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Mahdi Al-Kaisi

Iowa State University, malkaisi@iastate.edu

Brad ONeal

Iowa State University

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Agronomic and soil quality trends after five years of different tillage and crop rotations across Iowa

Mahdi Al-Kaisi, associate professor and extension soil management specialist, Agronomy, Iowa State University; Brad O Neal, research associate, Agronomy, Iowa State University

Introduction

The variability in soil conditions is a key factor in selecting tillage and cropping systems that will influence crop response and ultimately yield expectations. However, crop response to tillage systems has been demonstrated to be different for the same tillage systems in different parts of the state or different regions elsewhere. Different tillage systems affect soil temperature, soil moisture conditions, soil compaction, soil productivity, and nitrogen movement and N availability differently. These effects will be reflected in crop response to different tillage systems and crop rotations, where soil temperature plays a significant role in early seed germination, organic N mineralization, nutrient and residue incorporation, and weed and pest control.

Understanding site specific effects of tillage can help significantly reduce input costs and reduce the negative impact on water, air, and soil quality. Conservation tillage systems continue to be a very important component of a crop production system in terms of economic return and environmental benefits. However, the challenges in managing such systems, and namely no-tillage, are related to the proper management practices, such as the availability of drainage in poorly drained soils, use of residue management attachments, seeding depth, and fertilizer management. Also, the timing of conducting field operations, N application, manure injection, etc., has to be done when soil moisture condition is below field capacity to avoid serious soil compaction problems.

Tillage systems have a significant effect on N dynamics by affecting N pools in the soil system. Soil disturbance during the tillage process and the incorporation of surface residue increases soil aeration, which can increase the rate of residue decomposition (McCarthy et al., 1995). This process impacts soil organic N mineralization whereby readily available N for plant use is increased (Dinnes et al., 2002). The type of tillage system can influence the amount of N available for loss in the soil profile. Deep accumulation of $\text{NO}_3\text{-N}$ in the soil profile represents a potential for $\text{NO}_3\text{-N}$ leaching into shallow water tables (Keeney and Follett, 1991).

Tillage practices and crop rotations can greatly alter agronomic performance and physical and biological properties of the soil. The effects that occur from these tillage practices and crop rotations are greatly influenced by the type of landscape, soil characteristics (i.e., drainage class, slope, soil texture, etc.), crop rotation, and type of tillage practices. Many states have been urging farmers to practice conservation tillage due to its ability to minimize surface runoff and soil erosion. Conservation tillage systems and extended crop rotations offer an alternative to minimize the negative effect of conventional tillage systems or mono-cropping systems such as continuous corn on yield and soil quality. In addition to improving soil quality, conservation systems can improve hydraulic properties such as infiltration rate (i.e., no-tillage system). However, changes in soil physical and especially biological properties can be very slow and gradual. In many studies, changes in soil carbon or physical properties in response to no-till for example was very slow and insignificant in the short-term (<10 years).

Materials and methods

Field Study

The field studies were conducted on the Iowa State University Research Farms and farmers' fields across Iowa for the past five years. Research sites consisted of over 30 sites in different parts of the state where soil and climate conditions are relatively different. Crop rotations varied and included continuous corn, corn-soybean rotation, and corn-corn-soybean rotation. The study included many tillage systems, such as no-tillage, strip tillage, chisel plow, deep rip, and moldboard plow. All tillage treatments were conducted in the fall following the harvest of the previous crop. The experimental design used in these studies was a randomized complete block.

Soil measurements and data collection

Soil samples were collected at four different depths with 6 inch increments for soil organic carbon, total N, bulk density, soil pH, soil nitrate, aggregate stability, soil compaction, and microbial biomass carbon analyses.

Soil samples for aggregate stability were collected from the top 6 inches. The samples were collected by using a golf course hole cutter of 4-inch diameter. The aggregate stability was determined using the wet method after soil samples were passed through an 8-mm sieve. A 100 g of the soil sample was placed on a nest of sieves in the following order from top to bottom: 4 mm, 2 mm, 1 mm, 0.5 mm, and 0.25 mm.

