CONSERVATION INNOVATION GRANTS

Final Progress Report

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Demonstration of Enhanced Technologies for Land Application of Animal

Nutrient Sources in Sensitive Watersheds

Project Background

Land application of animal manure has been implicated as a contributing factor of non-point source pollution. The application of these manure nutrient sources are often made without adequate knowledge of its nutrient content, resulting in application rates far in excess of crop removal. In addition, application methods have lead to inefficient use of manure nutrients and are pollution potentials. Consequently, residual fertility has increased, and so have N and P leaching from soil environments.

Several pieces of legislation have been enacted to limit non-point source pollution including the Clean Water Act of 1972 (Public Law 92-500) and the Safe Drinking Water Act of 1974 (Public Law 93-523). The result of these legislative acts is that the USDA-NRCS has been tasked with carrying out training for, and implementation of nutrient management plans (NMPs). To develop a NMP, a manure sample must be collected and analyzed for total nitrogen (TN) and total phosphorus (TP) on an annual basis. The justification for requiring manure samples in NMPs is that published manure nutrient characteristics show significant variability as far as actual concentrations (Dou et al., 2001; and Lindley et al., 1988).

Because laboratory analysis of submitted manure samples can require up to two weeks, it has been suggested that on-farm methods for determining TN and TP would allow producers to rapidly assess concentrations of nutrients in manure for calculating application rates. Although rapid methods exist for determining TN and TP (Cheschier, 1985; and Van Kessel et al., 1999), their use has not been widely adopted. A rapid on-farm method for determining TN and TP in swine slurry has been proposed by Higgins et al. (2004a,b), to provide producers with a means of predicting manure TN and TP to calculate application rates to meet crop and NRCS-NMP requirements. However, even if manure samples are collected and nutrient determinations are made, an obstacle for producers is how to alter land application rates, where to vary rates, and how to apply manures effectively.

Previous work suggests that surface application, in contrast to sub-surface injection, may result in elevated odor levels and volatilization of ammonia (Jokela and Côté, 1994). Pain et al. (1991) demonstrated that subsurface manure injection reduces odor emissions by up to 80%. Misselbrook et al. (1996) reported that subsurface injection reduced ammonia volatilization by up to 79% on grasslands when contrasted with surface application. The resulting quantity of nitrogen available for crop growth is significantly reduced (Schmitt et al., 1995). Manure applied to soil in addition to fertilizer N is a significant source of excessive soil NO_3-N (Angle et al., 1993; Jokela, 1992). There is evidence that manure increases NO_3-N leaching compared to fertilizer N applied at equivalent nitrogen rates (Jemison and Fox, 1994; Roth and Fox, 1990). Because most NMPs are based on plant N requirements, this invariably means that P is over-applied relative to needs. Although many soils have considerable P sorption capacity, residual inorganic and organic P will build up with time, resulting in increasingly greater opportunities for P to leach and/or be carried to sensitive waters by surface runoff. Once soil test P values exceed crop requirements, the potential for P loss far exceeds any agronomic benefits (McDowell et al., 2002).

Recent work suggests that surface application of manure to pasture lands can make grasses less palatable to animals, and may create disease and pathogen problems. Warner and Godwin (1988) have shown that injection prevents the risk of crop contamination and pathogenic activities. Manure injection or incorporation provides more available nutrients to the plant (Schmitt et al., 1995). Injection was determined to cause grass damage as a result of soil disturbance in two investigations (Hann et al., 1987; and Warner and Godwin, 1988). Alternately, Hultgreen and Stock (1999) found a yield increase associated with manure injection and incorporation.

Objectives

The major issue with respect to watershed protection is how to manage manure application in ways that are not detrimental to water, soil, and air quality. The goal of this project was to demonstrate state-of–the-art nutrient management technologies and application practices for the purposes of educating producers and custom waste applicators. These techniques enable producers to maintain crop yields while increasing nutrient utilization, and reduce the potential for leaching and off-site movement of nutrients. This project was accomplished by completion of the following objectives:

- Demonstrate a rapid on-farm model for determining total N and P contents using historical manure data and solids content.
- Demonstrate the efficacy of guidance aids and map-based manure application to reduce the potential for offsite nutrient movement in environmentally sensitive areas when used in conjunction with subsurface and aerated injection application systems.
- Demonstrate the use of variable-rate manure management and real-time solids content sensing for injection application systems.
- Quantify the environmental benefits and costs associated with producer adoption of one or more of these technologies and management practices.

Methods

To accomplish the goals and objectives of this project a series of cooperator visits were conducted at multiple sites within three physiographic regions of Kentucky. During the course of this project these site visits were designed to establish the current level of technology being utilized to manage land application of animal nutrient sources, to quantify existing soils fertility levels, and to characterize environmentally sensitive sites within close proximity to cooperator farmsteads. For the balance of the project, investigators l worked with the producers to adapt one or more technologies to improve manure utilization and reduce the potential for off-site movement of nutrients.

***GPS Survey of Application Areas* --** Manure application sites were mapped to establish landscape features (i.e., slope, soil types, cropping history, existing conservation practices) and to identify the physical relationship to environmental sensitive areas. These data were used to establish best management practices (BMPs) that will attain optimum crop yields while protecting soil and water resources.

Establish Background Soil Fertility Levels -- Background grid soil samples were collected, analyzed, and cataloged using a geographic information system (GIS). Use of GIS will facilitate fertility level comparisons in accordance with changes in management practices for the duration of the project. Soil samples were extracted using Mehlich III, and were analyzed via ICP (inductively coupled plasma spectroscopy) to determine reactive phosphorus (P_m) and exchangeable cations (Ca, Mg, K, Zn). Soil nitrate (NO_3^-) and ammonium (NH_4^+) was determined by a colorimetric microplate procedure after extraction in 1M KCl. Soil pH was determined by using a water solution. The purpose of measuring soil phosphorus (Mehlich III), and extractable (KCl) nitrate and ammonia was to demonstrate how over-application of manures increases these concentrations, which could lead to manure applications being restricted to P based rates and environmental degradation.

