Tilth of Virgin, Cultivated, and Zero Till Soils

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Tilth is generally defined as those soil properties that describe soil conditions that determine the degree and fitness of a soil as an enviroment for the growth and development of crop plants. Deterioration of tilth is sometimes difficult to measure because tilth can not be represented by a single number or index. Tilth is a dynamic soil state and can be altered by both tillage and by such environmental factors as rainfall and wind.

Russell (1978) has stated that the productivity of the world's arable agricultural soils is decreasing. He has attributed this soil deterioration to repeated cultivation which has resulted in a loss of soil fertility, loss of soil by erosion, decreasing crop yields and increasing difficulty in growing crops. The degree of soil deterioration is generally measured by comparing changes in soil properties of undisturbed or recently disturbed grassland and parkland soils to those of arable cultivated agricultural lands. This paper will also examine the effect of zero tillage on some of the soil qualities.

Cultivation shears and pulverizes the natural soil aggregates and exposes new soil surfaces containing organic matter to increased microbial attack (Rovira and Greacen, 1957). The resulting loss in organic matter reduces agregate stability and results in a less aggregated soil. Loss of organic matter due to physical pulverization can render soils more susceptible to water and wind erosion and compaction, and can result in restricted moisture infiltration, reduced plant root extension, and poorer aeration.

Ground Cover

Probably one of the main effects of cultivation is the reduction in ground cover. Cultivation has destroyed native plant cover and has left the soils exposed and more susceptible to wind and water erosion. Grass cover and residue material on native grasslands helped absorb and deflect the impact of raindrops, protecting the dispersible soil, and preventing or reducing surface sealing and increasing infiltration. Cover also traps soil particles, protecting a soil from wind erosion. The effect of cover in reducing water erosion losses is depicted in Table 1.

Table 1 Effect of Crop Type on Soil Erosion Losses

Location	Erosion Losses (Metric tons/ha/yr.)		Reference
Edmonton, Alta	Sod	0.007	Toogood (1963)
	Stubble	0.94	
	Fallow	2.0	
Swift Current, Saskatchewan	Sutbble	0.11	Nicholaichuk and Read (1978)
	Fallow	0.43-0.88	
Guelph, Ontario	Cont. Hay	0.01	Webber (1964)
	Cont.Corn	17.4	
Clarinda, Iowa	Cont. Bluegrass	0.5	Johnston et al (1942)
	Rotation Oats	20.0	
	Rotation Corn	25.0	
	Cont.Corn	37.0	

Aggregation

Soil aggregation is decreased by tillage and increased by the incorporation of fibrous-rooted grasses and legumes. Olmstead (1946) showed that Kansas soils have lost 80% of their water-stable aggregates in the cultivated layer in a little over 40 years of cropping and tillage. Low (1972) compared the water stability of aggregates on an old grassland, recently plowed grassland, and old cultivated soil and showed that aggregate stability of plowed grassland can decrease very rapidly (Figure 1). Toogood and Lynch (1959) found that the mean weight-diameter of water-stable aggregates of Gray-wooded soils in a legume-grain rotation were almost double the diameter of soils in a fallow-wheat sequence.

Dry aggregates ≥ 0.84 mm in size are generally thought to be resistant to wind erosion. Seedbed preparation and summerfallow can increase the erodibility of soils (Dew, 1968 and Keys et al, 1970). Smika and Greb (1975) showed that tillage operations with the V-blade, rodweeder, cultivator and one-way decreased initial aggregation from 70% to 60, 54, 48, and 30%, respectively (Figure 2).

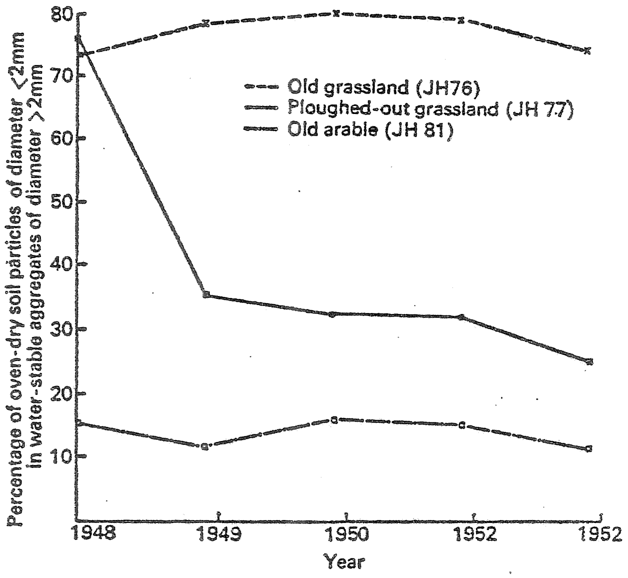

Figure 1. Changes in water-stability of aggregates after ploughing out old grassland compared to the remaining grass and to an old cultivated field. (from Law, 1972).

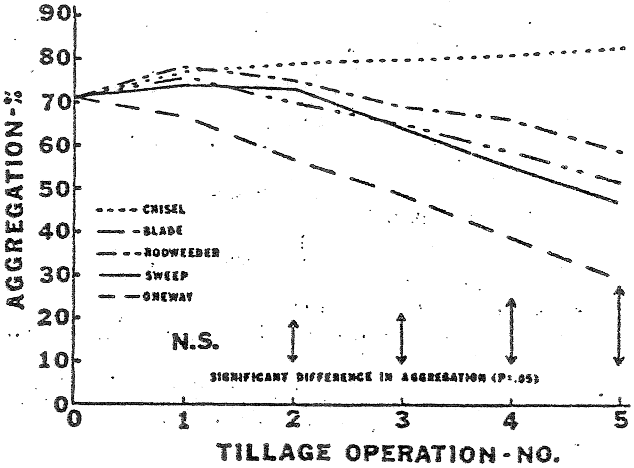

Figure 2. Change in nonerodible aggregation with tillage implement and number of operations. (from Smika and Greb, 1975).

