Simulation of Dairy Manure Management and Cropping Systems

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Introduction

In recent years, environmental concerns regarding surface and groundwater quality have led to an increasingly restrictive, tightly regulated and costly operating environment for livestock producers. Legislation has been enacted at the Federal level to regulate tillage and manure management practices. Most states have Right-to-Farm legislation to protect crop and livestock producers from nuisance suits if they follow recommended or best management practices. The challenge for dairy farmers is to select and manage tillage and manure handling systems in a cost effective and environmentally safe manner. An analysis of the complex interactions of tillage and manure management with other operations and processes on the dairy farm requires a systems approach. This analysis must integrate the effects of weather, machinery, labor, tillage, planting, manure handling and other relevant factors on the management of the dairy herd. DAFOSYM, a simulation model of the dairy forage system, provides a basis for such an analysis.

Methods

DAFOSYM is a comprehensive computer model that simulates alfalfa and corn growth, harvest, storage, feeding, and manure production on a dairy farm. Submodels were added to enable an evaluation of the interaction of manure storage and application with tillage and planting. New submodels were developed to predict suitable days for tillage, planting and manure application operations under a range of soil and crop residue conditions; draft of a wide range of tillage and seeding implements; and scheduling of tillage, planting and manure application operations.

The timeliness of tillage, planting and manure handling is influenced by labor availability and the type of equipment used. Ten hours were available for field work during each suitable day. Manure spreading began in the spring as soon as the soil was thawed and trafficable. Manure application was immediately followed by the sequence of tillage and planting operations. Fall tillage and manure spreading began after corn silage was harvested and continued as land became available following corn grain harvest. Corn grain harvest was custom hired and thus did not interfere with the scheduling of tillage or manure spreading operations. A fourth cutting of alfalfa began in mid-October and this could delay tillage and manure hauling. Depending upon equipment and labor available, tillage and manure handling were scheduled either in series, where completion of manure spreading was required before tillage could begin, or as parallel operations where tillage and spreading progressed simultaneously.

Three tillage systems were modeled. Conventional tillage included fall tillage with a moldboard plow. In the spring, corn land was disked once and field cultivated once before planting. Alfalfa land was disked twice and field cultivated twice before seeding. Mulch-tillage included primary tillage with a coulter-chisel plow in the fall and spring seedbed tillage with a combination disk/field cultivator/coil-tine harrow. Land to be planted in corn required one pass for manure incorporation and seedbed preparation in the spring while alfalfa land was worked twice prior to seeding. A modified no-till system included fall tillage with a rolling-tine aerator. The aerator buried very little residue yet loosened the soil to improve water infiltration and alleviate shallow soil compaction. Crops were planted with a zone-till planter.

Manure handling systems included short-term storage with frequent hauling in a V-tank spreader and three systems using long-term storage: slurry tanker spreading, slurry tanker injection, and slurry irrigation. Manure was removed from long-term storage by irrigation or hauling with top loaded slurry tankers. Seven months storage capacity was provided. Pit agitation and tanker loading used a tractor powered pump/agitator. Agitation began two hours prior to the start of spreading and then continued only during tanker loading. Agitation was continuous during irrigation. The average hauling distance for manure was 0.8 km for the 150-cow herd and 2 km for the 400-cow herd. A pressure pump capable of pumping up to 1 km was located at the storage pit when manure was irrigated. An auxiliary pump was added to extend the pumping distance for the 400-cow herd. Slurry injection was not used with the modified no-till system.

Results and Discussion

The highest machinery, fuel and labor costs for manure hauling were associated with slurry injection and the lowest with daily hauling. Costs for daily hauling were sensitive to spreader loading method. Fuel and labor costs were similar to slurry systems when the spreader was loaded with a front-end loader. Direct loading of the spreader from a push-off ramp reduced fuel use in handling by 20 to 40% and labor use by 60 to 80% compared to bucket loading. The manure system used had a large effect on the timeliness of tillage and planting. Daily hauling of manure distributed labor throughout the year and allowed little interference with the timeliness of tillage and planting. Long-term manure storage concentrated labor for spreading in the spring and fall. Injection or surface spreading of stored slurry delayed tillage and planting and increased feed costs as much as $24/cow-yr when manure hauling, tillage and planting occurred in series. When labor and machinery were available for parallel field operations, manure handling method had little effect on the timeliness of tillage and planting.

The highest machinery, fuel and labor costs for tillage and planting were associated with conventional seedbed tillage. Compared to conventional tillage, mulch-tillage reduced machinery, fuel and labor costs about 30%; the modified no-till system reduced machinery costs about 25%, fuel costs 45% and labor costs, 50%. The tillage system used had a large effect on the timeliness of fall tillage. Chisel plowing was finished about two weeks earlier and soil aeration about four weeks earlier than moldboard plowing. There was little difference in timeliness of planting between tillage systems.

Compared to slurry injection, daily hauling increased net return as much as $54/cow-yr on the 400-cow farm and $78/cow-yr on the 150-cow farm. This economic advantage for daily hauling diminished if credit was not given for the fertilizer value of the manure nutrients when spread daily. Manure irrigation increased net return $23 to $29/cow-yr over slurry injection. The highest net return among tillage systems was associated with mulch-tillage, returning $15 to $25/cow-yr over conventional tillage. Use of the modified no-till system increased net return $6 to $16/cow-yr over conventional tillage, but when compared to mulch-tillage, savings in fuel and labor were more than offset by higher costs for seed, fertilizer and pesticides.

Conclusion

The expanded DAFOSYM model provides a flexible and useful tool for comparing the long-term performance and economics of tillage and manure handling systems and their interaction with feed production on dairy farms.