the financial performance of broiler producers.

Producer panels were convened in Lawrence and Barry counties, and McDonald and Newton counties. These two panels provided the data needed to develop the "representative" farm models used to evaluate current and alternative litter management systems.

The objectives of these studies are to

- assess the environmental impacts on surface and ground waters of adopting alternative poultry litter management strategies compared with current practices and
- assess on-farm financial impacts of adopting alternative poultry litter management strategies compared with current practices.

METHODOLOGY

The Agricultural Policy Environmental eXtender (APEX) model was used to simulate the crop production and environmental impacts of the current and alternative crop and management practices. This model is one of a system of models developed by the Grassland Soil and Water Research Laboratory, Agricultural Research Service, United States Department of Agricultural and the Blackland Research Center, Texas Agricultural Experiment Station in cooperation with other government agencies and universities.

APEX simulations were made to estimate the soil movement and loading of nutrients with

- current management practices,
- pasture forage change and commercial fertilizer instead of poultry litter,
- alternative changes in grazing management and/or pasture forages, and
- alternative forages harvested for hay with no grazing.

The Farm Level Income and Policy Simulation (FLIPSIM) model developed by Dr. James Richardson at Texas A&M University was used to simulate the economic viability of the representative broiler operation over a one to ten-year period. The simulated results include

- income statement,
- balance sheet,
- cash flow,
- income tax summary, and
- risk analysis.

Integration of the environmental and financial analyses helps producers and policymakers compare the environmental and economic benefits and costs of alternative litter management systems.

Description Of Key Nutrient And Tillage Processes

The APEX model contains over 300 equations to simulate many of the physical and environmental processes that impact soil nutrient accumulation and water quality. The following brief description is designed to help the reader understand the farm results that follow.

Nitrogen occurs in the soil in many forms. APEX simulates denitrification, mineralization, volitalization, nitrification, crop uptake, and nitrogen movement with water and sediment. When poultry litter is applied to crops, all of these processes interact to simulate the impacts of poultry litter. For example, 2 tons of poultry litter contain approximately 1 lb of elemental nitrogen in nitrate form, 111 lbs of nitrogen in ammonia form, and 64 lbs of nitrogen in organic form. These contents vary with ration and manure handling. The nitrate form is readily available for crop use, movement with water, or denitrification. The ammonia form may volatize (highly likely if not incorporated in the soil) or may be converted to nitrate form with nitrification. The organic nitrogen may move with sediment or be mineralized to nitrate form. Crop uptake varies from approximately 62 to 214 lbs/ac among the alternatives analyzed. Some of the alternatives require supplemental nitrogen to meet crop needs.

Phosphorus also occurs in the soil in many forms and goes through multiple chemical processes. APEX simulates mineralization, crop uptake, and phosphorus movement with water and sediment. To continue the example, 2 tons of poultry litter contain approximately 29 lbs of phosphorus in soluble form and 45 lbs of phosphorus in organic form. Phosphorus contents also vary with ration and manure handling. The soluble form is readily available for crop use or movement with water. The organic phosphorus may move with sediment or be mineralized to soluble form. Among the alternatives analyzed, crop uptake varies from approximately 9 to 21 lbs/ac.

APEX accounts for livestock grazing by removing biomass from the growing crop, depositing a portion of that biomass as dead crop residue to account for trampled forage, and adding livestock manure each day, all at rates consistent with the stocking rate of the livestock. The harvested crop nitrogen uptake for the grazing alternatives is estimated to be 62 lbs of nitrogen per acre. However, approximately 40 lbs of nitrogen in ammonia form and 17 lbs of nitrogen in organic form are returned to the pasture in the manure. The harvested crop phosphorus uptake is estimated to be 13 lbs of phosphorus per acre. Approximately 5 lbs of soluble phosphorus and 4 lbs of organic phosphorus are also returned in manure. The no-cattle, hay production only alternatives remove 85 to 214 lbs of nitrogen and 9 to 21 lbs of phosphorus with no nitrogen or phosphorus returned in manure.

Runoff water extracts nitrogen and phosphorus from the surface soil (upper centimeter [.4 in] in the APEX model). Incorporating nitrogen and phosphorus into lower soil layers has the potential to reduce nutrient movement with runoff water and sediment. Incorporation is accomplished in two ways, tillage and biological mixing, e.g., earthworms. Plowing before seeding or sprigging are the tillage practices considered in this study. Because so little tillage occurs in pasture and hay production, the surface soil layer builds up phosphorus with manure application. As a result, movement of nitrogen and phosphorus with runoff water and sediment is very sensitive to biological mixing and any tillage that occurs.