The water infiltration rate was measured using a Cornell Sprinkle Infiltrometer (Rain Simulator) (Cornell University, Ithaca NY) (Ogden et al., 1997). This system consists of a portable rainfall simulator placed on a single 24.1 cm (9.5 in) inner diameter ring inserted 7 cm (3 in) into the soil. The ring is equipped with an overflow tube to determine the time to runoff and runoff rate. Rainfall simulator intensity rates of 0.4 to 0.5 cm (0.15 to 0.20 in) min⁻¹ were used. Every three minutes, runoff was measured until steady infiltration occurred. Water infiltration (i) was calculated by using the following equation:

$$i = r - \text{rot.}$$

Where r is rainfall intensity and rot is surface runoff.

Results and discussions

Yield trends and economic return

Figures 1 and 2 summarize corn yield of different tillage systems and crop rotations over many years at the Nashua location, one of seven long-term tillage study locations in Iowa. The yield results presented are for no-till, strip tillage, and conventional tillage system, which include the average yield across chisel, deep-rip, and moldboard plow for two crop rotations of corn-soybean and corn-corn-soybean rotation. There was yearly variability of corn yield within each tillage system and crop rotation (C-S and C-C-S). The overall yield average, regardless of the crop rotation, shows that both strip-tillage and conventional tillage over performed no-till by 12 and 16%, respectively at the Nashua site (Fig. 1). However, the corn yield of each tillage system shows that second year corn in C-C-S rotation was lower than that for corn after soybean in all tillage systems (Fig. 2). Generally, corn yield in the second year of a C-C-S rotation was 7% lower than corn yield in C-S rotation.

The trend in soybean yield was much different from corn with same tillage systems. Figure 3 summarizes soybean yield results, where great yearly variability is observed for all tillage systems, but no differences in yield between tillage systems within each year. The lack of significant soybean yield differences between different tillage systems at the Nashua site was also observed at the other 7 sites across the state.

The comparison of soybean yields of c-S and c-c-S rotation show that a soybean yield after two years of corn was on average 9% greater than soybean after one year corn across all tillage systems at the Nashua site (Fig. 4). The differences were variable among different years and range from 0-25%. In these studies of seven locations across Iowa and at the Nashua site, no-tillage soybean yields generally were not significantly different from other tillage systems. This is encouraging news for producers who are reluctant to switch to no-tillage soybean after corn due to concerns of poor crop performance.

In another long-term study comparing different tillage and crop rotation systems across Iowa, it was found that no-tillage corn and soybean yields were competitive with moldboard plowing, deep-rip, chisel plowing, and ridge tillage for more than 8 years after no-tillage was established (Al-Kaisi and Yin, 2004; Yin and Al-Kaisi, 2004). No-tillage typically yielded 5 percent less, especially in poorly drained areas compared to other tillage systems.

The economic return of different tillage systems showed that no-tillage had an advantage over other tillage systems due to the lower input cost associated with no-tillage (Table 1) (Al-Kaisi and Yin, 2004; Yin and Al-Kaisi, 2004). On average, the No-tillage system reduced input cost for corn production by approximately \$18/acre under corn-soybean rotation and \$18.50/acre for corn following corn compared to all conventional tillage systems (Table 1). These input costs in Table 1 did not include the land cost and they may vary from one farm to another based on level of management and other additional inputs. No-tillage shows saving in input cost for soybean production of \$12/acre compared to conventional tillage systems as well.

An effective no-tillage system depends on properly selecting and setting up the planter, adequate fertility program, and efficient drainage system especially in poorly drained soils. The success of any conservation system depends heavily on how the system is managed. Generally, conservation systems require less input costs. The advantage of conservation systems is in the fuel saving, where no-tillage generally requires one gal per acre compared to 4.1 gal per acre for conventional tillage operations. The reduction in the number of implements and horsepower needed is also a significant savings in capital and maintenance costs. Fewer trips across the field reduce the fuel and labor needed.

Table 1. Total production input costs per acre for different tillage systems for corn and soybean under different crop rotations.

