RESEARCH REPORT

ENVIRONMENT

Title: Demonstrating Innovative Use of Precision Farming Technologies to Optimize Manure Nutrient Utilization and Reduce Environmental Concerns **- NPB #08-131**

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Abstract

The uniform application of manure is difficult and often leads to questions of available nutrient credits. For these reasons farmers and their consultants often discount the value of these nutrients and over-apply nutrients to ensure their crops have adequate nutrients to maximize yields (Nowak et al., 1998). In this research project we have begun to demonstrate and research how Precision Farming Technologies can be used to optimize manure nutrient utilization and reduce environmental impacts. We have linked sampling of manure to manure application and recording with the use of precision agriculture equipment. We have also used GIS controlled steering systems to evaluate how broadcasting or banding swine or dairy manure under or in the middle of the rows effect corn yields.

With this research we have been able to demonstrate how Precision Agriculture Technologies can be linked together to accurately apply manure and more accurately record manure nutrients applied. We can then use this nutrient application information to accurately develop prescription maps for applying additional nutrients to fields to maximize yields and minimize environmental concerns. .

Introduction

The uniform application of nutrients from manure is difficult and often leads to questions of available nutrient credits. As a result farmers often miss-apply manure nutrients to fields because of the lack of reliable information about the rate of application, the location where the manure was spread, and the actual nutrient content of the applied manure. For these reasons farmers and their consultants often discount the value of these nutrients and over-apply nutrients to ensure their crops have adequate nutrients to maximize yields (Nowak et al., 1998). The main goal of this project is to use new technology that will make more efficient use of manure nutrients to maximize crop yields while at the same time reducing the risk of nutrients being lost to the environment.

Precision farming tools that control the steering of manure application equipment, monitor and record application rates and location in geo-referenced files are commercially available. This should improve nutrient use and translate into more efficient nutrient use and higher yields with less environmental risk. Precision steering systems can also be used in combination with no-till manure injection systems to place nutrients near the plant's root zone to minimize surface runoff of nutrients while at the same time maintaining a no-till system.

Objectives

1. Develop a manure sampling protocol that farmers can use to evaluate the uniformity of their manure.
2. Research and demonstrate how to link precision farming systems with manure sampling to develop nutrient application maps.
3. Research and demonstrate how nutrient application maps can be used in combination with soil test and yield maps to develop a nutrient prescription map.
4. Research and demonstrate variable application of nutrients based on the nutrient prescription maps to ensure nutrients are used efficiently and with minimal environmental risk.
5. Develop recommendations for inclusion of precision manure application in the Wisconsin 590 nutrient management standards.
6. Research/demonstrate how different placements of dairy and swine manure with steering systems affect yield and nutrient uptake.
7. Demonstrate how steering and recording systems can make on-farm research easier and more accurate.
8. Provide training sessions for farmers, industry, extension, and agency personnel on these emerging technologies.
9. Offer several field day opportunities to share this new technology and information with farmers, consultants and agency personnel.

Materials and Methods:

Two farms, one in southern Wisconsin and the other in northwestern Wisconsin were used to evaluate and demonstrate these innovative management approaches. The farm in southern Wisconsin is a 1200 cow dairy that uses a hose drag manure application system to which precision steering and a system that automatically records manure application rates was added. Extensive manure sampling was conducted as manure was taken from storage and applied to the fields. This information will be used to develop a manure sampling protocols that can then be applied to other farms in the future as they adopt this technology. Precision agriculture software was used to link these intensive manure sampling results to automated precision farming manure application information. This will allow the development of site-specific manure application maps which can then be used to create prescription maps for variable rate application of additional nutrients as fertilizer.

The study on this farm will also be used to evaluate variable rate manure application on a field that has highly variable soil tests. This field was grid soil sampled on a one-acre sampling density using University of Wisconsin Soil Testing Recommendations to develop an accurate site-specific map of soil test levels at the start of the research and will be re-sampled four years later at the end of the research. These maps will then used in combination with yield maps from the farm to help develop a nutrient application plan for this field which is in a corn/soybean rotation. The soil tests will also allow us to determine if the soil test have changed over the four year research period. Manure was applied to crop need plus to build soil tests in areas of the field where soil tests are below optimum.

The second farm in northwestern Wisconsin markets approximately 10,000 hogs per year and uses a no-till system to raise 650 acres of corn and soybeans. Fields in the study on this farm were grid soil sampled on a one-acre sampling density using University of Wisconsin Soil Testing Recommendations to develop an accurate site-specific map of soil test levels at both the start of the research and will be re-sampled four years later at the end of the research. These maps were used in combination with yield maps from the farm to help develop nutrient application plans and to evaluate soil test changes from the beginning to the end of the study. A no-till manure injection system will be combined with a precision steering system to accurately place swine or dairy manure nutrients either 5” from the row or broadcast randomly in 30” bands. Dairy manure will be obtained from a nearby cooperating dairy. This will allow us to compare yields and manure use efficiency with broadcast versus precision manure application.

The project has been promoted statewide and involved local advisory committees with representation from NRCS, Land Conservation, VTAE, and Extension Offices to provide outreach from the research. Industry representatives who have supplied much of the equipment will be able to share the information with their customers.

Results

Objective 1: Develop a manure sampling protocol that farmers can use to evaluate the uniformity of their manure.

The best way to evaluate the sampling frequency on any given farm's manure storage is to over-sample to establish the uniformity of the manure samples within a storage system and determine how frequently manure samples need to be drawn. Our data shows manure is quite variable in composition as it was sampled every 4 hours during application (Table 1).

Table 1. Simple statistics for manure analysis sampled over time at the Larson Farm, Fall 2005 – 2009.