Both water and nutrients must be available in a soil layer for the roots to absorb the nutrients. Large amounts of nutrients in the near surface layers may change the crop availability and uptake in dry months when the soil surface lacks the moisture to carry nutrients into the roots.

Environmental data was obtained from the panel members and entered into the APEX model. Soil nutrient concentrations for the top 6 inches are based on panelist management discussions and University of Missouri research. Litter nutrient levels from the APEX fertilizer data were compared to University of Missouri estimates for consistency and then used. The APEX model determines the environmental performance at the representative farm edge of field, accumulates this edge of field data and moves it to the outlet(s) of the representative watershed. The environmental output data was used to validate the representative farms with the panel members.

Financial information obtained from the panel members was entered into the FLIPSIM model and simulated for 1998. The financial output was used to validate the farm with the panel.

Computer simulations for 50 years were used to generate a distribution of yields and environmental impacts across many alternative weather years. Daily rainfall, temperature, relative humidity, radiation, and wind were generated for 50 years based on Springfield, Missouri, weather statistics.

The panelists identified different management alternatives. For each alternative, financial and environmental data was gathered from the panel. Using the 1999 and 2000 FAPRI Baselines and the FLIPSIM model, a 6-year financial outlook for each alternative was developed. Panel members are then able to compare the financial and environmental results for each alternative to the baseline.

REPRESENTATIVE FARMS

Lawrence/Barry Counties Representative Broiler Farm

This farm has 160 acres of land with 130 acres of fescue pasture and 50 cow/calf pairs. It is split into 3 fields of 30, 50, and 50 acres each. Litter is applied at a rate of 2 t/ac annually.

Soil Characteristics: The Tonti silt loam (slope 2%, slope length 250 ft.) soil map unit was the dominant soil for this representative farm. It has a restrictive soil layer, fragipan that inhibits water, and nutrient movement which increases runoff.

Alternative Poultry Litter Management: The farm panel identified five alternatives to their current poultry litter management practice. One was to use no litter, another was to adopt an improved fescue/legume pasture, and the remaining three all converted from cow/calf grazing and hay production to hay production only with either Bermuda grass, alfalfa, or eastern gama grass hay. Hay production recycles more phosphorus than grazing but it does not recycle all the phosphorus currently applied. This results in phosphorus buildup in the soil and movement with water and sediment.

After discussing the results of these alternatives with the farm panel, the panel suggested that we consider another alternative, which was to maintain the current system but apply litter every other year and sell the litter not applied. The environmental and economic impacts of the current management and three alternatives (no litter, eastern gama grass hay production, and applying litter on alternate years with current management) are presented in Figures 1-3. The beginning soil phosphorus levels vary slightly because the 50-year period of simulation begins after 3 years of simulation to allow pasture and hay rotations to be established.