Tillage System	Corn after Soybean	Corn After Corn	Soybean After Corn
	----- \$/acre -----		
No-tillage	348	392	186
Strip tillage	355	399	193
Chisel Plow	366	411	196
Deep Rip	372	417	202
Moldboard Plow	366	415	201

- Input costs account for machinery costs, labor, seed, nutrients, chemicals, and insurance. Input cost does not include land rental (\$190 cash rent equivalent).
- Labor was figured at \$11.00/hr, nutrients are based on crop removal rates, and insecticides were accounted for in corn after corn.
- Herbicide tolerant soybeans were used in input costs considerations.
- Input costs based from ISU Extension publication FM 1712 and Ag Decision Maker file A1-20

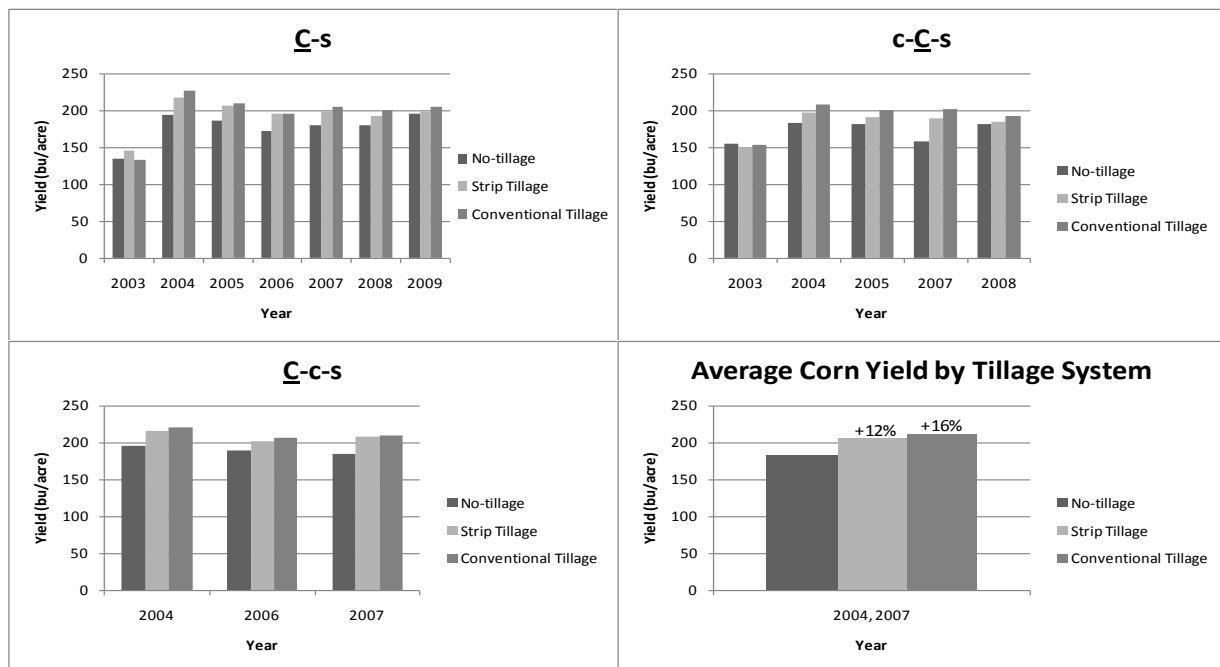


Figure 1. Corn yields by tillage system in different crop rotations at the ISU Nashua Research Farm. Percentage differences in yield were calculated using corn yield of no-tillage as a baseline.

