Nicholas Institute for Environmental Policy Solutions
NI R 14-03 Supplemental Paper 3
March 2014

Management Options for Animal Operations to Reduce Nutrient Loads

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Acknowledgments
This supplemental paper was solicited and produced in support of "Refining Models for Quantifying the Water Quality Benefits of Improved Animal Management for Use in Water Quality Trading," which was prepared with support from the U.S. Department of Agriculture, Office of Environmental Markets.

How to cite this report
Chelsea Morris. 2014. *Management Options for Animal Operations to Reduce Nutrient Loads*. NI R 14-03 Supplemental Paper 3. Durham, NC: Duke University.

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FOR ENVIRONMENTAL POLICY SOLUTIONS

ABSTRACT

The size, intensity, and management practices of animal facilities influence the facilities' effects on water quality. A facility can implement a variety of alternative practices to reduce nutrient and sediment loss and decrease the impact on local water quality. These practices generally reduce nutrient quantities through fewer animals or different diets, better manure collection and containment from barnyards and feedlots, preventing nutrient loss from storage and processing facilities, proper use of manure on cropland, and land and crop management to reduce, capture, or treat runoff and erosion. Practices can be implemented where animals are housed, within the field when manure is applied, and at the edge of the field or farm. Not all practices are equally effective on all operations, and determining the most effective practices and means of implementation can be difficult.

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The size, intensity, and management practices of animal facilities influence the facilities' effects on water quality. A facility can implement a variety of alternative practices to reduce nutrient and sediment loss and decrease the impact on local water quality. These practices generally reduce nutrient quantities through fewer animals or different diets, better manure collection and containment from barnyards and feedlots, preventing nutrient loss from storage and processing facilities, proper use of manure on cropland, and land and crop management to reduce, capture, or treat runoff and erosion. Practices can be implemented where animals are housed, within the field when manure is applied, and at the edge of the field or farm. Not all practices are equally effective on all operations, and determining the most effective practices and means of implementation can be difficult.

The feasibility of these practices depends on the desired level of reliability, cost, and efficiency. Some structural practices require a one-time installation and regular maintenance; others necessitate ongoing documentation of practice. The impact of these practices also varies by animal species, climate, soils, topography, and distance to surface or ground waters.

The following is a partial list of best management practices applicable to reducing nutrient loads on animal feeding and rangeland operations. The purpose of this list is to provide a sample of common management practices in use on livestock and rangeland operations. This list is not exhaustive nor does it speak to the challenges of quantifying their impact for generating credits in a trading context. The list includes some practices that would likely be required under other local, state, or federal conservation programs (e.g., nutrient management plans), and thus would serve as baseline practices in a water quality program. Other practices, such as building manure storage containers and managing grazing, generate credits in existing water quality trading programs.

AGRONOMIC PRACTICES

***Balancing inputs and outputs*:** In animal operations, nutrients can be imported in feed and fertilizer and exported in manure and animal products. On farms where inputs consistently exceed outputs, nutrients accumulate over time in areas where significant manure is placed, increasing the risk for nutrient loss to surface waters. Maintaining the balance between farm-scale nutrient inputs and outputs is a critical first step in reducing long-term, chronic nutrient loss (Tilman et al. 2002; Koelsch 2005; Robertson and Swinton 2005) (Robertson and Vitousek 2009). This is often done through a Nutrient Management Plan designed in cooperation with the Natural Resource Conservation Service. Animal operations may choose to decrease the number of animals on site or acquire additional land for manure spreading. Even when balance is nearly achieved, nutrient loss can occur through poor or inappropriate animal and manure management, including storage, processing, and use (Hart, Quin, and Nguyen 2004; Sharpley, Kleinman, and Weld 2004; Koelsch 2005). On such farms, additional practices, such as the ones that follow, can close or minimize nutrient loss pathways.

