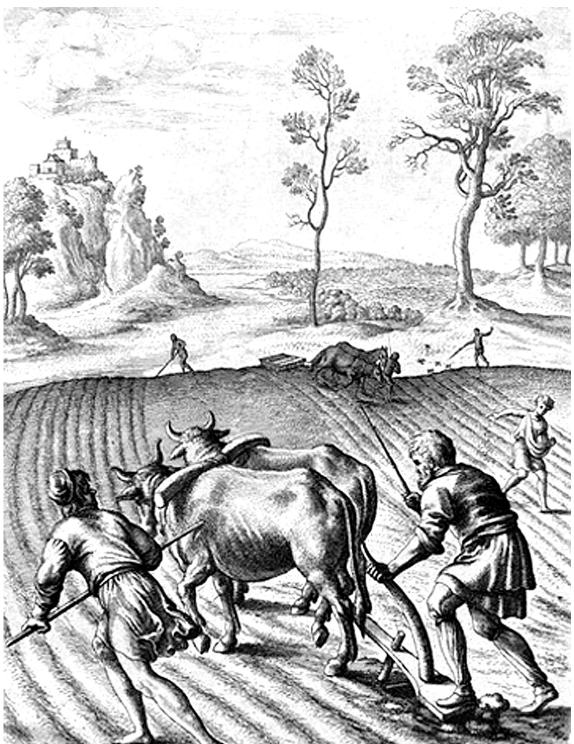
ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY



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Journal of Agronomy 3 (1): 31-35, 2004
ISSN 1680-8207

Impacts of Conservation Tillage Systems on Maize and Soybean Yields of Eroded Illinois Soils

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Abstract: In the United States, millions of hectares of highly erodible cropland have been in the Conservation Reserve Programme (CRP) for the past 10 to 20 years. Any conversion of CRP land back to maize (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) production would require the use of conservation tillage systems such as conservation tillage to meet federal and state soil erosion control standards. Evaluations of crop yield response of these conservation tillage systems such as no-till (NT) and chisel-plow (CP) over time are needed to assess the return of this land to crop production. A 14-year study was conducted in southern Illinois on land similar to that being removed from CRP to evaluate the effects of conservation tillage systems on maize and soybean yields and for the maintenance and restoration of soil productivity of previously eroded soils. In 1989, NT, CP and moldboard plow (MP) treatments were replicated six times in a Latin Square Design on sloping, moderately well drained, moderately eroded soil. The 7-year average maize yields were similar (9.53, 9.26 and 9.46 Mg ha^{-1}) for NT, CP and MP systems, respectively, as a result of a significantly higher yield with the MP system in the first year which offset the higher yields with the NT and the CP systems during the last six years of maize. The 7-year average soybean yield with NT (2.57 Mg ha^{-1}) was 7% higher than with MP (2.38 Mg ha^{-1}) and CP (2.38 Mg ha^{-1}) systems. Crop yields for 14 years (7 years maize and 7 years soybean) appear to show improved long-term productivity of NT compared with that of MP and CP systems.

Key words: Conservation tillage, erosion, crop growth, plant population, maize, soybean

INTRODUCTION

In the United States, the Food Security Act of 1985, the 1990 and 1995 Farm bills and the Illinois T by 2000 Programme have resulted in millions of hectares of erodible land previously in row crops being put into the CRP for 5 to 15 years. Any conversion of CRP land back to maize and soybean production could require the use of conservation tillage systems such as no-till (NT) and chisel plow (CP) to meet soil erosion control standards. Evaluations of yield response of these conservation tillage systems over time are needed to assess returning this land to crop production.

The severity of erosion can be reduced by maintaining crop residue on the soil surface[1,2]. At planting, with chisel plowing residue cover is 30% and much higher with no-till due to a lack of, or minimum, soil disturbance[3]. Lueschen *et al.*[4] for a maize-soybean rotation in Minnesota, observed 69 to 82, 49 and 10% of soybean residue cover on the soil surface after maize planting in no-tillage, chisel plow and moldboard plow system plots, respectively.