Factor	Mean	Standard Deviation	Range
2005 (n=29)			
Dry Matter (%)	3.87	1.11	1.9 – 6.3
N (lb/1000 gal)	6.73	0.83	4.92 – 8.58
P_2O_5 (lb/1000 gal)	3.08	0.77	1.69 – 5.59
K_2O (lb/1000 gal)	16.76	3.30	11.05 – 21.62
2006 (n=40)			
Dry Matter (%)	3.58	1.42	1.5 – 7.8
N (lb/1000 gal)	6.43	1.17	3.72 – 8.55
P_2O_5 (lb/1000 gal)	3.76	1.73	1.21 – 8.69
K_2O (lb/1000 gal)	12.07	2.86	6.19 – 19.58
2007 (n=68)			
Dry Matter (%)	3.39	1.48	1.3 – 7.7
N (lb/1000 gal)	5.65	1.23	3.82 – 8.44
P_2O_5 (lb/1000 gal)	3.09	1.78	0.70 – 8.14
K_2O (lb/1000 gal)	12.68	2.98	7.27 – 21.19
2008 (n=49)			
Dry Matter (%)	3.51	1.81	1.20 – 8.10
N (lb/1000 gal)	6.60	2.03	4.06 – 12.66
P_2O_5 (lb/1000 gal)	3.65	1.82	0.88 – 7.52
K_2O (lb/1000 gal)	11.98	6.42	3.86 – 32.21
2009 (n=42)			
Dry Matter (%)	2.25	0.56	1.30 – 3.70
N (lb/1000 gal)	5.65	0.85	4.14 – 6.97
P_2O_5 (lb/1000 gal)	2.75	1.09	0.74 – 4.67
K_2O (lb/1000 gal)	13.57	2.05	9.34 – 19.77

Table 2. Correlation matrix for manure analysis sampled over time at the Larson Farm, Fall 2005 - 2009.

	Time	Dry Matter	N	P_2O_5	K_2O	Time	Dry Matter	N	P_2O_5	K_2O	Time	Dry Matter	N	P_2O_5	K_2O
	2005					2007					2009				
Time	--					--					--				
Pr>F															
Dry Matter	-0.21	--				0.22	--				-0.54	--			
Pr>F	0.27					0.07					<0.01				
N	-0.51	0.70	--			0.19	0.73	--			-0.74	0.84	--		
Pr>F	<0.01	<0.01				0.11	<0.01				<0.01	<0.01			
P_2O_5	0.17	0.48	0.50	--		0.62	0.54	0.59	--		-0.26	0.83	0.73	--	
Pr>F	0.37	<0.01	<0.01			<0.01	<0.01	<0.01			0.10	<0.01	<0.01		
K_2O	0.83	-0.15	-0.65	-0.06	--	0.45	0.29	0.14	0.29	--	-0.18	-0.09	0.02	-0.06	--
Pr>F	<0.01	0.43	<0.01	0.74		<0.01	0.02	0.26	0.02		0.26	0.59	0.91	0.68	

	Time	Dry Matter	N	P_2O_5	K_2O	Time	Dry Matter	N	P_2O_5	K_2O
	2006					2008				
Time	--					--				
Pr>F										
Dry Matter	-0.56	--				0.32	--			
Pr>F	<0.01					0.02				
			--							
N	-0.46	0.81				0.13	0.85	--		
Pr>F	<0.01	<0.01				0.36	<0.01			
			0.32	--						
P_2O_5	0.27	0.40	0.05			0.52	0.76	0.71	--	
Pr>F	0.08	<0.01				<0.01	<0.01	<0.01		
			0.40	0.25	--					
K_2O	-0.22	0.49	0.01	0.13		-0.31	0.58	0.67	0.22	--
Pr>F	0.18	<0.01				0.03	<0.01	<0.01	0.13	

Time expressed as hours from initial agitation; Dry Matter (%), nutrients (lb/1000 gal)

Table 2 shows the correlation between components of the manure analyses and how the manure analyses changed throughout the sampling period.

Historically dry matter content decreased with time, significantly so in 2006, but tended to increase in 2007 and 2008. In 2009 dry matter content was somewhat stable, then dropped and climbed back to where it started. (Figure 1). Nitrogen (N) decreased with time significantly in years 2005,2006 and 2009, but showed a trend for an increase in 2007 and 2008. Phosphate (P) tends to increase with time, with significant increases in 2007 and 2008, however in 2009 P decreased and then began to rise until the sampling was finished. Potassium (K) significantly increased in 2005 and in 2007, but tended to decrease in 2006 and 2008 and 2009. DM was positively correlated with N and P in all years, and DM was positively correlated with K in 2006, 2007 and 2008, but not in 2005 and 2009. Individual nutrient content was correlated among the nutrients, presumably because of their close relationship with DM content.

The following charts show how the manure nutrient contents varied throughout the agitation and lagoon emptying event that occurred over a period of more than 2000 hours.

Figure 1. Relationship between time and dry matter content, 2009.

