DETERMINING WHOLE-FARM CONSERVATION SOLUTIONS FOR SMALL FARMS IN NORTHEASTERN UNITED STATES

T. L. Veith

Pasture Systems and Watershed Management Research Unit
USDA-ARS
University Park, Pennsylvania

L. T. Ghebremichael

Rubenstein School of Environment and Natural Resources
University of Vermont
Burlington, Vermont

ABSTRACT

Optimal water quality pollution control comes from locating critical nonpoint source pollution areas within a watershed and applying site-specific conservation practices. However, management decisions are implemented at the farm-level. While site-specific conservation practices are crucial for environmental protection, reduction strategies must have economic benefit to the producer if they are to be implemented and maintained. Increased fuel, fertilizer, and grain prices are greatly impacting farmer profits in small (<100 ha) northeastern U.S. farms, which have historically imported sizable quantities of nutrients (feed and fertilizer) and corn grain and use proportionally high levels of fuel due to non-contiguous fields and hilly topography. Economic and environmental impacts of conservation practices suitable to the small farms of the northeastern United States were evaluated using field-level experiments, a process-based farm model, and watershed-based tools. The goal was to determine sets of practices acceptable to farmers in the region that minimized nutrient imports and treated or controlled excess nutrients while maintaining or increasing long-term farm profits. Potential practices include precision feeding, intensive forage production, crop substitution, cover crops, and manure application techniques.

Keywords: whole-farm simulation, feeding, reduced inputs, forage management, manure incorporation

INTRODUCTION

Increased prices in fuel, feed, and fertilizer are contributing to difficulties by farmers in the northeastern United States to maintain a profitable system. These farms are small relative others in the United States and specialize in livestock production (mostly dairy) with crop production (typically pasture, hay, and corn) as needed to support the livestock. For example, 89% of cattle farms in New York State have fewer than 200 cattle while 92% operate on fewer than 200 ha (USDA-NASS, 2007). These farming systems have little flexibility to accommodate large increases in cost or nonpoint source pollution, regardless of temporal permanence of any such fluctuations. Hence, there is a growing need for the latest in precision conservation to achieve higher economic returns with reduced environmental impacts. Low-productivity of homegrown feed (including grazing land) coupled with low utilization of these feeds in the animal diet and, consequently, reliance on purchased protein and energy feed supplements to meet animal requirements for growth and production (milk, meat, and others) all contribute to the phosphorus (P) imbalances on these farms.

Precision conservation, as defined by Barry et al. (2003) and Delgado et al. (2005), involves the use and analysis of spatial technologies and procedures to maximize environmental conservation on and off the farm in addition to maximizing farm productivity, which is the focus of precision agriculture. In the agricultural production systems of the northeastern United States, the tools required for successful precision conservation necessarily extend beyond enhanced electronic and mechanical technologies to include the experience of the farmer and local extension personnel as well as process-based simulation modeling of the whole-farm system and its watershed. For example, designing an automated feed system that varies by cow-specific milk production and composition may be realistic for large dairy farms but is much less feasible for a small family-owned dairy. The same is true of milking robots, which ease the work of dairy operators and allow cows to schedule milking. Use of enhanced technology for crop production is limited by the smaller-sized fields of the region, which, for a given farmer, are often separated by several miles of road traversing ridge and valley topography. These examples support the idea that implementation of precision conservation, as conceptually defined above, must be customized according to the regional context of the agricultural production system to which it is applied. This paper presents several precision conservation techniques effective on the small farms in the northeastern United States.

PRECISION CONSERVATION PRACTICES

Soil P build-up, and subsequent loss to water bodies, is one of the major environmental concerns in the northeastern United States. Soil P build-up is largely caused by more P being imported to farms as feed and fertilizer than exported in milk, manure, and other products. To address this issue, efforts need to focus on assessing and identifying sources areas for P. Most northeastern U.S. dairy herds are fed dietary P levels in excess of the published recommendations because of the misguided belief that high P diets improve animal reproductive performance. However, studies have shown that feeding P in excess of their requirement will significantly impact P excretion beyond the economic impacts associated with cost of the excess feed (Dou et al., 2002; Ebeling et al., 2002). Dietary P that is consumed but not used within the body for maintenance, growth, milk production, or reproduction is excreted directly in manure, increasing the amount of P in the manure that needs to be managed within the limited available land area.

