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TRANSPORTATION DISTANCE EFFECTS ON APPLICATION COSTS IN TWO DIFFERENT LIQUID MANURE TRANSPORT AND APPLICATION SYSTEMS

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Abstract

Manure application costs were evaluated for tank wagon applicators (TWA) and drag line applicators (DLA) for transport distance increments of 1.6, 3.2, 4.8, 6.4, and 8.0 km. Certain fixed and variable costs were analyzed for three application rates of 37,416, 46,770, and 56,124 liters per hectare to calculate the total operating costs. Increase in transport distance caused the variable cost to increase for both transport methods leading to increase in total operating costs, although the increase was stair-stepped in case of DLA system mainly due to addition of booster pump, fuel, and an employee at 3.2 km and 6.4 km transport distance. Increase in application rate caused the TWA system cost to drop more than the DLA system at any given distance mainly due to the variable cost being higher for the TWA system. Overall, the total operating costs were lower for the DLA system when compared to the TWA system for the three corresponding manure application rates. Data presented in this paper is a partial analysis of the total costs as it only considers transport and application costs, and does not include several additional incidental costs.

Keywords: Manure management, land application, method, tank applicator, drag line applicator, economics.

Introduction

Manure storage for finishing swine production in the upper Midwest has transitioned over time. Current structures are capable of storing twelve months or more of manure production. The main purpose of such large storage structures is to adapt manure land application into the row-crop production system for nutrient utilization and to make use of opportunities which minimize environmental risk. Large volumes of manure makes it necessary to transport it farther distances as adequate land may not be available near the storage site. Livestock producers have either applied manure themselves or have utilized the services of commercial applicators to apply manure to farm fields.

Manure is typically applied for its nutrient value based on nitrogen or phosphorus uptake within the limits allowed by manure management plans. Manure management planning takes into consideration phosphorus index, soil and manure test results, amount of annual manure production, and method of in-field application in addition to the nutrient uptake of the crops in rotation. Depending upon the application rate and the method of transportation used, the cost of manure application can vary due to the differences in equipment involved.

One common method of transportation and application includes liquid manure being mixed and transported to crop fields in tank wagon applicators (TWA system). Each of these TWAs has a tool-bar mounted on it and is pulled with a tractor to the field to apply manure. These wagons can typically range from 18,927 to 31,176 liter (5,000 to 8,500 gallon) capacity. The combined equipment and manure weight can produce axle loads which can potentially limit transportation with TWAs if the roads involved cannot bear the axle loads. Another limitation to transportation can exist in the form of load limits on rural bridges which can prohibit manure transportation or make transportation distances longer due to use of alternate routes to application fields. At certain times of the year, soil moisture can be such that traffic from TWAs can potentially create compaction issues for the subsequent crop in the farm fields.

An alternate method to transporting manure in TWAs typically used includes manure being pumped through flexible hoses to manure application fields. This eliminates the traffic created by manure tank wagons, both on the roads and in the field. In this methodology, manure is pumped from the storage site with a lead pump to the manure applicator in the field which applies the manure. The manure applicator is a tool-bar pulled by the tractor which does not leave the field and continuously applies manure being pumped to it. Manure being pumped from the lead pump into the main line typically needs a booster pump every 3.2 kilometers (two miles) or less due to frictional pressure loss and other factors. Once the manure reaches the edge of the field, it is transmitted to the manure applicator with the drag line that transverses across the field with the applicator, thus, also known as the drag line applicator (DLA) system. Main lines transporting manure are only moved once application is completed in a field.

Use of either method of manure transportation and application has its benefits and constraints. While the desire is to apply manure in the most environmentally and culturally friendly methods, swine producers are faced with the decision of selecting either method of application. This decision of selecting the manure transportation and application method is not simple and is capital intensive. Either method uses significantly different equipment such that it cannot be easily adapted to the other method in case of equipment failure or fields being too wet to not allow TWAs to apply manure. Thus, the need exists to carefully evaluate the variables influencing efficiency in either methodology such as transportation distance to help aid in choosing the better suited manure application methodology.