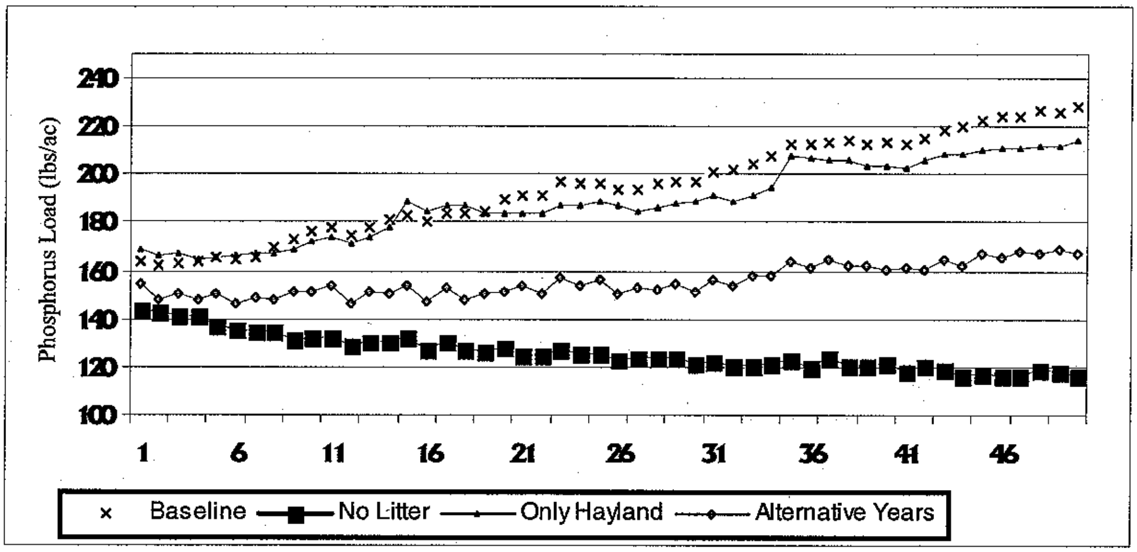


Figure 1. Projected Accumulated Soil Phosphorus Loading in the Top Six Inches of Soil

Soil Phosphorus Accumulations: The soil phosphorus accumulation in the upper six inches of soil relative to the baseline is reduced slightly by the hay production alternative and nearly reduced to zero by alternate year litter application. The no litter management reduces the soil phosphorus.

Annual Phosphorus movement: The annual phosphorus movement in runoff varies greatly from year to year due to the weather variability, particularly rainfall. There is a response to reduced litter application particularly in the later years of the 50-year period because the soil phosphorus available for runoff is much less.

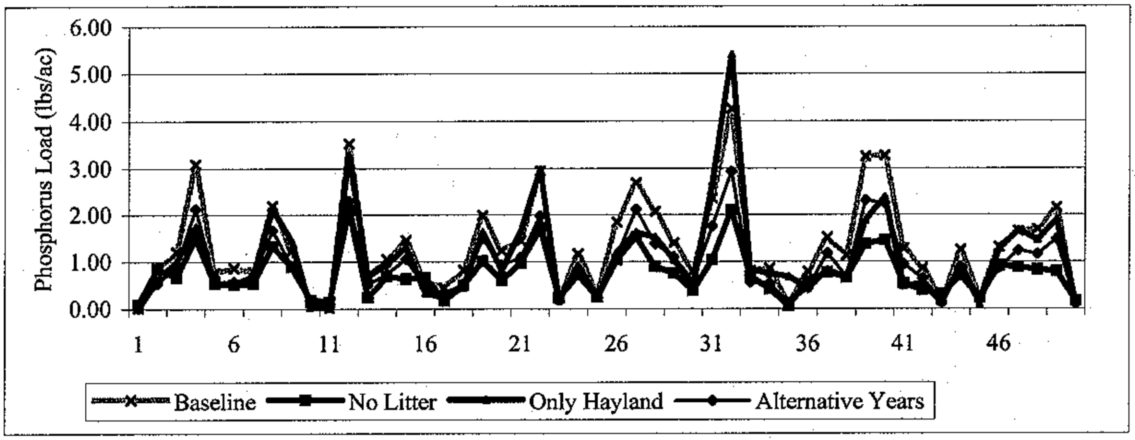


Figure 2. Projected Phosphorus Loading in Runoff

Economic Impacts: The hay production alternative is the only scenario that maintains a positive ending cash reserve throughout the simulation period (1998-2003). This is due to the increase in receipts associated with the sale of hay. The other three scenarios build a large deficit cash reserve the first five years (1998-2002). After 2002, all four scenarios show a sharp increase in ending cash reserves because the farm pays off their poultry houses.