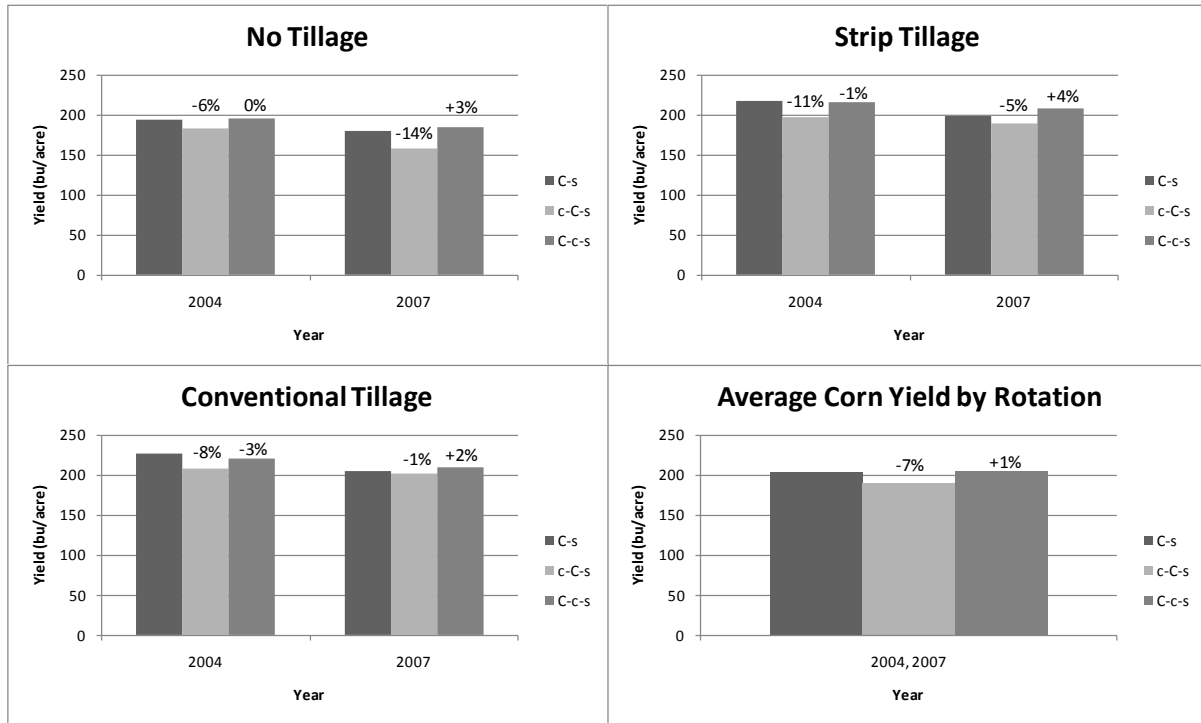


Figure 2. Corn yields by rotation in different tillage systems at the ISU Nashua Research Farm. Percentage differences in corn yield were calculated using the corn yield from corn-soybean rotation as a baseline.

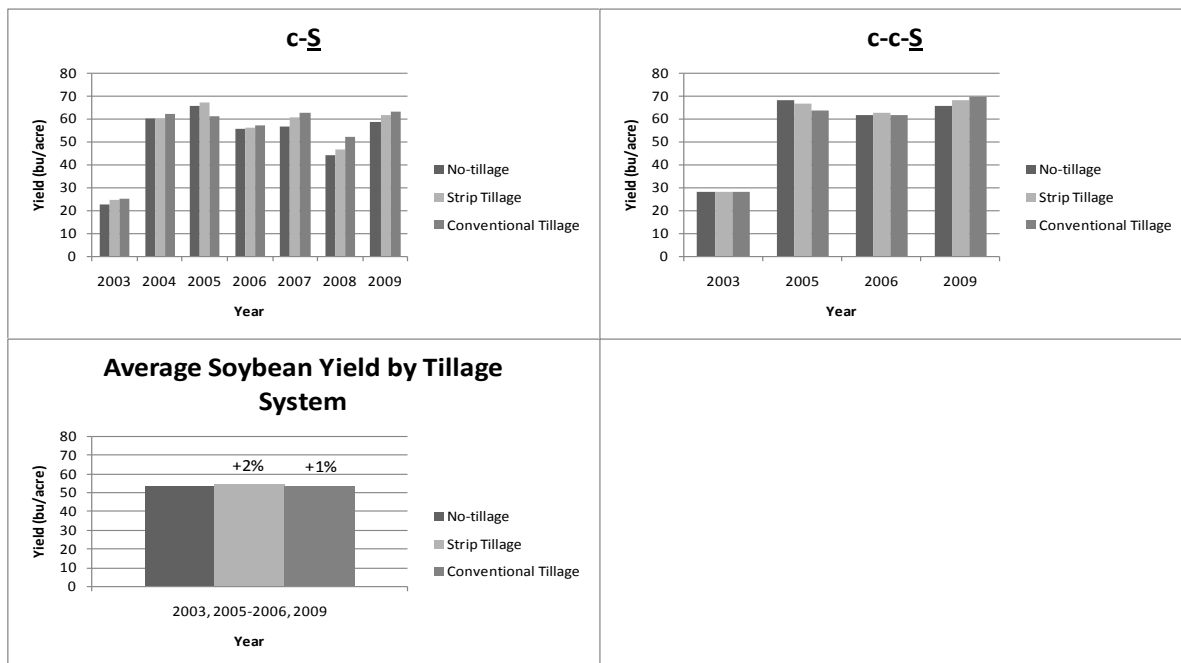


Figure 3. Soybean yields by tillage system in different crop rotations at the ISU Nashua Research Farm. Percentage differences in yield were calculated using soybean yield of no-tillage as a baseline.

