Evaluating the profitability and environmental impacts of poultry litter sub-surfer technology

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Abstract

Commercial fertilization has long been the preferred method amongst Kentucky grain farmers. However, emerging technology of poultry litter sub-surface injection will challenge the normal fertilization methods though there have been concerns over added costs and time in the field. A resource allocation linear programming model was performed in AIMMS software comparing the two methods. Results showed that the injection method yielded higher net returns then the typical commercial fertilization despite the additional costs and field hours. This information will be useful to farm managers looking to increase profit margins once the technology hits the market.

Keywords: Farm Management, Linear programming, Poultry litter fertilization, Sub-surface injection

Introduction

In recent years, grain farmers have seen very low market prices and rising input prices leading to a reduction in profit margins. In efforts to reduce costs, some Western Kentucky grain farmers are using a relatively abundant supply of poultry litter as a cheap fertilizer source. Not only is poultry litter easy to obtain for these farmers, but it has proven to be a good fertilizer source because it benefits both the crops and the soil when used as suggested.

Using poultry litter as a fertilizer source is similar to applying commercial fertilizers. Poultry litter provides significant amounts of the main three nutrients needed for efficient crop growth: nitrogen, phosphorous, and potassium (Funderburg, 2009). Litter usually is in a solid form and is applied to the field using a spreader. Even though poultry litter is a great organic fertilizer, it has been applied irresponsibly in the past causing damage to nearby waterways (Gerber et al, 2009). It is important for farmers to apply the litter based on soil test recommendations. In Kentucky, agronomists advise litter application to be based on the phosphorus needs of the soil (Rasnake, 1996). If litter is applied based on nitrogen needs, then there will be an over application of phosphorus and potassium which leads to negative impacts on the environment. A problem that arises when applying based on phosphorus needs is that most times the farmer will need to apply additional nitrogen commercial fertilizers to meet the soil needs.

When discussing how much litter, the farmer must consider application timing. Research has proven that the optimal litter application timing to recoup the most nutrients is in the spring before planting (Rasnake et al, 2000). However, this is not what most farmers are doing.

Due to time constraints in the spring, local farmers fall, or winter apply the litter (Tewolde et al, 2013). In fact, Initial studies across the state have proven that farmers want to use poultry litter as a fertilizer, but the largest concern comes with enough suitable days to complete field operations. Since the litter needs to be applied as close to planting as possible to achieve maximum benefits, farmers are unwilling to delay planting. By doing this, nearly all of the nitrogen in the litter is lost due to leaching or volatilization. This means that farmers will need to apply more nitrogen commercial fertilizer in the spring increasing their costs of production. Often time's farmers don't realize the loss of nutrients and don't adjust by applying more nitrogen. Therefore, the plant will not be getting the required nutrients to reach maximum growth potential. At any application time, incorporating the litter into the soil will help preserve some of those nutrients that would otherwise be lost (Rasnake et al, 2000).

Poultry litter is typically spread on top of the fields with a spin spreader. This equipment allows for a lot of ground to be covered in relatively little time. The downside is that the litter stays on top of the soil until it is incorporated by another piece of equipment. This analysis will focus on a new application method, the poultry litter sub-surface injector. The sub-surface injector inserts poultry litter directly into the soil preventing nutrient loss due to excessive rains. Like with the typical poultry litter application, some nitrogen will still be lost and will have to be made up for with commercial fertilizer. This method has however, proven to increase yields which makes it a viable option for farmers (McGrath and Ritchie, 2016). This paper will compare commercial fertilization and the poultry litter injector method from both an agronomic and economic standpoint to determine which one is the most beneficial to Kentucky farmers.

Literature Review

Over the last decade, soil scientists and other researchers have been studying the effects of poultry litter on the soil and on the different crops it is applied to. Most articles on this topic suggest that poultry litter as a fertilizer source will increase soil health over time as compared to commercial fertilizers and eventually increased yields will be realized. Specifically, the organic matter contained in the litter could be especially beneficial to places where topsoil has been lost due to erosion (Rasnake, 1996). Another advantage of using poultry litter is that it does not acidify the soil like commercial fertilizer does. Poultry litter offers a range of benefits starting with providing nutrients to the soil, eases some environmental concerns, and is often cost effective (Pratt, 2014).