Generally, conservation tillage resulted in an increase in crop yield compared with that of a moldboard plow system. Lawrence *et al.*[5] showed in a 4 year study in a semi-arid environment in Australia that no-till had a higher crop yield than did reduced till fallow or conventional till fallow. A positive linear response between yields of maize and soybean and amount of residue applied to a no-till system was observed by Wilhelm *et al.*[6]. Lueschen *et al.*[4], in a maize-soybean rotation in Minnesota, found an increase of 6.30 Mg ha^{-1} in yield of the NT system above the MP system in a dry year. Kapusta *et al.*[7] studied the effects of tillage systems for 20 years and found equal maize yield in no-till, reduced till and conventional tillage despite the lower plant population in no-till.

The crop yields with different tillage systems vary from year to year due to the fluctuations in weather. No-till corn yielded more in drier than normal years, whereas maize yields with moldboard plow were higher in the

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wetter than normal years in the moderately well-drained soils on Ohio[8]. No-till maize yields are lower in the early years which could be due to lower soil organic C and nitrogen mineralization and higher immobilization of fertilizer nitrogen, than those of conventional tillage[9,10]. Rice *et al.*[11] and Kapusta *et al.*[7] also reported no differences in maize yield with no-till and conventional tillage over time.

Since limited data were available on the long-term tillage responses on sloping and eroded soils in southern Illinois, this project was started in 1989. Tillage effects were not profound in the early years of the study[12]. The study was continued with the objective of evaluating long-term tillage systems (no-till, chisel plow and moldboard plow) effects on maize and soybean yields and the maintenance and restoration of soil productivity of previously eroded soils in southern Illinois.

METHODS AND MATERIALS

A tillage experiment was started on April 12, 1989, at the Dixon Springs Agricultural Research Center in southern Illinois. The soil at the study site was a moderately eroded phase of Grantsburg silt loam (Albic Luvisol)[13] (fine-silty, mixed, mesic Typic Fragiudalf)[14] with an average depth of 64 cm to a root-restricting fragipan. The area with an average slope of 6% had been in tall fescue hayland for more than 10 years prior to the start of this experiment. Three tillage treatments, no-till (NT), chisel plow (CP) and moldboard plow (MP) were established on April 27, 1989. Starting with maize in 1989, maize and soybean were grown in alternate years. The experimental design was two Complete Latin Squares and each square having three rows and three columns[15] that allowed for randomization of the tillage treatments (NT, CP and MP) both by row (block) and by column. This replication was used to control random variability in both directions. Each treatment was randomized six times in 18 plots with a size of 9x12 m. The columns were separated with 6 m buffer strips of sod.

The implements used in each tillage system and depth of tillage were as follows: NT (no-tillage) (John Deere No-Till planter with wavy coulters), CP (straight-shanked chisel plowed to 15 cm with diskings to 5 cm) and MP (moldboard plowed to 15 cm with diskings to 5 cm). In the spring of each year the MP and CP plots were moldboard and chisel plowed followed by 2 diskings and planting. In odd years maize was planted at the seeding rate of 64,000 seeds ha^{-1} with fertilizers of 218 kg ha^{-1} N, 55 ha^{-1} P and 232 kg ha^{-1} K. In even years soybeans were planted at 432,000 seeds ha^{-1} with no fertilizer. Chemical weed control practices were used during the study.

The percentage surface residue was determined after planting by the line-transect method[16]. Plant population for the center 0.001 ha of each plot was determined by counting at 25 days after planting. The crop yield and plant population data from 1989 to 2002 were collected as part of this study. The soil loss rates were determined using USLE[17].

Statistical analysis for all parameters were performed using the procedures from Statistical Analysis System (SAS) computer software[18]. Analysis of variance and least square means of selected variables (in the case of crop yield) were performed by General Linear Model (GLM) procedures.

RESULTS AND DISCUSSION

The NT system maintained a significantly higher amount of residue on the soil surface as compared with that of the CP and MP systems at planting during each selected year (Table 1). Crop residue on the soil surface was higher with maize as previous crop, compared with that of soybean because of higher residue production from maize and lower rate of decomposition of maize residue[4] than soybean residue. On Grantsburg soil with 5-7% slopes, the estimated annual soil loss, measured with USLE, was 8, 21 and 30 Mg ha^{-1} with the NT, CP and MP systems, respectively (Table 1) (Walker and Pope, 1983). The higher the percentage of crop residue (Table 1) on the soil surface with the NT system protected the soil from erosion keeping it below the tolerance level of 8.4 Mg ha^{-1} yr^{-1}[17]. On the other hand rill erosion was observed with the MP and CP systems due in part to less residue on soil surface compared with that of the NT system.