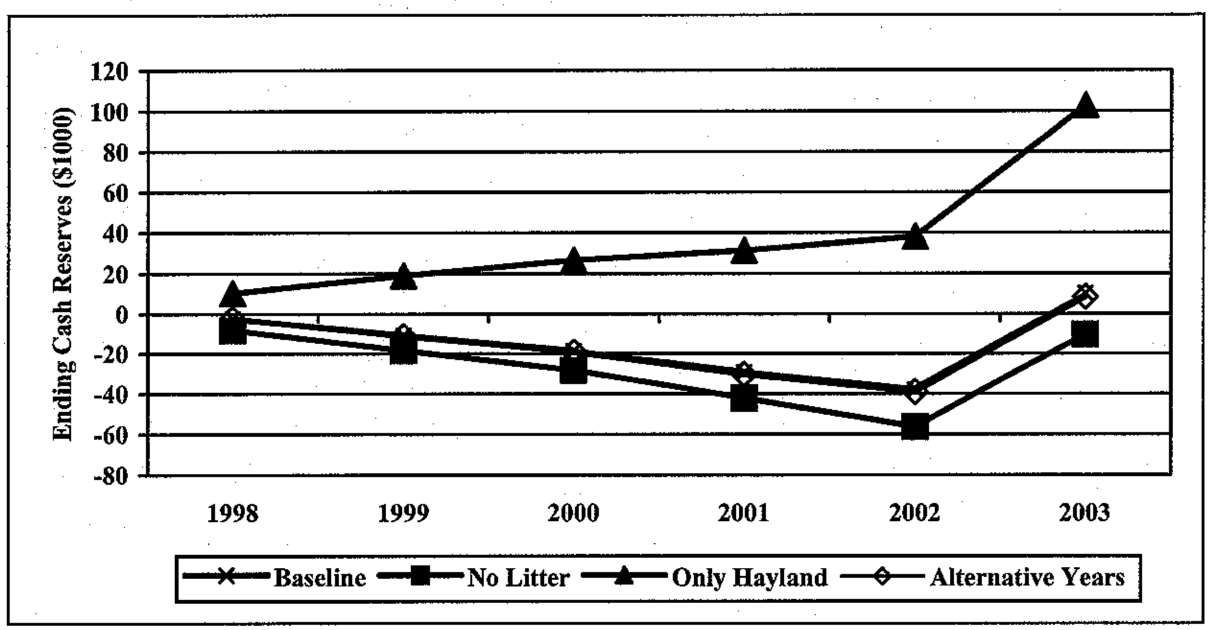


Figure 3. Ending Cash Reserves for Lawrence and Barry Counties
Contract Broiler Representative Farm

Mcdonald/Newton Counties Representative Broiler Farm

This farm has 200 acres (five 40 acre fields) of clover/tall fescue pasture with 50 cow-calf pairs. Hay is harvested once per year in the spring from one field. Litter is applied at a rate of 2 t/ac annually.

<u>Soil Charactistics:</u> Each soil map unit within the following two soil groups is simulated as the dominant soil for the entire field and farm.

- Soil map units Tonti silt loam (slope 2%, slope length 250 ft.), Hoberg silt loam (slope 2%, slope length 250 ft.), and Nixa very gravelly silt loam (slope 5%, slope length 200 ft.) are grouped as having a fragipan.

- Soil map units Clarksville very gravelly silt loam (slope 12%, slope length 200 ft.) and Crackerneck very gravelly silt loam (slope 5%, slope length 200 ft.) are grouped as non-fragipan located in karst regions.

<u>Alternative Poultry Litter Management:</u> The McDonald/Newton counties farm panel initially identified two alternatives to their current poultry litter management practice. The alternatives converted 20 acres of the 40-acre field that was harvested for hay to Bermuda grass hay or Caucasian bluestem hay production. Litter was applied at a rate of 2 t/ac annually.

After discussing the first two alternatives, a third was proposed that converted all fields to Fescue/clover pasture grazed 150 days each spring and summer by 300 stockers with 2 t/ac of litter applied annually. This alternative increased income, but had a negligible impact on nutrient movement.

Subsequently, the panel proposed two new alternatives. One applied litter every second year at 2 t/ac on Matua bromegrass/clover pasture grazed 150 days annually by 300 stockers. The other applied litter every third year at 2 t/ac on Matua bromegrass/clover pasture grazed 150 days annually by 300 stockers. These alternatives increased income and reduced phosphorus build up in the soil and phosphorus movement.

