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THE UNIVERSITY OF ALBERTA

THE WIND ERODIBILITY OF ALBERTA SOILS AFTER SEEDING

BY

J. MALCOLM.W. BLACK ©

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

IN

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled: **The Wind Erodibility of Alberta Soils After Seeding.**
Submitted by **J. Malcolm W. Black** in partial fulfillment of the requirements for the degree of Master of Science in Soil Conservation.

DS Chanasyk
Supervisor

J. A. Robertson

Pettapiece

Date: April 14, 1989

DEDICATION

I dedicate this thesis to my wife Fiona and daughters Roslyn and Carolyn who gave me constant encouragement during this project. Without such loving support this thesis would not have been completed.

ABSTRACT

Wind erosion of soils is a continuing problem on the Canadian Plains. The design and implementation of soil conservation practices requires an appraisal of soil erodibility. Recent Canadian research has indicated that criteria developed to estimate the wind erodibility of soils in the USA may not be applicable to soils on the Canadian Plains. This project investigated the wind erodibility of Alberta soils after seeding.

The proportion of soil material >0.84 mm in diameter from surface soil samples, as determined by dry sieving, is commonly used as an index of the wind erodibility of soils. Samples from a variety of Alberta locations were sieved by a Modified Rapid Rotary Sieve (MRRS). A relationship between aggregate breakdown and sieving time was developed, allowing quantification of aggregate comminution during sieving. This relationship was also used to test the reliability of the Wind Erodibility Groups commonly used to predict the wind erodibility of soils.

Regression analysis between field-obtainable parameters (soil texture, carbonate content, number of pre-seeding tillage operations, and type of post-seeding implement) and aggregation explained 60% of the variability of the proportion of soil aggregates >0.84 mm in samples. Laboratory parameters (medium and coarse sand, very fine sand, organic carbon, and adsorbed potassium) explained 50%

of the variability of dry aggregation. An aggregation index derived from the relationship between aggregate breakdown and sieving time was poorly correlated with field and laboratory parameters.

Conclusions were: (1) the model developed to estimate aggregate comminution during sieving successfully predicted aggregate breakdown during sieving for 98% of the soil sample sieved, (2) the 0.5 min sieving time recommended for the [illegible] was found to be inadequate for complete sieving, (3) the Wind Erodibility Groups did not successfully estimate the proportion of soil material resisting wind erosion, (4) the proportion of dry soil aggregates could be predicted from field and laboratory variables, (5) soil management plays a major role in the proportion of soil material resisting wind erosion.

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This project was made possible by the granting of educational leave and financial support to the author by PFRA.

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LIST OF SYMBOLS, NOMENCLATURE, AND ABBREVIATIONS

a = a sieving rate constant (the proportional rate of aggregate breakdown).

A = the proportion of sieve robust sand and aggregates >0.84 mm in a sample.

AlOx = aluminimum oxide.

B = sand >0.84 mm in aggregates expressed as a % of the whole soil sample.

basic soil factors = invariable or slowly changing soil properties which affect the dry aggregation of soils.

C(d) = the rate of passage of material diameter (d) through the sieve.

D = the total percentage of aggregates which break down in the sieve in relation to the total sample weight.

dummy variable = a variable employed in multiple regression analysis to accommodate discontinuous data.

dynamic soil factors = soil factors affecting dry soil aggregation which change seasonally or more frequently.

FeOx = iron oxide (no distinction is made between Fe^{++} of Fe^{+++}).

G = an index of aggregate stability, the average rate of aggregate breakdown.

homoscedastic = a term describing a scatter plot of data which displays a pattern having the same width along its length.

I = the total percentage of aggregates which break down in the sieve in relation to the total weight of material passing the sieve.

J = % total soil material >0.84 mm.

MRRS = Modified Rapid Rotary Sieve.

m = a sieving parameter which varies with the rate of breakdown of aggregates in the sieve.

management factors = a complex set of factors affecting dry soil aggregation as a direct result of tillage, rotations, crop husbandry, or crop residue management.

multicollinearity = correlation between two or more "independent" variables.

N = % non aggregated sand >0.84 mm in the whole soil sample.

P(t) = the proportion of material that has passed through the sieve at time t.

r = correlation coefficient.

r^2 = coefficient of determination.

R = multiple correlation coefficient.

R^2 = coefficient of multiple determination.

region 1 sieving = the first stage of sieving when a large proportion of material smalle than sieve size is present.

region 2 sieving = a later stage of sieving when there remains on the sieve a small proportion of material smaller than sieve size.

S = % sand >0.84 mm in the whole soil sample.