ANIMAL PRODUCTION

Feeding strategies: Feeding strategies over the past 40 years have decreased N excretion per animal unit (Doering, Galloway, Theis, and Swackhamer 2011). Similar results have been described for P (Ghebremichael et al. 2007; Ghebremichael, Veith, Hamlett, and Gburek 2008). Animal practices that match production requirements with feed content can reduce total nutrients in storage, processing, and land application. Livestock nutrient excretion models are necessary to quantify the impact of these reductions.

STORAGE AND PROCESSING TECHNOLOGIES

***Physical treatment*:** Physical processes alter the pollutant content of manure. Solid-liquid separators portion the solids from a liquid manure stream (Hjorth, Christensen, Christensen, and Sommer 2010) and provide more options for nutrient use. For example, liquids can be more economically applied to land via irrigation, and solids can be transported longer distances for land application or off-farm export. Although the total amount of nutrients remains the same during the separation process, the amount, timing, and form of post-separation loss may differ. Other treatment possibilities include thermal conversion of manure by combustion or gasification (Cantrell, Ducey, Ro, and Hunt 2008). These also produce energy from syngas and biochar. Ammonia, nitrous oxide, and odor emissions are undesirable atmospheric by-products of a physical treatment process, but mitigation is possible.

***Biological treatment*:** Biological processes reduce organic matter, nutrient content, and remove other pollutants. Composting can reduce the mass of a solid material (Lazcano, Gómez-Brandón, and Domínguez 2008; Bernal, Alburquerque, and Moral 2009), and stabilize N in the organic forms, which is helpful in land application and hauling manure longer distances. However, emission of N as NH_3 or N_2O gas is undesirable. Aerobic processes in waste lagoons such as activated sludge treatment, aeration, and use of media biofilters rely on the consumptive activity of microbes to breakdown, transform, and remove nutrients, organic matter, and possibly hormones and pharmaceuticals. Engineered systems can achieve annual targets for nutrient removal, but can be expensive to install and operate, especially for very low target effluent concentrations and smaller animal operations. Effectiveness of biological treatment relies on maintenance of the system and specialized knowledge of bioremediation.

***Chemical treatment*:** Chemical precipitation draws out targeted pollutants and trace metals that can be disposed of in a separate waste stream (Sievers, Jenner, and Hanna 1994). Struvite precipitation is effective at removing ammonia and phosphate from animal manure (Nelson, Mikkelsen, and Hesterberg 2003; Uludag-Demirer, Demirer, and Chen 2005; Çelen et al. 2007). Phosphorus precipitation with calcium has also been demonstrated in a treatment unit developed by USDA-ARS (Vanotti, Szogi, and Hunt 2003). Chemical treatment for P removal is regularly utilized in municipal wastewater treatment applications, but its use in animal agriculture has not been widely documented.

***Storage*:** Manure storage structures allow operators to utilize manure at times most desirable for crop production and water quality impact (NRCS 2009, Code 359). Structure size and placement are the most important design factors, as undersized structures may be prone to failure and catastrophic contamination of surface waters. Manure spills are more easily prevented than rectified.

LAND MANAGEMENT

***Grazing density*:** More grazing animals per land area increases the waste load and the potential to affect water quality (Hubbard, Newton, and Hill 2004; Agouridis, Workman, Warner, and Jennings 2005; Bilotta, Brazier, and Haygarth 2007). Over-grazing reduces vegetative cover and infiltration, which increases runoff, erosion, and pollutant transport. Balancing animal density with forage production rates lessens negative impacts. Seasonal rotational grazing at moderate densities is an effective practice for water quality protection (NRCS, 2009, Code 528; Briske, Derner, Milchunas, and Tate 2011).

***Cross-fencing and supplemental water placement*:** In rangelands and pastures, non-stream water sources and fencing keep animals out of streams and near-stream areas, which can reduce bank erosion and direct deposit of nutrients in streams (Godwin and Miner, 1996). In some regions, near-stream areas frequently generate runoff so keeping livestock out of these areas can reduce nutrient transport.