During 1990, 1996 and 2002 the high April and May rainfalls (Table 2) contributed towards lower plant population with the NT system compared with that of the MP system (Table 3). Higher plant population with the MP system than with the NT and CP systems during 1995 was also observed (Table 3). Better seed-soil contact with the MP system could have increased the germination compared with that of the NT system during 1996 and

Table 1: Effect of different tillage treatments on plant residue after planting and soil loss at Dixon springs

Tillage	Residue present from previous crop (% Cover) 1996	1997	1998	1999	Soil loss† ($Mg\ ha^{-1}$)
No-till (NT)	91a	75a*	95a	83a	8c
Chisel plow (CP)	18b	21b	21b	29b	22b
Moldboard plow (MP)	6c	6c	17c	5c	30a

* For each year, means with in a same column followed by same letter are not significantly different at the P = 0.05 probability level

† Soil loss is calculated by Universal Soil Loss Equation (USLE)

Table 2: Rainfall data during the growing season from 1989-2002 at Dixon Springs in southern Illinois

	Rainfall (cm)						
Year	April	May	June	July	August	September	Growing Season
1989	6.1	4.1	14.3	12.8	10.0	4.6	51.9
1990	14.5	28.2	4.4	6.4	10.5	8.8	72.8
1991	12.5	8.9	1.8	3.7	4.0	12.4	43.3
1992	6.1	6.7	7.6	13.4	3.9	19.1	56.8
1993	12.3	13.0	17.8	13.4	10.9	19.4	86.8
1994	16.2	1.5	10.2	6.0	9.8	7.0	50.7
1995	17.7	22.0	15.2	7.3	8.2	4.8	75.2
1996	14.8	14.2	9.0	13.1	1.4	14.8	67.3
1997	9.5	14.9	14.5	5.8	7.5	4.0	56.2
1998	15.3	6.5	19.3	10.3	11.8	2.5	65.7
1999	10.3	6.8	16.8	10.0	2.3	1.5	47.7
2000	6.2	15.8	15.1	6.8	3.8	8.3	56.0
2001	6.0	8.4	9.3	15.9	9.8	9.3	58.7
2002	19.0	24.7	3.1	5.1	7.2	18.8	77.9
1989-2002 average	12.31	1.51	1.9	9.3	7.3	8.9	62.0
30-Year average	11.2	12.4	9.8	10.3	8.6	7.8	60.1

Table 3: Effect of different tillage treatments on the maize and soybean population during 1989-2002 at Dixon Springs

Tillage	Plant population (plants ha^{-1})							
maize	1989	1991	1993	1995	1997	1999	2001	Average†
NT	55300b*	57900a	51400a	58800ab	46900a	69200a	64500a	57,800a
CP	59200ab	47400b	54100a	55700b	51900a	64200ab	56530b	56,300a
MP	62900a	52200ab	52600a	62200a	51900a	62700b	65900a	58,000a
Soybean	1990	1992	1994	1996	1998	2000	2002	Average†
NT	191000b	344000a	303000a	263000b	270700b	422400a	289000b	298900a
CP	247000a	335000a	229000b	277000b	273400b	397700b	387800a	306300a
MP	249000a	343000a	181000c	309000a	293900a	405100a	415000a	313700a

Table 4: Effect of different tillage treatments on maize and soybean yield during 1989-2002 at Dixon Springs

Tillage	Crop yield (Mg ha^{-1})							
maize	1989	1991	1993	1995	1997	1999	2001	Average†
NT	8.99b*	6.57a	11.79a	11.60a	9.87a	8.12a	9.73a	9.53a
CP	9.99b	6.10a	11.61a	11.55a	9.32a	6.78b	9.60a	9.26a
MP	11.26a	6.60a	10.98a	10.37a	9.59a	6.98b	10.34a	9.46a
Soybean	1990	1992	1994	1996	1998	2000	2002	Average†
NT	2.37a	3.74a	2.87a	2.63a	2.63a	2.32a	2.20a	2.57a
CP	2.62a	3.46a	1.81b	2.27a	2.63a	2.38a	1.77b	2.38a
MP	2.62a	3.65a	1.49b	2.43a	2.75a	2.32a	1.83b	2.38a

*For each crop, means with in a same year followed by same letter are not significantly different at the P = 0.05 probability level   † 7-year averages

2002. On the other hand, in 1994 and 2000 the plant population was higher with the NT treatment compared with that of the MP treatments, which could have been due to relatively greater water availability in the NT system compared with MP tillage system at planting. Seven-year average plant population (Table 3) for maize and soybean were not statistically different from NT and MP systems. From 1989 to 2002, the MP system had a significantly higher plant population than CP in 6 of 14 years (Table 3) and the other 8 years were similar. The NT system had a significantly higher plant population than CP in 4 of 14 years while CP had 2 of 14 years with higher plant population than NT. The other 8 years were similar. In 1989, 1996, 1998 and 2002, the NT had a lower plant population (Table 3) compared with that of the MP system which was probably due to insufficient soil-seed contact, lower germination and greater soil strength in the NT system (Kitur *et al*., 1994).