So = the proportion of sub-mesh material origionally present in the sample.

secondary aggregates = dry soil aggregates composed of a number of water-stable aggregates.

TEC = total extractable cations.

t = time.

true aggregates (TA) = an estimate of the proportion of dry aggregates >0.84 mm in a soil sample.

T = time at which no more material passes through the sieve.

WEG = wind erodibility groups.

WEQ = wind erosion equation.

w(t) = the proportion of sub-mesh material in the sieve at time t.

x(t) = the proportion of origional material >0.84 mm still in the sieve at time t.

y = the proportion of material >0.84 mm retained on the sieve.

CHAPTER 1

1.1 INTRODUCTION

"Wind erosion of soil is the process by which loose surface material is picked up and transported by the wind, and surface material is abraded by windborne particles" (Wilson and Cooke 1980).

Natural or "geologic erosion" has always occurred on the Canadian Plains: however, the incidence of erosion increased following agricultural settlement. After breaking, the soil was exposed to wind action due to the adoption of summerfallow, intensive tillage, crop failure, and the effects of pests resulting in "accelerated erosion". Serious soil drifting from agricultural fields was first reported in 1887 at Indian Head, Saskatchewan (MacKay 1890). The wind erosion problem escalated with further agricultural development culminating in the disastrous erosion which occurred during the droughts of the 1930's. Despite the adoption of conservation practices and modern crop husbandry, wind erosion is still a serious problem in Alberta. Of Alberta's 11 million hectares of agricultural land some 400,000 ha were seriously affected in 1984 and 2-300,000 ha in 1987 (Timmermans 1987 [quoted by Bailey 1987]).

The effects of wind erosion on soil fertility can be serious and long lasting. Erdman (1942) reported that coarse textured soils from southern and eastern Alberta had lost up to 50% of the nitrogen, organic matter, and silt; and up to 25% of the clay which they had originally contained, due to wind erosion. Ibrahim (1961) reported similar results with soils from southern Alberta. Dormaar et al. (1986) reported that the full productivity of an artifically eroded soil (which had the topsoil removed) at Lethbridge was not fully restored after 14 crops despite green manuring and fertilizer application.

The factors responsible for wind erosion have been established by Bagnold, Zingg, Chepil and others (Zachar 1982). The primary factors identified are: soil erodibility, surface roughness, climate, unsheltered fieldwidth, and vegetative cover. They have been incorporated into the Wind Erosion Equation (Woodruff and Siddoway 1965) which is used to estimate soil loss due to wind erosion for planning soil conservation strategies. The nature of the relationship between the factors requires that calculations be applied sequentially beginning with an estimate of soil erodibility (Woodruff and Siddoway 1965). Consequently, the accuracy of soil loss estimates using the Wind Erosion Equation is strongly dependent on a good estimate of soil erodibility.

The amount of erosion from a dry, bare, unsheltered soil surface at a particular windspeed is dependent on the proportion, size distribution, and stability of erodible particles (Chepil 1958). Most common erosive winds[1] are incapable of moving soil aggregates larger than 0.84 mm in diameter. This size is commonly used to differentiate between erodible and non-erodible soil fractions (Chepil and Bisal 1943; Zingg 1950.)

Chepil (1953a) reported four distinct phases of structure in undisturbed soils after rain, each of which had different degrees of erodibility by wind. These phases were: primary aggregates (water-stable aggregates), secondary aggregates, surface crust, and consolidated materials between the secondary aggregates. Secondary aggregates were composed of primary water-stable aggregates held together by water dispersible cements. The resistance of soils to wind erosion was found to be primarily dependent on their ability to form secondary aggregates (Chepil 1953a). Secondary aggregates exposed at the surface are generally fragile and easily disrupted by rain, frost, tillage, and sandblast (Chepil and Woodruff 1963).

Although water-stable aggregates frequently exceed 0.84 mm in size, Chepil (1953b) demonstrated that the proportion of water-stable aggregates >0.84 mm in a soil bears no simple or consistant relationship to the amount of soil eroded in a wind tunnel. Unfortunately the proportion

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[1] 11.2-14.2 m sec^{-1} measured at 10.1 m (Chepil 1941).

of water-stable aggregates >0.84 mm is sometimes erroneously taken as an index of the wind erodibility of soils e.g. Dormaar (1987).