By modifying dietary P rates to match National Research Council recommendations (NRC, 2001), the amount of P in manure can be reduced and farmers benefit economically by purchasing less dietary P supplement. The effect of this modification on the whole-farm system was evaluated for two typical dairy farms in New York, through extensive communication between farmer and extension agent and also through simulation with a process-based, whole-farm model called the Integrated Farm Systems Model (IFSM; Rotz et al., 2009). Manure P excretion was reduced 33%, on average, by on-farm manipulation of ration P rates based on different animal groups: lactating cows, dry cows, and heifers (Cerosaletti et al., 2004). Using farm-specific field and livestock input, IFSM was used to simulate this strategy in which dietary P needs were matched by animal group (Ghebremichael et al., 2007). For both farms evaluated, this strategy resulted in average annual reductions in manure P (negative percentage change from zero: the status quo; Scenario 1, Fig. 1) while increasing the farmers' net returns (positive percentage change from zero; Scenario 1, Fig. 1).

Another critical source of P imbalance for these small farms involves the manner in which forages grown on-farm are managed and used for livestock feed. Typically these farmers classify corn silage crops as a higher management priority than grass or small grain forage crops, particularly during the narrow weather windows for ideal planting and harvesting. IFSM was used to model the impact of intensively managing grass forage production and harvesting at the expense, when necessary, of the corn silage crop. The high-quality grass forage then reduced or replaced corn silage feed as much as possible while maintaining good body condition of the cows. As compared to the status quo (zero percent change in Fig. 1), this strategy (Scenario 2, Fig. 1) reduced soluble P losses from both farms modeled, improved the farms' overall P balances, and increased net returns. Because these farms are in a ridge and valley physiographic region, most of the corn fields are on the hillsides and are at high risk for erosion and associated P loss. Scenarios 3 and 4 (Fig. 1) evaluated the environmental and economical impacts of converting 50% and 100%, respectively, of the corn crops to grass. While there was no appreciable change in farm P balance due to this conversion, erosion and associated P losses were reduced.

Focusing on on-farm forage management and utilization has a high potential of benefiting both farm budgets and the environment. In this study, as productivity of homegrown grass forages increased, feed P imports decreased, which in turn promoted recycling and re-use of P on the farm, improved the efficiency of farm resource utilization, and increased farm net-returns. The increase in net return with increased prioritization of grass forage over corn silage could be substantial as corn production costs increase.

