Tillage Effects on Water Use and Yields of Wheat From Reclaimed Soils

Kevin C. Vining and **Stephan A. Schroeder**

Agricultural production in western North Dakota is limited more by water availability than by any other environmental factor. Rainfalls, although often of short duration, can be intense, creating water runoff and soil erosion problems. Therefore, soil preparation to maximize water infiltration and preserve existing soil water is a serious concern for crop producers.

Mining companies are also concerned about the preparation and rapid revegetation of reclaimed agricultural minesoils. State laws require that reclaimed soil productivities be equivalent to those prior to disturbance. Lands must be held in bond by the mining companies for 10 years after soil replacement to demonstrate that adequate production levels have been attained and that reclamation had been successful.

Even with proper reclamation techniques, problems may arise. Water movement into reclaimed soils in North Dakota is often slower than into comparable undisturbed soils due to disruption of pore continuity during soil replacement (Potter et al., 1988). Smaller crop yields may be produced from reclaimed soils during years with low or poorly distributed rainfall (Schroeder and Halvorson, 1988). These occurrences could jeopardize land release opportunities and future land utilization.

Soil reclamation procedures and traffic from heavy equipment create layers of compacted soil. Restricted water percolation and root development deep into the soil profile as a result of these layers may make plants vulnerable to prolonged dry conditions. Tillage, especially subsoiling, has been shown to improve soil conditions, which may enhance water availability and root growth leading to increased crop productivity (Bennie and Botha, 1986). Long-term benefits from subsoiling have been shown to persist for up to five years (Ide et al., 1987), but are dependant on soil types and climatological conditions.

Schroeder (1988) described an experiment to compare the effects of chiseling, deep ripping, and other subsoil and topsoil tillage treatments on reclaimed soil bulk densities at two minesites in western North Dakota. Subsoil was respread on the sites and tillage treatments were applied. Topsoil was then respread using normal respreading techniques and final tillage treatments were applied. Finally, the sites were windrowed to remove rocks, and chiseled and packed to produce a seedbed for forage grasses. Soils were sampled for bulk density immediately after reclamation operations were completed. Statistical analyses showed no significant subsoil tillage treatment effects and few topsoil tillage treatment effects on bulk density. These results were attributed to recompaction from the heavy machinery used during respreading and surface smoothing operations.

A companion tillage study was initiated in 1989 which minimized post-treatment traffic. The main objective of the study was to compare the effects of conventional chisel and subsoil tillages on compaction, root growth, soil water status, and yields of various crops grown on reclaimed agricultural minesoils. Results from this study concerning the effects of tillage on soil water usage and yields of spring wheat (Triticum aestivum L.) will be discussed in this article.

MATERIALS AND METHODS

Research sites were established in May 1989 at the Basin Cooperative Services Glenharold Mine southeast of Stanton and at the Knife River Coal Mining Company South Beulah Mine near Beulah. The soils at these sites had been reclaimed the previous autumn using normal respreading techniques. Surface rocks were removed and the sites tilled with a chisel plow. Each site was located on nearly level land and was slightly greater than one acre in size. The primary textures of the soils at the Glenharold and Knife River sites were loam and sandy loam, respectively.

Surface tillage treatments applied to each site consisted of chiseling (6-inch depth, 12-inch shank spacing) and subsoiling (24-inch depth, 42-inch shank spacing). Each treatment was applied randomly in two strips each 42 feet wide along the length of the sites. The subsoiling implement was pulled twice through the subsoiled strips producing a 21-inch tillage spacing. Large soil surface clods formed during subsoiling were crushed by disking. The sites were fertilized with 100 pounds per acre of ammonium nitrate (analysis 34-0-0), then disked and harrowed to produce a firm seedbed. Each site was divided into two equal blocks perpendicular to the tillage treatments. Crop strips, consisting of five forage mixes and monocultures and Stoa spring wheat, were seeded on each block perpendicular to the tillage treatments. Wheat was planted each spring at one million live seeds per acre in 6-inch rows. Wheat strips were chiseled each autumn after harvest and disked each spring prior to planting. Soil fertility tests were made each winter on the wheat

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Vining is associate soil scientist and Schroeder is soil scientist, Land Reclamation Research Center, Mandan.

subplots to determine the amount of fertilizer needed at planting to produce a 40 bushel per acre (bu/ac) crop.