***Rapid On-Farm Nutrient Determination* –** Manure nutrient concentrations were predicted using the rapid on-farm method described in Higgins et al. (2004) for farm cooperators. Manure application rates were determined using NRCS-590-KY (2001) standards and University of Kentucky Cooperative Extension Service (AGR-1, 2002) fertility recommendations, which were easily, determined using a pre-existing spreadsheet (Sikora, 2004). Higgins et al. (2004 b) established a protocol for using an historical record of waste nutrient content to develop predictive models of agitated and un-agitated manure slurries. Prior to land application this prediction technique was utilized to establish TN and TP concentrations. Laboratory analysis of validation samples were compared to the predicted TN and TP values to determine the accuracy delivered. Regressions of actual versus predicted TN and TP nutrient concentrations provided linear equations containing slopes and intercepts. The model will be complied and entered into a unique spreadsheet in time to be utilized by the producers during the next regular pumping. Validation samples were collected and analyzed for each unique spreadsheet. The initial data collection to characterize manure nutrient concentrations on each farm was completed during year 1 of the project. Validation samples collected during the second year of the project were used to assess the accuracy of the rapid on-farm determination approach.

Demonstration of Technology -- The project demonstrated three levels of technology adoption: 1) model prediction of nutrient content; 2) model prediction with map-based application to avoid sensitive areas; and 3) model prediction with map-based variable rate technology (VRT) applications. The overall goal of the project was to have producers apply manures to achieve the greatest soil/manure contact. Participating producers and their operations were evaluated for implementation of innovative technologies, which could be used to increase crop yields while at the same time reduce nutrient losses, and thereby reduce pollution potential to soils and water resources. For simplicity we are proposing application classes that may involve 1) subsurface injection, 2) surface application with incorporation, and 3) incorporation using an aerator. In addition, precision ag technologies used to control manure application rates using pinch valves and variable rate controllers were demonstrated. GPS mapping of fields was employed to identify sensitive areas, which include distances from blue line streams, sinkhole locations, crop yield potential, and existing soil fertility. Low technology systems using a simple on/off control were demonstrated to limit land application of manures based on environmentally sensitive areas.

To support the demonstration portion of this project a 3000 gallon capacity tank applicator was obtained with both aeration and subsurface sweeps for injection of manure on both pastures and cropland. An existing tractor equipped with GPS receiver, automated steering, light-bar guidance, and variable-rate control was utilized to pull the applicator. The applicator-tractor combination was moved to cooperator farms to allow producers to gain firsthand experience with each of the application technologies.

The University of Kentucky's Woodford County Animal Research Center (ARC) was utilized as a demonstration site for all possible levels of technology – model prediction, map-based VRT application, automatic guidance, and real-time solids sensing. This site served as a proving ground for the most innovative technologies that are appropriate for land application on animal manures in Kentucky. Producers, custom applicators, government agency personnel, and other interested parties were invited to the ARC for training and field days in conjunction with this project.

Producer Feedback

Feedback on manure sampling, the rapid on-farm nutrient content determination, and the results they provide was discussed and shared with involved participants. Issues related to existing and innovative manure application practices were discussed to evaluate adoptability and acceptance for use by the participant and possibly other producers. Farm visits occurred before, during, and after manure applications to assess and compare the effect of existing application practices and innovative technologies on soil fertility and crop yield. Also, the opinion of the participating producer was documented to determine acceptance.

Project Location and Size

Demonstration farm sites were selected by partnering with producers who are respected and considered leaders in the farming community. Ten producers in Harrison, Marion, Nelson, Hardin, Breckinridge, Davies, and McLean counties expressed willingness and intent to cooperate in this project (Appendix A). These producers are located in four different physiographic regions of Kentucky. The size and scope of these animal producers ranges from a cluster of small (approximately 100 sows on each farm) operations to those in excess of 4,000 sows owned by an individual operator.

Producer Participation

Every effort was employed to provide innovate technologies to all participating producers. In addition, we included as many producers as possible in the project to insure a minimal number of long-term participants throughout the duration of the project. Since every farm is different, at least one producer in each physiographic region of the state was selected as the location for demonstrations of innovative practices for each level of technology used in the project. As part of our relationship with the producers, we agreed to not use their actual names. From this point on participating producers will be referred to by one of the following names: Booker, Beam, Blanton, Mattingly, Moore, and Williams.

Plan and Timeline

We proposed a three year project, which was extended to four years after a one year no-cost extension was granted. The first year we developed TN and TP prediction models, soil sample, conduct attitude surveys, and evaluate the nutrient management plans of cooperator farms. Levels of technology were added through the duration of the project depending on existing producer equipment, manure application methods, and willingness to adopt new manure management practices. Manure samples were collected during the first land application, which were used to develop nutrient prediction models. Validation and demonstration of the prediction models can be conducted for the producer during the next land application of manures. The timeline depended on the size of the manure storages and whether a variable for seasonal effects was needed in the models. Yield comparisons between producer manure application rates and practices to recommended application rates using innovative practices were conducted using a simple pairwise observation analysis. In some cases these pairwise plots were used as demonstration sites to highlight yield potential and management strategies.

Benefits and Transferability

The benefits of this study were increased producer awareness of manure nutrient concentrations and changes in nutrient concentrations as stored manures land applied. The end result of this project was that swine producers may adopt new technologies and management practices that lead to improve application methods and better utilization of manure nutrients. The adoption of injection or incorporation of manure into the soil reduces the amount of ammonia volatilization and odor emissions. Incorporation reduces off-site movement of N and P nutrients, as well as pathogens. Mapping technologies and soil testing defined land limiting application areas that were avoided. Results of soils analyses created an awareness of environmental concerns, which lead to better matching of nutrient application to crop needs and elimination of application in environmentally sensitive areas and improved environmental quality. Unpublished field study results of soil analyses have demonstrated how over-application of manures causes increases in soil fertility levels without increasing crop yields. This project reinforced to producers that over-application of manure nutrients is not an effective use of a valuable nutrient source, and leads to potential environmental pollution.

This project assembled a team of scientists and researchers who were able to not only improve producer adoption of these technologies, but could work toward getting the technology into the appropriate NRCS technical guides. Observations and results of this project were documented and compiled for the purposes of generating best management practices (BMPs) for publishing technical guides and extension publications. Although this project deals with swine producers the approaches used in this study could be transferred to dairy and beef cattle producers, as well as industrial liquid wastes.

Evaluation

Studies have shown that incorporation of manures at application has a net positive effect on air, soil, and water quality. The scope of this project was to demonstrate to producers the efficacy of innovative incorporation practices in the hope that they would adopt practices that are appropriate for their operations. Producer attitudes were evaluated at the beginning of the project, and again at the conclusion to determine how their awareness of manure nutrient concentration, conservation practices, and willingness to adopt technology had changed. A more quantitative environmental assessment was be done by comparing soil and manure sample analyses data that provide an indication of how innovative manure management techniques improve soil and water resources.