***Timing and location of grazing*:** Reducing or prohibiting grazing when fields are saturated reduces compaction and related runoff (Briske, Derner, Milchunas, and Tate 2011), and keeping animals out of runoff-prone areas will reduce pollutant transport.

***Vegetated filter strips*:** Vegetated strips between production areas and surface waters can reduce dissolved and particulate nutrients in runoff (Dillaha, Sherrard, Lee, and Mostaghimi 1988; Sheridan, Lowrance, and Bosch 1999; Hoffmann et al. 2009; Stevens and Quinton 2009; Collins 2009; Zhang et al.

2010) by increasing infiltration and trapping eroded sediments. Effectiveness depends on site-specific conditions of hydrology, climate, soils, topography, and upland management practices (Dickey and Vanderholm 1981; Dillaha, Sherrard, and Lee 1986; Dillaha, Reneau, Mostaghimi, and Lee 1989; Daniels and Gilliam 1996; Dosskey et al. 2002; Munoz-Carpena and Parsons 2004; Helmers, Eisenhauer, Franti, and Dosskey 2005).

***Animal lot management*:** Outdoor lots often hold many animals, concentrate wastes, and produce runoff with a very high concentration of pollutants. Collecting waters or diverting runoff to treatment or storage facilities can reduce nutrient loss (Brown et al. 1989; Gitau, Veith, and Gburek 2004; Bishop, Hively, and Stedinger 2005). Depending on lot size, the benefits of lot management may be less than other land management practices, especially given the high cost of some lot management practices (Gitau, Veith, Gburek, and Jarrett 2006; Easton, Walter, and Steenhuis 2008).

***Cropping and tillage practices*:** Promoting crop establishment and soil structure through crop rotation, intercropping, cover crops, and reduced tillage can increase nutrient use by crops and reduce runoff and erosion (Unger and Vigil 1998; Zhang and Li 2003; Knudsen, Hauggaard-Nielsen, Jornsgard, and Jensen 2004; Li et al. 2007; Gardner and Drinkwater 2009). Effectiveness depends on site-specific hydrology, climate, soils, topography, and management. Crop yield benefits make these practices more attractive than practices that require land be removed from production (e.g., vegetated filter strips).

***Contour planting and terraced farming practices*:** These practices slow runoff, increase infiltration, reduce erosion, and decrease pollutant transport by diverting runoff from flowing directly downhill to around the hillslope (NRCS 2009, Code 330 & 600). Contoured strips of forage or grains are planted between row crops. Terraces are earthen embankments constructed along hill contours.

***Constructed wetlands*:** Wetlands can capture runoff and increase nutrient entrainment and uptake by plants and microbes, and promote N transfer to gaseous forms (Knight et al. 2000). Wetlands have lower installation and maintenance costs compared to engineered treatment systems, but removal rates may be slower. Nutrient removal is moderately effective and sediment removal highly effective, although long-term P removal is doubtful.

***Sensitive area protection*:** Depending on climate, soils, vegetation, and topography, certain areas are more likely to generate runoff and transport pollutants (Walter et al. 2000; Agnew et al. 2006). Practices to combat this transport of pollutants include eliminating or limiting manure application. Many state P indices have incorporated this concept into their definitions (Qiu 2003; Walter et al. 2009; Dosskey, Qiu, and Kang 2013).

Soil amendments: Application of flyash, iron oxides, or gypsum to soils can decrease P solubility in soil water (Anderson, Tuovinen, Faber, and Ostrokowski 1995; Callahan, Kleinman, Sharpley, and Stout 2002; Rhoton and Bigham 2005; Uusi-Kämppä et al. 2012). Amendments do not address the problem of soil P content in excess of crop requirements, but they can disrupt transport to streams. Also, flyash can contain heavy metals, which may introduce other problems.

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