At the initiation of erosion, soil erodibility of an uncrusted soil may be satisfactorily estimated by the proportion of soil material >0.84 mm determined by dry sieving (Chepil 1958). Sieving of soils in the field is not always practical or convenient so Chepil et al. (1963) grouped soils of similar erodibility into Wind Erodibility Groups (WEG). The WEG provide an estimate of the proportion of soil material >0.84 mm before seeding in the spring. Slevinsky (1984) discussed the most recent grouping used in North Dakota (Table 1.1). The WEG have been used extensively (Troeth et al. 1980) but may not be applicable to all soils without some modification. Carreker (1965) reported sieving data from South Carolina soils divergent with the WEG. Similarly Hayes (1965) reported sieving data for coarse soils which did not fit the WEG. Langman (1985) discussed the dry sieving of Manitoba Soils (Table 1.2). Before seeding, all of the soils except two fine sand samples had fewer aggregates >0.84 mm than estimated by the WEG. A review of much of the data from dry aggregate studies of soils from the Canadian Plains reveals a poor relationship between actual sieving results and aggregation predicted by the WEG.

The Wind Erosion Equation (WEQ) is the only tool currently available for the cost effective design of integrated soil conservation practices for wind erosion control. A good estimate of soil erodibility is required for successful use of the equation and will be required for any subsequent upgrading or replacement of this model.

1.2 PROJECT GOALS

This project investigates the factors contributing to the dry aggregation of Alberta soils after seeding. It assumes that the proportion of dry soil aggregates >0.84 mm provides a good estimate of the wind erodibility of these soils as reported by Chepil (1958).

Five goals were identified at the start of the project:

GOAL #1

To compare the proportion of material >0.84 mm from a wide variety of Alberta soils to estimates made using the North Dakota Wind Erodibility Groups.

GOAL #2

To develop a regression model to predict the proportion of dry aggregates >0.84 mm in Alberta soils from field-obtainable parameters with sufficient precision for use in the Wind Erosion Equation.

GOAL #3

To develop a regression model to predict the proportion of aggregates >0.84 mm in Alberta soils from the analytical information typically obtainable in soil survey reports.

GOAL #4

To develop a regression model to predict the stability of aggregates >0.84 mm in Alberta soils from soil, and soil management factors.

Dry aggregates >0.84 mm were determined by sieving soil on a Modified Rapid Rotary Sieve (MRRS) (Fryrear 1985). Preliminary tests revealed that the sieve did not perform as expected. This led to the establishment of a fifth goal:

GOAL #5

To develop a method to evaluate aggregate comminution during sieving in the MRRS.

Investigation of the spatial variability of soil material >0.84 mm and an analysis of the Wind Erosion Equation (Appendices 1 and 2) led to the establishment of a number of objectives to meet these goals. These objectives are discussed in Chapters 2-5 of this thesis.

1.3 ORGANIZATION OF THESIS

Four papers were written to discuss the results of this project and are included as separate chapters. The titles are:

Chapter 2

"Precision of a Modified Rapid Rotary Sieve and a Methodology to Estimate Aggregate Comminution During Sieving for Wind Erodibility Studies".

This chapter addresses Goal #5.

Chapter 3

"The Wind Erodibility of Alberta Soils After Seeding (1) In Relation to Field Obtainable Parameters".

This chapter addresses Goals #1 and 2.

Chapter 4

"The Wind Erodibility of Alberta Soils After Seeding (2) In Relation to Laboratory Evaluated Parameters".

This chapter addresses Goal #3.

Chapter 5

"The Effect of Field and Laboratory Estimated Parameters on the Dry Aggregate Stability of Albreta Soils After Seeding".

This chapter addresses Goal #4

The papers are followed by two further chapters.

Chapter 6

"Discussion of Project Results" which evaluates the degree of success in achieving the project goals. This chapter also discusses some of the implications of the ject results.

Chapter 7

Which has two sections: "Conclusions" which lists the main deductions of the project, and; "Suggestions for Further Work" which pinpoints several areas where the information necessary to provide an accurate appraisal of the wind erodibility of soils is still lacking.

Table 1.1. Description of the Wind Erodibility Groups Used in North Dakota.

WEG	Soil Texture	% Dry Soil Aggregates >0.84 mm	K Factor*
1	Sands	3	1.0
2	LS, LFS	10	1.0
3	VFSL, FSL, SL	25	1.0
4	C; SiC,CL and SiCL with >35% clay	25	0.75
4L	Calcareous L & SiL; Calcareous CL & SiCL with <35% clay	25	0.75
5	L & SiL with <20% clay; SCL, SC	40	0.75
6	L & SiL with >20% clay CL with <35% clay	45	0.75
7	Silts; SiCL with <35% clay	50	0.50
8	Very wet or stoney soils not usually subject to wind erosion	-	-

* Soil ridge roughness factor at the critical period (April 1st). Adapted from Slevinsky (1984).