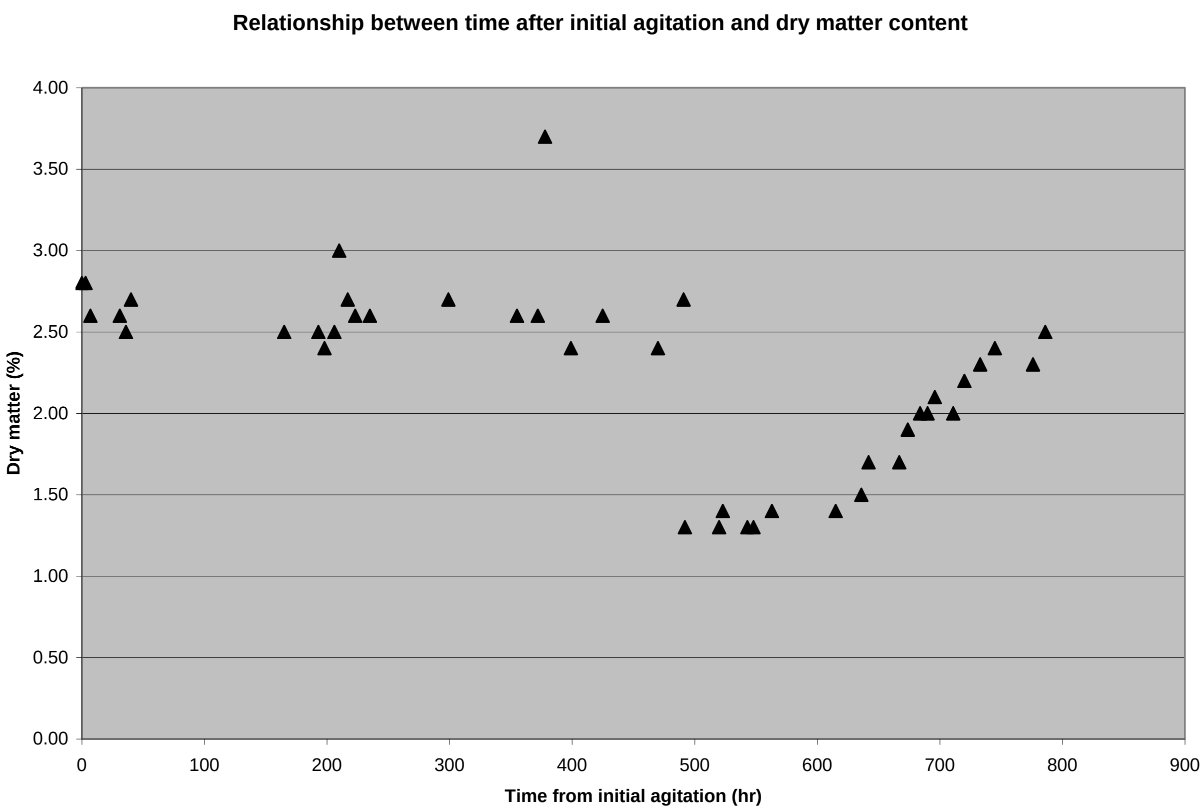


Figure 2. Relationship between time and N content, 2009.

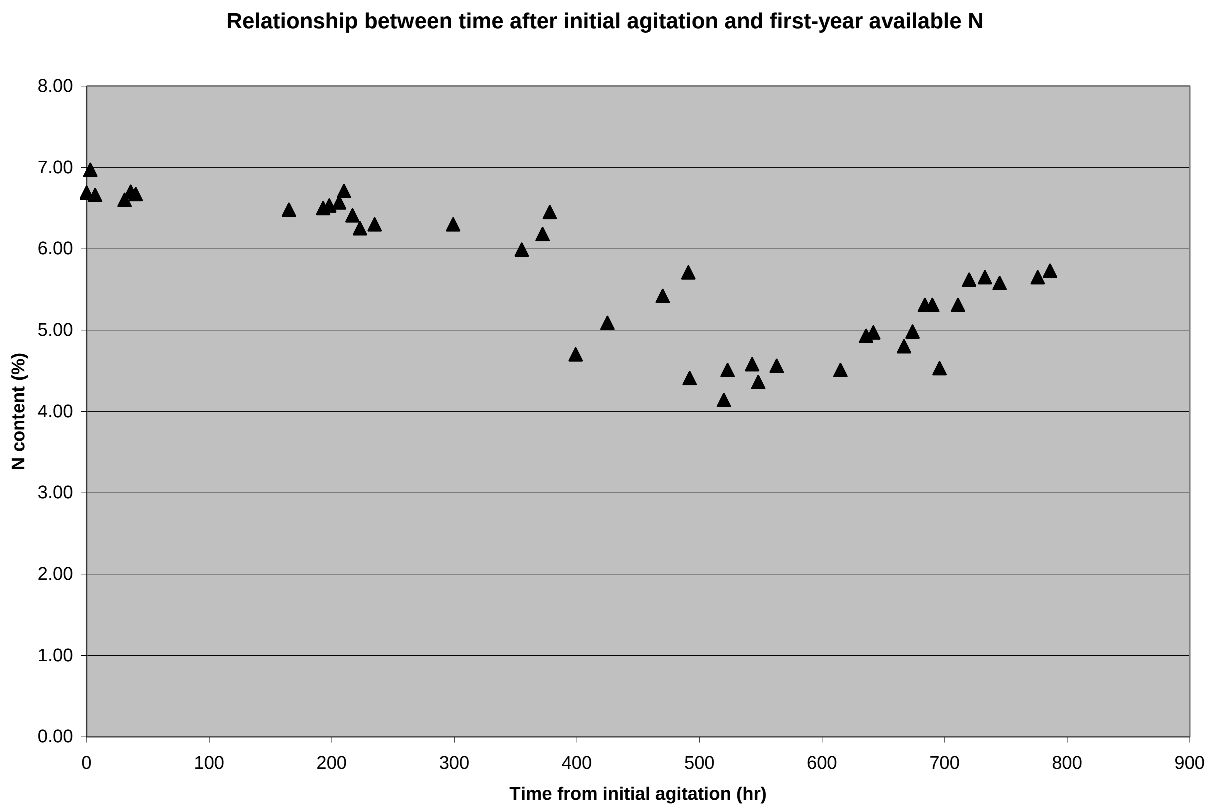


Figure 3. Relationship between time and P content, 2009.