Soil water contents in 1-foot increments were measured every two weeks at each site using neutron moisture devices. Steel tubes were installed to 5 feet in two of each crop-by-tillage subplots to permit access. Recording raingauges were used to measure weekly precipitation at each site throughout the growing seasons. Total water used by the wheat was calculated as the difference in soil water contents from planting to harvest plus the total rainfall during the same period. Only soil water contents above 3 feet were used in calculating total water use due to an absence of observed wheat roots and little or no change in soil water contents below that depth.

Wheat was sampled each year from each site. Four 1 square yard subsamples were harvested and combined to form one sample from each subplot. The samples were dried for 48 hours at 140°F and then threshed. Yields were calculated at kernel water contents of about 10 percent by weight.

In an attempt to assist forage establishment during the dry summer of 1989, the Glenharold site was sprinkle irrigated with approximately 0.5 inches of water in July. Since the wheat crop was in the dough stage, it was assumed that the additional water did not significantly impact yields.

RESULTS AND DISCUSSION

Table 1 shows measured growing season rainfall from the Glenharold and Knife River sites during the three years of the study. The amounts for 1989 were only about 50 percent of climatological normal (1951-1980) precipitation measured at nearby stations. However, Table 1 does not show estimated rains of 0.5 and 1.5 inches which fell in 1989 at the Glenharold and Knife River sites, respectively, immediately after tillage treatment application but prior to crop planting and raingauge installation. Rainfall was variable during each growing season. Much of the rain during 1990 and 1991 fell during late spring with lesser amounts during grain filling in July.

Table 1. Monthly precipitation measured at the Glenharold and Knife River tillage sites during the 1989,1990, and 1991 wheat growing seasons (planting to harvest).

Month	Year 1989[a]	1990[b]	1991[c]
	(inches)		
	Glenharold		
April	——	0.48	1.42
May	0.85	1.54	2.10
June	1.15	5.41	3.82
July	1.26	1.93	0.55
August	0.03	0.02	——
Total	3.29	9.38	7.89
	Knife River		
April	——	0.60	1.72
May	0.75	2.29	1.84
June	1.24	5.38	2.53
July	1.65	1.27	0.23
August	0.05	0.07	——
Total	3.69	9.61	6.32

[a]Raingauges installed 5/25.
[b]Raingauges installed 4/20.
[c]Raingauges installed 4/10.

Figures 1 and 2 show mean estimated soil water changes from planting each year within the 0 to 3-foot depth of each tillage treatment at the Glenharold and Knife River sites wheat subplots, respectively. Generally, greater amounts of water were

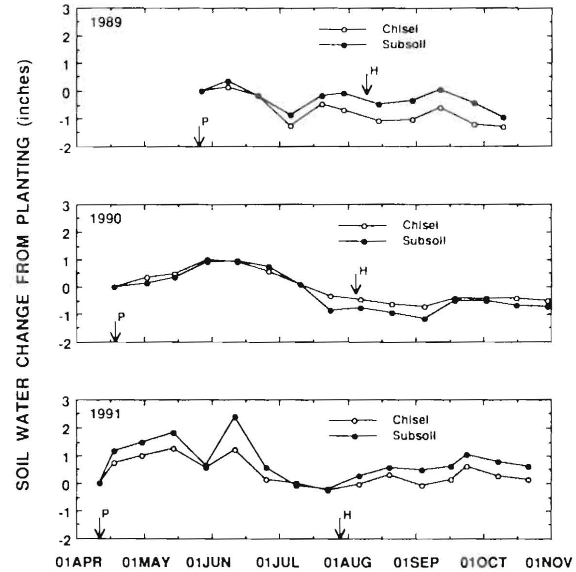

Figure 1. Estimated available soil water (0 to 3 foot depth) averaged by tillage treatment from the Glenharold site wheat subplots for the 1989, 1990, and 1991 growing seasons. Arrows indicate dates of planting (P) and sample harvesting (H).