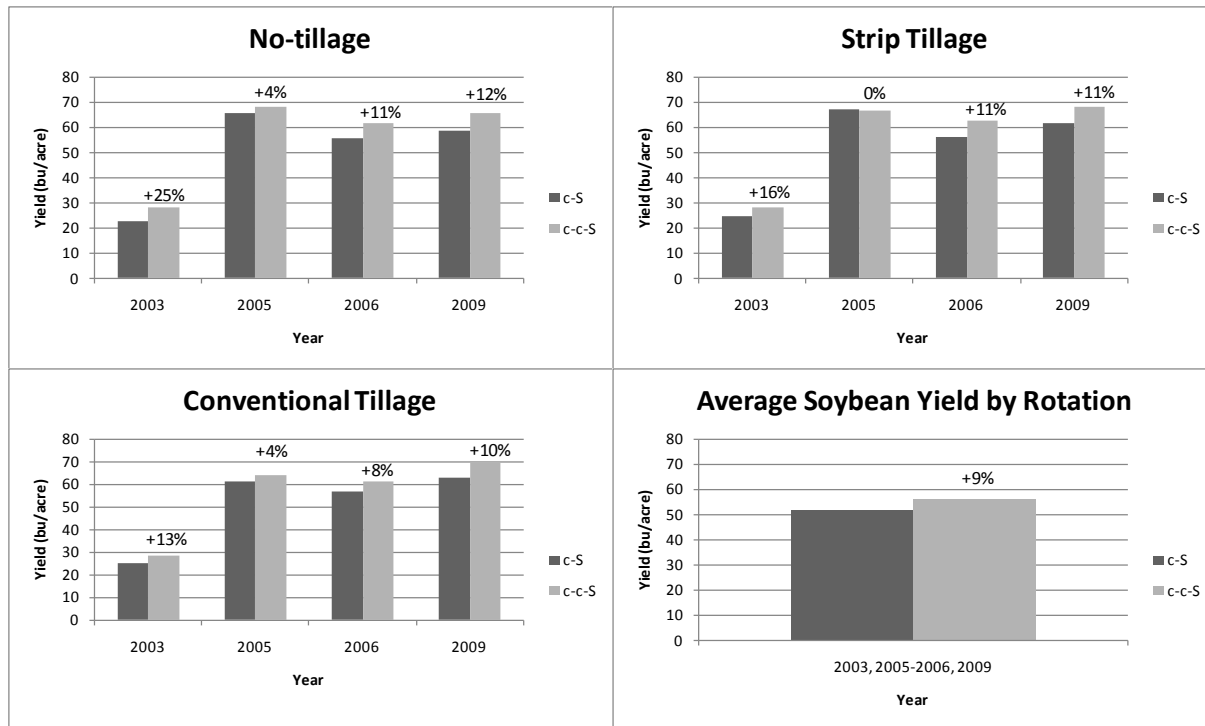


Figure 4. Soybean yields by rotation in different tillage systems at the ISU Nashua Research Farm. Percentage differences in soybean yield were calculated using the soybean yield from corn-soybean rotation as a baseline.

Trends in Soil Organic Matter and Other Soil Quality Indicators

- **Soil Organic Matter:** Soil organic matter trend over four years was summarized in figure 5 for four regions in the state. The changes in soil organic matter generally are not significant for all tillage systems over the four years. This is not surprising due to the short-time of the study. Generally, changes in organic matter are very slow and especially in rich organic matter soils as in Iowa. The differences in organic matter due to different tillage systems were also not significant due to the short-term of this study. However, some variability in soil organic matter between years was observed, but not very significant and that can be attributed to potential sampling error and other factors during the sampling process, especially for large field studies. Intensive tillage operations can have a negative effect on soil organic carbon by oxidizing organic matter. It was documented that soil organic matter loss can be very significant in the long-term. The loss of organic matter due to tillage is site specific affected by soil and climate conditions among many other factors (Fig 5).
- **Erosion and water quality:** Surface residues from both corn and soybean provide protection from both wind and water erosion. Cover crops following soybean and corn silage harvest can be used to increase the amount of residue cover and stabilize the surface soil. Additionally, waterways, terraces, and buffer strips provide living protection that controls the flow of surface water runoff and allow for sediments and nutrients to settle out before leaving the field.
- **Crop residue:** The more intensive a tillage pass is, the more residue will be broken down and buried. Crop residue is important to hold surface soil in place and protect the soil surface from raindrop and wind impacts. Crop residue also helps hold snowfall in place, which in the spring will contribute to subsurface soil moisture.
- **Soil structure:** Tillage operations break soil aggregates and decrease pore spaces that are responsible for enhancing water infiltration. By switching to conservation tillage and using cover crops the soil will build better soil structure due to less soil disturbance and increased soil organic matter.

