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Original Research Article

Runoff and losses of nutrients and herbicides under long-term conservation practices (no-till and crop rotation) in the U.S. Midwest: A variable intensity simulated rainfall approach

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ABSTRACT

The U.S. Farm Bill includes conservation practices that benefit both the environment and the farmer. The USDA Conservation Effects Assessment Project (CEAP) is a multi-agency effort to assess the efficiency of conservation practices to minimize non-point source pollution. This is follow-up study of a 28-year experiment design to assess the influence of the conservation practices of no-till and crop rotation systems (corn [*Zea mays*]-soybean [*Glycine max*]), compared to chisel tillage and monocropping systems (continuous corn) on soil health and water quality. In this study, changes on soil C and N, soil water content, runoff, and losses of ammonium-N, nitrate-N, soluble reactive P (SRP), atrazine, metolachlor, and glyphosate were compared to determine the influence of no-till and corn-soybean rotation systems, relative to chisel tillage and continuous corn, on plots planted with corn using variable intensity rainfall simulations. The long-term no-till systems had a positive impact on soil C and N, soil water, runoff, and losses of ammonium-N and nitrate-N; however, no effect was observed on losses of SRP, atrazine, metolachlor, and glyphosate. The corn-soybean rotation negatively influenced, compared to the continuous corn, soil C and N, soil water content, and increased runoff and the losses of all nutrients and herbicides measured in this study. These results suggest that additional conservation practices, in conjunction with no-till and corn-soybean rotations are needed to reduce surface losses of nutrients and pesticides while improving soil health.

1. Introduction

Food security is a worldwide concern in which modern agriculture depends on inputs, including fertilizers and pesticides to achieve optimum production. From the launch of the commercial-available glyphosate-ready corn (1998) to 2014, the average annual usage (by mass) of herbicides to control weed on corn in the state of Indiana (USA) decreased by 1.8%; of which the average annual usage of atrazine decreased by 2.7%, but of glyphosate increased by 26.5% (NASS, 2017). Furthermore, for the same period, the average annual application rate of atrazine in Indiana decreased by 1.0% and of glyphosate increased by 9.5% (NASS, 2017). Conversely, from 1998 to 2014 the average annual N and P usage (by mass) for corn in Indiana increased by 0.3% and 2.0%, respectively and the average annual application rate increased by 0.6% and 3.6% for N and P, respectively (NASS, 2017).

Some agricultural inputs may impair water quality if suitable management practices are not implemented to offset the possible runoff losses of these inputs, including nutrients and pesticides. For example, the enrichment of nutrients, mainly N and P, in water may lead to eutrophication of bodies of water and impair ecosystems and drinking water sources (Conley et al., 2009). Like nutrients, the runoff of pesticides may impair water quality; for example, atrazine concentrations in streams can reach levels that are above the threshold concentrations for drinking water sources ($3\ \mu g\ L^{-1}$), especially if rainstorms occur within days of atrazine application (Shipitalo & Owens, 2006; Warnemuende, Patterson, Smith, & Huang, 2007). Hence, the need to assess conservation practices that may reduce nutrient and pesticide losses from agricultural fields to bodies of water. The U.S. Farm Bill supports the use of conservation practices to protect the environment while helping the farmer. Moreover, through the U.S. Department of Agriculture, the Conservation Effects Assessment Project (CEAP) is a multi-agency endeavor to assess the efficiency of conservation practices to minimize non-point source pollution and to develop new or modified existing conservation practices on science-based information. Several conservation practices, including reduced

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tillage and crop rotations, have been implemented to minimize soil erosion and promote soil health (Blanco & Lal, 2008).

