Long and short-term variability of aggregate size distribution in tillage and chemical fallow.

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Abstract

Size distribution of aggregates is one of the most important factors which affect soil erodibility with respect to wind erosion. A long-term study was established in 1968 to investigate the influence of tillage and chemical fallow systems on aggregate size distribution. The cropping systems involved fallow with herbicides only, herbicides in combination with one or two tillage operations, and tillage alone. Significant differences in aggregate size distribution were found between years during the period between 1968 and 1986. It was clear that in some years Melfort soils were highly erodible. In 1991, aggregate size distribution was measured at 5 times during the fallow season in order to evaluate the effects of the different cropping systems, determine aggregate size distribution with depth, and to compare variability over the long and short term. The percentage of aggregates at the surface in the 0 to 0.5 mm size fraction decreased after tillage with a double disk, and increased with time thereafter despite further cultivation with a field cultivator, but remained relatively constant under chemical fallow. During the period of this study it was clear that there were two distinct sources of variability in soil erodibility. Both sources of variability should be taken into account if soil erodibility is to be predicted over the long term.

Introduction

Current equations for predicting wind erosion are based on the observation that the proportion of dry sieved aggregates < 0.84 mm is highly correlated with soil erodibility. Aggregate size distribution has been used in the wind erosion prediction equation (Woodruff and Siddoway 1965) to calculate an index of soil erodibility which in turn is used predict the amount of soil lost to wind erosion. It will also be an important variable in the wind erosion prediction system, a new decision support system designed to predict wind erosion (Zobeck and Popham 1990).

Aggregate size distribution has been studied over both long and short terms at several sites in Saskatchewan. Two studies of long-term variability of aggregate size distribution have been conducted in Saskatchewan at the Swift Current Research Station. Anderson and Wenhardt (1966) found that the percentage of aggregates < 0.84 mm in a Wood Mountain clay loam decreased from completion of tillage in fall to prior to preseeding tillage. This trend was attributed to over winter aggregation, although Bisal and Nielsen (1964) indicate that there is no consistent trend with respect to changes in aggregate size distribution over winter. There was considerable variability in aggregate size distribution measured in a study conducted over a 12 year period by Bisal and Ferguson (1968). Bisal and Ferguson concluded that aggregate size distribution is dependent on the date of sampling although no attempt was made to coordinate soil sampling with cultural operations in this study.

In a study of short-term variability, Hilliard and Rostad (1991) reported an increase in the erodible fraction for the period from July 1989 to May 1990 for clay soils in the Dark Brown Soil Zone, and a decrease immediately after seeding and tillage. Similar increases occurred in fine textured soils from fall to spring (Hilliard et al 1988, Chepil 1954).

Given the importance of the relative proportion of smaller aggregate fractions in equations and models which predict wind erosion, data from a long-term study on Melfort soils at the Melfort Research Station was used to evaluate long and short-term variability of soil erodibility. The data are from a long-term study which was established in 1968 to investigate the influence of tillage and chemical fallow systems on aggregate size distribution. In addition a study of variability during the fallow season was initiated in 1991 on the same long-term study.

Methods

The experiment was established in 1969 on the Agriculture Canada Research Station at Melfort, Saskatchewan. The soil, a Melfort silty clay (Mitchell et al. 1944) with 16% sand, 40% silt, 44% clay, is an Orthic Black Chernozem (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978) with an organic nitrogen content of 0.55% (0-15 cm depth) and a surface pH in water paste of about 6.0 (Nuttall et al. 1986). Seven summerfallow-spring wheat systems (Table 1) were established on plots 6.7 m by 53 m in a randomized complete block design with 4 replicates. Two fallow-wheat series were established on adjacent blocks such that fallow and crop were alternated every year and each system was cycled on its assigned plots.

Fallow treatments using tillage and/or herbicides are summarized in Table 1. Most field operations associated with management of the treatments were performed using field-size equipment. A field cultivator, equipped with 40 cm sweeps and operated at a depth of 5-6 cm, was the main implement used for tillage operations on summerfallow areas; in some years, a rodweeder operated at 3-4 cm depth, replaced one or more of the cultivation operations on the tillage alone (control) treatment. The first summerfallow tillage operation was usually performed in early June with a double disk cultivator, subsequent operations performed with a field cultivator (subject to treatment specifications) on an 'as needed' basis usually at 2 to 3 week intervals. Treatments using only herbicides for weed control generally received a first spraying in late May or early June with repeat applications as required usually in July and August. Other treatments which involved combinations of tillage and herbicides relied on tillage for early season weed control and on herbicides (paraquat or glyphosate plus dicamba) for summer and fall weed control.

