Optimal Selection of Management Practices for Phosphorus Abatement: Using GIS and Economic Methodology in the Modeling of a Watershed

A Report of Progress
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In eastern Oklahoma and western Arkansas, poultry litter from broiler producing operations has saturated the land, causing nitrate leaching and runoff of potassium and phosphorus, harming water supplies. In response to this problem, our research had two objectives:

Objectives:

1) To identify combinations of Best Management Practices (BMPs) that will meet the Total Maximum Daily Load (TMDL) for the Eucha-Spavinaw watershed at least cost.

2) To estimate the firm-level costs and benefits of a proposed enterprise to convert poultry litter to methane (for use in generating electricity) and commercially-saleable nitrogen, phosphorus, and potassium fertilizers. If financially feasible, this plant could help meet the TMDL for the watershed.

Procedures, Objective 1:

For the first objective, a biophysical model has been developed to determine the best management practice (BMP) for each of 695 locations within the Eucha Spavinaw watershed. This model uses Geographic Information System (GIS) data together with a Soil Water Assessment Tool (SWAT) simulation model to identify the lowest cost BMP for each localized piece of land identified by the GIS data that will ensure that overall pollution targets are met. The BMPs were selected to minimize the total cost to: poultry producers within the watershed; the city of Decatur, Arkansas (the source of 25% of the phosphorus entering the lake); and users of water from the watershed. The management practices considered were 1) reduced application of litter, 2) use of alum-treated litter, 3) shipment of litter within and from the watershed, 4) improving the management of overgrazed pasture, 5) converting row crops to pasture, and 6) increased phosphorus abatement at the city of Decatur. The cost of treating water by the city of Tulsa and loss of recreation values to users of lakes Eucha and Spavinaw was also considered. The model was based on an Arcview-Swat GIS simulation that was formulated and calibrated by Storm et al. (2000) for the Eucha-Spavinaw watershed.

Findings, Objective 1:

Total costs to poultry producers, the city of Decatur, the city of Tulsa, and to recreation users of the lakes would be minimized when total annual phosphorus loads are reduced from 50.6 short tons to approximately 27.5 tons per year.

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The table below shows the costs to all parties as annual P loadings are reduced from 50.6 to 19.8 tons per year. Achieving lower annual P loadings reduces cost of phosphorus pollution, but raises cost of abatement. Total abatement plus damage costs are at a minimum when total phosphorus loading to the lake is reduced to 27.5 short tons (25 metric tons) per year.[*]

Maximum Phosphorus Loading (tons/year)	**Total Abatement Cost for Agricultural Enterprises** ($/year)	**Total Abatement Cost to Point Source** ($/year)	**Total Abatement Costs** ($)	**Total Damage Cost** ($/watershed)	**Sum of Total Abatement and Damage Costs** ($/watershed)
50.6	0	0	0	1,071,335	1,071,335
44.0	20,933	0	20,933	658,335	679,268
38.5	55,136	0	55,136	370,707	425,843
33.0	100,963	0	100,963	152,246	253,209
27.5[a]	**134,672**	**33,113**	**167,785**	**52,281**	**220,066**
22.0	139,446	101,207	240,653	7,693	248,346
19.8	160,688	112,484	273,172	0	273,172

[a] Level of phosphorus that minimizes costs to all parties.

The reduction in annual soluble phosphorus loading to 27.5 tons would be accomplished by the following:

a. Removing 11 of the 12.8 tons of phosphorus currently discharged by the city of Decatur, Arkansas.
b. Applying alum to 70,000 tons (out of 92,400 total tons) of litter. Thus most of the applied litter would be treated with alum which was assumed to reduce the runoff of soluble phosphorus by 75% as compared to the runoff of phosphorus from untreated litter.
c. Applying no more than 1 ton of litter on the 57,500 acres of well maintained pasture.
d. Limiting applications of litter to 2.7 tons or less on the 32,000 acres harvested for hay and hauled from the basin.
e. Converting all 16,000 acres of overgrazed pasture to well maintained pasture.
f. Converting 2,700 of the 6,500 acres of row crop to hay land.
g. The solution indicated that it was not necessary to ship litter out of the basin at the present, although the long term prospects are being investigated.