Project Summary

Outcome I – Land Application Timing

One aspect of this project was to develop and distribute a questionnaire to the producers involved with the project. Questionnaire results showed that producers used concrete storages beneath slatted floors, earthen storage structures, and a combination of the two methods for storing liquid manures. The intent of these storages is to provide adequate storage at the time interval necessary for land applications. For many of the producers land applications of manure are restricted to times when crops are not growing in fields and when field conditions are not well suited for high traffic loads (wet conditions). Additionally, manure applications must be delayed during conditions that include frozen ground or when significant rainfall events are eminent.

One of the questions of the survey was “How often do you land apply manures?” All of the producers responded twice a year. The next question was “What time of the year do you land apply?” Again, all of the producers responded “Spring” and “Fall”. However, as part of this project, we measured the size of the pits under the slatted floors, quantified the number of animals in the barn, their housing period, and their average weight. These data were used to calculate the volume of manure generated by the housed animals. The results indicated that the swine barns used for farrowing were found to hold only a month of waste. Most swine nursery and some finishing barns held approximately three to four months of liquid, while the majority of finishing barns held between four to six months of liquid manure.

Lessons Learned

Older facilities do not have adequate storage capacity, leading to manure applications under inclement conditions. Newer facilities are constructed with deeper pits, allowing the producers the opportunity to apply manures in best possible conditions.

Outcome II – Soil Fertility

The issue that liquid swine manure pits were being pumped monthly and quarterly was a concern to us, because this meant that the nutrients in the manure were being land applied to pastures and open grass areas, and were not being fully utilized and removed by the crop. We followed up on this issue by requesting and collecting soil test data. Soil test data showed that the areas immediately around the cooperating farmsteads contained high concentrations of phosphorus compared to soils in more distant fields. The increase in soil fertility from repeated applications of manure showed that many of the cooperating producers have reached a level of fertility (P) that would require reducing their manure application rates to either a crop phosphorus removal rate or phosphorus index. In a few cases, the soil fertility on some fields required that the producer lower application rates to apply phosphorus based on half the removal rate.

On one particular farm the soil test phosphorus had increased by four-fold (@175 lb STP to @800 lb STP) in six years of operation. In working with this producer we found that they considered the manure to be a waste and pumping down the waste storage ponds as a task. Irrigation data collected from this farm showed that approximately 55,000 gallons of swine manure was being applied per acre. Calculations showed that approximately 400 and 600 pounds of phosphorus and nitrogen, respectively, were being land-applied to this field. Even though land application calculations indicated and demonstrations showed that 7,000 gallons per acre would provide the same yield. In addition, the producer also applied a supplemental application of nitrogen as a side-dress application, even though they had the ability to turn off the application using GIS and variable rate technology on the equipment. The result was that the corn lodged before it could be harvested and the soils increased in fertility.

Lessons Learned

The main point that we learned from this project was that livestock producers did not have a nutrient management plan; they were not sampling the manure to determine nutrient concentrations; and, they were not calculating application rates based on a realistic yield goal. Applications of animal nutrients were being applied to areas closest to the farmstead. Soil test data shows that phosphorus levels decrease as the distance to the farmstead increases. It was not until this project was about to end, that producers began to consider manure a resource and this was attributed to the rising cost of inorganic fertilizer.

Outcome III – Nutrient Modeling

This project was originally designed to develop a rapid method for determining nutrient concentrations in manures on the farm using historical data. Benefits of on the farm nutrient testing include improved productivity, increased profits, improved environment. Improved productivity comes from an increased efficiency from proper nutrient applications. Demonstration of a rapid on-farm model for determining total N and P contents using historical manure data and solids content was shown to succeed on manures stored beneath slatted floors that are removed for land application on a regular frequency. The nutrient concentrations in earthen storage ponds have show more variability because of their exposure to the elements and the infrequency of removal for land application. Interviews with producers, during the course of this project, revealed that they did not sample their manures nor did they plan to. Even a large swine CAFO did not sample their manures and relied on the data from our project to supply analysis to regulators. We did not believe that the producers would utilize the model, even if we built it for them. Therefore, we modified the nutrient modeling aspect of the project to demonstrate, to the producers, that the nutrient concentrations of their storages would not change as long as their management did not change, and that they could use this information to develop manure application rates. To this end manure samples collected by depth from unagitated earthen manure storage structures was accomplished in spring of 2005 to demonstrate that complete agitation of manure storages was not necessary to achieve uniform land applications of manure N. A paddleboat was used to facilitate manure sample collection. Positioning the boat, near the center of the earthen storage structures, was accomplished using ropes. Sample collection started just below the pond surface and was repeated at 0.6 m increments continuing to the sludge layer (approximately 2.4 m, 8-ft). Sample collection was accomplished using a three-meter apparatus holding a 1-liter wide-mouth HDPE Nalgene bottle in a cradle. Manipulating an actuator rod allowed the bottle to be opened and closed at various depths.

The data from this project showed that nutrient concentrations (TN, TP, and TS), from the six earthen storage structures, were not significantly different ($\alpha > 0.05$) as depth increases. However, TN, TP, and TS concentrations were significantly different ($\alpha > 0.05$) when the layer of sedimentary deposits was reached (NOTE: depth of sedimentary deposits varies depending on depth of structure). There were however significant differences with the Williams Farm Stage 3 and the Booker farm, which can be seen in Table 1. The differences in Stage 3 can be explained by the lack of solids in this structure. Table 2 shows a significant reduction in solids in Stage 3 compared to Stages 1 and 2. The Booker farm underwent major remodeling after the first year of sampling. Years 1 vs.2 and 1 vs. 3 showed significant differences, but years 2 vs. 3 revealed no significant differences. The reasoning behind this is due to a disruption of the structure's equilibrium. The storage structure was enlarged thus altering the solid concentration and microbial content. It took about two years before the structure was able to attain equilibrium and produce consistent concentrations. Table 2 shows the data averaged from 2005-2007 in terms of four depths (surface, shallow, deep, bottom). Stage one of the Williams shows oddities when compared to the as expected results from stages 2 and 3. Reasoning for his could be based on its relatively small size and high amounts of solids. It could be argued that the entire Stage 1 on the Williams Farm structure is a sedimentary deposit. All six earthen structures have statistically higher ($\alpha < 0.05$) TN, TP, and TS concentrations in the sedimentary deposits depth than concentrations above this depth.