The addition of residues to soil and stubble mulching has been shown to have a positive effect on aggregation. Zero tillage also improves both water-stable and wind-stable aggregation (Table 2).

Table 2 Effect of Zero Tillage on Aggregate Stability

Location		Description		
			Direct Drilled	Plowed
Tomlinson (1974), England	Water Stability	0-5 cm	21%	5%
		5-10cm	17%	10%
			Direct Drilled	Plowed
Hamblin (1980), Australia	Water Stability SL Soils		17.8%	13.8%
		Cult.	Direct Drilled	Undisturbed
McNeill and Aveyard (1978) Australia	Water Stability	6.1%	12.1%	12.6%
			Fallow	Chem. Fallow
Black and Power (1965) USA	Wind Stability		64.7%	73.7%
Anderson (1971) Saskatchewan	Wind Stability		61%	68%

Bulk Density and Porosity

Cultivation pulverizes soil resulting in smaller particles, reorientation of the particles and more tightly packed particles. As a result, cultivated soils are generally denser than native grassland and forest soils (Table 3). Zero tillage or direct-drilling of previously cultivated soils tends to increase bulk density (Table 3). However, direct-drilling of undisturbed grassland or pasture will probably not increase bulk density substantially, although we did not find any data to prove or disprove this.

Air porosity is inversely related to bulk density and this decreases when virgin lands are cultivated. Often cultivation reduces the macopore space by one-half that of virgin soils (Laws and Evans, 1949; Webber, 1964; and Aina, 1979). European zero till researchers have found a reduction in total pore space ranging from 1% to 7% on direct-drilled plots (Baeumer, 1970), however, they found a much more homogeneous pore space. Dowdell et al (1979) from England found winter oxygen concentrations to be generally higher on zero till plots than plowed plots. They attributed the higher O_2 concentration to a more continuous pore space system, undisturbed by plowing.

Table 3 Soil bulk densities of virgin, cultivated and zero till soils

Reference and Location	Virgin	Cultivated
Williams and Cooke (1961) Rathamsted	0.94	1.19
Skidmore et al (1975) Kansas	1.29	1.38
Aina (1979) Nigeria	1.28	1.57
de Jong (1981) Saskatchewan	1.17	1.43

	Cultivated	Zero Till
Finney and Knight (1973) England	1.08	1.17
Fleige and Baeumer (1974) Germany	1.49	1.66
Pidgeon (1980) Scotland	1.23	1.32
Cameron (1980) Saskatchewan	1.07	1.23

Water Storage

Cultivation changes the pore size distribution of soils by pulverizing the soil aggregates and reducing the number of large pores, thus reducing the water infiltration rates (Table 4). Zero tillage tends to improve the water transport characteristics and this has been attributed to a more continuous pore space from the surface to deeper depths, to increased earthworm activity in zero till soils, and to the presence of trash or crop residues that reduce rainfall impact and prevent surface sealing (Baeumer, 1970; Goss et al, 1978; Ehlers, 1975; and Ellis et al, 1977).

Table 4. Rates of Water movement in virgin, cultivated and zero till soils

	Water movement rates (cm/hr)	
Skidmore et al (1975) Kansas	Sod	2.32
	Cultivated	0.02
Saini and Grant (1980) New Brunswick	Potato-Oat-Sod	55
	Continuous Potatoes	47
Aina (1979) Nigeria	Undisturbed	115
	Cultivated	15
Lal (1978) Nigeria	No-till	48
	Plowed	24
Hamblin (1980) Australia	Direct Drilled	27
	Cultivated	17

Most researchers have found in subhumid regions that moisture contents, particularly in the surface soil are higher under zero till than adjacent plowed fields. In the drier regions chemical fallow has resulted in higher water storage gains than conventional fallow. Lindwall (1977) has shown that chemical fallow can conserve an extra 3 cm of available water over that of conventional fallow. (Table 5).

Table 5 Effect of Summerfallow treatments on moisture storage and yields (from Lindwall, 1977).

Summerfallow Treatment	Available Moisture in Spring (cm)	Yield (kg/ha)
Oneway	13.5	1835
Blade	13.2	1800
Chemical	16.3	1970
Chemical, fall blade	14.2	2100

Other Areas of Concern

Soil crusting is a problem associated with intensively cultivated seedbeds, particularly after a heavy rain storm. Gray Luvisols are particularly prone to crusting, although it can occur on almost all soils. On agriculture soils, crusts cause two major problems: seedling emergence is hindered and runoff increased. If crusting is severe, tillage and reseeding will be required to remedy the situation.

Soil compaction is not yet a problem in most areas of Western Canada. In poorly drained soils, soils with high water tables and saline soils, trafficability can be a problem. These soils should be worked when they are dry enough to support the weight of farm tractors.

Tillage does offer the advantage of warming-up soil temperatures earlier in the spring. In the wetter climates of north east U.S.A. and Europe, the absence of tillage lowers the soil temperature. The lower soil temperature has been attributed to shading effect of the trash cover (undisturbed by cultivation) and the higher water content in these soils. Gauer and Shaykeiwich (1979) from Manitoba have suggested that the difference in soil temperature when no-till is practiced should not be a limiting factor in crop production.

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