INFLUENCE OF CROPPING/TILLAGE MANAGEMENT ON SOIL FERTILITY AND QUALITY OF FORMER CRP LAND IN THE CENTRAL HIGH PLAINS

Doran, J.W., A. Kessavalou, G. L. Hutchinson, M.F. Vigil, and A.D. Halvorson
USDA-ARS & University of Nebraska, Lincoln, NE
USDA-ARS, Ft. Collins & Akron, CO & Mandan, ND

ABSTRACT

A field study was conducted to evaluate the effects of cropping and tillage on the quality and fertility of 'simulated' Conservation Reserve Program (CRP) grassland at Akron, CO during 1992 and 1993. Treatments, initiated in 1991, were a winter wheat-corn-fallow cropping rotation under different tillage management (no-till, reduced till and conventional till) and mixed grass CRP for comparison. Soil quality assessment and trace gas flux measurements were made in September 1992 and May 1993. A large decline in labile organic C and N pools (microbial biomass C and mineralizable N) and microbial activity in surface soil (0-3 in.) was observed after 19 months of cropping, the decline being lowest with no-till management. This 'early warning' of long-term declines in soil organic matter due to cropping and tillage of CRP lands was supported by the observation that 'organic' carbon levels in the surface 12 in. layer of cropped soils were 6-9% lower ($p=0.08$) than the CRP. Again the decline was smallest with no-till management. Cropping also resulted in a 4- to 5-fold increase in NO and N_2O flux as compared to CRP grass land. Increased fluxes of these N gases from cropped soils were associated with higher soil ammonium levels and higher nitrification rates that apparently resulted from addition of ammoniacal fertilizer N. However, the relevance of higher N gas fluxes with cropping to atmospheric quality requires further evaluation and comparison to the magnitude of other natural and human derived sources of these N trace gases. Under the conditions of our study, higer residual soil nitrate levels with cropping and tillage were closely predicted by soil electrical conductivity, a measurement which can be easily used in the field by either specialists or producers.

Our results suggest that cropping, fertilization, and tillage of CRP land can alter soil quality, long-term soil stability, and environmental quality. These effects were apparently smaller under no-till management, but more research is needed to define best management practices for such marginal land.

INTRODUCTION

The Conservation Reserve Program (CRP) was initiated in 1985 to protect our soil resources from degradation by converting agricultural lands that are highly susceptible to erosion of soil and productivity into land that is not tilled and is maintained in permanent vegetative cover. It is likely that over ten million acres of marginal agricultural lands now under grass vegetation will be returned to annual cropping with expected expiration of many 10-yr CRP contracts in 1995 and 1996. Limited information is available on what impact such farming practices will have on the quality and fertility of these protected soils. Therefore, we initiated a study to evaluate the changes that may occur in soil fertility and quality (physical, chemical and biological characteristics) when land now under CRP grass production is returned to annual crop production under various tillage management practices. The extent to which soil quality benefits accrued during CRP are lost when this land is returned to row cropping can be influenced by tillage management (Gilley et al., 1996).

MATERIALS AND METHODS

The study was conducted on the U.S. Central Great Plains Research Station near Akron Colorado during 1991 to 1993. The experimental site was under a winter wheat-fallow cropping system for over 50 years before it was converted to grassland in 1960-1963. The grass-legume composition was wheatgrass (80 %), blue gramma (14 %), sand dropseed (2 %), and alfalfa (4 %). The predominant soil series were Colby and Weld loams. Because of its history, the experimental site was assumed to represent typical CRP land and was therefore called 'simulated CRP land'. The treatments were winter wheat-corn-fallow cropping pattern under different tillage management, and simulated CRP grass for comparison. The experimental design was a randomized complete block with three replicates. Tillage treatments included: i) no-tillage (NT), ii) reduced tillage (RT, with two V-bladings) and iii) conventional tillage (CT, with three V-bladings). Tillage treatments were imposed in April 1991 and glyphosate (Roundup, 0.22 lb ai ac^{-1}) and 2-4 D (0.51 lb ac^{-1}) were sprayed several times to kill the CRP plant species. On September 20, 1991, wheat (Tam 107) was drilled in 7 in. rows at 809,700 seeds ac^{-1} with P fertilizer at the rate of 15 lb P ac^{-1}. Winter wheat and grass were harvested on July 9, 1992 and the first week of June, respectively, and yields were estimated on a dry weight basis. During the first week of May, 1993, corn (Pioneer 3732) was planted in 30 in. rows at 14,600 seed ac^{-1}. Prior to planting wheat in 1992 and corn in 1993, 80 lb N ac^{1} as NH_4NO_3 was surface broadcast in April on all plots including the CRP grass plots.