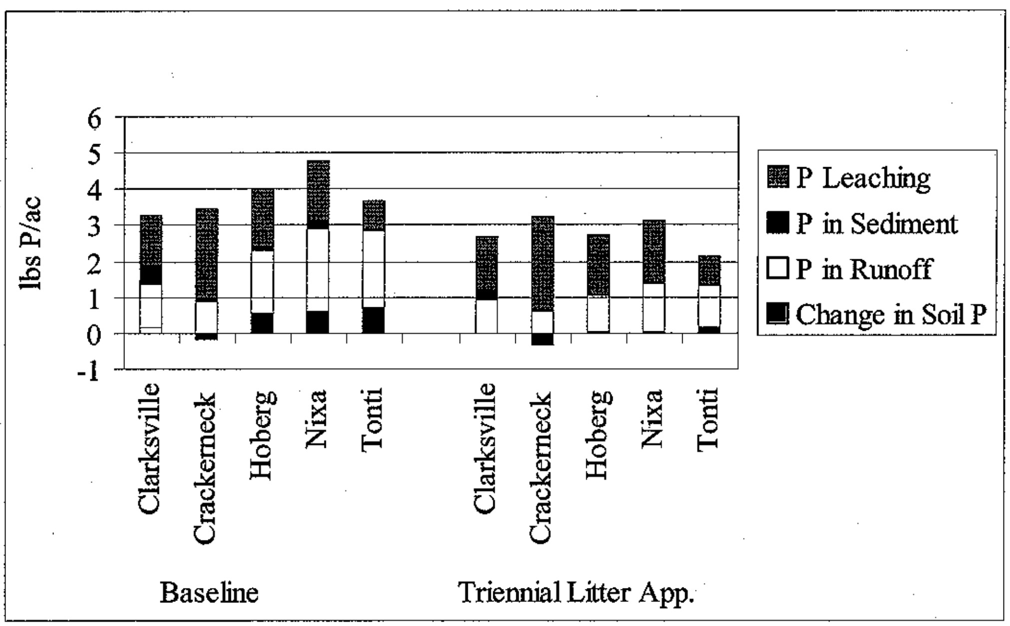


Figure 4. Phosphorus Movement Across Soils: Baseline Versus Triennial Litter Application

Phosphorus Movement Across Soils: Differences among the five soil mapping units are greater than the differences among alternatives. Figure 4 reflects the impact of slopes, the presence of restrictive soil layers, and the water storage capabilities of the soil for the baseline management and for the alternative with litter applied every third year. The Clarksville soil has a 12% slope and limited water storage which leads to high runoff, percolation, and sediment loss. The Tonti and Hoberg soils have low slopes (2%), but have fragipans that restrict percolation. The Nixa and Crackerneck soil have moderate slopes (5%). The Nixa soil has a fragipan. The Crackerneck soil has considerable rock and little water storage which results in high percolation.

CONCLUSIONS

Two types of management options appear to have some potential to improve the environmental and/or the economic impacts of poultry litter management. One is to produce forage crops instead of pasture because they recycle more nutrients and increase revenue at current prices. However, the local demand for forage may soon be saturated requiring more distant marketing, and adding transportation costs that may make this alternative economically unfavorable.

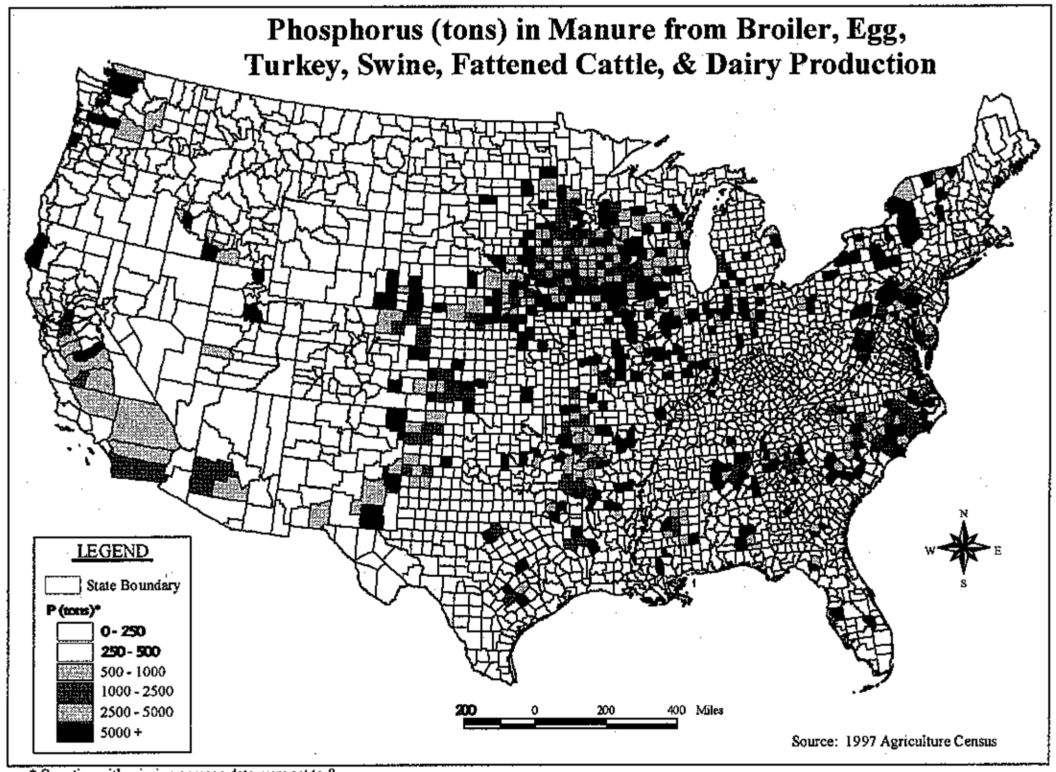
The second management option focuses on reducing the amount of litter applied and marketing, or removing, the litter off-site. The challenge with this option is that there may not be many local alternatives available for marketing this litter and what markets do exist may quickly become saturated. Figure 5 is a map of the potential phosphorus available from likely confined animal production and Figure 6 is a map of potential phosphorus needs of harvested crops by county based on the 1997 agricultural census. Many poultry production areas such as southwest Missouri have more phosphorus available than phosphorus needs.