During 1969-1976, areas being cropped had the seedbed prepared with a cultivator and mounted harrow. Spring wheat (cv 'Manitou' or 'Neepawa') was planted at a rate of 100 kg ha^{-1} in mid May of each year using a hoe-press drill. Since 1977, the plots were split, with one half receiving conventional seedbed preparation, and the other half receiving chemical weed control. Straw was chopped and spread uniformly back on the plots with a straw chopper and spreader attachment on the combine.

Table 1. Summerfallow Preparation Treatments Studied

Treatment Description	Number of Operations	
	Tillage	Spray
1. Tillage Alone[x]	3-7	0
2. Three Tillage Operations (Rest Herbicides[y])	3	0-2
3. Two Tillage Operations (Rest Herbicides[y])	2	1-3
4. One Tillage Operation (Rest Herbicides[y])	1	2-4
5. Herbicides Only 1 (paraquat or glyphosate[z] used in combination with bromoxynil plus MCPA ester (1:1) 0.56-0.84 kg ha^{-1})	0	2-6
6. Herbicides Only 2 (paraquat or glyphosate[z] used in combination with 2,4-D ester 0.42-1.12 kg ha^{-1})	0	2-6
7. Herbicides Only 3 (paraquat or glyphosate[z] used in combination with dicamba 0.14-0.28 kg ha^{-1} plus 2,4-D ester 0.42-0.84 kg ha^{-1})	0	2-5

[x] The field cultivator was the main implement used for tillage operations.

[y] The herbicides used were those of treatment 7.

[z] Paraquat was applied at rates of 0.56 to 0.84 kg ha^{-1}, and glyphosate was applied at rates of 0.42 to 0.84 kg ha^{-1}. All herbicide rates are in units of active ingredient.

Gravimetric moisture content was measured for the 0 to 120 cm depth. Precipitation was recorded at a meteorological station located about 0.5 km from the test site. Winter precipitation is defined as the water equivalent of precipitation received from October 1 to March 31 prior to sampling. Growing season precipitation is defined as precipitation from May 1 to August 31.

Aggregate samples were sampled from 1968 to 1986 to a depth of 5 cm with 5 replicates per plot. Both the crop and fallow phases of the wheat-fallow rotation were sampled prior to preseeding operations and after harvest in most years. After air drying, samples were sieved with a rotary sieve into 7 fractions: <0.5 mm, 0.5-1.3 mm, 1.3-2.0 mm, 2.0-7.2 mm, 7.2-12.7 mm, 12.7-38 mm, and >38 mm.

In 1991, aggregates were sampled in fallow plots at 5 times during the summer. Samples were taken prior to seeding, and after tillage operations. Three replicates were taken from each plot at the 0 to 5 cm depth, while two samples were taken in 5 cm increments from 5 to 20 cm.

Treatment effects were analyzed with variability for series and years included in the general linear model. Regression was conducted on annual means of aggregates < 0.5 mm, yield and climatic variables. Honest different intervals were calculated for means within years (Andrews et al 1980).

Results and Discussion

Long-term variability

Aggregates < 0.5 mm varied considerably from year to year as did growing season precipitation (Figure 1). In 1974, a year preceded by high growing season precipitation, the proportion of aggregates in this fraction was low. Conversely, in 1982 a year preceded by low growing season precipitation, the proportion was high.