Literature review and objectives

Different types of decision support tools exist for evaluating manure management in livestock operations. Simulation models exist which evaluate the farming operations on a whole-farm basis for its manure management practices. Rotz et al. (2008) developed the Integrated Farm System Model (IFSM) which uses weather data simulations to evaluate dairy production costs, income and economic returns, cropping systems, manure production, and return of dairy manure nutrients to farm fields. The effect of manure hauling systems on cropping practices of tillage and planting were evaluated by Harrigan et al. (1996) using DAFOSYM, an earlier version of IFSM. This analysis was performed on two different sized dairy herds of 150 and 400 cows respectively by using labor availability as a constraint in the model. Simulations showed that greater labor availability helped in timely completion of manure application, tillage, and planting operations. Koelsch et al. (2007) developed a decision support system to evaluate costs of a manure transport system using animal feed and cropping system as the simulation basis. With this model, simulations can be performed using the number of animals housed, animal weight, feed ration fed to the animals, housing type, fertilizer needs based on crop to be grown, manure analysis, manure application method, and average manure hauling distance. All of these whole farm decision support systems require significant user inputs which may or may not be available for analysis, thus limiting their on-farm use.

Spreadsheet-based decision support tools have also been developed which can help focus on sub-sets of the manure management on the farm. Leibold and Olsen (2007) evaluated swine manure application using a spreadsheet-based analysis comprising of number and size of hogs, fertilizer prices, average manure analysis, five-year average crop yields, and planned application rate. Using this spreadsheet tool, value of manure nutrients (nitrogen, phosphorus, and potassium) in terms of costs to the farm can be compared to cost of equivalent commercial fertilizer for meeting the continuous corn and corn soybean crop rotation fertilization needs in Iowa. Koehler et al. (2009) developed a manure value spreadsheet calculator which expanded the work done by Leibold and Olsen (2007). This calculator is capable of calculating the value of manure for different livestock enterprises (beef, swine, dairy, and poultry), solid or liquid manure, amount of manure and its analysis, manure application method of broadcast or injection, planned application rate, crop nutrient needs, and cost of commercial fertilizer. Hadrich et al. (2010) developed a manure transport and land application decision support tool, MANURE$HAUL, for top-loading tank applicators and nurse tanks. This model predicted that the manure hauling capacity was a function of the machinery set selected, manure tank capacity, and the transportation distance. It did not compare different methods of manure transportation and manure application.

Both spreadsheet calculators as well as the whole farm simulation models developed so far have not compared the costs of transporting and applying manure for the TWA or the DLA systems. Several commercial manure application businesses have emerged in the upper Midwest due to the need to quickly apply manure in the short time window available either after harvest or prior to planting. The commercial manure application businesses have the potential to use either the TWA or the DLA methodology. As such, an analysis was performed to compare the costs of owning and operating equipment under either method of manure transportation and application. This analysis is different from the on-farm manure application as it is common for the farm tractors used in manure application to also be used in crop production activities. Commercial manure applicators typically have to use farm fields which may not be adjacent to the livestock operation. As such, they may travel or pump manure to longer distances to complete manure application. An increase in the distance of the manure application field from the storage site increases the time it takes to complete manure application. The analysis was, therefore, performed to evaluate the impact of distance on the cost of owning and operating manure application equipment in a commercial manure business under either method of TWAs or DLAs.

United States Department of Agriculture Census of Agriculture for 2012 was reviewed and it showed about 23 million finishing pig spaces for Iowa, with an inventory of about 20 million pigs, and annual sales of 50 million pigs. Using an estimate of 4.16 liters of manure produced per pig space per day and that the spaces were occupied for 340 days out of 365 days in a year, estimated manure produced in 2012 was approximately 32,563 mega-liters. This amount of finishing pig manure would have been land applied neglecting all rainfall water additions and any evaporation losses. According to Iowa Department of Natural Resources, the number of commercial manure applicator businesses registered in the state is approximately six hundred eighty-eight. Iowa State University Extension and

Outreach conducted a survey of commercial manure applicators in Iowa. Fifty-two commercial manure applicators responding indicated that they land applied 21 mega-liters on the lower end and 1,136 mega-liters on the upper end on an annual basis. This range was mainly due to the differences in the size of the commercial manure application business.

Materials and methods

A commercial manure applicator business comprising of TWAs was considered for comparison with a similar business applying manure using DLAs. The TWA system comprised of three-32,176 liter capacity tank wagons (8,500 gallon, $160,000 each), three-257 kilogram-force kilometer per second (350 horse power (h.p.)) tractors to pull tank wagons ($370,000 each), two manure agitation pumps ($14,000 each) and two-110 kilogram-force kilometer per second tractors (150 h.p., $130,000 each) to run the agitation pumps, and a load stand ($7,000). This business comprised of four employees, one employee managing one of the agitation pumps with the load stand attached, and one employee each driving one of the TWA. Each tank wagon had a 6.1 meter wide (20 feet) applicator tool-bar attached at its rear end to apply manure in the field.