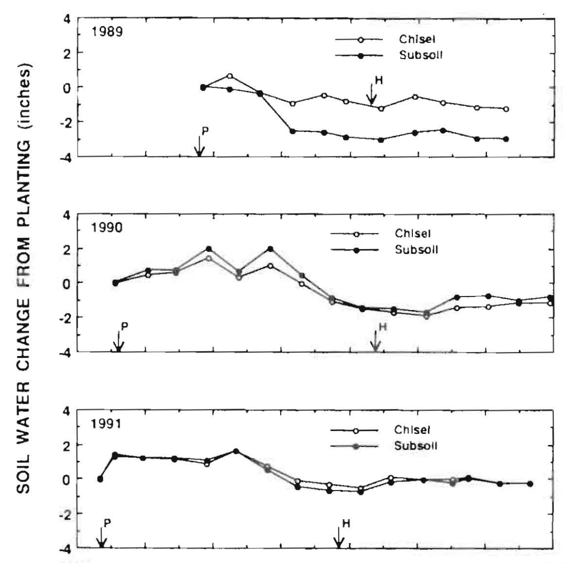

Figure 2. Estimated available soil water (0 to 3 foot depth) averaged by tillage treatment from the Knife River site wheat subplots for the 1989,1990, and 1991 growing seasons. Arrows indicate dates of planting (P) and sample harvesting (H).

used from the subsoil treatments during the periods from planting to harvest. Wheat roots probably followed the channels made during subsoiling and extracted water from deeper in the soil profile. By the end of 1989, the soils had became very dry. Spring soil water recharge in 1990 and 1991 was insignificant at either site, meaning that crops had to rely mostly on growing season precipitation. Rainfall from April to June in 1990 and 1991 increased soil water amounts enough for good crop growth. However, by July, rainfall was low and soil water reserves again became depleted. A small amount of soil water recharge occurred by the end of 1991 at the Glenharold site (Figure 1).

Table 2 shows mean wheat yields from the Glenharold and Knife River sites. Mean yields from both sites were small in 1989 due to drought. Increased precipitation in 1990 and 1991 led to larger mean yields at both sites. Unfortunately, hail in 1990 led to greatly reduced wheat yields. Mean yields were significantly greater from the subsoil treatment in 1989 and 1991 at Knife River. The significant increase in 1991 was probably due to sampling variability. However, the four-fold yield increase in 1989 can be attributed to an estimated 1.5 inches of rain which fell onto the Knife River site the day after application of the tillage treatments. Water was presumably able to percolate deeper into the subsoiled subplots and became available to the crop during the dry growing season. In the chisel subplots, water was retained mostly in the upper part of the soil profile and was depleted rapidly through evaporation.

The significant wheat yield increase observed in 1989 from the subsoil treatment at Knife River corresponded directly to greater planting-to-harvest water usage from the subsoil treatment (Figure 2). Root exploration in the subsoil treatment may have been enhanced by a greater number of mechanically-induced soil pores which led to increased plant water use and grain yields. Conversely, subsoiling provided no apparent benefit at the Glenharold site during any year of the study. Mean