Further research is needed to examine the capability of current programs to provide incentives, regulations, or both for relevant parties to implement these changes.

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[*] The USGS land use land cover digital maps indicated the Eucha-Spavinaw basin contained 245,000 acres. However, only 112,000 acres are in agricultural use. There are approximately 32,000 acres of land harvested for hay, 57,500 acres of well maintained pasture, 16,000 acres overgrazed pasture, and only 6,500 acres of cultivated land. Some 957 poultry houses were located from photographic maps. These houses were assumed to produce 92,400 short tons of litter per year. Only some 53 short tons of phosphorus from all sources were assumed to enter the lake each year. Of this, 37 tons were attributed to agricultural sources while 12.5 tons were from the city of Decatur and about 3.5 tons was from forest and other background sources.

Procedures, Objective 2:
The results from Objective 1 do not consider the beneficial impact of a proposed waste-to energy-plant or the addition of a recently proposed discharge facility by the city of Centerton, Arkansas. If a waste-to-energy plant were to begin operation, it could convert some of the litter to energy and saleable fertilizer, further reducing the cost of limiting phosphorus loading. Moreover, under reasonable assumptions, the processing plant may actually be profitable, which would greatly reduce cost of limiting phosphorus loading.

Thus, the second objective of the research is to investigate the economic viability of such a plant. Since a major cost of processing litter is cost of transporting it to a processing plant, a key feature of the analysis is a GIS analysis. Rather than using straight-line “as the crow flies” map distances between poultry producers and the proposed processing plant, actual road miles were used to calculate transportation cost from each poultry farm to the plant. The difference is potentially significant because of the relatively small number of adequate roads in this section of the state.

Costs of several technologies were considered, using economic engineering estimates of both fixed (capital) costs and variable (processing) costs. Since actual production processes and output markets can be quite variable, another key feature of the analysis is a risk assessment of the proposed plant. Since the production process is new, there is uncertainty about the yield of electricity, nitrogen (N), Phosphorus (P), and Potassium (K) that can be obtained from each ton of litter. In addition, since prices of these outputs are uncertain, the analysis treated each of these variables as statistically random, with specified probability distributions. The simulation also assumed variability in capacity utilization of the plant, such as might result from operating difficulties or variability in “quality” of litter.

Findings, Objective 2:
Financial feasibility simulation of the proposed plant over a 20-year planning horizon, using conservative assumptions (although the supplied engineering coefficients have not been verified by us), would achieve an internal rate of return on investment of 16%. Years with low or negative returns are few and mild so that viability of the firm is not threatened. This simulation assumed that the firm receives the federal “green energy” tax credit. Without the “green energy” credit, the plant would achieve an internal rate of return of -2%.

Work in Progress
Research extending this project is linking these two objectives together, so that the impact of the processing-plant’s litter-reducing benefits for the entire watershed can be measured. Preliminary results suggest that including the processing plant in the analysis could significantly reduce the cost of reducing phosphorus loading in the watershed. Further research is needed to verify the engineering coefficients of the processing plant.

Publications

Prado, Baltazar. 2005 An Economic Examination of Potential Electricity and Fertilizer Production in the Eucha-Spavinaw Watershed "M.S. Creative Component," Dept. of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, 44 pp.

Sadhu, Joy. 2005 Evaluation of Economic Gains to Broiler Producers by Modulating Ventilation and Using Alum for Ammonia Control, M.S. Thesis, Edmond Low Library, Oklahoma State University, 84 pp.

Papers at Meetings.

Stoecker, A.L. R. Alviar, and T. Ancev, "Use of GIS Simulation and Mathematical Programming to Determine Economically Efficient Pollution Abatement in a Watershed", Inv. Paper, International Seminar on Agricultural and Natural Resource Economics, Medellin, Columbia, Dec. 2004.