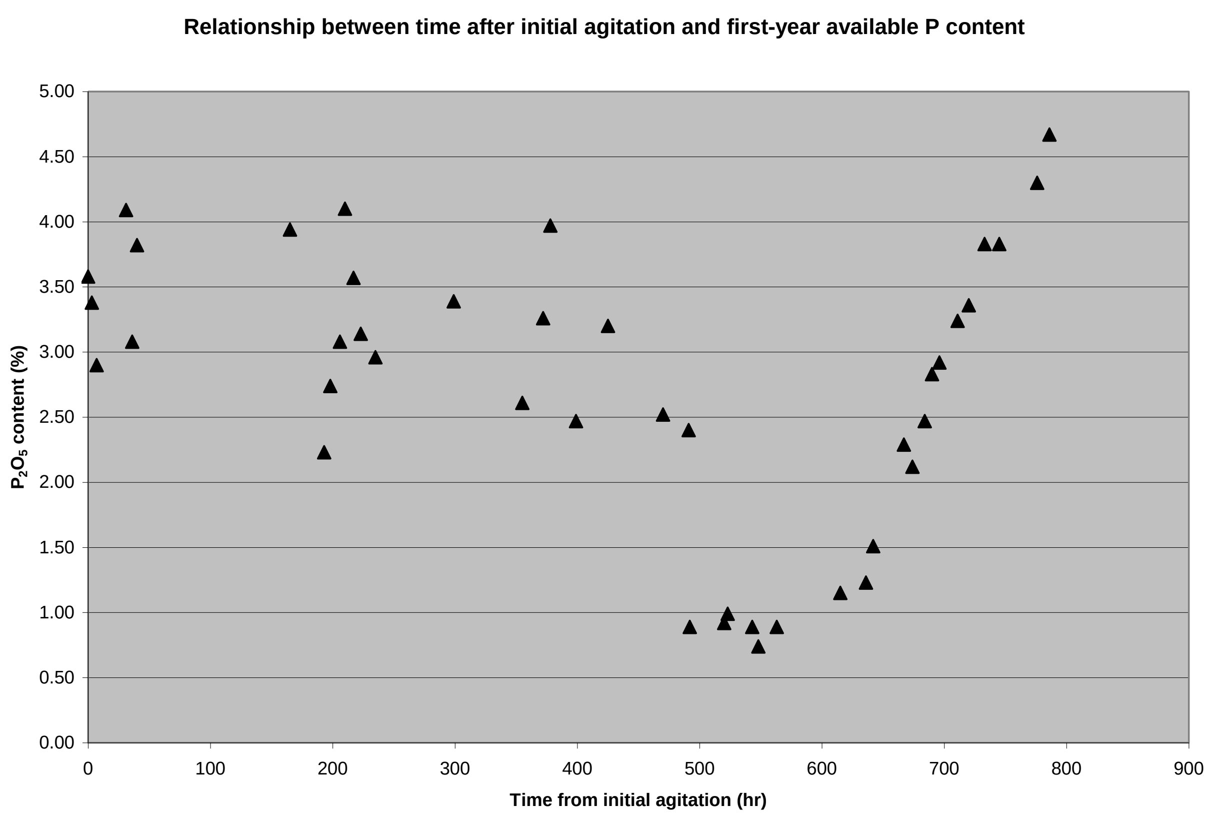
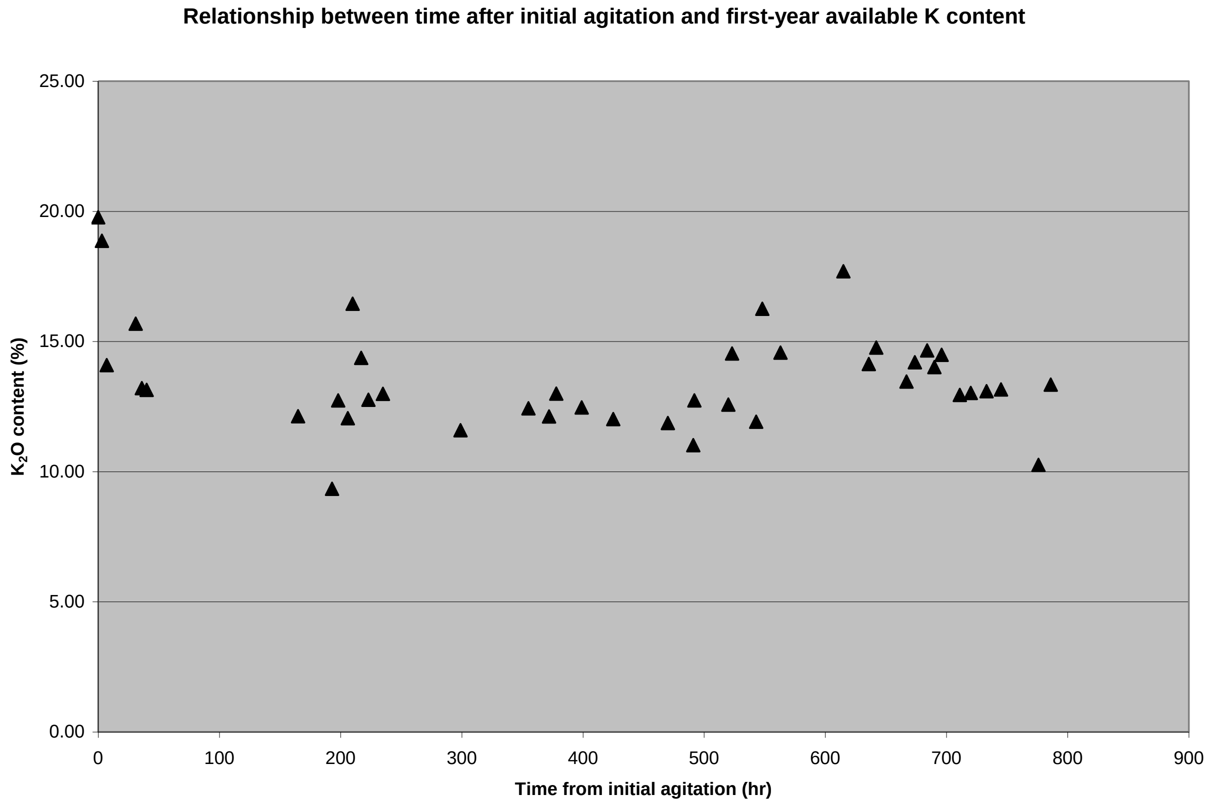
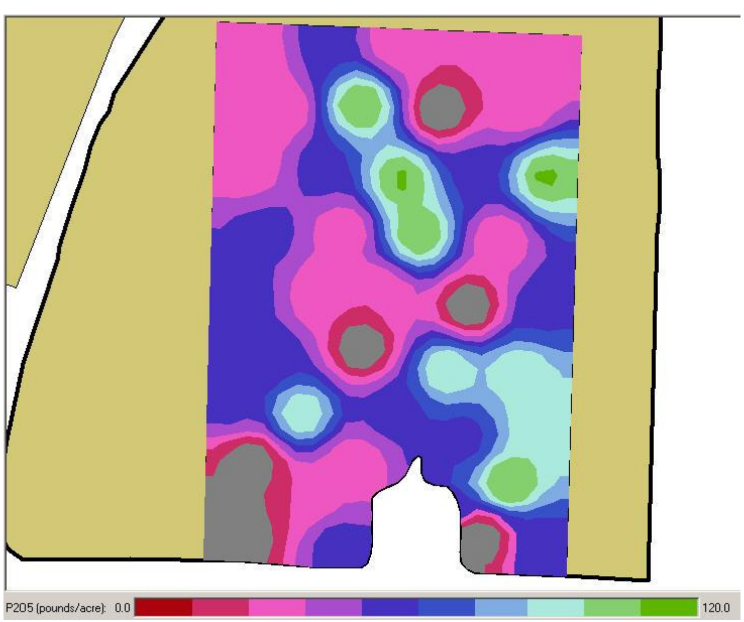


Figure 4. Relationship between time and K content, 2009.