During September 16-17, 1992 (after wheat harvest) and May 17-18, 1993 (after corn planting), soil was sampled to a depth of 12 in. in increments of 0-3, 3-6, 6-12 in. for soil quality assessment using procedures described by Doran and Jones (1996). Also, NO, N_2O and CH_4 fluxes were monitored during these times. Soil quality indicators, namely, soil bulk density, water-filled pore space (WFPS), soil temperature, soil pH, electrical conductivity, infiltration rate, NO_3-N, NH_4-N, microbial biomass C & N, mineralizable N by anerobic incubation, soil respiration (field and lab), mineralizable-N and nitrifiable-N were determined using methods described by Gilley et al. (1996) and Doran and Jones (1996).

RESULTS AND DISCUSSION

Wheat Grain and Stover Yields and Grass Dry Matter Production

Wheat grain and stover yields were not influenced by tillage management and averaged 935 and 1497 lb ac^{-1}, respectively, across treatments. Above-ground grass dry matter yield averaged 1043 lb ac^{-1} per year. Grain yields were greatly reduced by drought conditions which occurred in 1991/92. Overall, about 25 lb N ac^{-1} was removed from the soil through above ground grass and wheat N uptake. At harvest, wheat residues recycled nearly 600 lb ac^{-1} of C into the system.

Management Effects on Physical, Chemical, and Biological Properties

Bulk density of the surface soil (3 in.) did not vary among treatments and ranged from 1.2 to 1.3 g cm^{-3} (Table 1). At lower depths, however, bulk density of the cropped soils was higher than CRP grass plots (data not shown). Although water holding capacity of the soil did not change as a function of soil management, cropped plots exhibited a water infiltration rate comparable to or higher than that of CRP, with the first 1 in. water entering the soil in 7 to 19 minutes. The infiltration rate for a second 1 in. of water was less in no-till and reduced-till soils (56 to 85 minutes) than CRP soil (44 minutes), but that for conventional till was higher (29 minutes). Such infiltration rates would probably not represent a serious potential for erosion and runoff in this climatic zone, as the expected frequency of a 1 in. rainfall of 1/2 hours duration is 2-5 yrs and for a 2 in. rainfall of one hours duration is 10 to 25 years (Hershfield, 1961). During spring 1993, WFPS of the surface soil (3 in.) before wetting ranged from 9 to 21 % across treatments, which is in a range that would severely restrict biological activity. This was reflected by the relatively low rates of soil respiration measured at this time. Sixteen hours after saturation, soil WFPS averaged 58 %, which is close to the optimum level for aerobic microbial activity (60% WFPS). This more optimal soil condition was reflected by a two- to ten-fold increase in soil respiration. This increase was primarily due to the effect of water as the temperature of surface soil (0-3 in.) varied little between treatments or times of measurement (range: 68 to 72°F).

Total Carbon and Nitrogen, pH, Electrical Conductivity, and NH_4 & NO_3 Levels

Total C and N levels in surface soil (0-3 in.) ranged from 4.5 to 5.7 ton C ac^{-1} and 0.5 to 0.6 ton N ac^{-1}, respectively, with highest levels occurring in CRP plots. These differences were maintained throughout the top 12 in. ($P < 0.08$) of soil as indicated by 6 to 9% higher levels of soil organic C in CRP than cropped soils (Table 1). Organic C contents were calculated by subtracting carbonate C content from total C as determined by dry combustion, to avoid the confounding of interpretations caused by the increase in carbonates with depth at this site.

