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Eleven years of runoff and phosphorus losses from two fields with and without manure application, Iowa, USA

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ABSTRACT

Monitoring runoff at field edges can show how cropping systems and conservation practices affect runoff hydrology and water quality. Multi-year records are needed to characterize these effects, because of the variable, ephemeral nature of rainfall-runoff events. This study compared runoff and phosphorus (P) losses from two fields in central Iowa from 2000 through 2010. Both fields were managed in the same three-year, corn (*Zea mays* L.)–corn–soybean (*Glycine max* (L.) Merr.) rotation, but one field received applications of swine manure for each year of corn. Results comprised 116 events at the manured site and 94 events at the non-manured site, with 74 events common to both locations. Rainfall-runoff relationships for the two fields were similar; annual runoff averaged 54 mm from the non-manured field and 47 mm from the manured field. Large storms (>60 mm rainfall) comprised about 10% of the runoff events in both watersheds, producing 12–16% of the total P loads. Moderate storms (30–60 mm rainfall) generated most (65–70%) of the P load from both watersheds. Losses of P averaged 1.8 kg P ha^{-1} $year^{-1}$ from the manured watershed and 1.05 kg P ha^{-1} $year^{-1}$ from the non-manured watershed. Relationships between runoff-volumes and P-loads differed between the two watersheds ($p < 0.05$). Results highlight the challenge of maintaining adequate soil P levels while minimizing runoff P losses under a corn–soybean rotation, but indicate conservation practices that can limit runoff from storms of 30–60 mm of rainfall can help producers meet that challenge.

1. Introduction

Direct assessment of hydrologic and water quality responses to installation of agricultural conservation practices involves measurements of runoff volumes and collection of water samples at field edges. Measuring conservation-practice effects at the field scale allows the runoff response to be observed in a shorter time-frame compared to assessments conducted at watershed scales, where significant lag times occur (Meals et al., 2010). However, in field-edge monitoring, multi-year studies are still necessary to show conservation-practice benefits for water quality. Studies in the U.S. Midwest have shown that three years of monitoring were needed to identify effects from establishing perennial (native prairie) filter strips (Zhou et al., 2014), and from making changes in nutrient management practices (Jaynes et al., 2004), when monitoring of nutrient losses in runoff or subsurface tile drainage was conducted at field edges and in small (field-sized) watersheds. Water quality responses to conservation can take several years because perennial vegetation planted as part of a practice can take several years to become fully established. In addition, conservation practices that involve vegetation changes can trigger changes in soils and soil properties that occur slowly (Brye et al., 2002), and which may only fully affect changes in runoff over decades.

Monitoring conservation effects at the field edge is challenging not only because multiple years of monitoring are required, but also because of the ephemeral nature of field-scale runoff. Monitoring runoff from fields inherently involves long periods without runoff that are punctuated by short-duration runoff events, which must be accurately gauged and representatively sampled using consistent procedures. Runoff responses to rainfall events can be highly variable, being dependent on antecedent conditions and on the timing and intensity characteristics of individual storms. This means that a large number of events may need to be observed to be able to statistically compare field-scale runoff and nutrient losses between fields with and without conservation practices installed. In addition, the influence of widely ranging climatic conditions can seldom be taken into account with only a few years of monitoring data. While the lag time in response to management change in fields is decreased as compared to larger watershed scales (Meals et al., 2010), long-term monitoring should still be considered important for conservation

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effects assessments at the field scale, because of the needs to ensure representative data, to include as wide a range of climatic conditions and storm characteristics as possible, and to understand how the effectiveness of a practice may change with vegetation, soils, and in time, with practice maintenance needs.

The consistent effort needed to obtain multiple years of good-quality monitoring data can be difficult to maintain under short-term (i.e., two or three year) research funding cycles. Therefore, long-term field-scale assessments of runoff water quality are not commonly reported in the literature. There are important exceptions, including field-scale watersheds in western Iowa (Karlen et al., 2009), northern Missouri (Udawatta et al., 2011), central Iowa (Zhou et al., 2014), eastern Ohio (Shipatalo and Edwards, 1998), central Texas (Harmel et al., 2006), and northern Mississippi (Locke et al., 2008). These studies have provided valuable information on the long term benefits of strategically placed perennial vegetation, nutrient management, and/or minimal or- no-tillage systems on runoff and water quality.

The objective of this study was to compare eleven years of runoff and total P loads from two cropped fields in central Iowa. The two fields were managed identically under a three year rotation of corn (*Zea mays* L.), corn, and soybean (*Glycine max* (L.) Merr.). However, one of the two fields received applications of liquid swine manure to meet crop nitrogen requirements for every year of corn. Our primary objective was to compare differences in P loads between these two fields, as influenced by this difference in source of P. Because tillage practices were similar, we hypothesized that runoff characteristics should be similar between the two fields, and that any differences in P loads should be associated with the difference in nutrient management alone. Therefore, our approach was to verify the similarity in runoff characteristics between the two fields and then compare P losses between them.