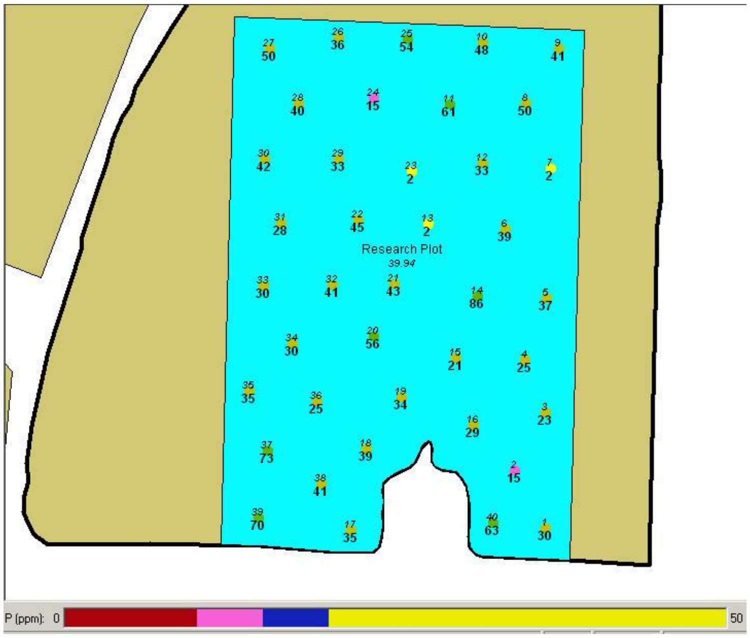
Objective 2: Research and demonstrate how to link precision farming systems with manure sampling to develop nutrient application maps.

At the Larson farm liquid manure was sampled at the applicator every four hours as the manure was applied to the fields. These sample results were then entered into Mapshots software so we could track the changes of this manure throughout the application period. Rate coupled with manure quality results allowed us to develop the nutrient application maps. Below is an example map which shows how much phosphorus was actually applied to a field:

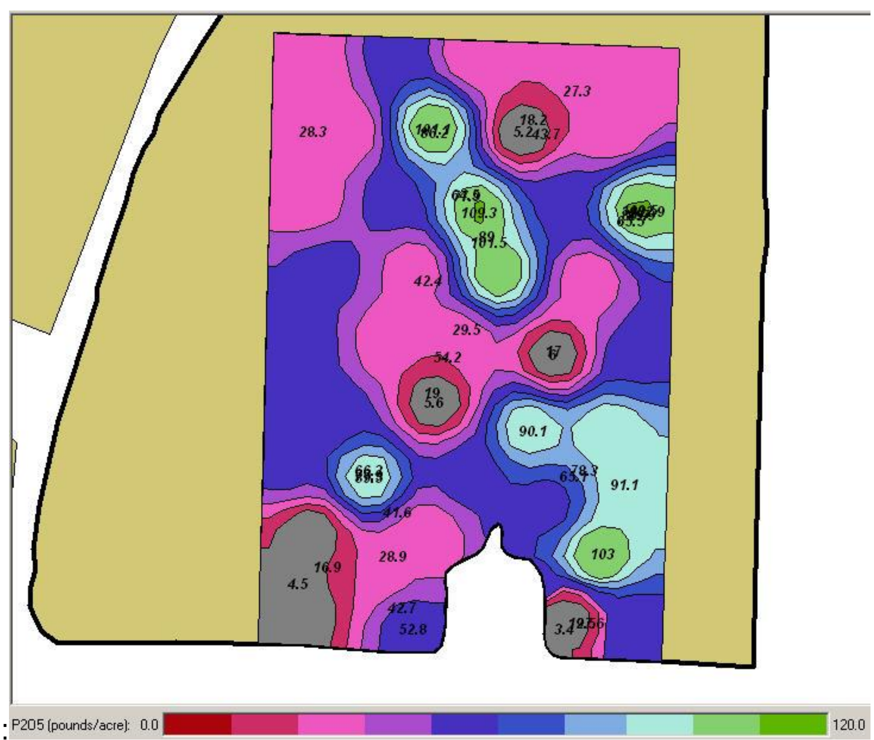


Objective 3: Research and demonstrate how nutrient application maps can be used in combination with soil test and yield maps to develop a nutrient prescription map.

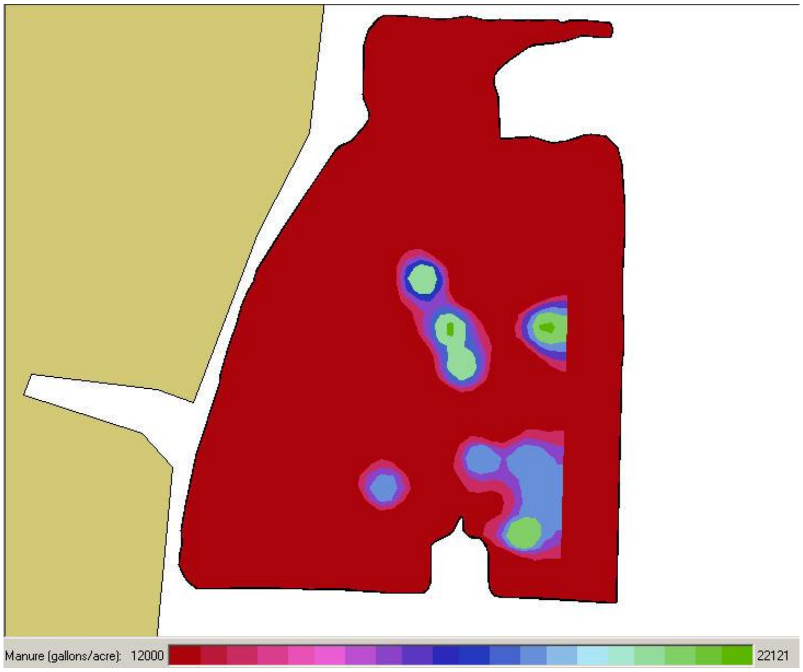
The field for this study was grid soil sampled so we could develop soil pH, P and K maps. Maps of each nutrient were stored as layers of information in Mapshots. Below is an example of the P layer map which shows the soil test P at each of the soil sampling sites:



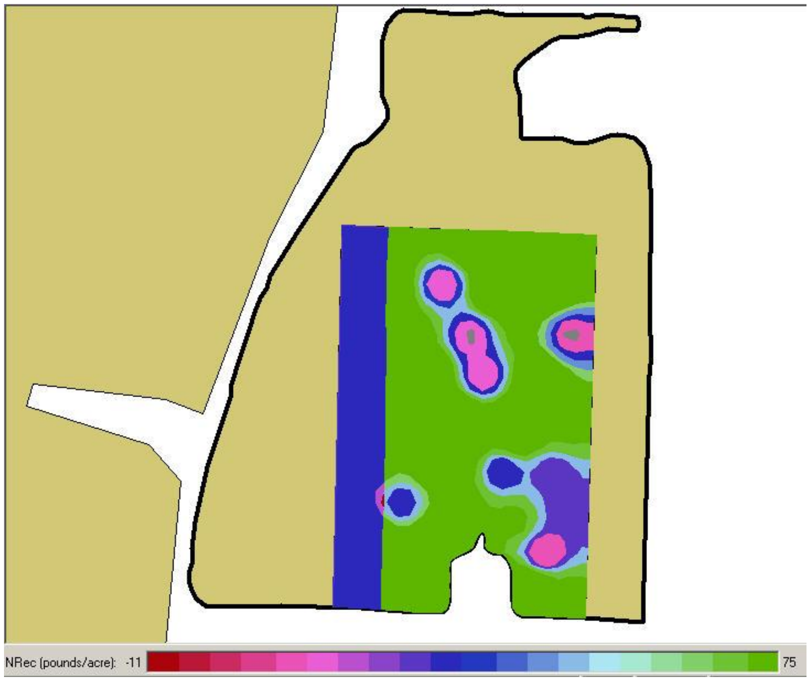
From this soil test P map and yield information we were able to produce the P205 prescription map to apply the appropriate amount of P for each site specific area of the field.



From this P205 prescription map we then developed a spreading prescription map which the manure monitor used to control the amount of gallons per acre of manure to be applied to meet the crops P need at each specific site in the field. Thus, we were able to apply P to crop need rather than over or under applying P to the field. Below is an example of this prescription map:



From this map we then generated the nutrient amounts needed for each site in the field. The site specific manure nutrient application map layers showing the amount of each nutrient applied were then overlaid over the total nutrient map layers and from these two layers we were then able to a site specific nutrient prescription maps for each nutrient. These prescription maps were use by Landmark Coop variably apply additional nutrients to meet crop needs and build soil tests where applicable. Below are is an example of a variable rate nitrogen map:



Objective 4: Research and demonstrate variable application of nutrients based on the nutrient prescription maps to ensure nutrients are used efficiently and with minimal environmental risk.

As described in Objective 3 above we were able to apply manure at variable rates throughout the field to meet the crops P need on a site specific basis. This ensured that the P was used efficiently and with minimal environmental risk. We were also then able to determine how much manure nitrogen was applied at each site specific area in the field and then subtract that manure nitrogen from the crop's total nitrogen need at each site in the field to create another Nitrogen prescription map for applying the correct amount of Nitrogen to meet the crops need again without over and/or under applying Nitrogen. This ensured that we used the nitrogen efficiently and minimized the opportunity for Nitrogen loss. Economic calculations of fixed rate manure and nitrogen applications versus variable rate manure and nitrogen applications showed a $4.85 per acre savings of Nitrogen to the variable rate program. This technology would also allow us to use the farm's manure P more efficiently throughout the farm.

Objective 5: Develop recommendations for inclusion of precision manure application in the Wisconsin 590 nutrient management standards.

From this research we will explore with Wisconsin 590 nutrient management standard policy setters how they can use precision ag technologies to help producers to automate the recording of their application records and to adjust their nutrient management plans with precision ag software tools that are becoming more available to producers.

Objective 6: Research/demonstrate how different placements of dairy and swine manure with steering systems affect yield and nutrient uptake.

Dairy and Swine manure were injected either 5” from the row, 15” from the row and/or broadcast on the surface in fall of 2005 at a rate of 4500 gallons per acre. This application of dairy or swine manure either met or exceeded the P and K needs of the corn crop, thus no more additional P and K were applied to the field.

		Placement		
Manure Type	Between Rows	In-Row	Surface	Average
	------------------------------------- bu/a -------------------------------------			
Dairy	187	182	182	184
Swine	190	188	132	170
Average	188	185	157	
Significance (Pr>F)				
Manure Type (T)	0.14			
Placement (P)	<0.01			
M*P	<0.01			

The swine manure provided the nitrogen needs of the crop. The dairy manure supplied approximately 40 pounds of the crops nitrogen need, thus an additional 135 pounds of liquid nitrogen fertilizer was added to dairy manure treatments to meet the crops needs.

Table 3 shows the yield differences with the different manure treatments in 2006, Table 4 shows the yield differences with different manure treatments in 2007. Table 5 shows the yield differences with different manure treatments for 2008. Table 6 shows the yield difference with different manure treatments for 2009.

In 2006, this data shows the swine manure resulted in lower yields, but this was mainly because of a much lower yield when the swine manure surface applied. A similar effect was not observed with dairy manure. Grain yield where manure placement was between rows was not different than where placed in row in 2006 and there was a significant interaction between manure type and placement, which again was caused by the lower yield where the swine manure was surface applied.

Table 3. Effect of manure type and placement on corn grain yield at Harrison farm, Elk Mound, Wis., 2006

Table 4: Effect of manure type and placement on the yield and moisture of corn and soybean grain Elk Mound, Wis., 2007.