Soil pH in the top 3 in. ranged from 5.9 to 6.8 and increased with soil depth to a maximum of 8.1. Soil pH was a sensitive indicator of the presence of carbonates, which increased directly with pH above 7.2. Surface soil pH values under wheat plots were less than simulated CRP plots, which may have resulted from acidification associated with nitrification of ammoniacal fertilizer N and less efficient N use by wheat (greater leaching) than by grass (Bouman et al., 1995). Electrical conductivity in the surface soil (0-3 in.) varied with management, with lowest values (< 0.1 dS m^{-1}) under grass and highest values (0.48-0.58 dS m^{-1}) for cropped soil. Soil electrical conductivity was closely related to soil NO_3 level (and to some extent ammonium levels), as demonstrated by the fact that measured NO_3 levels in surface soil were closely estimated from conductivity readings (Table 1). Cropping, tillage, and fertilizer management significantly influenced NO_3-N and NH_4-N levels in the top 12 in. of soil during 1992 and 1993 (Fig. 1). Soil NO_3 in the top 12 in. averaged 5.4 lb ac^{-1} under simulated CRP plots, while it ranged from 20 to 81 lb ac^{-1} under wheat plots. Presumably, increased net N mineralization under wheat with different tillage management led to high NO_3 accumulation in the soil profile. Large amounts of NO_3 were found in non-CRP soil profiles during the spring of 1993 due, in part, to the lack of active crop N uptake and increased net N mineralization. Low NO_3 levels under simulated CRP plots suggested high demand for NO_3 by grass uptake. Among tillage treatments, larger amounts of NO_3 were found under no-till than conventional tillage. In fall 1992, more NO_3-N was found between 6 and 12 in. than in the top 6 in. under wheat, suggesting increased NO_3 leaching under cropped soils during the 1992 growing season. Similar patterns were observed for NH_4-N distribution in the top 3 in., especially in 1993 (fertilizer effect), but were of lower magnitude.

Soil Respiration, Biomass C & N, and Mineralizable Nitrogen

In-field soil respiration is a measure of total soil biological activity as it includes the respiration of both microorganisms and plant roots. Under water-limiting conditions in the field, soil respiration was about 10 times higher in CRP than cropped soils (Table 1). However, the day after wetting from infiltration tests, when soil water status was optimal for microbial activity, the respiration of cropped soils increased 5- to 10-fold and was similar to that observed under laboratory conditions of optimal water status and temperature (77°F). Similar trends were observed in the laboratory for the 3-6 in. and 6-12 in. soil layers as well.

The microbial biomass C and mineralizable N levels in surface soil of CRP and cropping management systems differed significantly, with highest levels generally being present in CRP or no-till management and lowest levels in reduced and conventionally tilled cropped soils. In 1993 (after 19 months cropping), mineralizable N in the surface soil ranged from 23 to 45 lb N ac^{-1} across treatments (Table 1). Overall, cropping and tillage led to about 30 to 38% reduction in mineralizable N in the top 6 in. of soil. No significant cropping and tillage effects on mineralizable N were observed in fall 1992. Microbial biomass C in the surface soil ranged from 263 to 482 lb ac^{-1} across treatments and was about 33 % lower in cropped soils than CRP. However, among cropped treatments, the microbial biomass C levels of the no-till soil were higher than those of conventional and reduced till soils. Unlike microbial biomass C and mineralizable N, microbial biomass N showed little effect of cropping and tillage management, especially in the surface soil. Overall, the biomass N ranged from 24 to 30 lb N ac^{-1} between fall 1992 and spring 1993.

Net Mineralization and Nitrification Rate

Net mineralization and nitrification rates of the surface soil ranged from 0.5 to 1.7 lb N ac^{-1} d^{-1} during the fall of 1992 and were not influenced by cropping or tillage. During spring 1993, however, non-CRP plots exhibited high net mineralization (1.3-1.7 lb N ac^{-1} d^{-1}) and net nitrification (3.3-3.8 lb N ac^{-1} d^{-1}) rates. At this time, net mineralization and nitrification rates of cropped soils were 17 % and 45 % higher, respectively, than CRP soils.

Soil Available P

In general large amounts of available P were found in the top 12 in. of soil in all treatments. It ranged from 25 to 58 lb PO_4-P ac^{-1} under CRP plots and 65 to 130 lb PO_4-P ac^{-1} under cropped plots during 1992 and 1993. Among tillage treatments, higher accumulation of PO_4-P was observed under no-till plots