The use of poultry litter as a fertilizer source has been popular for several years. Farmers realized that it was a cheap fertilizer source for crops and was an easy way to dispose of the litter from the production of poultry. Years down the road, scientists saw places in water sources where there were extreme amounts of phosphorus or nitrogen buildups (Gerber et al, 2009). Some of these spots are now known as dead zones where little to no aquatic life is present. These zones are often, but not always, downstream from large commercial poultry operators. Since then, the EPA and USDA has implemented nutrient management strategies which help prevent the overuse of poultry litter and other fertilization techniques.

As previously discussed, typical application leads to a loss of the valuable nutrients through volatilization and leaching. Current research is looking at ways to combat this problem. The newest application method, sub-surface injection, will increase yields because less of the nutrients are lost to volatilization or leaching (Crummett, 2015). As expected, the typical application method of spin spreading litter on top of the soil has received some complaints such as an unpleasant smell and environmental concerns such as runoff. With the injector, air quality around the areas of application has improved because the amount of ammonia released into the air is reduced by about 95% as compared to spin spreading (Pratt, 2014). In addition, there is less chance of runoff meaning a reduction in water pollution. Studies have shown that near the end of corn growth, biomass and nutrient uptake was greater with the injector as compared to the spreader which explains the increase in yields (Pratt, 2014).

The injector operates like a no-till planter. This piece of equipment pulverizes the litter into ultra-fine particles just before slicing the ground about 3 inches deep, allowing the litter to flow right in before another blade moves the dirt over it, keeping the litter from being exposed. This technique is unique in the fact that it incorporates the litter into the soil without unearthing the ground. Many Kentucky grain farmers have adopted no-till methods making this injector an appropriate solution for the runoff of nutrients caused by not incorporating the poultry litter.

Methodology

The Hypothetical Farm

For this analysis, a hypothetical farm was used to better understand the fertilization methods and the net returns expected. Henderson County, Kentucky was chosen because of the massive amount of grain production and historically high yields. Henderson is also home to major grain companies such as ADM, Bungee, and CGB which have elevators located along the

Ohio River allowing farmers to have direct access to the buyers of their product. It is characteristic of farmers in the county to grow both corn and soybeans in order to diversify and maximize their farming potential (Lee, 2007). There are many different rotation possibilities, but a typical rotation is devoting 50% of the land to corn and the other 50% to soybeans.

The hypothetical farm this analysis is based on has 2000 acres available to plant crops. Per the rotation method mentioned above, 1000 acres will be devoted to corn and another 1000 acres will be devoted to soybeans. All crops will be planted under a no tillage system. There are two fertilization strategies that will be the focus of this study. In each scenario, the only factor changing is the fertilization method and timing. The first strategy, commercial fertilization, includes the use of what is considered typical synthetic fertilizers. For the nitrogen requirements farmers can chose between liquid UAN, liquid-gas Anhydrous, or solid UREA. For this analysis, there is an assumption that the farmer uses UAN 32% for the nitrogen requirement. Similarly, for the phosphorus and potassium requirements, assume the farmers use DAP and Potash, respectively.

The next fertilization technique is with the use of the sub-surface injector. Poultry litter is applied at a rate of 2 tons per acre which results in the phosphorus and potassium requirements to be met. Only about 40% of the nitrogen required for production is available to the crop. Therefore, nitrogen will need to be supplemented through commercial UAN. Ideally, injection occurs in the spring right before planting. This method increases variable costs but has a benefit of increased corn yields.

Economic Model

The primary purpose of most farming operations is to manage their production and costs as efficiently as possible. With this goal in mind, farmers are faced with the decision of what to produce and how to produce it. This analysis looks specifically at which of the previously discussed fertilization decisions allows for the most efficient operation. To determine efficiency, a whole farm plan was created. A whole farm plan is described as a forward planning tool that organizes multiple farming enterprises into one plan to determine production levels and possible net returns. For the mathematical calculations, the plan was entered into a linear programming model in AIMMS. There are several types of linear programming models. This analysis uses a resource allocation model to maximize net returns subject to constraints.