Table 1. SAS nutrient concentration results comparing years 1 vs. 2, 1 vs. 3, 2 vs. 3.

Difference of Least Square Means

Williams					
Stage - 1	Year	Pr>[t]	Booker	Year	Pr>[t]
	1 vs. 2	0.02		1 vs. 2	0.01
TN	1 vs. 3	0.44	TN	1 vs. 3	0.02
	2 vs. 3	0.83		2 vs. 3	0.98
	1 vs. 2	0.9		1 vs. 2	0.02
TP	1 vs. 3	0.48	TP	1 vs. 3	0.03
	2 vs. 3	0.33		2 vs. 3	0.82
	1 vs. 2	0.97		1 vs. 2	0.01
TS	1 vs. 3	0.41	TS	1 vs. 3	0.05
	2 vs. 3	0.36		2 vs. 3	0.6
Stage - 2			Beam		
	1 vs. 2	0.02		1 vs. 2	0.07
TN	1 vs. 3	0.61	TN	1 vs. 3	0.12
	2 vs. 3	0.06		2 vs. 3	0.97
	1 vs. 2	0.15		1 vs. 2	0.61
TP	1 vs. 3	0.54	TP	1 vs. 3	0.26
	2 vs. 3	0.47		2 vs. 3	0.46
	1 vs. 2	0.16		1 vs. 2	0.59
TS	1 vs. 3	0.65	TS	1 vs. 3	0.2
	2 vs. 3	0.37		2 vs. 3	0.27
Stage - 3			Blanton		
	1 vs. 2	0		1 vs. 2	0.26
TN	1 vs. 3	0.06	TN	1 vs. 3	0.71
	2 vs. 3	0		2 vs. 3	0.47
	1 vs. 2	0		1 vs. 2	0.2
TP	1 vs. 3	0	TP	1 vs. 3	0.34
	2 vs. 3	0.29		2 vs. 3	0.87
	1 vs. 2	0.01		1 vs. 2	0.22
TS	1 vs. 3	0	TS	1 vs. 3	0.45
	2 vs. 3	0.14		2 vs. 3	0.71
Mattingly			Moore		
	1 vs. 2	0.05		1 vs. 2	0.84
TN	1 vs. 3	0.04	TN	1 vs. 3	0.24
	2 vs. 3	0.32		2 vs. 3	0.17
	1 vs. 2	0.36		1 vs. 2	0.32
TP	1 vs. 3	0.98	TP	1 vs. 3	0.18
	2 vs. 3	0.38		2 vs. 3	0.38
	1 vs. 2	0.3		1 vs. 2	0.91
TS	1 vs. 3	0.87	TS	1 vs. 3	0.3
	2 vs. 3	0.4		2 vs. 3	0.21

Table 2. 2005-2007 nutrient and solids averages (in lbs/1000 gal). Table is shown in four stages of depth (surface, shallow, deep, bottom). This was done to create an easier comparison between the lagoons (actual lagoon depths ranged from 6 to 15 feet).

		2005-2007 Averages Lb/1000 gal		
Williams Farm		N	P	TS
	Surface	22.88	13.71	73.97
	Shallow	18.21	9.62	100.15
	Deep	42.32	38.18	653.04
Stage 1	Bottom	41.85	44.51	550.73
	Surface	7.8	0.73	48.4
	Shallow	8.01	0.74	49.73
	Deep	8.43	4.83	47.9
Stage 2	Bottom	25.45	15.23	366.68
	Surface	5.56	0.52	25.12
	Shallow	5.3	0.51	24.2
	Deep	5.31	0.54	23.58
Stage 3	Bottom	6	0.53	23.84
Mattingly Farm				
	Surface	5.41	0.75	20.82
	Shallow	5.63	0.79	22.13
	Deep	5.61	1.86	21.17
	Bottom	34.72	41.39	407.71
Moore Farm				
	Surface	1.94	0.57	15.16
	Shallow	2.22	0.53	15.33
	Deep	2.12	0.53	15.11
	Bottom	9.49	10.27	172.75
Booker Farm				
	Surface	2.23	0.32	4.63
	Shallow	7.91	8.48	6.17
	Deep	7.49	17.26	6.17
	Bottom	20.74	34.27	103.26
Beam Farm				
	Top	3.97	0.34	14.54
	Shallow	4.06	0.34	14.55
	Deep	5.07	2.54	13.22
	Bottom	17.94	12.07	69.57
Blanton Farm				
	Top	8.26	0.45	13.47
	Shallow	7.76	0.46	13.94
	Deep	7.71	0.54	14.49
	Bottom	33.52	28.46	305.31

These data indicated to the collaborating investigators on this project that instead of agitating earthen manure storage structures that the liquid should be siphoned from the surface of the structure (Figure 1) to apply the soluble nitrogen, and then to manage the sludge, containing high concentrations of phosphorus, by hauling it further away from the farmstead to lower P soils (a departure from traditional BMPs). Furthermore, the combination of advanced manure application practices with the siphoning of unagitated earthen manure storages will improve water and soil quality. To this end, the researchers established field demonstration sites for field days that took place in Shelby, Hardin, and Woodford Counties. Consequently, the manure P found in sludge could be managed and land applied to reduce the potential for contaminating surface waters. To test this hypothesis, a total of six swine farms using earthen storage structures were sampled three times from Spring 2005 to Spring 2007 before land applications commenced. Single cell structures were sampled at the Mattingly, Moore, Booker, Beam, and Blanton Farms. A triple cell structure was sampled at the Williams Farm.

Figure 1. A sealed barrell is being used as a "bobber" to hold the siphoning line at the surface. The barrel is attached with at rope, which allows the user to set the desired siphoning level. In this picture the siphoning end is at 1 foot below the surface.

Benefits and Drawbacks

The draw back to the on farm modeling method is that it is not automatic. The producer still has to take the time to build and maintain the model. The model will remain relevant as long as the management of the animals stays the same (no changes in diet).

Lessons Learned

Interviews revealed that producers do not, and don't plan to, sample their manure. The best compromise to this problem was to show the producer that the nutrient concentrations would not change as long as their management did not.

Outcome IV – Application Techniques

The major issue with respect to watershed protection is how to manage manure application in ways that are not detrimental to water, soil, and air quality. The goal of this project was to demonstrate state-of–the-art nutrient management technologies and application practices for the purposes of educating producers and custom waste applicators. These techniques have enable producers to maintain crop yields while increasing nutrient utilization, and reduce the potential for leaching and off-site movement of nutrients.