Rainfall data (30-year average growing season rainfall by month for the southeastern Illinois) and 1989-2002 growing seasons are shown in Table 2. The 30-year average cumulative rainfall during April-September in southeastern Illinois was 60.1 cm. During the study, three of the years (1991, 1994 and 1999) could be characterized as dry years with a growing season rainfall of 43.3, 50.7 and 47.7 cm, respectively. In 1991, the driest year, the maize yields were low for all treatments (Table 4) since all plant available water above the fragipan was extracted from all treatments including the NT system. In 1994, another year of low rainfall, the soybean yields were low for all treatments, but NT yield (Table 4) was substantially higher than CP and MP yields. In 1999, the NT maize yield of NT system was significantly higher than CP and MP. The 14-year average rainfall for the April through September period was 62.0 cm which is slightly above the 30-year average (Table 2). Years 1990, 1993, 1995 and 2002 were considered wet years.

From 1989 to 2002, tillage affected crop yields in only 1989, 1994, 1999 and 2002 (Table 4). In 1994 and 2002 the NT system produced significantly higher soybean yield. Soybean yield with the NT system was higher than with the CP and MP systems due to better plant population in 1994. Since 1994 was a dry year and 2002 had a dry June to August period, the NT system could have provided more soil water to soybean at planting and later in the season compared with that of the other tillage systems. This enhanced soil water storage could have resulted in an improvement in nutrient availability and played an important role in 100 and 60% higher soybean yields in 1994 and the 20 to 25% higher soybean yields in 2002 with the NT system as compared to MP and CP systems. Higher crop yield with the NT system than MP system in a dry year was also noted by Lueschen *et al.*[4]. Although the differences in soybean yield in 1996 were not significant by tillage treatment, the NT system had 7 and 15% higher yield than the MP and CP systems, respectively. In 2002 the NT soybean yield (Table 4) was significantly higher than MP when the plant population (Table 3) was significantly lower. Year 2002 was considered a wet year; however, the combination of a dry period (between June and August of 2002) and the high plant population in MP resulted in less water available per plant.

The 7-year average maize yield and the 7-year soybean yields were not affected by tillage (Table 4). Seven-year average soybean yield was 7% higher with NT than with CP and MP systems, while the maize yields were nearly equal in all tillage systems. At the beginning of the experiment, the MP system produced 21 and 11% higher yield compared with that of the NT and CP systems during 1989. After 3 years, the NT system crop yields were 3 to 100% higher than the MP system (Table 4) during the 1992-2002 period. The NT yields were lower in the early years of study but improved with the passage of time. The NT performance relative to MP and CP (Table 4) was better during dry years or years with extended dry periods than wet years (Table 2), which was also observed by Eckert[8].

The NT yields were lower during the 3 early years (1989 to 1991) of the study but the NT system out-yielded the MP system during the last 11 years of study. No-till yields were 5-20% lower than MP system in wet years (except 2002 with a dry period from June to August) but were 10-100% higher in relatively dry year (Table 4). The higher yields with the NT and CP systems in dry years was probably due to the conservation of more soil water than the MP system (Table 2). Chisel plow yields were 5-10% lower in wet years and were 20% higher in dry years as compared to MP system (Table 4).

Based on 14 years of crop yield measurements (7 years maize and 7 years soybean), the NT system appears to have resulted in improved long-term productivity compared with that of the MP and CP systems. The results of this study should be applicable to similar root-restricting, sloping and moderately eroded soils in Illinois, Indiana, Missouri and Kentucky.

ACKNOWLEDGMENT

Published with the approval of the Director of the Office of Research at the University of Illinois, Urbana, IL. Funded as part of Regional Research Project 367 and in cooperation with North Central Regional Project NC-174 (Soil Erosion and Productivity).

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