In this analysis there are two models which represent each of the fertilization strategies. The decision variables in each model are the number of acres planted of both corn and soybeans at each of the 14 possible planting dates. The resulting acreage will determine the net returns of the farm. There are multiple constraints modeled to reflect the farmer's production situation. One of these constraints is the acreage restriction which is 1000 acres for each crop. The next constraint considered is labor hours. While grain production isn't necessarily known as labor intensive, there are still only so many suitable field days/hours that can be used for planting, spreading fertilizer, harvesting, etc. Suitable field days are broken down by week as is the farming operations and the hours required for it. The results of each model will determine if the farmers have enough time to fertilize and plant each crop to maximize the acreage they have available.

To start, a single enterprise budget needed to be created for each commodity produced under the different fertilizing scenarios mentioned above. This resulted in two different corn enterprise budgets. In each one the only factors that changed were the fertilizer related operations, which includes the cost of fertilizer and application. Corn produced using commercial fertilizer is the base scenario and all comparisons are based from it. There were also two soybean budgets created. Since there is an assumption of crop rotation, the first budget has soybeans being produced after commercial fertilized corn. The second budget has soybeans being produced after poultry litter fertilized corn. The reason for this distinction is because unlike commercial fertilizer, poultry litter leaves nutrients in the soil that will still be available for the soybeans in the next year (Rasnake, 1996). This reduces the production costs which affect the net returns. These enterprise budgets provided the core information needed to develop a whole farm plan that is executed using AIMMS.

It is important to mention several calculations that occurred prior to entry into the linear programming model. The first is the ownership costs of the fertilization equipment. Ownership costs consist of the interest expense and depreciation of the piece of equipment. The main piece of equipment used in commercial fertilization is the liquid fertilizer applicator. Likewise, the sub-surface injector along with the liquid fertilizer applicator is used in the injection model. Information needed for this calculation included purchase price, useful life, and performance rate. This information is readily available for the liquid fertilizer applicator but Since the injector isn't available for purchase yet, estimates had to be obtained.

Data

The majority of the data needed for this analysis was to determine a realistic farm. For the size of the farm, the 2016 Kentucky Farm Business Management Annual Summary Report was used. According to this report, the average size of a grain operation in Kentucky is approximately 2000 acres (Pierce, 2017). Using the assumed 50/50 crop rotation, 1000 acres will be devoted to corn and another 1000 acres will be devoted to soybeans.

Yield is a very important piece of information when looking at production analyses. The United States Department of Agriculture Statistics Service reports that in Western Kentucky between the years 2012 and 2016, the average corn yield is 147 bushels per acre and the average soybean yield is 48 bushels per acre. These numbers are the base yields for the model and depending on planting date and fertilizer method, the yields will increase or decrease (Schwartz et al, 2017).

Price received for grain will ultimately determine the profitability of the farm. Historical market prices were used for the years 2012 to 2016 for both corn and soybeans. This data was also extracted from United States Department of Agriculture Statistics Service. For the time periods selected, the average price of corn and soybeans was $4.64 per bushel and $11.44 per bushel, respectively.

This analysis adds on an extra level to the model by considering the different planting date options for both crops. According the to the 2017 Becks' Hybrids Practical Farm Research (PFR) book planting weeks include the week of March 16th, March 23rd, April 1st, April 8th, April 16th, April 23rd, May 1st, May 8th, May 16th, May 23rd, June 1st, June 8th, June 16th, and June 23rd.

Each of these weeks has either a yield increase or decrease depending on the crop. For both corn and soybeans optimal planting date is between April 16th and April 23rd increasing yields by 110% and 107%, respectively (Schwartz et al, 2017).

In each scenario, fertilizer was applied based on the recommendations given in the University of Kentucky's Cooperative Extension publication AGR-1 2014-2015. Those recommendations suggest that soils need 180 pounds of Nitrogen, 60 pounds of phosphorus, and 55 pounds of potassium per acre. As previously discussed, poultry litter meets some of these requirements but not all. An estimation of 50 pounds of nitrogen, 50 pounds of phosphorus, and 40 pounds of potassium was provided by the litter. Not all of those nutrients will be available to the plant depending on application timing and method. To determine the nutrient availability percentages in poultry litter, University of Kentucky Cooperative extension publication "Using Animal Manures as Nutrient Sources" was used (Monroe, Tom, and Sikora, 2000). If Kentucky farmers apply litter based on phosphorus needs as recommended, they should apply 2 tons of litter per acre.