		Dairy		Swine	
Crop	Placement	Yield	Moisture	Yield	Moisture
		bu/a	%	bu/a	%
Corn	Between	138	15.0	132	14.8
	In-row	141	15.0	152	14.8
	Surface	130	15.0	112	14.9
Pr>F		Yield		Moisture	
Animal		0.60		0.19	
Placement		0.03		0.72	
A * P		0.19		0.72	
Soybean	Between	37	9.7	40	9.7
	In-row	40	9.7	37	9.7
	Surface	39	9.7	36	9.7
Pr>F		Yield		Moisture	
Animal		0.68		0.42	
Placement		0.89		0.41	
A * P		0.59		0.41	

This table was developed from a split-plot analysis of variance conducted separately for each crop. The only significant response was for placement as it affected corn yield. In-row placement was superior to between row placement. Both were better than surface. Although the interactive term was not statistically significant (<0.05) it showed a trend that shows surface application of swine manure is a poor option.

In 2007, there was a significant difference in yield due to manure placement. Corn yield was higher where manure was applied in row and lower if applied to the surface. There was no difference between manure type (species). It was an extremely dry year, thus maybe the nutrient placement in the row gave the corn plants an advantage. There were no manure type of placement effects observed for soybean yield.

Table 5: Effect of manure type and placement on the yield and moisture of corn and soybean grain, Elk Mound, Wis., 2008.

		Dairy		Swine	
Crop	Placement	Yield	Moisture	Yield	Moisture
		bu/a	%	bu/a	%
Corn	Between	178	17.1	205	17.2
	In-row	184	17.2	204	17.2
	Surface	203	17.2	195	17.2
Pr>F		Yield		Moisture	
Animal		0.19		0.32	
Placement		0.81		0.20	
A * P		0.28		0.43	
Soybean	Between	49	11.3	49	11.2
	In-row	49	11.1	43	11.2
	Surface	48	11.6	47	11.2
Pr>F		Yield		Moisture	
Animal		<0.01		0.80	
Placement		0.06		0.57	
A * P		0.13		0.57	

This table was developed from a split-plot analysis of variance conducted separately for each crop. The only significant response was for placement as it affected corn yield. In-row placement was superior to between row placement. Both were better than surface. Although the interactive term was not statistically significant (<0.05) it showed a trend that shows surface application of swine manure is a poor option.

Table 6.Effect of manure type and placement on the yield and moisture of corn and soybean grain, Elk Mound, Wis., 2009.

		Dairy		Swine	
Crop	Placement	Yield	Moisture	Yield	Moisture
		bu/a	%	bu/a	%
Corn	Between	200.5	17.8	196.7	17.7
	In-row	195.6	17.8	196.0	17.8
	Surface	186.0	17.8	194.8	17.7
Pr>F		Yield		Moisture	
Animal		0.62		1.00	
Placement		0.22		0.62	
A * P		0.37		0.62	
Soybean	Between	45.9	10.6	44.1	10.4
	In-row	43.2	10.5	46.7	10.4
	Surface	44.0	10.5	47.1	10.4
Pr>F		Yield		Moisture	
Animal		0.27		0.23	
Placement		0.93		0.17	
A * P		0.27		0.89	

This table was developed from a split-plot analysis of variance conducted separately for each crop. The only significant response was for placement as it affected corn yield. In-row placement was superior to between row placement. Both were better than surface. Although the interactive term was not statistically significant (<0.05) it showed a trend that shows surface application of swine manure is a poor option.

In 2008 and 2009 there was a significant difference in yield due to manure placement. In-row placement was superior to between row placement. Both were better than surface. Although the interactive term was not statistically significant, the trend that shows surface application of swine manure is a poor option.

Objective7: Demonstrate how steering and recording systems can make on-farm research easier and more accurate.

On-farm research is much easier to accomplish with steering systems and the recording and controlling systems on the tractor. Steering systems were used to lay out our manure treatment plots which improved our plot accuracy immensely. Because it is often difficult to reset the planter or applicator between each treatment, we were able to set up the manure type and application rate. After we were done applying all the replications for that treatment we reset the applicators and went on to the next treatment and applied all the replications for that particular treatment and so on

The other benefit to doing research with precision farming systems is the ability to monitor if the tractor operator is actually applying the treatments as prescribed. The recording system in the tractor also allows this information to be stored on a site specific basis and then this information can easily be entered into precision agriculture software such as Mapshots and linked to harvest information so as to make the whole data recording and analysis process much easier and accurate.

Objective 8: Provide training sessions for farmers, industry, extension, and agency personnel on these emerging technologies.

In December of 2006 we have shared this technology at an On-Farm Research workshop that was held for Extension personnel. We also had a training session at the 2007 Midwest Manure Expo which was held in Prairie Du Sac, Wisconsin on 21 August 2007. Several hundred people learned of our research at this event. Our research has also been written up in the 2006 November/December Manure Manager Magazine.

In January of 2008, 2009 and 2010 we shared this technology at the Wisconsin Professional Nutrient Applicators Association. The teaching was used for level 2 training for the organization. Over the 3 years over 200 applicators attended the sessions and earned CEUs for certification. In December of 2008, the technology was taught at the 6th Annual Tri-State Regional Summit in Fennimore Wisconsin. Over 100 participants learned about the research and how it could be applied to their operations.

Objective 9: Offer several field day opportunities to share this new technology and information with farmers, consultants and agency personnel.

In 2007, we held a field day at the Harrison Farm which nearly 50 producers, extension and agency personnel attended and learned about the technology we are using. We also had a booth at the 2007 Wisconsin Farm Technology Days show in Rock County, which is a major farm show with field demonstrations and is held each year in Wisconsin. Hundreds, if not thousands of people, got to see our display at the Farm Technology Days Farm Show. Now that we have results to share with producers and industry representatives we will continue to hold field days to share this information. In 2009 we also shared this technology with national and state representatives of NRCS and EPA, when they attended our Pleasant Valley Watershed Field day.

Discussion

The primary objectives of this study are to help to understand how to manage manure sampling and how to utilize precision farming technologies to manage manure nutrients more efficiently. We are also demonstrating how producers can use Precision Agriculture Technologies to improve there on-farm research capabilities.