The DLA system comprised of two agitation pumps along with two tractors to run the agitation pumps, one 561 kilogram-force kilometer per second lead pump (763 h.p., $250,000) to pump the manure in the main line, one 220 kilogram-force kilometer per second booster pump (300 h.p., $225,000) every 3.22 kilometers (two miles) of main line, a drag line once the main line reaches the application field, a 12.2 meter (40 foot) wide manure application tool-bar ($150,000), and a 257 kilogram-force kilometer per second (350 h.p.) tractor ($370,000) to pull the tool-bar in the field. This business comprised of two main employees, one on the lead pump and one in the field on the manure applicator. Each time a booster pump was added to the system due to additional distance, an employee was added as well to manage the pump and hose. This setup delivered a full capacity manure flow rate of 7,750 liters per minute (2,000 gallons per minute) at the tool-bar in the field.

In either system, employee hourly wages were considered to be $20 per hour. Fuel costs in the system were considered to be $0.79 per liter ($3 per gallon). Costs used in the analysis in this document were in US dollar. For comparison purposes, either system was considered to be covering 3,642 hectares (9,000 acres) for one year application season. Usable life on tractors, pumps, and tank wagons, used in either system, was considered to be fifteen (15) years. The usable life on main line and the drag line was 10 and 5 years, respectively.

Ag Decision Maker Spreadsheet A3-29 (Edwards, 2015) was used to calculate the fixed and variable farm machinery costs for both tank wagon manure applicators and dragline manure applicators. Manure application rates in the field considered for analysis were 37,416, 46,770, and 56,124 liters per hectare (4,000, 5,000, and 6,000 gallons per acre, respectively). Distance from the manure storage site to the manure application site considered in this analysis were 1.6, 3.2, 4.8, 6.4, and 8.0 kilometers (1, 2, 3, 4, and 5 miles respectively). Using the different distance to transport manure and different application rates, costs of completing manure application for the two methods were analyzed in terms of cost per hectare (cost per acre).

Results and discussion

In the analysis presented in this paper for comparison purposes, either TWA (Tank Wagon Applicator) system or the DLA (Drag Line Applicator) system was considered to be covering 3,642 hectares (9,000 acres) for one year application season. Manure application rate of 37,416 liters per hectare (4,000 gallons per acre) indicated 130 mega-liters land applied by a commercial applicator on the lower end. On the upper end, if all 3,642 hectares received application at a rate of 56,124 liters per hectare (6,000 gallons per acre), the commercial applicator would have applied 204 mega-liters in one year. Both of these lower and upper end amounts of manure handled are with the range reported by the commercial manure applicator businesses.

Applying manure at higher application rates took less time than applying at lower application rates. Both systems, however, were considered to apply manure over 3,642 hectares in one year driving eight km per hour (5 mph) in the field with the applicator. Using a 6.1 m wide tool-bar, the TWAs took approximately 750 hours to cover 3,642 hectares. Using a 12.2 m wide tool-bar, the DLA system took approximately the same time for application with fifty percent time efficiency. This efficiency in the DLA system existed due to the time consumed in laying out the flexible hose, draining it to move from field to field, and to fix any pipe ruptures. As such, fixed costs in both systems were spread over 750 hour annual usage.

Fixed costs for the DLA system increased incrementally with increase in distance. This occurred as additional pipe was needed for each additional 0.2 km increase in transport distance. The fixed costs calculated for 1.6, 3.2, 4.8, 6.4, and 8.0 km as $21.82, $23.52,

$30.12, $31.65, and $38.25 per hectare respectively for all three application rates. There was a sharp increase from 3.2 km to 4.8 km, and again for 6.4 km to 8.0 km as an additional booster pump was added to maintain the flow rate in the main line. For commercial manure applicators, the fixed costs for 1.6 and 3.2 km distance are likely to be the same as for 3.2 km as they will likely equip their operation to handle application jobs based on the capacity of the lead pump (capable of pumping up to 3.2 km) and purchase the additional flexible pipe. Likewise, once the booster pump capable of pumping up to 3.2 km is added to the DLA system, additional pipe is likely to be purchased and added. Thus, the costs for 4.8 and 6.4 km distance are likely to be the same. The fixed costs for the TWAs calculated to be the same ($33.19 per hectare) for the range of distance considered in this analysis as no additional tank wagons were added to the operation.