Price of inputs is just as important as price received for grain when determining net returns. Again, Commercial fertilizer prices were determined by data from the United States Department of Agriculture Statistics Service. Average prices for UAN, DAP, and potash were collected for the years 2012-2016. Using a fertilizer price calculator (Halich, 2015) the prices per ton retrieved were converted into actual price per pound. The resulting prices were $0.40 per pound of UAN, $0.49 per pound of DAP, and $0.51 per pound of potash. According to the University of Maryland Cooperative Extension Poultry Enterprise budget, a ton of litter costs the farmer $25 figuring in removal and hauling costs.

In this model, it is assumed that the poultry litter is produced as a byproduct of poultry production. To capture this, assume the farmer has two broiler houses on his/her property and each produces 200 tons of litter a year (Rhodes, Timmons, Nottingham, and Musser, 2011). Only 400 tons will be available for the farmer to use as a fertilizer on crops.

Information on commercial fertilizer application is relatively easy to obtain. However, data on applying the litter using a sub-surface injector is virtually non-existent. This is because the injector isn't commercially available to farmers yet. For this analysis, University of Kentucky Plant and Soil Sciences Extension Specialist Josh McGrath gave good estimates on pricing values and machinery efficiency. The purchase price of the piece of equipment is the one that is likely to be the most variable but for this estimate a value of $50,000 was used. The machine is estimated to have a useful life of eight years, a salvage value of $5,000, and a performance rate of 3.2 acres per hour.

A big component in any farming analysis is the days suitable for field work. One must consider the days where weather doesn't allow the farmer to operate machinery. This will impact the amount of land that can be operated. The United States Department of Agriculture Statistics Service reports the number of days suitable for fieldwork per week going back to 1996 (Shockley and Mark, 2016). The numbers reported are averages based on all the years combined. While there is a wide range of days suitable, the median numbers were used. The days suitable are multiplied by an assumed 15-hour work day (assuming a one-person operator) resulting in the hours available to do farming operations on a per week basis. Calculating on a weekly basis will result in specific points where a farmer's time is constrained.

Enterprise budgets for each crop and fertilizer method were previously completed using the Mississippi State Budget Generator software. These individual budgets give information needed for the linear programming model to run efficiently. From each budget, costs of production and hours needed for each operation were calculated. Even though the two fertilizer methods are very similar, there are slight differences in each of the two previously mentioned categories resulting in the difference in net returns.

Results

According to the linear programming models described above, the optimal fertilization strategy was poultry litter using the sub-surface injector. Even though this approach displays higher production costs because of the lower performance rate of the injector versus the spreader, the increased yield received per acre drastically increased returns offsetting the costs. Optimal production was 1000 acres of corn, 200 acres fertilized with poultry litter and the remaining 800 fertilized commercially. Likewise, soybean production mirrored that of corn. Corn is planted in the weeks of April 1st through May 8th while soybeans are planted April 16th through May 1st. The net return of this solution was $679,589. The commercial fertilizer model resulted in net returns slightly lower, $631,507 while still planting all 2000 acres of crops. Tables 1 and 2 present the acreage and planting dates per crop while Table 3 shows the net return comparison.

The optimal solution, injected poultry litter, had several binding constraints. These binding constraints reveal the marginal value product or shadow price for additional units of the constraint. For example, labor hours in weeks 15 -18 and 35-37, poultry litter available, and number of acres in production are all limiting factors. It is no surprise that labor hours in the weeks mentioned are used up because they occur during planting and harvesting, the busiest time for any farmer. If the farmer can work longer hours or potentially hire another person, the net returns of the farm could increase $169 and $143 per hour added in weeks 18 and 36, respectively.