Questionnaire responses from participating livestock producers showed that most of the producers applied manures to the soil surface. Applying manures to the surface of the soil, as opposed to incorporation, has been shown to increase the risk of offsite movement of nutrients and pathogens. Ultimately, surface applications of manure, allows the producer to capture most if not all of the phosphorus in the manure, while potentially losing the majority of the nitrogen. The net effect of this practice is that the loss of nitrogen negatively impacts crop yields, thereby limiting the crops ability to remove manure P. This results in a net gain of P in the soil and the potential to contaminate subsurface and surface water quality.

To demonstrate manure incorporation techniques an existing Balzer manure tanker (Model 2250) was modified for field demonstrations on cooperator farms. The original configuration of the tanker was a top fill unit. However, this type of unit would not be conducive for collecting loads from storages on most cooperator farms. Therefore, components were purchased to convert the Balzer tanker to a vacuum tanker in support of on-farm demonstrations. Further modification of the Balzer 2250 includes the addition of a heavy toolbar that will accept a variety of injectors: rigid mount C-shank, Yetter No-till, and Dietrich injectors.

An Aerway applicator was purchased to demonstrate an alternative incorporation technique. The Aerway tillage tool was modified to attach to the Balzer tanker as an injector, as a standalone towed hose injection system, and as a tillage implement that can be towed behind a tractor. We anticipate using the Aerway in cooperator field prior to surface applications using a traveling gun and have commitments from two cooperators that have agreed to allow demonstrations of the Aerway implement prior to surface applications with traveling guns. It is our belief that we can reduce the potential of surface water contaminates contamination from run-off by using the Aerway to enhance infiltration and created additional surfaces capable of absorbing the applied nutrients.

A complete AutoTrac guidance system was supplied by John Deere for this project. The components include an RTK-GPS base station and rover receiver, user interface and mapping processor, steering motor, flow sensor, and SSU control unit. These components were added to a John Deere 8130 series tractor for demonstration use at the University of Kentucky's, Woodford County Animal Research Center near Versailles. The farmstead has buried mainlines and a towed injection system for incorporation of swine manure below the soil surface. An AutoTrac system allows for consistently parallel rows and maximizes plant population. Plant population is maximized because the AutoTrac keeps you from overlapping rows, and keeps row spacing to a desired distance. Another advantage of the system is its abilityl to efficiently farm environmentally sensitive areas. The locations of these areas are marked in the system and limit the manure application in those areas.

Figure 2. John Deere 8440 equipped with an AutoTrac guidance system

Figure 3. Balzer tanker equipped with flow meter, and pinch valve

In conjunction with the Balzer 2250 manure injection systems a dedicated 4WD tractor (used John Deere 8440) was purchased with University funds to insure the timely field operations of demonstration projects and field days. To insure that similar technologies were available for demonstration, a KEE technologies ProSteer universal guidance kit was purchased for installation. This was required in part because John Deere does not support many of their older tractors with AutoTrac. These additions not only reduced operator fatigue, but showed that older equipment (found on many farm across Kentucky) can be fitted with today's technology. The ability to update older equipment to make it competitive with today's advanced tractors at a fraction of the cost was well received by farm owner and assistant. A John Deere supplied AutoTrac guidance system was employed for better accuracy. The system includes an RTK-GPS base station and rover receiver, user interface, mapping processor, steering motor, flow sensor and SSU control unit.

Lessons Learned

The technology available to producers has the potential to not only save the valuable nutrients, increase yield, but to also protect environmentally sensitive areas. Environmentally sensitive areas include but are not limited to streams, sinkholes, and ponds (see fig. 2). All karst areas should be treated as environmentally sensitive; this includes a large portion of Kentucky as seen in fig. 3. By reducing nitrogen loss with the use of injection techniques (rigid mount C-shank, Yetter No-till, and Dietrich injectors) and by eliminating excess applications with the use of map based application the potential to pollute environmentally sensitive areas has been minimized. Demonstration of sweeps and spacing has shown their impact on corn production. The large flat area seen in figure 4 was divided into plots and was used to show producers the differences among the application types. Easily seen in the pictures below are color gradients within the plots. Figure 5 is a close up of a plot, notice how the shades of green cycle through the plot. The darker rows represent corn that was planted in the path of an injector (estimated yield of 210 bu/acre, fig. 6), while the lighter colored rows represent corn that was planted in between injector paths (estimated yield of 157 bu/acre fig. 6). With the aid of an auto-steer product (ProSteer, AutoTrac, etc.) producers are recommended to set their injector spacing equal to seed planter spacing to reduce the spatial effects. Several producers were hesitant to use manure tankers on their fields because of their concerns with compaction. Yield results (discussed later in this report) show that compaction was not a problem when compared to traditional nutrient applications. One reason for this is believed to be related to the injectors that are pulled through the ground (fig. 7), breaking and loosening the soil as they travel (fig. 8).

