LAND APPLICATION OF MANURE FOR BENEFICIAL REUSE

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The concentration of animal production systems has increased efficiency and improved overall economic return for animal producers. This concentration, along with the advent of commercial fertilizers, has led to a change in the way animal producers view manure. Manure, once valued as a resource by farmers, is now treated as a waste. Air and water quality concerns that arise primarily from the under-utilization or inefficient use of manure contribute to these changing views. However, when properly used, manure is a resource and should be regulated as such. In the United States, the *USDA/EPA Unified National Strategy for Animal Feeding Operations* outlines how animal feeding operations should be regulated and acknowledges that land application at proper agronomic rates is the preferred use for manures. However, many limitations such as water quality concerns, uncertainty regarding manure nutrient availability, high transportation costs and odor concerns cause some to question land application. This paper documents the benefits of land application of manure, discusses limitations that hinder greater manure utilization and outlines research and extension needs for improving manure utilization.

Manure is an excellent source of major plant nutrients such as nitrogen, phosphorus and potassium and the secondary nutrients that plants require. Plant nutrients in commercial fertilizers are mostly water soluble and readily available for plant uptake, while the nutrients in manure are less available. This complicates the determination of application rates, but the slower release contributes to improved plant utilization and decreased nutrient losses to surface and groundwater. Many studies have demonstrated that crop yields on land application areas are equivalent or superior to those attainable with inorganic fertilizers. Crop quality has also been improved by manure additions. These improved responses are usually attributed to manure-supplied nutrients or improved soil conditions not provided by inorganic fertilizer. Manure, especially poultry litter, can also neutralize soil acidity and raise soil pH. This liming effect can further increase the value of manure.

Research has shown manure application can have a significant impact on the chemical, physical and biological properties of the soil. Most of these effects are due to an increase in soil organic matter resulting from manure application. The ability of manure to promote formation of water-stable aggregates in the soil has a profound effect on soil structure and physical characteristics. Water-stable aggregates increase infiltration, porosity and water holding capacity and decrease soil compaction and erosion. Through improvement in soil physical properties, manure application also reduces the energy required for tillage and the impedance to seedling emergence and root penetration. Soil organic matter is known to affect a number of soil chemical properties, such as the cation exchange capacity and the soil buffering capacity that enable manure-treated soils to retain nutrients and other chemicals for longer periods of time. Soil organic matter is known to affect activity, degradation and persistence of pesticides, and several studies have shown reduced pesticide losses from manure-treated fields.

The land application of manure can affect soil

erosion and surface water runoff. Several laboratory and rainfall simulator studies on manure-amended soils indicate runoff and erosion rates are influenced by manure characteristics, loading rates, incorporation and the time between application and the first rainfall. The broad range of research objectives, underlying assumptions, manure types and environmental conditions create differing results. Field plots established to collect runoff from natural precipitation events consistently indicate that manure can substantially reduce both runoff and soil erosion when solid manures are land applied. Results using lagoon effluent or slurries are less conclusive. Nevertheless, this is a substantial benefit that should be considered when determining the water quality impacts of land application.

Land application of animal manures can help mitigate potentially negative consequences of rising atmospheric CO_2 on the global climate by contributing to greater sequestration of carbon in soil. In general, soil organic carbon sequestration on an area basis appears to be greater with an increased rate of manure application. Climate appears to affect potential retention of applied carbon in soil, with warmer regions tending to have lower carbon retention rates from manure (7±5%) than temperate or frigid regions (23±15%). Methane is also a significant contributor to global warming, and animal agriculture is a significant contributor of methane emissions globally. Land application of manure can significantly decrease the net quantity of methane emitted to the atmosphere compared with stockpiling or long-term lagoon storage of manure.

The benefits of utilizing manure through land application are apparent. However, there are several impediments that discourage greater use of manure nutrients in cropping systems. These include potential water quality problems associated with runoff, uncertainty associated with the nutrient availability, high transportation and handling costs that discourage transport and greater utilization, and public perception regarding odor issues.

Potential pollutants of concern in livestock wastes are organic materials, nutrients and pathogenic microorganisms. Surface water is primarily affected through soluble contaminants in runoff or insoluble pollutants carried on soil particles during soil erosion events. Groundwater can be contaminated with excessive pollutants from percolation, seepage and direct infiltration. Nutrients are the most common pollutant associated with animal waste. Several studies have documented that watersheds with predominantly animal agriculture tend to have higher nutrient levels in their drainage systems. Over-application of manure to crops or grasses can result in leaching of nitrate to groundwater or high levels of nitrogen in surface waters, resulting in eutrophication and low dissolved oxygen levels. Research has shown that the concentration of phosphorus in runoff increases as the phosphorus concentration in the topsoil increases. Manure presents a special problem because the nitrogen-to-phosphorus ratio in manures is lower than that needed by crops. As a result of the low nitrogen-to-phosphorus ratio in manure, excess phosphorus builds up to environmentally harmful levels in fields that receive repeated applications. Compared to nitrogen and phosphorus, much less research has been done on bacteria and other pathogens in manures and their impact on water quality.

