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Twenty years of conservation tillage research in subarctic Alaska II. Impact on soil hydraulic properties

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Abstract

Soil management practices are needed in the subarctic that stabilize the soil against the forces of wind and water as well as conserve soil water for crop production. There is a paucity of information, however, regarding the long-term effects of conservation tillage on soil hydraulic properties in subarctic Alaska. The objective of this study was therefore to characterize infiltration, water retention, and saturated hydraulic conductivity of a soil 20 years after establishing tillage and straw management treatments in interior Alaska. The strip plot experimental design, established on a silt loam and maintained in continuous barley (*Hordeum vulgare* L.), included tillage as the main treatment and straw management as the secondary treatment. Tillage treatments included no tillage, autumn chisel plow, spring disk, and intensive tillage (autumn and spring disk) while straw treatments included retaining or removing stubble and loose straw from the soil surface after harvest. Soil properties were measured after sowing in spring 2004; saturated hydraulic conductivity was measured by the falling-head method, infiltration was measured using a double-ring infiltrometer, and water retention was assessed by measuring the temporal variation in in-situ soil water content. No tillage resulted in greater saturated hydraulic conductivity and generally retained more water against gravitational and matric forces than other tillage treatments. Infiltration was greater in autumn chisel plow than other tillage treatments and was presumably suppressed in no tillage by an organic layer overlying mineral soil. Infiltration was also enhanced by retaining straw on rather than removing straw from the soil surface after harvest. No tillage is not yet a sustainable management practice in this region due to lack of weed control strategies. In addition, the formation of an organic layer in no tillage has important ramifications for the soil hydrological and thermal environment. Therefore, minimum tillage (i.e., autumn chisel plow or spring disk) appears to be a viable management option for maximizing infiltration in interior Alaska.

Keywords: Infiltration; Soil water retention; Soil water; Hydraulic conductivity

1. Introduction

Small grain crops (e.g., barley) are well adapted to the interior region of Alaska. Lack of precipitation during spring, however, can create water stresses as plants develop throughout the spring and summer. Indeed, limited water is a main determinant of crop production in the region (Sharratt et al., 2003). Lack of precipitation, in conjunction with spring tillage and sowing operations, may also create soil surface conditions susceptible to wind erosion. Agricultural lands in parts of interior Alaska are generally characterized by soils that are moderately to severely susceptible to wind erosion (Knight et al., 1979; Siddoway et al., 1984).

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Tillage and crop residue management can alter the physical matrix and thus the hydraulic properties of soils. Studies conducted in more temperate regions other than the subarctic suggest that soils are wetter (Lafond et al., 1992; Arshad et al., 1995) and retain more water at a given matric potential (Allmaras et al., 1977; Mahboubi et al., 1993) when subject to no tillage as compared with conventional tillage practices. Soils managed using no tillage have been found to have a higher (Mielke et al., 1984; Mahboubi et al., 1993) as well as lower hydraulic conductivity (Datiri and Lowery, 1991) as compared with soils managed using minimum or conventional tillage. These contrasting responses in hydraulic conductivity to tillage practices are also evident in infiltration. For example, infiltration has been found to be slower in soils subject to no tillage as compared with conventional tillage practices because soils subject to no tillage can be denser or be less prone to crust disruption (Lindstrom et al., 1984; Freebairn et al., 1989). Other investigators, however, have found that infiltration is higher in soils subject to no tillage as compared with conventional tillage practices (Mielke et al., 1984; Dao, 1993). Infiltration, as well as water retention of soil, can also be enhanced by the addition of straw to the soil (Barzegar et al., 2002).

There are but a few studies that have examined the impact of long-term tillage and crop residue management on soil hydraulic properties. Twenty-eight years after establishing tillage treatments on a silt loam in Ohio, Mahboubi et al. (1993) found that no tillage resulted in a higher saturated hydraulic conductivity and greater water retention as compared with conventional tillage. Chang and Lindwall (1989) did not observe any change in saturated hydraulic conductivity and water retention of a clay loam 20 years after establishing tillage treatments in Alberta, but they did find that infiltration was greater for no tillage versus conventional tillage. Arshad et al. (1999) found infiltration and water retention of a silt loam was greater after about 12 years of no tillage versus conventional tillage in northern British Columbia. In contrast to the above studies, Heard et al. (1988) found that saturated hydraulic conductivity of a silty clay loam was higher when subject to 10 years of tillage than no tillage in Indiana. They attributed the higher conductivity of tilled soil to larger or a greater number of voids and cracks caused by the tillage implement.

Studies that document the effect of long-term tillage and crop residue management on soil hydraulic properties are even rarer in the subarctic. Sharratt (1996) found in one such study that a silt loam retained more water and had a higher saturated conductivity after being subject to seven years of no tillage compared with intensive tillage in interior Alaska. We are unaware of other long-term studies that have examined the influence of tillage and residue management on the physical properties of subarctic soils, thus the purpose of this study was to characterize soil hydraulic properties 20 years after establishing tillage and straw management treatments in interior Alaska.

2. Materials and methods

This long-term tillage and crop residue management study was conducted at the University of Alaska Fairbanks Agriculture and Forestry Experiment Station located near Delta Junction, Alaska (63°N, 145°W). The research site was cleared of indigenous vegetation in 1979 and cropped to barley beginning in 1982. All tillage and straw management treatments were established by the autumn of 1983. The experimental design was strip plot with tillage as the main treatment and straw management as the secondary treatment. Tillage treatments included (1) intensive tillage in which the soil (coarse-silty over sandy or sandy-skeletal, mixed, non-acid Aquic Eutrocryept) was disked with an offset disk after harvest in the autumn and in the spring prior to sowing, (2) disking prior to sowing in the spring, (3) chisel plow after harvest in the autumn, and (4) no tillage. Straw treatments included (1) retaining stubble and loose straw on the soil surface and (2) removal of stubble and straw from the soil surface after harvest. Main plots (23 m × 120 m) were replicated three times and split to accommodate straw treatments.

Each year for the past 20 years, barley was sown in May using a 0.18 m double disk, press wheel drill and harvested in late August or early September using a combine equipped with a straw spreader. Fertilizer was applied at the time of sowing and broadleaf weeds were controlled using a post-emergence herbicide.

2.1. Soil properties

Soil hydraulic properties were measured after sowing (May 18) but prior to tillering of barley in 2004. Soil properties were assessed at this time of year due to the vulnerability of the soil to rapidly dry and erode. Indeed, little precipitation and the preponderance of strong winds in spring can contribute to soil drying and wind erosion. Soil properties were assessed between crop rows and wheel tracks at 10 locations within each plot.

Saturated hydraulic conductivity was determined by the falling head method (Klute and Dirksen, 1986). Soil