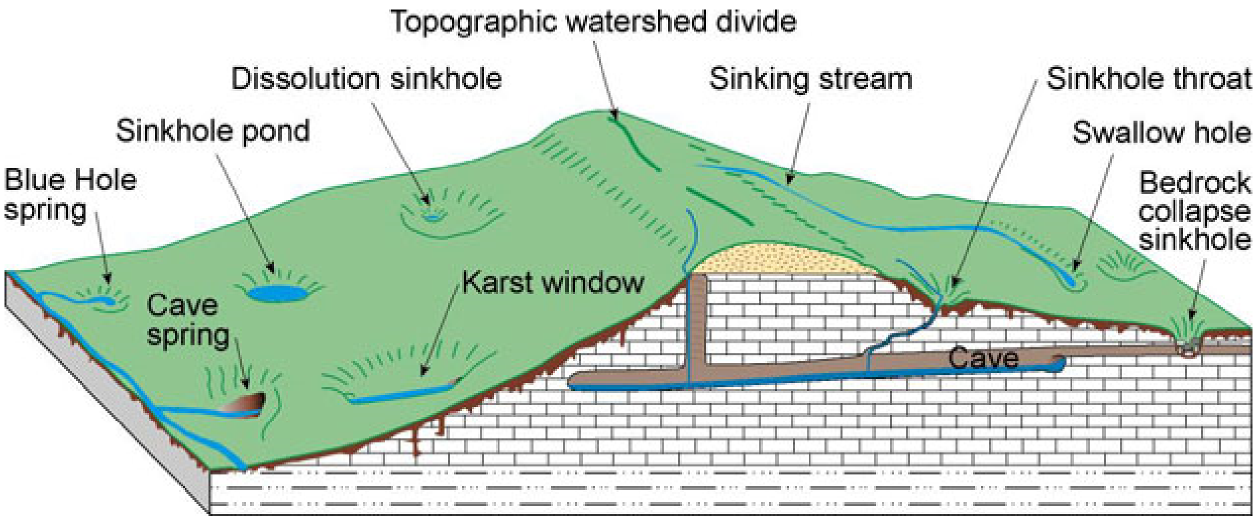

Figure 4. Illustration of environmentally sensitive features

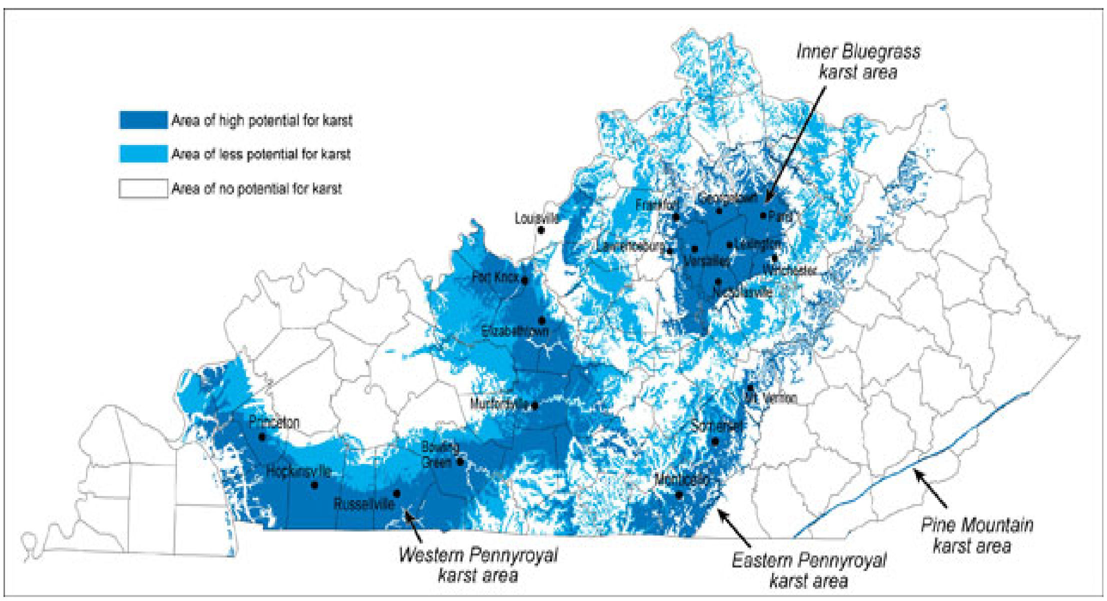

Figure 5 Generalized map of the karst regions of Kentucky. The darker blue areas are highly karst, and the lighter blue areas are less karst. For more information visit the Kentucky Geological Survey at the University of Kentucky

Figure 6. View of numerous plots; control, Aerway, and Injector plots included

Figure 7. Shades of green cycling through plots, representative of injector location

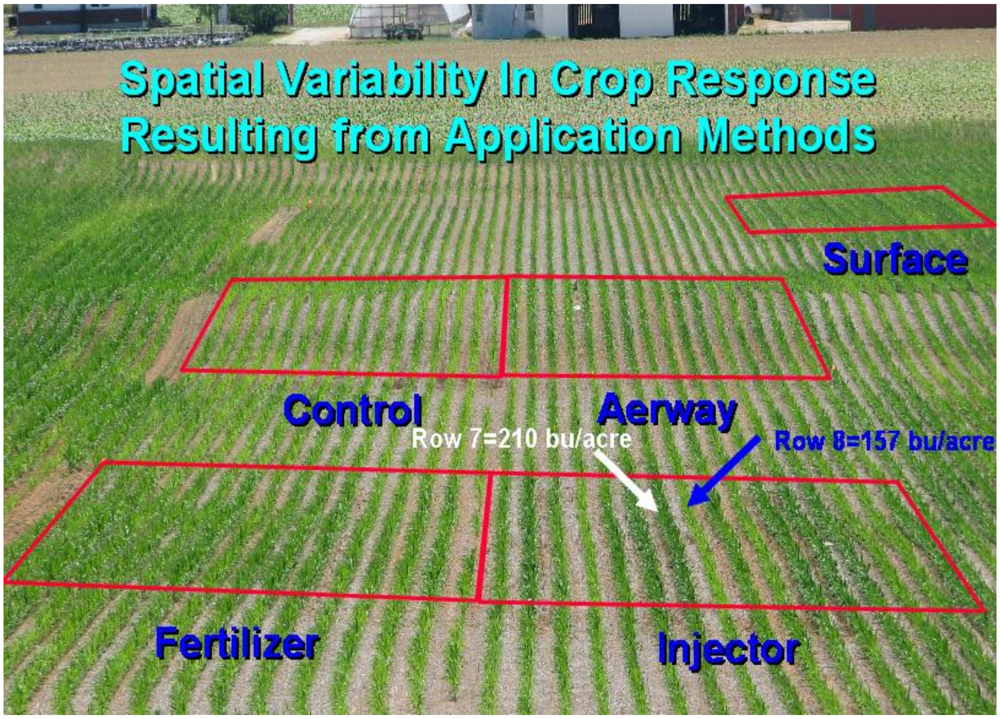

Figure 8 Effects of injector spacing on corn yield

Figure 9. Injectors pulled through ground

Figure 10. Broken/Loosened ground

Outcome V – Education and Outreach

There were several demonstrations conducted using our modified equipment. A few of the more significant demos were as follows; in June, 2007 a demonstration was set up for the University's Beef Unit manager and NRCS representatives. For this demonstration manure was loaded from a beef cattle solid liquid settling basin. This manure was then applied to a nearby pasture. The beef unit manager and NRCS personnel were impressed with the lack of odor, quality of incorporation, and the minimal ground disturbance. A second demonstration of the summer came in late July at the University of Kentucky's field day, held that year in Princeton, KY. This field day had approximately 2000 visitors who were shown the Balzer/Aerway setup, but also multiple guidance options (auto steering, light bars, etc.).

Figure 11. Balzer/Aerway combo being loaded with feed lot nutrients.