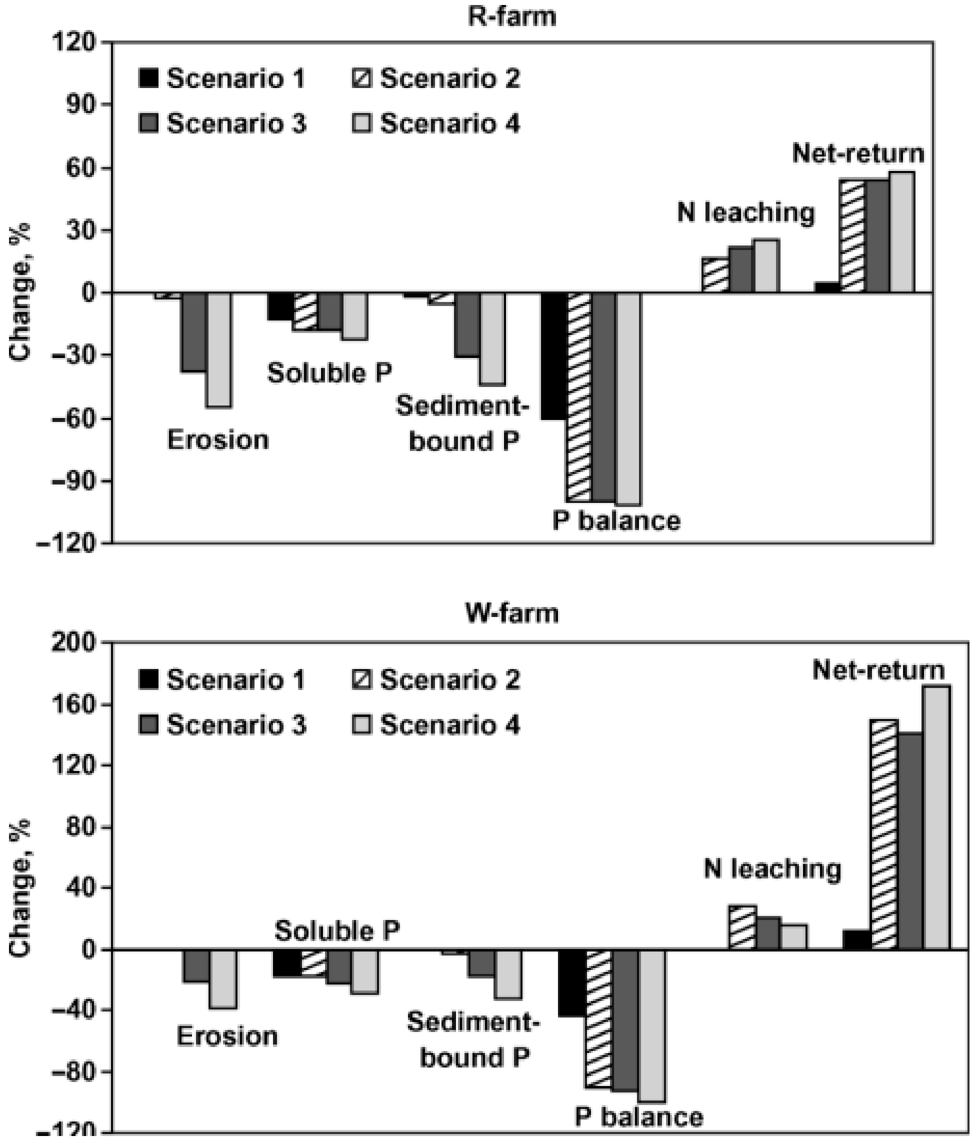

Fig. 1. Percentage change of Integrated Farm Systems Model (IFSM)-simulated outputs for precision feed management (PFM)-based farm strategies relative to the status quo (0%). Scenario 1 = precision diet formulation and delivery; scenario 2 = scenario 1 + increased grass productivity and a high-forage diet; scenario 3 = scenario 2 + 50% corn land converted to grass; scenario 4 = scenario 2 + 100% corn land converted to grass; P = phosphorus; N = nitrogen.

To offset increasing operating costs, some farmers in New York that had been purchasing corn grain as feed have begun planting additional acres of corn silage and cutting back on corn grain purchases. Due to the climate, corn grain crops are typically only feasible in the southernmost areas of New York. However, corn grain provides energy requirements for cattle and, thus, is purchased by dairy farmers to supplement the corn silage, and grass that they grow on the farm for feed.

Because corn is more erosive than grass or small grains, several additional scenarios were simulated to determine if enough corn could be grown to offset the rising costs and if it could be done without increasing sediment, nitrogen (N), and P loss or if there were other techniques that would work as well or better (Ghebremichael et al., 2009). Two of the farms in the region expanded their corn silage production by 3% of the cultivated farm area. IFSM simulation showed that this expansion increased sediment and sediment-bound P losses by 41% and 18%, respectively, from the farms. Implementing no-till planting controlled about 84% of the erosion and about 75% of the sediment-bound P that would have occurred from the conventionally-tilled, expanded corn production scenario. Similarly, implementing a conventionally-tilled cover crop with the conventionally-tilled, expanded corn production scenario controlled both erosion and sediment-bound P, but to a lesser extent than no-till corn with no cover crop.

In addition to erosion from the corn land, surface P loss from broadcast application of manure is a large source of loading to the streams. Surface broadcast of dairy slurry through daily-haul is common in this region (Dou et al., 2001). By applying manure on grassland and no-till cropland, sediment losses through erosion are minimized but losses of both dissolved and particulate P can be substantial (Kleinman and Sharpley, 2003; Sharpley and Kleinman, 2003). Incorporation techniques have been shown to reduce surface P losses, particularly dissolved P, but create more potential for higher runoff and erosion by extensively disrupting the soil surface (Kleinman et al., 2002). Several novel techniques for incorporating manure P into the root zone of the soil with minimal disturbance of the soil surface have been studied through field experimentation and farm-level modeling. Further details of the results described briefly here will be forthcoming in the scientific peer-reviewed literature.

Five manure application methods were evaluated under simulated, uniform rainfall on 10 m x 10 m well-drained, silt loam plots that were enclosed by berms inside fields of corn residue. The application methods were surface application without incorporation, surface application with chisel till incorporation, shallow disk injection, pressurized injection, and banded application with aeration. Shallow disk injection was found to result in the lowest average runoff P concentration of the five methods (Fig. 2). Shallow disk injection directly incorporates manure into soil, which lessens the availability of manure solids and nutrients to overland flow. Shallow disk injection disturbs the soil less than traditional deeper injection methods and was found to preserve roughly 40% of surface residue. Compared with traditional deep injection, shallow disk injection requires low draft power and is less likely to be blunted by the frequent large rocks encountered in the rocky soils of the northeastern United States. Compared with manure incorporation by tillage, shallow disk injection requires only one pass through the field per application event. Furthermore, shallow disk injection equipment is readily adapted to existing manure application equipment and does not require expensive retrofitting, as with pressurized injection. Indeed, shallow disk injection equipment is the least costly of the four incorporation methods. As a result, shallow disk injection meets both the environmental and economic criteria for precision conservation in the northeastern United States and is being promoted to the farmers as an effective conservation management practice.