Some combination of new products, new markets, reduction of phosphorus in manure, programs to encourage the development and adoption of new technologies, and research and education can lead to the appropriate solutions region by region. It is important that the discussions of alternatives focus on both the economic and environmental value of manure as a resource, not a waste.

Animal manures are valuable sources of nutrients, organic material, and beneficial organisms. Development of new value added products from poultry litter increases its monetary value directly. The benefits of recycling manures go beyond the direct monetary measures. It may also improve soil quality for future generations, sequester carbon, reduce nitrogen in runoff and leaching due to delayed nitrogen release, and extend the life of our mined phosphorus deposits. The value of these attributes should be included in the discussion.

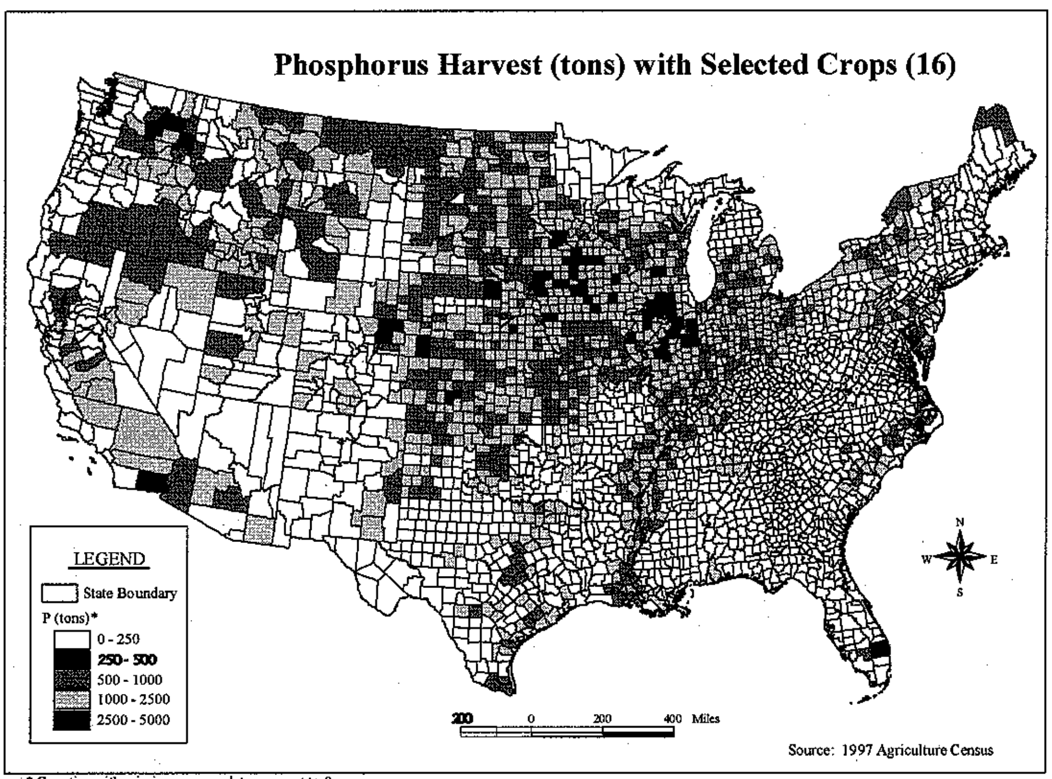
REFERENCES

1997 Census of Agriculture. United States Department of Agriculture, National Agriculture Statistics Service. Washington, D.C.



* Counties with missing acreage data were set to 0.

Figure 5. Potential Phosphorus Available from Confined Livestock



* Counties with missing acreage data were set to 0.

Figure 6. Potential Phosphorus Needs of Harvested Crops