The primary way to reduce the risks associated with land application of manure involves addressing the application rate, timing and location. These issues are commonly addressed through nutrient management planning. The *USDA/EPA Unified National Strategy for Animal Feeding Operations* establishes a national performance expectation that all Animal Feeding Operations should develop and implement technically sound, economically feasible Comprehensive Nutrient Management Plans (CNMPs). Traditionally, nutrient management has involved optimizing the economic return from nutrients used for crop production. Today the agronomic and economic requirements of nutrient management remain central, but the process is being expanded to include the potential environmental impacts of nutrients on the entire farm operation. This increases both the cost and complexity of these plans, yet few studies have documented the effectiveness of nutrient management plans, and

some studies suggest it is difficult for farmers to reduce environmental impacts even with well-developed plans. Often nutrient management plans do result in benefits for farmers and society, especially as an educational process; however, implementation has not been as great as desired.

Even under ideal conditions, there is still a significant risk of losses to the environment. Agricultural systems leak, and elimination of non-point source impacts is practically impossible. Therefore, secondary treatment or preventive systems should also be incorporated into the design of all land application systems, regardless of the choice of nutrient source. There are a number of best management practices (BMPs) that can be adopted to reduce the water quality impact of land-applied manure. The method and timing of manure application can be adjusted to reduce the amounts of constituents transported in runoff. Practices that limit soil erosion or runoff will positively impact surface water quality, while practices that reduce leaching should help prevent groundwater contamination. Conservation tillage, contouring and strip cropping, terraces and vegetated waterways have all been used effectively to minimize runoff. Narrow grass hedges have also been employed to reduce runoff, control erosion, decrease nutrient transport and provide wildlife habitat. Secondary treatment systems such as vegetative buffer zones, grass filter strips, riparian zones and/or other vegetative filters can prevent nutrient and pathogen movement to surface waters. Containment systems like ponds and diversions may also be used. Ultimately, the goal of these systems should not be treatment but should be a secondary system that ensures that contaminated runoff does not directly enter surface water. The need for these types of systems is highly dependent on the receiving water body, as often these secondary systems are not economically justified. Studies addressing the cost-benefit and efficiency of these systems on the farm and comprehensive watershed scale are needed to aid in producer decisions and help with water quality modeling efforts. Educational programs and policies to inform and to encourage adoption of current conservation technologies and BMPs by farmers are also an immediate need.

Farmers often choose to use commercial sources of fertilizers instead of manure because of variability and uncertainty concerning manure nutrient availability. Although estimates of nutritional content can be obtained through published literature, due to the variability in farming practices, animal diets, climate and waste storage facilities, manure nutrient analysis is usually recommended. Currently, most farmers sample their manure regularly but wait extended periods for test results. The development of inexpensive, on-farm nutrient tests would allow for testing at the time of application and more frequent and dependable test results. Obtaining representative manure samples presents unique challenges depending on the physical nature of the manure involved. In the case of wet manure, one of the main sampling challenges is to obtain a representative sample from manure slurry that has different liquid and solid phases.

Where animal production is concentrated, the land base available for manure application is usually limited. This limitation arises from restrictions imposed by the economics of manure transportation. The transport, collection, intermediate storage and general handling of manure to and from the point of processing or use are and will continue to be problems. Little research emphasis is being placed on the concepts of materials handling and metering for animal manure, yet the economics of transporting the material to the point of use is often the greatest concern limiting livestock producers from maximizing the use of this biomass resource. The export of manure from surplus to deficit areas for use as a fertilizer is often economically viable at larger scales. However, large-scale transfers of manure are not occurring, suggesting a need for increases in the incentives given to commercial firms to provide manure brokering. Better integration of farms that produce crops and livestock, and educational programs aimed at showing farmers the economic value of manure as a fertilizer are other methods of reducing the transport costs. Separation, screening, condensing and dewatering technologies could also be used to produce more transportable products; however, little research is being conducted in these areas.

Public perception of agriculture in general and land application in particular is critical to continued acceptance of manure application as the primary utilization strategy. Public concerns with animal manures can be broken into three major categories: water quality, air quality and food quality. Land application of manures has the potential to negatively impact all three. Improved technical information should be communicated to the general public about environmental, social and political concerns and potential solutions.

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