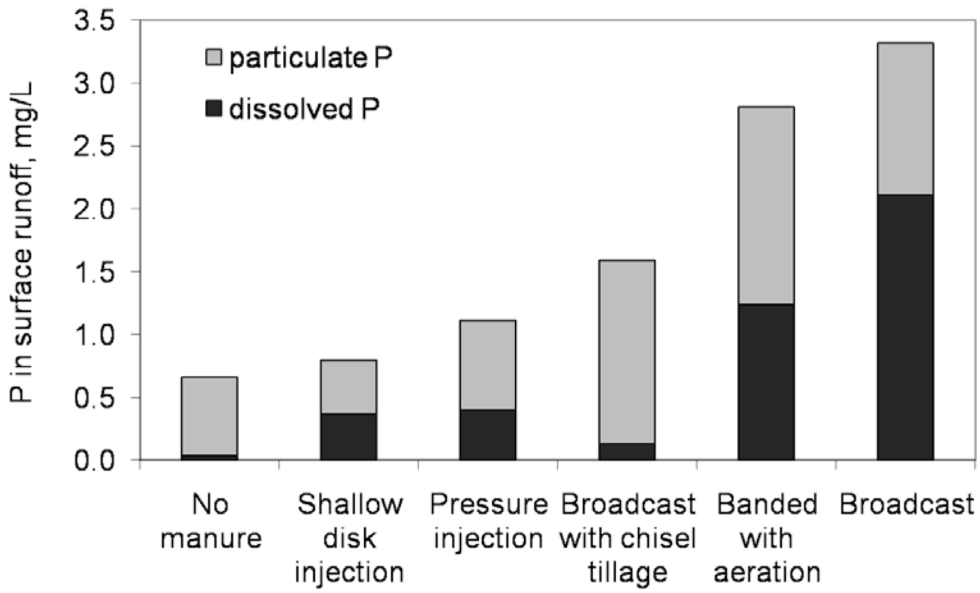

Fig. 2. Particulate and dissolved surface P from each of five manure application methods to well-drained silt loam plots covered in corn residue.

In addition to farm-wide management, precision conservation in terms of optimizing conservation practices within the watershed has been shown to reduce implementation costs while maintaining or reducing pollutant loads at the outlet. Despite the need to control nonpoint source water pollution at the watershed level, implementation and maintenance of the conservation practices generally occur at the farm level. Thus, cost implications of establishing and maintaining environmentally effective conservation practices are often a crucial factor in selecting and adopting those conservation practices in accordance with the concepts of precision conservation. Maintaining explicit field-level boundaries enables further customization of conservation practices to best meet the economic needs of the farm system. A methodology developed by Veith et al. (2003) for determining cost-effective farm- or watershed-level scenarios through optimization was customized and applied to a New York farm and watershed (Gitau et al., 2004; 2006). By optimizing conservation practices with regard to the critical source areas of the watershed, both in terms of pollution loss and pollution control costs, solutions were found that removed an identical amount of P for $10/kg less per year than proposed conservation practices. Additionally, fencing efforts by the Conservation Research Enhancement Program (CREP) to exclude cattle access to streams within Cannonsville Watershed, New York was estimated through field and modeling study to reduce in-stream deposition of manure P by 32% (James et al., 2007).

CONCLUSIONS

Precision conservation is important in minimizing the impact of agricultural systems on the environment while maintaining farm profitability. However, the set of tools and techniques used to implement precision conservation is dependent on the characteristics of agriculture within the region of focus. In the small, livestock-based farms of the northeastern United States, precision conservation techniques involve an expanding focus from cow to field to farm to watershed and must accommodate both animal and crop production systems within a given farm. Tools tend to be less specialized and automated than those used on large farm operations. Because farms in the northeastern United States are small and nestled among forests and shrubbery within a mountainous terrain and generally have noncontiguous fields, their management practices notably impact off-farm portions parts of their watershed(s), including multiple fields and farms downstream. Thus, precision conservation in the northeastern United States requires evaluation of both the whole-farm system and the watershed.