- Soil compaction: There is a misconception of increased soil compaction with conservation systems. Research shows that fields under conservation systems have much better developed soil structure and pore spaces than conventional systems. The improved soil structure provides soil the strength to withstand heavy field equipment load.
- Soil moisture: A major benefit of conservation systems is the enhancement of subsurface soil moisture due to improvement of soil organic matter and water holding capacity. This is critical in areas where precipitation is limited and conservation of soil moisture is a priority.

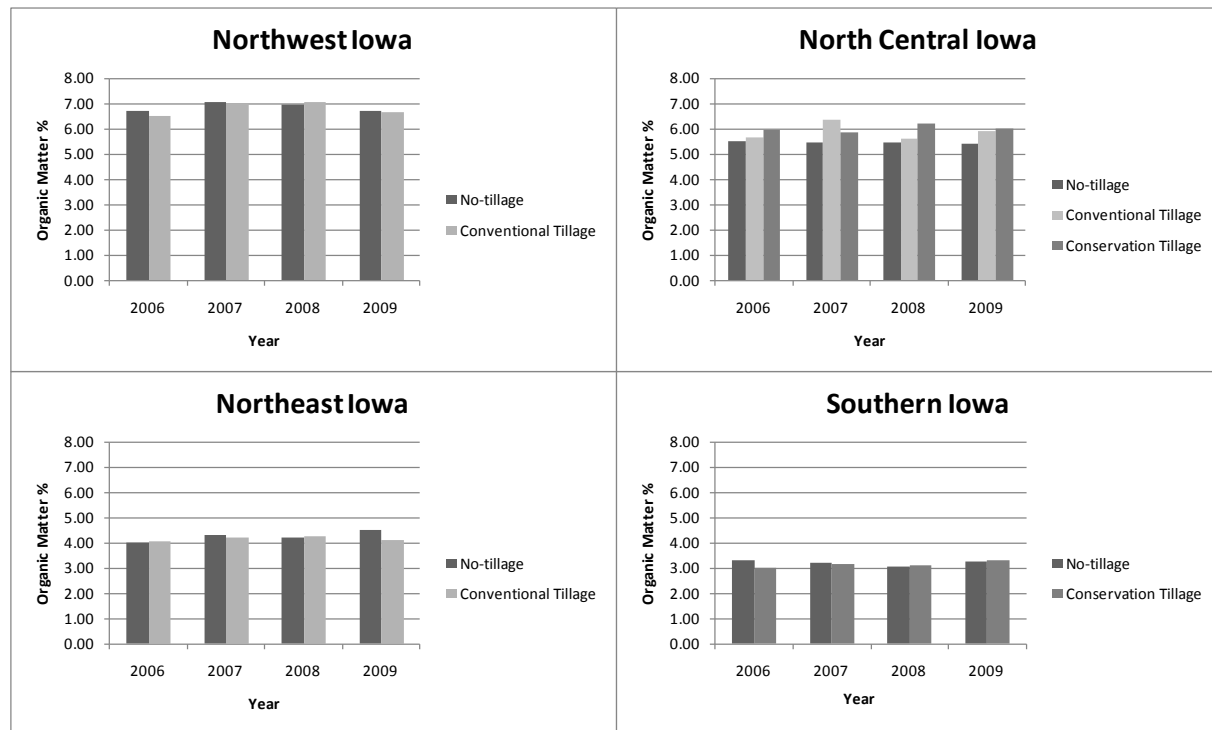


Figure 5. Four year trends in soil organic matter percent by tillage treatment of four major soil regions across Iowa.

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