The best way to evaluate the sampling frequency on any given farm's manure storage is to over-sample to establish the uniformity of the manure samples within a storage system. From this information a farmer can determine how frequently manure samples need to be collected, assuming handling procedures are unchanged. Data from our research shows that the manure is quite variable in composition even though it was sampled as often as every 4 hours. Thus frequent sampling of manure throughout the agitation and application period are essential to accurately identify the amount of nutrients that are actually being applied to producer's fields.

The proper protocol for sampling manure will more than likely vary from farm to farm depending on the farm's ability to uniformly agitate their storage facilities and the ability to collect frequent samples. The farm we are studying uses excellent agitation practices, yet manure samples are quite variable. Extra sampling does indeed take more time and money, but the benefits of being able to manage a 30% change in nutrient content are very important for ensuring manure nutrients are accounted for correctly and that manure nutrients are used efficiently and yields are optimized by applying the correct amount of nutrients.

Frequent manure sampling information linked with site specific application information and current precision agriculture software will allow producers to develop very accurate site specific manure nutrient application maps. These maps will allow producers to know with certainty the amount of nutrients that have been applied to fields. This will permit them to accurately supplement crop nutrient needs with fertilizer. This should provide producers a greater level of confidence with respect to the amount of manure nutrients they have applied and allow them to put a true economic value on these nutrients.

Once producers actually know how much N, P and K they have applied with their manure, they can more precisely apply additional nutrients with variable rate technology. This variable rate technology may be too expensive at the present, but as this technology becomes more affordable it will become profitable to manage nutrients and improve nutrient application records. This should help to ensure that nutrients are used efficiently and with minimal environmental risk.

As we learn how to use precision agriculture tools with more confidence, we will also have the ability to automate manure nutrient application information. The acceptance of this information may allow future policy developers to consider the inclusion of these ideas into the Wisconsin 590 nutrient management standards. These recommendations will not be developed until we have several years of research data to ensure our results are consistent from year and so we have adequate replicated results over multiple years to make recommendations from.

Research/demonstrate how different placements of dairy and swine manure with steering systems affect yield and nutrient uptake. Dairy and Swine manure were injected either 5" from the row, 15" from the row and/or broadcast on the surface in fall of 2005 at a rate of 4500 gallons per acre. This application of dairy or swine manure either met or exceeded the P and K needs of the corn crop, thus no more additional P and K were applied to the field. . The swine manure provided the N needs of the crop. The dairy manure supplied approximately 40 pounds of the crops nitrogen need, thus an additional 135 pounds of liquid nitrogen was added to dairy manure treatments to meet the crops needs.

The effect of manure type and placement at the 2006 Harrison farm yields is shown in Table 3. These data show that the swine manure resulted in lower yield, mainly because of a much lower yield when the swine manure surface applied. A similar effect was not observed with dairy manure. This was likely due to loss of N as volatilized ammonia from the swine manure. Since the manure made up a smaller amount of the nitrogen supplied with the dairy manure, ammonia volatilization may not have been as great an issue. Grain yield where manure placement was between rows was not different that that where placed in row. There was a significant interaction between manure type and placement, which again was caused by the lower yield where the swine manure was surface applied.

In 2007, 2008 and 2009, the effect of manure type and placement was similar in the respect that surface applying swine manure was not a good management practice as yields were reduced. 2007, 2008 and 2009 were dry years and the placement of nutrients closer to the row in corn significantly increased corn yields in comparison to placing manure between the rows. Placing the manure closer to the row may have made it easier for the plants to access the nutrients and consequently improved yields.

On-farm research is much easier to accomplish with steering systems and recording and controlling systems on the tractor. The steering systems allow the farmers and researchers to lay out several plots on the steering system by treating each plot area as a swath on the steering system. Because it is often difficult to reset the planter or applicator between each treatment, the operator can set up the tool to apply one treatment and apply all replications of that treatment by using the steering system to find the correct swath to apply the replications for that particular treatment. Then the operator can set up the next treatment on the applicator and go to the appropriate swaths to apply all replications of that particular treatment and so on. This makes on-farm research much easier and allows for proper research design.
The recording system in the tractor also allows this information to be stored on a site specific basis and then this information can easily be entered into precision agriculture software such as Mapshots and linked to harvest information so as to make the whole data recording and analysis process much easier and accurate.

Now that we have results to share with producers and industry representatives we will hold several field days to share this information. We have been meeting with local farm advisory groups and to plan these educational events. We have shared this technology at an On-Farm Research workshop that was held for Extension personnel. This upcoming year we are planning to share our results with producers and industry representatives

Lay Interpretation

Precision Agriculture Technologies are here to stay as more combines, applicators, and tractors are equipped with GPS receivers, steering systems and data recording systems. These technologies offer producers and researchers a whole new set of tools to do their work. In this research project we have been using the technology to improve manure management and demonstrate how to use the technology to implement on-farm research.

There is a steep learning curve for this technology, but it appears we can use the technology to effectively manage manure nutrients more precisely on swine and dairy farms. This will minimize the over and/or under application of nutrients and allow producers to accurately measure and record the application of nutrients. After this information is recorded, we can then develop more precise application prescriptions so as to improve the efficiency of the manure and other nutrients being applied.

This will also provide a permanent record of nutrient application which may be useful in situations where liability for producer's actions are challenged. Producers who have attended our educational programs have been very interested in this technology and are interested in implementing it on their farms.

We are also studying whether manure placement relative to the crop row has any significant effect on yield and/or manure utilization. The first year's results show no distinct advantage to injecting either dairy or swine manure under the row versus between the rows. However, broadcasting swine manure rather than injecting it significantly reduced yields, thus it is important to inject swine manure and/or work it into the soil. This is likely due to loss of volatile nitrogen in the swine manure and hence a nitrogen shortage for the crop. In our second year of data we did see some benefit to placing manure under the corn rows rather than placing the manure between the rows. This may be because it was easier for the corn plants to access the nutrients when they were placed closer to the row, during periods of dry weather.

Precision Agriculture Equipment definitely makes on-farm research easier to conduct and record field operations. Laying out plots and replication of plots is much easier to accomplish with the assistance of steering systems. Data collection and measurement is also enhanced with the ability to measure and record information with monitors in tractors and combines. The adoption of these technologies on swine and dairy farms will allow producers to refine their management through better measurement and recording of information. This improved management should also result in and improve farm profitability.