REFERENCES

Barry, J.K., J.A. Delgado, R. Khosla, and F.J. Pierce. 2003. Precision conservation for environmental sustainability. J. Soil Water Conserv. 58(6):332-339.

Cerosaletti, P.E., D.G. Fox, and L.E. Chase. 2004. Phosphorus reduction through precision feeding of dairy cattle. J. Dairy Sci. 87(7):2314-2323.

Delgado, J.A., C.A. Cox, F.J. Pierce, and M.G. Dosskey. 2005. Precision conservation in North America: Special section introduction. J. Soil Water Conserv. 60(6):340-341.

Dou, Z., D.T. Galligan, C.F. Ramberg Jr., C. Meadows, and J.D. Ferguson. 2001. A survey of dairy farming in Pennsylvania: Nutrient management practices and implications. J. Dairy Sci. 84(4):966-973.

Dou, Z., K.F. Knowlton, R.A. Kohn, Z. Wu, L.D. Satter, G. Zhang, J.D. Toth, and J.D. Ferguson. 2002. Phosphorus characteristics of dairy feces affected by diets. J. Environ. Qual. 31(6):2058-2065.

Ebeling, A.M., L.G. Bundy, J.M. Powell, and T.W. Andraski. 2002. Dairy diet phosphorus effects on phosphorus losses in runoff from land-applied manure. Soil Sci. Soc. Am. J. 66(1):284–291.

Ghebremichael, L.T., P.E. Cerosaletti, T.L. Veith, C.A. Rotz, J.M. Hamlett, and W.J. Gburek. 2007. Economic and phosphorus-related effects of precision feeding and forage management modeled at a farm-scale. J. Dairy Sci. 90(8):3700-3715.

Ghebremichael, L.T., T.L. Veith, P.E. Cerosaletti, D.R. Dewing, and A.C. Rotz. 2009. Exploring economically and environmentally viable northeastern US dairy farm strategies for coping with rising corn grain prices. J. Dairy Sci. 92(8):4086-4099.

Gitau, M.W., T.L. Veith, and W.J. Gburek. 2004. Farm-level optimization of BMP placement for cost-effective pollution reduction. Trans. ASAE 47(6):1923-1931.

Gitau, M.W., T.L. Veith, W.J. Gburek, and A.R. Jarret. 2006. Watershed level best management practice selection and placement in the Town Brook Watershed, New York. J. Am. Water Resour. Assoc. 42(6):1565-1581.

James, E., P.J.A. Kleinman, T.L. Veith, R.C. Stedman, and A.N. Sharpley. 2007. Phosphorus contributions from pastured dairy cattle to streams of the Cannonsville Watershed, New York. J. Soil Water Conserv. 62(1):40-47.

Kleinman, P.J.A., and A.N. Sharpley. 2003. Effect of broadcast manure on runoff phosphorus concentrations over successive rainfall events. J. Environ. Qual. 32(3):1072-1081.

Kleinman, P.J.A., A.N. Sharpley, B.G. Moyer, and G.F. Elwinger. 2002. Effect of mineral and manure phosphorus sources on runoff phosphorus. J. Environ. Qual. 31(6):2026-2033.

NRC. 2001. Nutrient Requirements of Dairy Cattle. National Research Council. 7th ed. Natl. Acad. Press, Washington, DC.

Rotz, C. A., M. S. Corson, D. S. Chianese, and C. U. Coiner. 2009. Integrated Farm System Model (IFSM): Reference manual version 3.2. Pasture Systems and Watershed Management Research Unit, USDA Agricultural Research Service, University Park, PA. Available at http://www.ars.usda.gov/Main/docs.htm?docid=8519 (verified 30 April, 2010).

Sharpley, A.N., and P.J.A. Kleinman. 2003. Effect of rainfall simulator and plot scale on overland flow and phosphorus transport. J. Environ. Qual. 32(6):2172-2179.

Veith, T.L., M.L. Wolfe, and C.D. Heatwole. 2003. Optimization procedure for cost-effective BMP placement at a watershed scale. J. Am. Water Resour. Assoc. 39(6):1331-1343.

USDA-NASS. 2007. Table 11. Cattle and Calves – Inventory and Sales: 2007 and 2002.Census of Agriculture-County Data. vol 1, chap 2: New York [online]. Available at http://www.agcensus.usda.gov/, “2007 Census”, “Full 2007 Census Report”, “State and County Reports-All Counties by State Table”, “New York”, “Table 11” (verified 30 April, 2010). USDA National Agricultural Statistics Service, Washington, DC.