In the U.S., no-till was implemented commercially in 1962 by a farmer in the state of Kentucky (Young & Young, 2017) and since then, no-till has been successfully implemented as a conservation practice to reduce soil erosion (Triplett & Dick, 2008) and improve soil health (Choudhary, Lal, & Dick, 1997). From 1990–2017 in the state of Indiana, the corn area under no-till has increased by 122%; yet, in 2017 only 20% of the total area planted with corn was under no-till (ISDA, 2017). Although no-till is a proven conservation practice to reduce erosion, there are some environmental concerns with this conservation system; e.g. under rainfall simulations, atrazine and glyphosate losses were higher under no-till plots compared to relative new chisel-tilled plots (Warnemuende et al., 2007).

Crop rotation is other conservation practice that improve soil health by reducing soil erosion, improving soil physical properties, and promoting carbon storage, nutrient cycling, and disease resistance (Blanco & Lal, 2008). The type of crop residue cover, an indirect result of crop rotation, influences soil erosion; e.g. with soybean residue, soil erosion was higher than with corn residue (Dickey, Shelton, Jasa, & Peterson, 1985). In addition, crop residue inputs influence soil properties, including soil organic matter; crops that produce high below-ground biomass increase soil aggregation, improve macro-porosity (Blanco & Lal, 2008), and increase water infiltration (Bullock, 1992), and consequently decrease runoff. However, there is a lack of information on the effect of crop rotations on the runoff losses of nutrients and pesticides.

This study is part of an ongoing effort to assess the impact of long-term conservation practices on soil health and water quality. The objective of this study was to evaluate the influence of the conservation practices no-till and corn-soybean (C-S) rotations (and the confounding soybean residue), relative to chisel tillage and continuous corn (C-C, and the confounding corn residue), on soil C and N, soil water content, runoff, and losses of nutrients (ammonium-N, nitrate-N, and soluble reactive P) and herbicides (atrazine, metolachlor, and glyphosate) under simulated rainfall with variable rain intensities to represent a 200-year return period.

2. Materials and methods

2.1. Site description

The site has been described by Nouwakpo, Song, and Gonzalez (2018). Briefly, the research site is located in West Lafayette, IN, USA (Fig. 1). In 1983, sixteen research plots were established with four crop rotations (continuous soybean, soybean followed by corn, C-S, and C-C) under four tillage systems (ridge, moldboard, chisel, and no-till). Since 1998, the crop rotations were kept, but the tillage systems were reduced to no-till and chisel (*2 tillage systems X 4 crop rotations X 2 reps*); in any given year, 8 plots are planted with corn and 8 plots planted with soybean. For this study, we used only the eight plots planted with corn in 2013, i.e., the C-S and C-C plots (Fig. 1). Thus, in this study, tillage consisted of two levels (no-till and chisel) and crop rotation consisted of two levels (C-S and C-C). The soils in the experimental plots are silt loam Hapludalfs (USDA-NRCS, 2017).

2.2. Plot management prior rainfall simulations

On May 15, 2013, the four plots under chisel tillage were disked; whereas the four no-till plots did not receive any soil disturbance. On June 8, 2013, all eight plots were planted with corn, fertilized, and sprayed with herbicides. Planting was performed using a John Deere 7200 MaxEmerge2 6-row planter (John Deere, Moline, IL, USA) with a vacuum seed meter system to control seed population. Starter fertilizer (17-19-0) solution was placed below the seed ("5 cm × 5 cm" approach) using a knife applicator (final rate of 24.9 kg N and 9.8 kg P ha^{-1}). A mixture of commercial herbicides was prepared with Lexar® (1.46 kg ha^{-1} atrazine and 1.46 kg ha^{-1} S-metolachlor) (Syngenta, Wilmington, DE, USA), Makaze® (1.68 kg ha^{-1} glyphosate) and Choice Weather Master® (water conditioning agent, 4.14 kg ha^{-1}) (Loveland Products, Loveland, NE, USA) were mixed in 281 L water and then this mixture was surface-sprayed. From 2008–2012, only glyphosate was applied to control weed in all plots.

The crop residue cover was determined by the line-transect method (Laflen, Amemiya, & Hintz, 1981) and soil water content was measured from the average of seven readings using a Field

Fig. 1. Location of the plots used in this study (adapted frome Google Earth Pro).