

Winter Manure Application: Research Needs and Future Direction

Introduction

Manure has long been a valuable component of agricultural practices to improve soil health, as it is a key source of organic matter and macronutrients necessary for productive soil. The use of manure also remains one of the best examples of wastes as resources in any industry. However, when and how to apply manure to soil in order to maximize soil health and minimize accidental environmental releases has long been a concern and a point of academic study. The practice of manure application on frozen or snowy soils is a particularly important topic for both agriculturalists and environmentalists. Many scholars and policy makers have long recognized that the application of manure to frozen, impermeable soils can increase the risk of manure nutrients, pathogens, and emerging contaminants, such as pharmaceuticals, running off of fields during spring thaw events, resulting in an impact to surface water. As such, organizations such as the US Environmental Protection Agency (EPA) and the Natural Resource Conservation Service (NRCS) have traditionally discouraged the application of manure under winter conditions. Additionally, the loss of nutrients during spring thaws means a loss of soil productivity for farmers and an added expense to purchase soil amendments.

With that said, winter manure application still offers many benefits to agriculturalists. Fleming and Fraser (2000) pointed out winter manure application has several key benefits to farmers.

- Smaller or fewer manure storage structures.
- Ability to spread the manure when logistics suit the farmer.
- Less soil compaction by avoiding compressible soil conditions.

As a result, winter manure application allows farmers to optimize workload efficiency by making use of a season that traditionally has fewer activities and keep capital costs low by reducing the infrastructure needed to store manure.

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However, the emergence of environmental issues downstream of livestock operations such as algae blooms and fish kills has led some states to ban winter manure application all together. These bans do not address the larger systems issue of manure management and, in fact, do not eliminate winter spreading all together, but rather allow for emergency spreading. In some cases, smaller farms are exempt from such regulations. In an effort to better understand the state of the science and to de-risk the present state of winter manure application a literature review was performed by Smith and Safferman, 2017.

In the process of writing this review, a wealth of studies were found dating back to 1945. However, there is still a considerable amount of research that is essential. This is partly a function of the numerous variables that occur in nature and the need to isolate and evaluate these variables. Many studies did not use or compare consistent conditions as expected, as often site and climate-specific conditions were being examined, resulting in great difficulty in comparing results. Further, it is also an undeniable relationship in science that the more we learn and the more we do, the more questions that will ultimately arise. In this instance, the increasing understanding of potential contaminants of concern (COCs) in manure as well as emerging changes in policy, the agricultural economy, and climate have shown data gaps that need to be addressed. This document outlines the key data gaps that were observed in the generation of “Winter Manure Application: Management Practices and Environmental Impact”, Jason S. Smith and Steven I. Safferman, that was prepared for the North Central Region Water Network Manure and Soil Health Working Group in August 2017 (Smith and Safferman, 2017).

In each of the sequential sections, important factors concerning winter manure application are first described followed by research gaps that require attention.

Contaminants of Concern

The following categories of contaminates are found in manure. Each is first described, including its relative impact and fate, followed by research needs.

Nutrients

Nitrogen and phosphorus are the most commonly studied nutrients due to their relation to downstream impacts such as eutrophication and harmful algae bloom formation in aquatic environments. The mechanisms for their release into the environment are well understood, though there continue to be disagreements on best management practices to limit their movement. This is largely a product of the large number of unconstrained variables that exist in any natural environment that can contribute to their release (snow volume, soil type, topography, soil moisture content, REDOX environment). Additionally, the form of nutrient has been found to be critical. All of these factors impact the mechanisms of nutrient loss: plant uptake, sorption, polymerization, microbial degradation, volatilization, advective movement, and dispersive transport. Consequently, the fate of particulate forms may be very different than soluble, depending on the site and management-specific conditions.

As such, the industry will benefit from continued experiment and field research in an effort to account for very specific, definable variables and nutrient form. Further, because of the extensive list of relevant variables, the development of precise and accurate mathematical models are essential as experimentally modeling the infinite number of site and management-specific conditions is impossible.

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Phosphorus is more scarce than oil and its cost is highly variable (Cordell et al., 2009). Nitrogen production is fossil fuel intensive and emits substantial amounts of greenhouse gases. Many commercial and emerging technologies are available to separate, concentrate, and mineralize nutrients from manure such as composting, physical separation with coagulants, screens, membranes, stripping, pelletizing, gasification, and evaporation. Such separation allows for more precise application and more complete utilization, ultimately offsetting the cost and production of commercially produced nutrients (Safferman et al., 2017; Safferman and Wallace, 2015). Further, concentrated nutrients can be economically transported to needed locations, such as an orchard that has a high phosphorus demand. More intensive nutrient management is also more likely to reduce the risk to water quality. The value of more optimized manure use should be researched. Included is the development of decision support tools that enable life-cycle accounting for site-specific conditions.