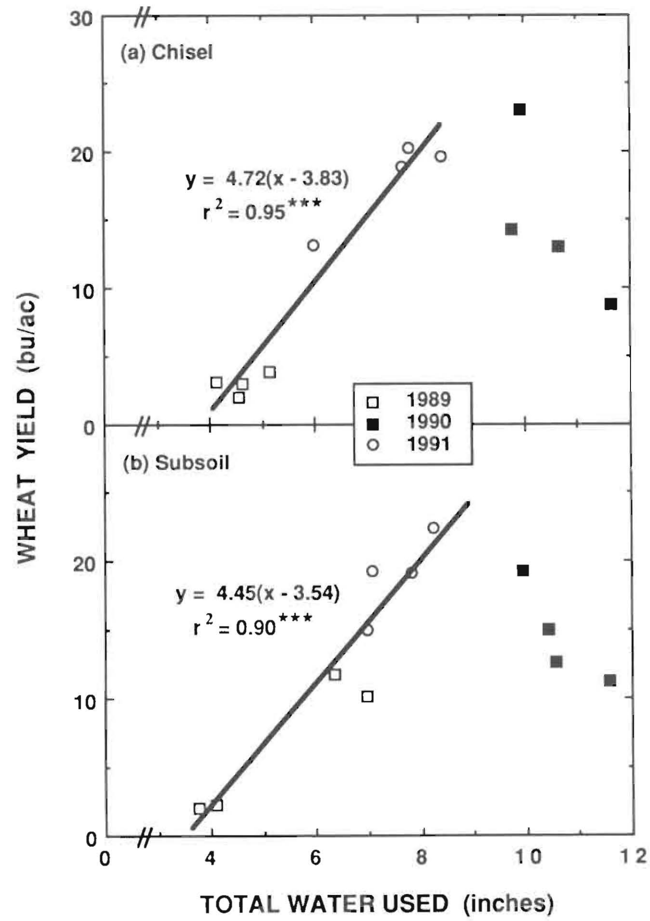

Figure 3. Relationships of wheat yields and total water used for the (a) chisel and (b) subsoil tillage treatments using combined data from the Glenharold and Knife River sites.

wheat yields in 1989 and 1991 were similar for both tillage treatments. In 1990, yields were 9 percent greater from the chisel than subsoil treatment (not significantly different) even though soil water use was greater from the subsoil treatment during the planting-to-harvest period (Figure 1).

Figure 3 shows the relationships of total growing season water used by wheat and wheat yields from the chisel and subsoil tillage treatments using combined data from the Glenharold and Knife River sites. Yields and total water usage varied widely during these three years, from the drought in 1989 to good growing conditions in 1990 and 1991. Overall, the relationships were proportional: higher yields were associated with greater amounts of water used. The 1990 crops were affected by hail and did not follow the linear trend. Correlations between yields and water usage on both tillage treatments calculated using the 1989 and 1991 data only were highly significant.

Regressions of yields on water use for each tillage treatment were also calculated using only the 1989 and 1991 data from the Knife River and Glenharold sites (Figure 3). Results show that the average amounts of total water used from the 0 to 3-foot soil layers of the chisel and subsoil treatments before the realization of grain yields were 3.83 and 3.54 inches, respectively. Each

Table 2. Comparisons of mean wheat sample yields obtained from the Glenharold and Knife River tillage sites.

	Tillage treatment		
Year	Chisel	Subsoil	LSD (0.10)*
		(bu/ac)	
		Glenharold	
1989	1.7	1.5	NS
1990	19.7	18.0	NS
1991	21.5	21.1	NS
Average	14.3	13.5	NS
		Knife River	
1989	2.7	10.9	1.7
1990	11.1	12.8	NS
1991	15.7	17.6	1.8
Average	9.8	13.8	0.9

*Least significant difference between mean yields (P=0.10). NS indicates no significant difference.

additional inch of soil water used produced 4.72 and 4.45 bushels of wheat per acre. These values are similar to those reported for western North Dakota by Bauer and Black (1991). Further analyses showed, however, that the regression equations from the tillage treatments were not significantly different from each other. In addition, no significant differences were found at either Glenharold or Knife River between the regression equations of wheat yields on water use calculated for the chisel and subsoil tillage treatments (not shown). Similar wheat yields could have been expected from either tillage treatment at either site provided soil water was available. The varied meteorological conditions which occurred during the three years of the study did not permit soil water recharge. Therefore, except for the 1989 results from Knife River, consistent improvements in soil water use by wheat, and hence wheat yields, were not apparent from the subsoiled treatments.

SUMMARY

Wheat was grown from 1989 to 1991 on research sites at the Knife River Coal Mining Company mine and the Basin Cooperative Services Glenharold mine to study the effects of surface-applied chisel and subsoil tillage on water use and yields. Total water used from planting to harvest was greater from the subsoil treatment at the Knife River site in 1989 and 1991. Consequently, wheat yields from the subsoil treatment were significantly greater than those from the chisel treatment. Much of the yield difference in 1991 was due probably to sampling variability. At the Glenharold site, water use was not consistently greater from either tillage treatment throughout the three-year study. However, mean wheat yields were greater from the chisel treatment each year.

Results from this study indicate that improvements in soil water storage or use and wheat yields produced by subsoiling are inconsistent. Precipitation during the period of study was unevenly distributed and often light preventing soil water recharge deep into the soil profile. Potential subsoiling benefits to root growth and soil water extraction were thus negated. The four-fold yield increase from the subsoil treatment at Knife River in 1989 was probably an extraordinary occurrence which may be repeated only rarely.

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