Figure 12. Similar loading techniques used when loading from earthen storage structures

In the summer of 2008 a poster was presented at the National Water Quality Conference in Reno, NV that displayed the background, motivation, and key features related to this project. The Soil and Water Conservation Society made up the bulk of the conference's audience and included state and federal agencies and non-government organizations. Discussions were directly mostly at general soil and water issues, however there were people at the conference involved in waste management. Discussions with these individuals centered on comprehensive nutrient management plans and management of animal waste.

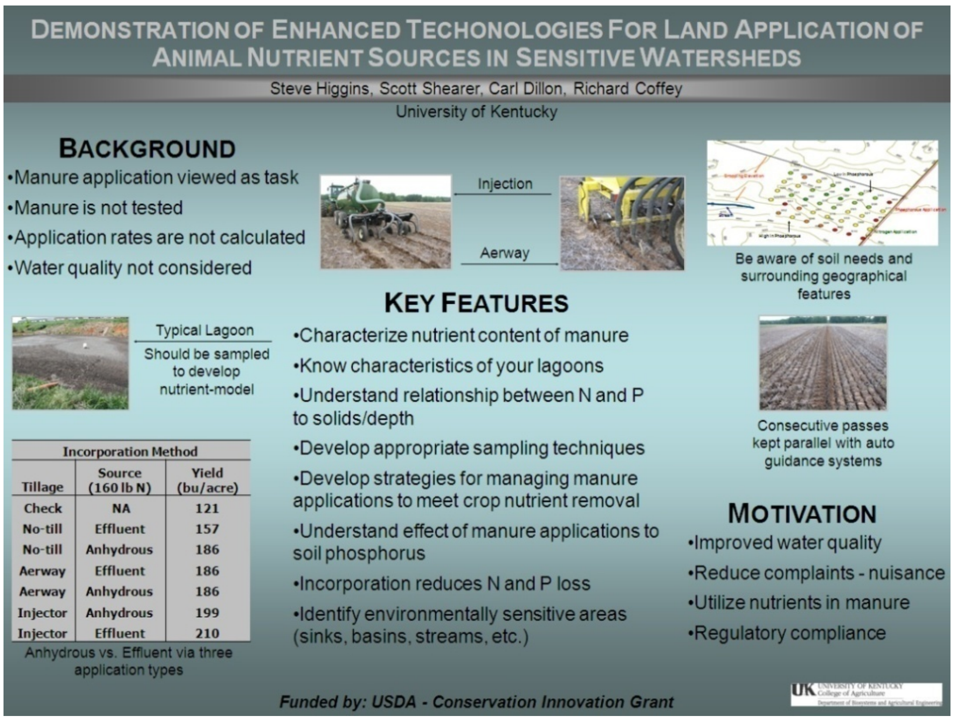

Figure 13. Poster that was displayed in Reno, NV.

Benefits and Drawbacks

Benefits of the new equipment and technologies are improved application efficiency of not only liquid manures but also purchased fertilizers (with use of guidance aids and map based spray restriction). Preventing overlapping applications as well as missed areas leads to increased yields and nutrient savings. The environment is benefitted by this technology as well. By using the Aerway and more so the injectors, runoff is greatly reduced as is the volatilization of nitrogen. When this equipment is combined with the mapping technology environmentally sensitive areas and grass waterways are kept healthier and clean. The largest drawback is the expense. Convincing anyone that a new technique can save them money is easy, as long as the new technique does not require expensive purchases.

Lessons Learned

The combination JD 8440 tractor, Blazer 2250, Aerway tool, and KEE Technologies automated guidance systems proved to be an effective combination for demonstration of injection technologies. Producers were impressed with the ability to integrate new technology with older equipment and the ability to repeatedly make straight parallel passes. Map-based applications also proved to interest farmers. Additions that utilizes the GPS equipment makes the packages itself more desirable. Flow control is a great addition that uses ground speed to vary the application flow rate. When ground speed increases the flow rate is increased as well. Map based applications allow the producer to set areas off limits to applications. When the applicator enters prohibited area the application is stopped until the applicator exits the area. Predetermined flow rates can also be set in map based applications. This allows for variable rate application when used in conjunction with a flow meter. Trying to remember application rates, calibration setting, and adjusting them on the go would be nearly impossible.

Observations, Future Uses, Recommendations, and Limitations

Through the numerous field days and seminars, the biggest "advertising" impact came from the exposure at the 2007 National Farm Machinery Show in Louisville that drew over 302,000 visitors. We were able to take advantage of the booth by displaying 33 graphics entitled Advanced Technologies for Managing Animal Nutrients. Subtopics included; Lagoon and Pit Sampling Strategies, Manures Solids/Liquid Analysis, Lagoon Pumping Options, Incorporation Tools, Map-Based Application Method and Variable-Rate Application Equipment. Using a combination of words, pictures, drawings, charts and graphs, injector options, and Balzer/Aerway setup, we were able to get the attention of many visitors. There was new interest sparked from what many people were seeing for the first time. There were also new questions from those who wanted to know more about the ideas. What seemed to interest people the most were the graphics showing nutrient makeup in the lagoons, the crop yield results using the various application techniques, and modifications made to the Balzer tanker.

Figure 14. View of booth at the 2007 Farm Machinery Show

Figure 15. Balzer/Aerway setup

Figure 16. Graphics plus display model of three injector types

Adoption of innovative technologies to protect the environment and take advantage of manure nutrients proved to produce mixed results. Although many producers had GPS and variable rate technologies installed on their cropping equipment we saw these systems were not being used effectively (lack of map based application for example). What we have observed time and again is the division of management to handle the crops and livestock enterprises. Managers concerned with animals do not show much interest in the amount of water used to cool their animals (and the resulting run-off produced) or the amount of wash water used to clean facilities. Observations have shown that liquid storages have and continue to overflow as a result of too much volume and not enough liquid storage capacity.

The map-based applications technology works well with flow meters and by combining them with solid sensing units a producer would have dynamic application rates of liquid manures. The mapping technology would define the rate of application, while the solids sensor would determine the nutrient concentrations of P and N in the liquid manure. The ability to determine P concentrations by solids content has been proven in previous work. The combination of these technologies would allow the operator to set varied application rates without the worry of calibrating the equipment/speed/engine rpm. Of course in order for this setup to work the system would need a pinch valve. We have been developing such a system during the latter stages of this project. All parts and pieces are in place. Time is needed to finish and fine tune the system.