Pathogens

Fecal coliform has received attention from several studies, though disagreement still exists about whether or not freezing and thawing of soil will result in significant fecal coliform kills. More research on this topic is needed to identify the factors that have resulted in this dichotomy. Of particular interest is the impact of warming soil temperatures. Slight variations can result in substantial microbial ecological changes. Further, it is well understood that the use of fecal coliform as a pathogen indicator is flawed. New microbial genetic techniques enable the identification of pathogens of greatest risk. Research should monitor for these specific, likely pathogens and their fate during freeze/thaw cycles.

Emerging Pollutants

Antibiotics are highly hydrophilic and will move with melt water similar to soluble nutrients. Although this mechanism seems clear, movement during winter spreads are poorly understood. The mechanisms that determine their fate are the same as that of nutrients: plant uptake, sorption, polymerization, microbial degradation, volatilization, advective movement, and dispersive transport. However, this fate is poorly understood, especially in regard to the amount that will reach the field and streams when comparing different seasonal applications. Fate studies under diverse farm field conditions is essential. Further, some studies suggest prolonged storage in aerobic manure environments helps facilitate breakdown particularly at higher temperatures. However the question remains whether or not these effects are present in winter storage.

Further, other pharmaceuticals are often commonly found in water and soil. Each are distinct compounds making generalizations difficult. Those of most importance should be reviewed, as discussed above.

Policy Considerations

Several drastic policy changes have occurred in the last decade as several states have instituted winter bans while others have adopted risk mitigation strategies. This provides several unique opportunities for research on a watershed level, as suggested below.

- Review the incidences of emergency spreading on frozen ground, especially incorporation during cold weather. In theory, emergency spreading events run a high risk of occurring during this vulnerable time period. Understanding the frequency and timing of emergency spread events will be critical to crafting any necessary updates to future policy and BMPs.

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- Evaluate compliance with the new rules to determine if the intended impacts are realized, including comparing COC watershed level results across state lines and timelines to view the impacts of policy change. Is the policy effective? Are there modifications that need to be made?
- Determine if application in early spring, when soil is saturated and precipitation events are frequent, is more desirable than winter application. In particular, application before a deep freeze allows for incorporation. Related is the impact of soil moisture content on the fate of COCs during thaw events.
- Determine the economic impact of winter bans on producers and the potential loss of small to medium sized farms. One of the most often cited criticisms of unconditional winter manure application bans is that it can disproportionately disadvantage smaller producers that need to build additional manure storage to ride out the winter. Due to simple economies of scale, it is suggested that smaller producers would be impacted more than CAFOs. For instance, in a MI survey of small producers, 27% of non-CAFO dairy farmers suggested they would need to suspend operations if such a ban were instituted (Miller et al., 2017). An important task is to survey, with time, states that have banned winter manure application to determine if a ban resulted in a statistically significant shift with regard to average producer size. If so, what are the economics of the environmental benefits that may have occurred? A further consideration that may be as hard, if not harder, to access, is also the impact a reduction in producers has on national biosecurity.
- Verify the effectiveness of risk indices such as Michigan's Manure Application Risk Index (MARI), Wisconsin's Online Manure Advisory System, and other individual state's P-indeces. Many of these indices were developed based on recommendations from research and the practical experience of experts, but at the time of this writing, little literature exists attempting to empirically validate their efficacy.

Emerging Issues and their Relation to Winter Manure Application

The shift from dispersed agriculture to larger farms and the increased prevalence of CAFOs represent a seismic change in agriculture that has taken place over only a couple of generations. All of the ramifications of these changes are not understood. With regard to winter manure application, CAFOs represent an easier point source to regulate and have more capital resources to achieve benchmark standards for manure storage structures. In short, they can easily follow winter spreading bans and apply their manure in bulk during fall and spring openings in crop systems. However, it is worth noting that adherence to bans, as well as CAFOs geographic concentration of livestock, means that there is more manure being spatially and temporally applied in a more condensed area than ever before. This begs the question, are there any potential unintended consequences of this shifting macro-agronomic paradigm? Specifically, recent articles have cited legacy phosphorus (Jarvie et al., 2013), or a buildup of soil phosphorus outside of the traditional root zones as a major potential contributing factor to subsurface loss of soluble bioavailable phosphorus, a key contributor to harmful algae blooms. Is it possible that short-term gains in water quality have led to a potential issue in the future, and, if so, are there any relevant changes in practice to be made? At this point, the literature does not have an answer.

Further, climate change could also play a role in the dynamics observed in winter manure application. Experts suggest that the future could involve changes in duration and intensity of winter temperatures in addition to changes in frequency and intensity of precipitation events. If this comes to pass, BMPs should reflect the resiliency to adapt to changing conditions. Specifically, set dates for winter spread banning may need to be relaxed in favor of more adaptable metrics such as frost depth, depth of snow, ability to incorporate spread or time to forecasted thaw event. The industry could benefit from research on such factors.

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