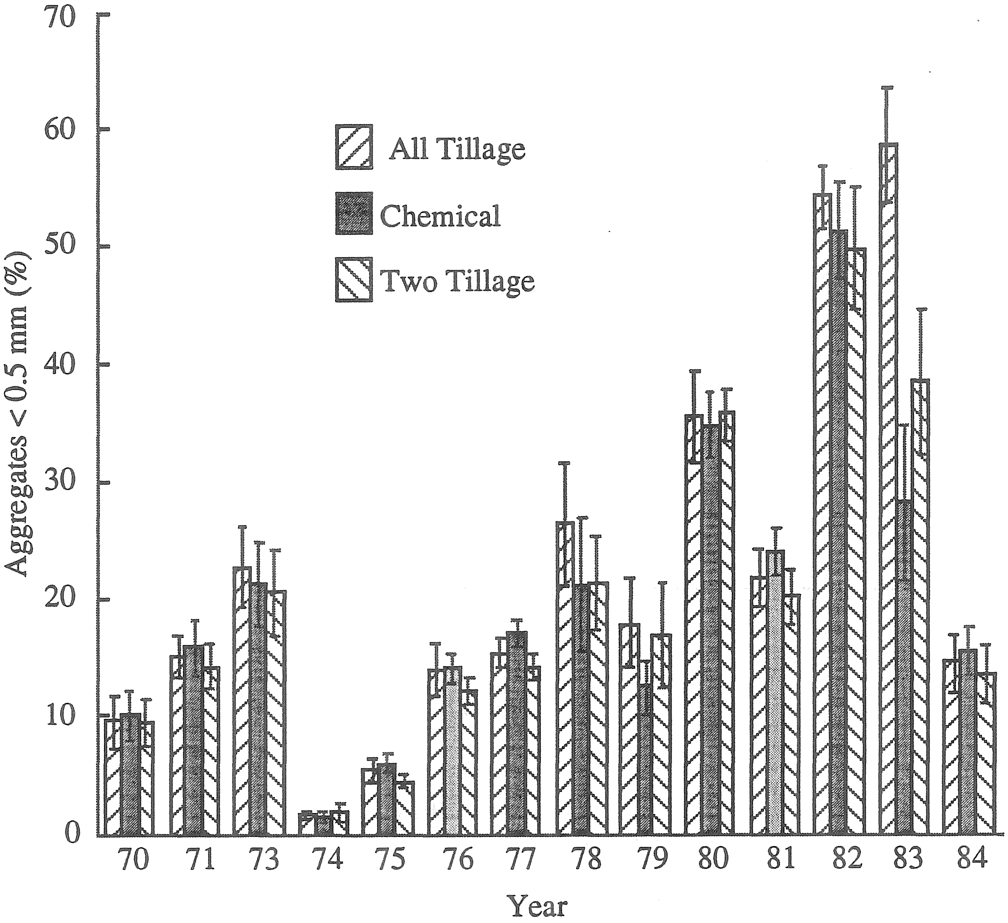

Figure 1. Aggregates < 0.5 mm (%) for spring samples from plots which were tilled before seeding and cropped during the previous year. Error bars represent the honest significant interval within years calculated with the error for each treatment.

During the period from 1974 to 1983 aggregates < 0.5 mm increased at the same time that growing season precipitation decreased. Growing season precipitation for the year prior to sampling and aggregates < 0.5 mm are negatively correlated ($P<0.012$) during this period(Table 2). Aggregates < 0.5 mm were not correlated with growing season precipitation for more than one year prior to sampling, or size distribution in previous years.

Similar trends were also found during the same period of record for aggregate samples taken after harvest, and in plots which were cropped the previous year. In all cases, variation of aggregate size distribution between years was much higher than between treatments.

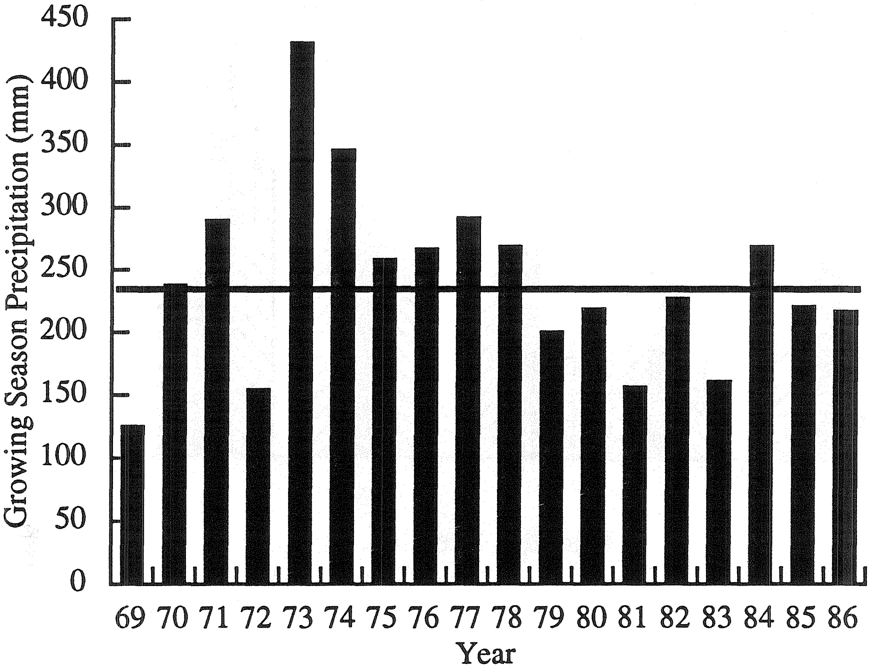

Figure 2. Total growing season precipitation (mm) for the period from 1969 to 1986. Line indicates mean growing season precipitation for the period.