Trace gas flux

When compared to CRP grass plots, about a 4-fold increase in NO and a 5-fold increase in N_2O emissions were observed from no-till and conventionally tilled cropped soils as compared to CRP, especially during the spring of 1993 ($P= 0.05$). During 1993, NO and N_2O fluxes averaged 0.17 and 0.14 oz N ac^{-1} d^{-1}, respectively, from fertilized cropped plots. Nitrogen oxide gases are known to be evolved during microbial nitrification of ammonium N, and in our study higher rates of N oxide evolution from fertilized cropped soils paralled higher rates of nitrification (Table 1). In general, NO and N_2O emissions were higher during spring 1993 than fall 1992, presumably due to increased microbial activity as a result of higher soil temperatures at this time. Methane uptake rate averaged 0.1 and 0.2 oz C ac^{-1} d^{1} in 1992 and 1993, respectively, and was apparently not influenced by cropping or tillage. In general, NO and N_2O emissions were positively correlated with soil water-filled pore space ($r = 0.80$ & 0.89), while methane uptake was negatively correlated with WFPS ($r = -0.67$).

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Table 1. Effect of cropping and tillage management on selected soil quality indicators in the top 3 in. at Akron CO, 1992-1993 (Measurements for May 17-18, 1993 unless specified otherwise).

Soil Quality Indicators	CRP Plot		Non CRP Plot	
	Grass	No-till	Reduced till	Conventional till
Total C, ton ac^{-1} (Mean, 1992 & 1993)	5.7 (1.2)*	4.8 (0.3)	4.5 (0.3)	4.5 (0.4)
Total N, ton ac^{-1} (Mean, 1992 & 1993)	0.57 (0.09)	0.50 (0.04)	0.49 (0.04)	0.48 (0.36)
Org. C, ton ac^{-1} (0-12 in., 1992 &1993)	16.6	15.7	15.2	15.5
Microbial biomass C, lb C ac^{-1}	482 (49)	397 (92)	263 (12)	312 (66)
Microbial biomass N, lb N ac^{-1}	29 (8)	33 (6)	26 (7)	29 (3)
Mineralizable N (anaerobic), lb N ac^{-1}	45 (8)	33 (2)	23 (4)	33 (10)
Lab mineralization rate, lb N ac^{-1} d^{-1}	1.1 (0.4)	1.7 (0.4)	1.5 (0.4)	1.3 (0.5)
Lab nitrification rate, lb N ac^{-1} d^{-1}	2.0 (0.6)	3.8 (0.6)	3.3 (0.2)	3.3 (0.9)
Soil respiration (lab), lb C ac^{-1} d^{-1}	27 (7)	15 (6)	9 (2)	13 (3)
Field respiration (Pre-wet), lb C ac^{-1} d^{-1}	22 (13)	3 (1)	2 (1)	2 (2)
Field respiration (Post-wet) , lb C ac^{-1} d^{-1}	54 (24)	13 (8)	17 (4)	16 (4)
Water-filled pore space (Pre-wet), %	9 (1)	19 (3)	21 (2)	14 (4)
Water-filled pore space (Post-wet), %	54 (13)	59 (2)	62 (8)	56 (3)
Field Soil Temperature, °F	70.3 (0.5)	67.6 (1.1)	68.5 (1.1)	68.0 (0)
Soil bulk density (oakfield probes), g cm^{-3}	1.19 (0.04)	1.30 (0.14)	1.29 (0.05)	1.23 (0.10)
Soil pH	6.8 (1.2)	6.6 (0.9)	5.9 (0.2)	6.2 (0.6)
Soil Electrical Conductivity (1:1), dS m^{-1}	0.03 (0.04)	0.58 (0.06)	0.48 (0.08)	0.49 (0.09)
Soil Nitrate (**estimated**)† , lb N ac^{-1}	1.2 (2)	69 (7)	56 (10)	55 (11)
Soil Nitrate, (measured) lb N ac^{-1}	1.1 (0.7)	71 (13)	61 (13)	50 (7)
Soil Ammonium, lb N ac^{-1}	14 (22)‡	38 (16)	31 (21)	32 (16)
Infiltration, minutes for 1st 1 in. water	14 (2)	18 (6)	19 (9)	7 (6)
Infiltration, minutes for 2nd 1 in. water	44 (11)	56 (32)	85 (35)	29 (8)
Field Water holding capacity, oz oz^{-1}	0.24 (0.02)	0.23 (0.02)	0.23 (0.02)	0.26 (0.02)
Sand, %	40	40	41	41
Silt, %	38	42	40	40
Clay, %	22	18	19	19
NO flux, oz N ac^{-1} d^{-1}	0.05 (0.03)	0.20 (0.06)	-	0.14 (0.08)
N_2O flux, oz N ac^{-1} d^{-1}	0.03 (0.01)	0.15 (0.02)	-	0.14 (0.05)
CH_4 flux, oz C ac^{-1} d^{-1}	-0.18 (0.07)	-0.25 (0.05)	-	-0.16 (0.02)