In the future a benefit to producers and the environment is for animal managers and crop managers to work more closely together. Because of excess water usage and minimal storage capacity a local dairy was retrofitted with a cooling system that runs on a 1 minute per 10 minute interval. The cooling system also implemented misting spray nozzles instead of what had been used, high volume lawn sprinklers. Water conservation for this dairy is estimated to be approximately 100,000 gallons per month during the summer. Conversely, managers interested in the management of crops have not shown an interest in counting nutrient credits, from manured areas, when supplementing inorganic nitrogen to crops. What we have observed is the gross application of manure to the same areas of a field repeatedly without any regard to soil fertility or crop removal rates. The results showed that the corn crops lodged as a result of too much nitrogen and the accumulation of soil phosphorus.

In either management case, the concern for the environment and proper utilization of waste water generated on several livestock farms has been essentially nonexistent. The term waste water is used, because several producers do not seem to realize the economic benefit from utilizing the nutrient concentration in animal manures from a nutrient management philosophy. However, refreshingly, there have been some producers, mostly those that manage the crops side of the operation, that have been interested in utilizing the nutrient content in animal manures for the production of crops. We attribute this mostly to the rising fertilizer and fuel costs required to grow and harvest this year's crops. We have also been able to shame some producers to manage their manures better after demonstrating our yields compared to theirs when application rates have been calculated (Table 3).

Table 3. Anhydrous vs. Effluent via three application types

Incorporation Method		
Tillage	Source (160 lb N)	Yield (bu/acre)
Check	NA	121
No-till	Effluent	157
No-till	Anhydrous	186
Aerway	Effluent	186
Aerway	Anhydrous	186
Injector	Effluent	210
Injector	Anhydrous	199

Final Thoughts

- Current practices of Kentucky producers
  - Kentucky producers surveyed during this project admit to applying manure twice a year, once in the spring and again in the fall. Storage capacity of the manure has a negative influence on producers because the storage structures were in many cases not designed with enough capacity to handle the manure load with Kentucky's weather patterns. Because of these factors, applications most often occur when there are no crops in the field and during inclement conditions.
  - Nutrient management plans although required by the government are often ignored by livestock producers even when benefits include; improved productivity, increased profits, and improved environment. By not having a nutrient management plan producers are applying manures without knowledge of nutrient concentrations and they are applications rates are based on unrealistic yield goals.
  - Producers who are often perceived to have a "slow" paced way of life still want instant results. This is not different than the average "Joe" but it does present a problem with on farm nutrient modeling. Manure sampling (the basis for the model) takes time and producers do not and don't plan to sample their manure.

- Numerous application techniques exist and are viable for Kentucky producers although most utilize surface application (via guns or tankers) and none of the available technology (guidance aids, map based application). Also producers utilize only a portion of the available area for land applications of manure. Most often this area is localized to fields nearest the farmstead.

- Recommended practices for Kentucky producers
  - Kentucky's unique topography and karst grounds, when money is ignored, often have the largest influence on the farm design. With this in mind we would recommend that storage structures be designed and built to a larger capacity than has historically been done.
  - Obviously the largest recommendation for producers would be to develop and follow a nutrient management plan. The plan itself would require producers to develop and upkeep a nutrient model. A nutrient model would require producers to utilize another recommendation, manure sampling. A nutrient management plan would also require the producers to monitor soil conditions and apply manure based on phosphorus concentrations in the soil.
  - Manure sampling is not a process that needs constant attention. Sampling can be accomplished twice a year and with proper techniques, record keeping and unchanged farm management will be the basis for the nutrient model. Over time a farms nutrient concentrations will remain statistically unchanged unless management styles are changed (i.e. change in feed, modifying storage structures)
  - The initial cost of technology can be staggering but is the key to future farm sustainability. To reap the improved productivity, increased profits, and improved environmental benefits that have been discussed in this report producer need to move away from surface application an incorporate *incorporation techniques* into their management practices. The use of injectors and Aerway type applicators are only start. Producers need to realize the benefit of using guidance aids as well as map based application units. A combination of these products will be more beneficial than just one product by itself.
  - The use of the different application technologies will make it easier for producers to use more of the available land. This would reduce the phosphorus loading that is found near the farmstead. Regardless if the application technology is used or not producers are recommended to utilize more of their land for manure applications where reasonable.

- Project Achievements
  - Convincing a producer to properly sample their manure is still a hard sell, but we did compile a nutrient model based on our samples. The compiled model was given to the producer for their use. Although not the outcome we were looking for, it is still a step in the right direction.

- Producers were impressed with the efficiency of the technology and the amount it saved in conventional fertilizers and potentially in diesel. The efficiency occurs with the use of auto-steer technology that duplicates parallel passes and reduces overlapping. Conventional fertilizers were conserved by maximizing the manure nutrient content, applying nutrients based on soil conditions and plant uptake, use of incorporation techniques, and map based applications. Incorporation of manure with the soil reduces runoff and volatilization, allowing plans to more effectively take up nutrients, increasing yields. The map based applications allow for the producer to use adjusted application rates through a field as well as prevent application of nutrients where they should not be applied.
- Producers are also more aware of the environmental impacts associated with over application of nutrients as well as surface applications. With proper applications rates, incorporation methods, and map based applications, the impact on the environment is being reduced one producer at a time.
- Best Management Practices development
  - Surface to Sludge Sampling: Recommends producers sample storage structures from just below the surface to the top of the sludge layer. This will allow producers to develop application rates based on the liquid level of the storage structure.
  - Manure Effluent Siphoning: Recommends producers siphon liquid manures from just below the surface of the storage structure for land application. This method incorporates the use of a float to siphon the supernatant from the surfaces of liquid earthen storages.
  - Manure Injection: Recommends producers inject manure into the soil instead of using surface application. Injection incorporates manure into the soil, reducing air and water pollution. In addition auto-steer technology should be utilized to match seed placement with manure placement.
  - Nutrient Management Plans: Recommends that producers develop and follow these management strategies. It is the law!

- Phosphorus Based Application: Recommends producers develop manure application rates based on crop phosphorus removal rates. Remaining challenges
  - Convincing producers of the benefits of adapting the techniques, methods, and technologies discussed in this report is still a difficult job, but one that is getting easier. The more producers that we have adapting these ideas the easier it becomes to convince the next producer they should do the same. Getting produces to adapt a nutrient management plan to their practices should become easier as government regulations become more stringent. With that said producers need a lot of work in the area of manure sampling and recording keeping. Still convincing someone to purchase expensive equipment will be difficult, but will hopefully become easier once they see the benefits of a relatively inexpensive nutrient management plan.

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