Poultry litter is limited because of the assumption that the farmer is only using what is produced as a byproduct of his poultry operation. An estimated 400 tons of litter is provided by the operation which is only enough to cover 200 acres of crop land (Rhodes, Timmons, Nottingham, and Musser, 2011). This leaves 800 acres unavailable to fertilize with poultry litter. If the farmer were to purchase additional poultry litter or expand the poultry operation, the net returns of the farm could increase $79 per acre.

Overall, crop production is very profitable for the farmer. The number of acres are a bound at 2000 because that was a forced constraint. If not for this limit, the model would allow an infinite number of acres to be produced. It is important to note that an additional acre of corn grown will increase net revenue by $348. Likewise, an additional acre of soybeans will increase net revenue by $275. One would interpret this as a signal to acquire more land. The most common way to do this is to lease land from someone else. Leasing land, especially in Western Kentucky, has historically been costly. However, a current average cash rent of $220 per acre (Halich and Pulliam, 2013) still leaves room for profit for the farmer.

Another economic principle that is important to be discussed the opportunity costs or reduced costs of forcing certain production outside of the optimal solution. For example, if the farmer was wanted to plant soybeans early, March 16th, net farm returns would decrease by $124 per acre. Same situation if the farmer was forced to plant them late, June 23rd, net returns would decrease by $168 per acre. Perhaps a more dramatic decrease in returns would occur if corn was planted between June 16th and June 23rd. Profit would be reduced by $715 per acre. This can be explained because labor hours are limited, and the majority of the soybeans are being planted in this time frame.

Conclusion

The goal of this analysis was to provide insight and evidence of the impacts of poultry litter sub-surface injection as compared to commercial fertilizer. To achieve this, a linear programming model was used to determine the optimal enterprise mix on a typical farm in Henderson County, Kentucky. The purpose was to determine how many acres of corn and soybeans to produce at what planting date and using the best fertilization strategy. Many factors were involved in the model including labor constraints, acreage limitations, input and output prices, and the data on the groundbreaking poultry litter injector. Results suggest that the poultry litter injection fertilizer method was the optimal fertilization strategy resulting in a net return of $679,589 proving that the sub-surface injector is not only a viable option for grain farmers in western Kentucky but the most profitable. This is somewhat of a shocking result considering most Kentucky farmers use commercial fertilizer. This analysis shows how much money the farmer is forfeiting by using this method.

In summary, the results of the model concurred with the hypothesis. Poultry litter benefits outweigh the extra cost associated with application largely because of the increase in corn yields. True impacts of increased soil quality and productivity because of poultry litter fertilization couldn't be completely measured in this analysis. With Kentucky poultry production continually increasing, it is important to dispose of the litter in an efficient and environmentally friendly way. This study proves that poultry litter is a viable fertilizer source that is economically feasible for grain farmers in Henderson County, Kentucky.

Appendix

Table 1: Commercial Fertilization Model - Planting Dates and Acreage

Planting Dates	Corn Acres	Soybean Acres
March 16th	0	0
March 23rd	0	0
April 1st	0	0
April 8th	0	0
April 16th	129	432
April 23rd	448	223
May 1st	423	35
May 8th	0	310
May 16th	0	0
May 23rd	0	0
June 1st	0	0
June 8th	0	0
June 16th	0	0
June 23rd	0	0
Total	**1000**	**1000**

Table 2: Sub-Surface Injection Fertilization Model - Planting Dates and Acreage

Planting Dates	Corn Acres- Commercial	Corn Acres- Poultry Litter	Soybean Acres- Commercial	Soybean Acres- Poultry Litter
March 16th	0	0	0	0
March 23rd	0	0	0	0
April 1st	0	47	0	0
April 8th	0	53	0	0
April 16th	0	0	639	82
April 23rd	605	0	161	0
May 1st	123	100	0	118
May 8th	72	0	0	0
May 16th	0	0	0	0
May 23rd	0	0	0	0
June 1st	0	0	0	0
June 8th	0	0	0	0
June 16th	0	0	0	0
June 23rd	0	0	0	0
Total	**800**	**200**	**800**	**200**

Table 3: Net Return Comparison

Fertilization Method	Net Returns	Difference from Baseline
Poultry Litter Sub-Surfer	$679,589	NA
Commercial Fertilizer	$631,507	($48,082.00) -7%

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