* Value in parenthesis is standard deviation.
† Soil Nitrate -N (ppm) = [EC (dS m^{-1}) - (background)] X 140 = (EC - 0.02) X 140.
‡ One replicate received wrong ammonium fertilizer rate, average of other reps = 1.4 lb N ac^{-1}

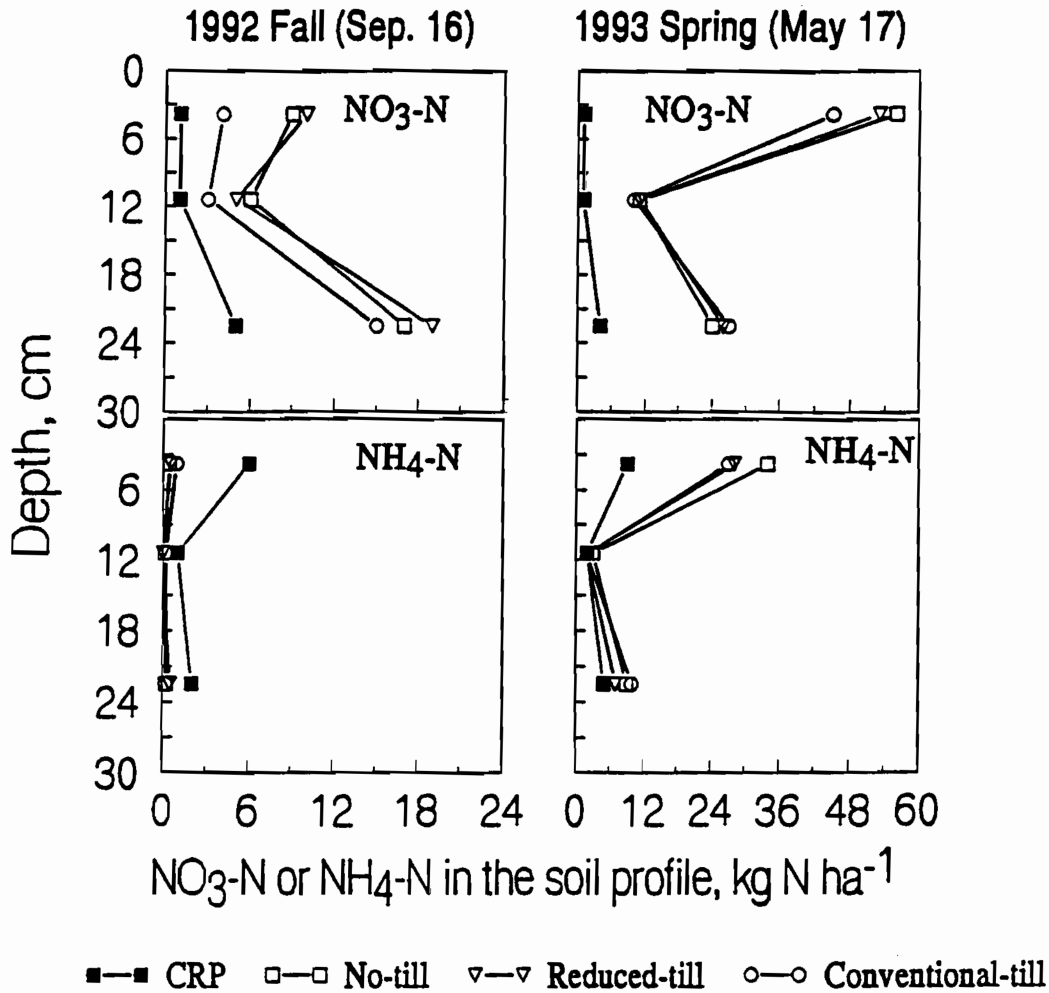

Fig. 1. Soil NO_3-N & NH_4-N (0-30 cm) under grass, and wheat-corn-fallow system under different tillage management during 1992-1993 at Akron, CO.