2. Materials and methods

2.1. Site description and management

Our study was conducted in two fields within the South Fork Iowa River watershed (Tomer et al., 2008) in north-central Iowa (Hardin County) from 2000 through 2010. This area receives an annual average 880 mm of precipitation, according to long term records from Eldora, within 15 km of these sites (Iowa State University, 2015). The two fields (Fig. 1) were 3.0 km apart from one another, and were both farmed by the same producer throughout the study and managed under the same three-year corn–corn–soybean rotation. That is, both fields were in soybean production during 2000, 2003, 2006, and 2009, and in corn production during 2001, 2002, 2004, 2005, 2007, 2008, and 2010.

One of the two fields (MAN01; see Fig. 1) received liquid swine manure prior to every year of corn onto 7.4 ha of cropped area. Manure application rates to the MAN01 field were based on nitrogen requirement for the next corn crop, which averaged 223 kg N ha^{-1}(range 202–232 kg N ha^{-1}). Manure applications were planned for and typically occurred in fall (i.e., early November), except after the 2007 season when wet conditions delayed application until April 2008. Fall application of manure has been a common practice in the upper Midwest because drier soil conditions are typical at that time of year, in comparison to spring when wet soils often restrict field access by manure applicators, which include large tanks that can easily damage (compact) wet soils. Manure was incorporated into the soil at application, using injection or surface banding with incorporation by disks. Phosphorus applied with manure in the MAN01 field averaged 39 kg P ha^{-1} and ranged from 25 to 54 kg P ha^{-1}, based on manure testing results and application volume data provided by custom applicators.

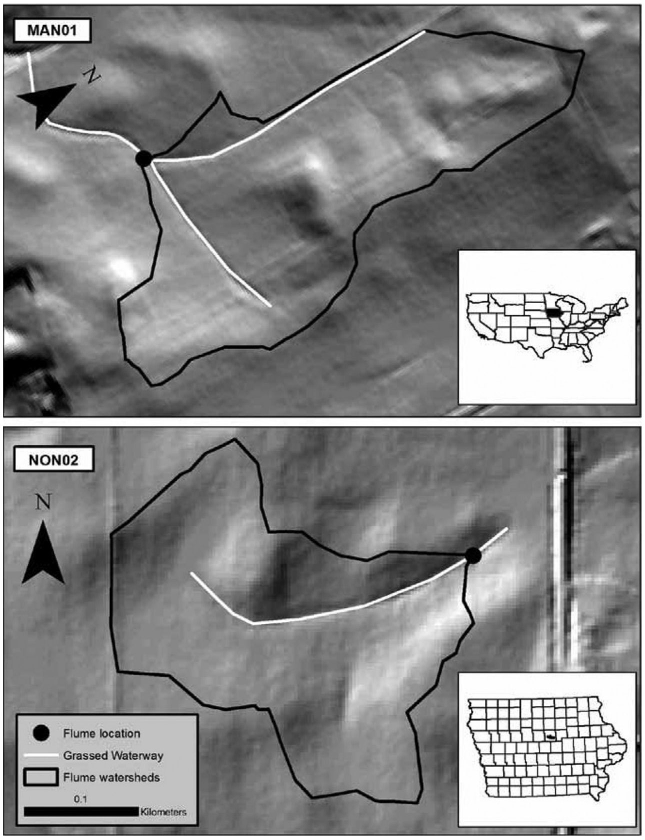

Fig. 1. Maps showing the layout of field-sized watersheds with locations of flumes and monitoring stations. MAN01 received annual fall applications of swine manure and NON02 received only commercial fertilizer.

The second field (NON02; see Fig. 1) received no manure applications; nitrogen applications were in the form of anhydrous ammonia, and applied to 5.7 ha of cropped area in late fall. Application rates were similar to those applied as manure at the MAN01 site, with the producer targeting 224 kg N ha^{-1} with these applications. Phosphorus applications were also made in fall at the NON02 site, and averaged about 30 kg P ha^{-1} year^{-1} generally as mono-ammonium phosphate in a maintenance (i.e., crop-removal rate) application by broadcast spreader, followed by a light chiseling operation to incorporate.

The farmer tracked soil test P levels in both fields, using a commercial service with 1.6-ha grid sampling of the soil plow layer (0–0.2 m depth), on a four year interval that differed between the two fields. In the NON02 field, Mehlich-3 soil P levels in fall 2007 soil samples averaged 16 mg P kg^{-1} of soil (ranging from 11–19 mg P kg $^{-1}$). Values less than 16 mg P kg^{-1} of soil are considered 'low' (Mallarino et al., 2013), therefore, a single application of 87 kg P ha^{-1} was then applied as mono-ammonium phosphate to the NON02 field in early November 2007. At the end of the experiment in 2010, soil-test results for the NON02 field consequently showed increased soil P, averaging 26 mg P kg^{-1} of soil, which is considered 'optimum'. Larger soil test P results were found in the MAN01 field, as would be expected following manure applications. Soil samples that were collected from the 0 to 0.2 m depth at the MAN01 field during fall 2009 showed Mehlich-3P levels averaged 37 mg P kg^{-1} of soil, and ranged between 30 and 47 mg P kg^{-1} of soil. Mehlcih-3 soil P levels greater than 35 are considered 'high' (Mallarino et al., 2013).

Conservation practices in both fields included grassed waterways and reduced tillage (light chiseling) to provide adequate (>30%) residue cover. In the MAN01 field, a 3.0 ha area with