Variable costs for both application methods consisted of labor, fuel, and repair costs. Repair costs were calculated from the Ag Decision Maker Spreadsheet A3-29 (Edwards, 2015) which uses American Society of Agricultural and Biosystems Engineers standards. Labor and fuel costs in the TWA system were calculated based on the number of hours it took to apply manure one hectare. This time calculation took into consideration the manure loading, driving to the application field, applying manure in the field, and driving back to the storage site. Using a driving speed of 32 km/h (20 mph), it took 3, 6, 9, 12, and 15 minutes to drive 1.6, 3.2, 4.8, 6.4, and 8.0 km respectively in each direction. The application time in the field to apply manure was 14, 10.1, and 6.2 minutes for the three application rates respectively. Variable costs increased for the TWA system with increase in distance and decreased with increase in application rate.

Labor and fuel costs for the DLA system were calculated based on labor being used for all 750 hours of operation, however, the fuel costs were considered only for 375 hours as the pumps would be shut-off during non-application time periods. As the pressure in the main line was high enough, the application rate was controlled by opening of the flow value. Fuel consumption was assumed to be the same as the operating pressure was un-altered. Increasing the transport distance from 3.2 km to 6.4 km increased the fuel consumption due to utilization of the booster pumps. Likewise, labor costs calculated to be the same for distances up to 3.2 km and then from 3.2 km to 6.4 km as the labor was busy with non-manure application tasks. Repair costs increased with each additional booster pump added to the DLA system at higher than 3.2 km and 6.4 km distances.

Variable costs and fixed costs were added together to calculate the total operating costs per hectare to apply manure in either system and are shown in Figures 1. This figure showed that the DLA system had an advantage over the TWA system even though its fixed costs increased marginally for distances up to 3.2 km and then from 3.2 to 6.4 km mainly due to the booster pump costs. Commercial applicators, thus, may consider DLA system over the TWA system if majority of the manure application tasks are at these specific distance break-points. The decrease in cost per hectare for the DLA system at any transport distance was smaller between the three application rates than the corresponding decrease for the TWA system. In other words, an increase in the application rates caused the TWA

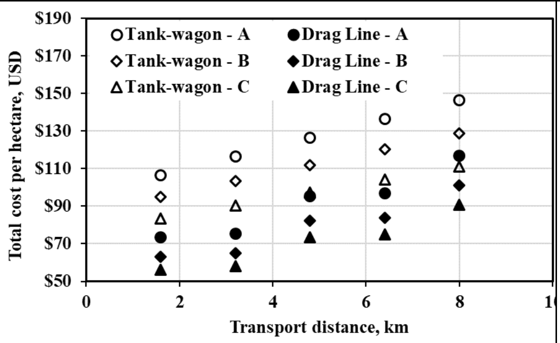

Figure 1: Total cost per hectare as a function of transport distance for two applications methods. A, B, and C refer to three manure application rates of 37,416, 46,770, and 56,124 liters per hectare, respectively.

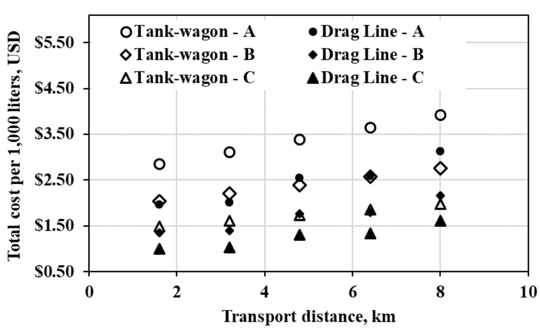

Figure 2: Total cost per 1,000 liters as a function of transport distance for two applications methods. A, B, and C refer to three manure application rates of 37,416, 46,770, and 56,124 liters per hectare, respectively.

system cost to drop more than the DLA system at any given distance. This was mainly due to the variable cost being higher to apply manure with the TWA system. Overall, the total operating cost with the DLA system was lower than the TWA system for each application rate. Figure 2 represents the total operating costs per 1,000 liters for the two methods and for the three application rates. These costs followed the same trends as the costs per hectare and no additional differences were observed.

Conclusions

The cost analysis presented in this paper considers only the application costs based on five different transport distances and three different application rates. It does not include any additional operating costs such as parts truck, employee trucks, manure sampling costs, manure management plan costs, record keeping, accounting, and other incidental overhead costs. As such, the analysis presented should not be considered a complete representation of total operating costs.

Increase in transport distance caused the variable cost to increase for both transport methods leading to increase in total operating costs, although the increase was stair-stepped in case of DLA system mainly due to addition of booster pump, fuel, and an employee at 3.2 km and 6.4 km transport distance.

Increase in application rate caused the TWA system cost to drop more than the DLA system at any given distance. This was mainly due to the variable cost being higher to apply manure with TWA system. Overall, the total operating costs were lower for the DLA system when compared to the TWA system for the three corresponding manure application rates.

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