Grain yield for the previous year and total precipitation over winter were not correlated with aggregates (<0.5 mm) sampled during spring. Growing season precipitation was significant ($P<0.05$) when included in a regression with aggregates < 0.5 mm.

Growing season precipitation may be related to those processes which affect aggregate size distribution. This may be due to the combined effect of crop grwoth and the physical effect of precipitation on aggregate stability and distribution.

Short-term variability

Short-term variability over the fallow season in 1991 was significantly different between treatments. The proportion of aggregates < 0.5 mm was reduced after the first tillage operation in tilled treatments, whereas it remained relatively constant in chemical fallow. Tillage effects were attributed to the effects of tillage with a double disk cultivator. Subsequent cultivation with a field cultivator did not affect aggregate size distribution.

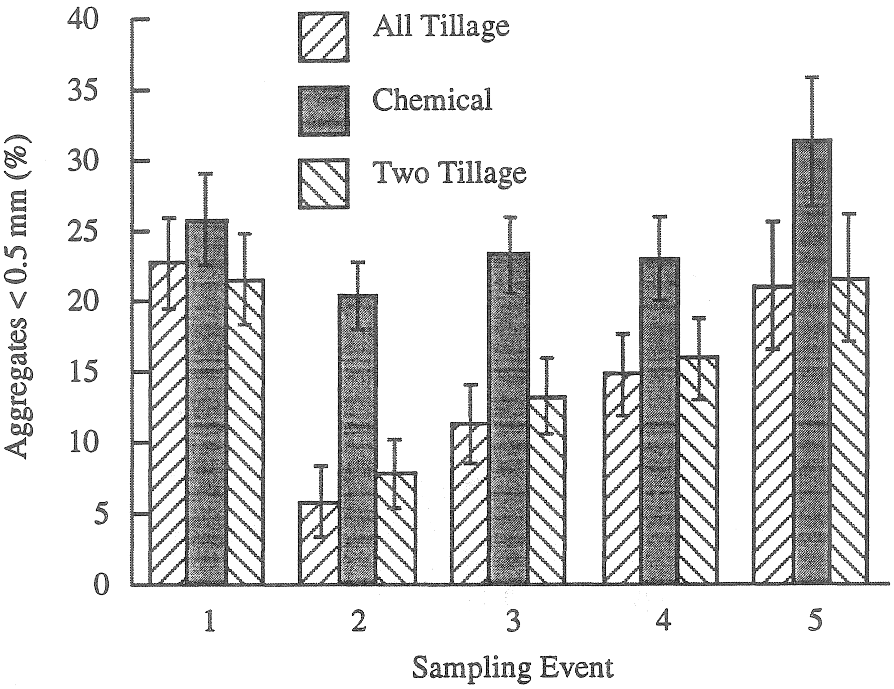

Figure 3. Aggregates < 0.5 mm (%) sampled at a depth of 0 to 5 cm in fallow plots for three fallow systems. Error bars indicate honest significant interval for means within sampling events.

Trends observed for aggregate size distribution of samples from 0 to 5 cm were not present at lower depths. The proportion of aggregates < 0.5 mm for samples taken in 5 cm increments from 5 to 20 cm was not significantly different between treatments. Percentage aggregates varied from 3 to 16 % and 2 to 5 % at depths of 5 to 10 cm and 15 to 20 cm respectively.

Conclusions

There are two types of variability which are correlated with temporal trends in the distribution of aggregates < 0.5 mm. A long-term trend was observed which was attributed to the effect of growing season precipitation in the year prior to sampling. Trends associated with long-term variability persisted from spring to fall, while short-term variability was a function of tillage operations and fallow systems. Both types of variability should be considered by farm managers who wish to control soil erosion, and scientists who develop models which predict aggregate size distribution and soil erodibility.

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