Table 1.2. Aggregation of soils from Westbourne R.M. Manitoba.

Soil Series	Texture	$CaCO_3$ Equivalent	%aggregates >.84 mm B.S.	%aggregates >.84 mm A.S. *	WEG Estimate
Reinland	LVFS	6.8%	2.7	11.1	10%
Gervais	CL	7.3	19.8	35.0	25
Gervais	CL	13.5	9.0	42.0	25
Reinland	VFSL	14.5	4.6	7.9	25
Long Plain	FS	0	8.7	24.2	1
Willowcrest	LFS	3.0	2.2	18.5	10
Almasippi	FSL	15.1	13.7	26.9	25
Long Plain	FS	4.5	9.8	21.0	1

* BS - Before seeding
AS - After seeding

(from Langman, 1985)

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CHAPTER 2

PRECISION OF A MODIFIED RAPID ROTARY SIEVE AND A METHODOLOGY TO ESTIMATE AGGREGATE COMMINUTION DURING SIEVING FOR SOIL ERODIBILITY STUDIES

2.1 INTRODUCTION

Wind erosion on the Canadian Plains causes the serious loss of topsoil with a consequent reduction in soil productivity (PFRA 1983; Science Council of Canada 1986). At erosive wind velocities prevalent on the Prairies, soil erodibility of an uncrusted soil is primarily dependent on the proportion and mechanical stability of soil aggregates >0.84 mm in diameter (Chepil and Bisal 1943; Zingg 1951; Chepil 1958). Other factors being equal, the proportion of non-erodible aggregates at the soil surface on a dry, flat unprotected field determines whether erosion will be initiated at a certain wind velocity. The severity of subsequent erosion is dependent on the stability of those non-erodible aggregates.

The percentage of aggregates >0.84 mm obtained by dry sieving on a rotary sieve has been accepted as the sole criterion of erodibility and is used to estimate soil loss to wind erosion (Woodruff and Siddoway 1965). Most sieve

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designs employ concentric cylindrical screens inclined at 4 degrees to the horizontal (Chepil and Bisal 1943; Chepil 1952; Chepil 1962; Lyles et al. 1970). Soil is fed at a constant rate into the centre screen which has the largest openings. A particular aggregate passes through various screens until it encounters a screen with openings too small to permit passage. It then rolls down the inclined surface of that screen into a collection pan. Soil aggregates are thereby separated into several size fractions.

The mechanics of sieving have been investigated by many authors (Whitby 1958; Kaye 1962; Jansen and Glastonbury 1967; Kaye and Robb 1979). Two regions have been identified through the graphing of sieving data. In region 1, at the commencement of sieving, there are many particles much smaller than mesh size on the screen and the rate of passage of material is high. Region 2 is entered some time later; it is characterized by low rates of passage. In region 2 there remains a small proportion of particles just smaller than mesh size which have to be precisely oriented to pass through the screen (Whitby 1958). Whitby (1958) recommended that sieving be continued until region 2 is reached. Unfortunately when the material being sieved is subject to comminution, greater attrition of particles will occur as sieving times are extended into region 2.

The rotary sieves commonly used to determine dry aggregation are designed so that region 2 sieving is attained (Lyles et al. 1970). Soil aggregate breakdown occurs under these circumstances but cannot be easily estimated. Chepil (1950) reported that aggregate breakdown during dry sieving had variable but considerable effects on soil erodibility when measured in a wind tunnel. No sustained attempt has been made to allow for aggregate breakdown using this design of sieve thereby reducing the accuracy of subsequent estimates of soil erodibility.

Fryrear (1985) developed a Rapid Rotary Sieve with one 0.84 mm cylindrical screen rotated in a horizontal plane. He reported that this design was cheaper to construct, quicker to operate, and yielded similar results to previous rotary sieves.

Aggregate breakdown also occurs in the Rapid Rotary Sieve. However the sieve design lends itself more readily to an estimation of aggregate comminution since the residence time of aggregates in the sieve is determined by the operator.

The objectives of the study were:

(1) To examine the sieving kinetics of the Modified Rapid Rotary Sieve (MRRS) in order to confirm the 2 kg sample size and 0.5 minute sieving time recommended by Fryrear (1985).

(2) To test sieving precision by comparing the sieving of paired soil samples.

(3) To compare the results obtained by sieving soil samples in the MRRS to those for duplicate samples passed through a Rotary Sieve.

During the study it was noted that significant quantities of fine material from soil samples failed to pass through the MRRS in the time of 0.5 minute recommended by Fryrear (1985). It became apparent that no universal sieving time could be adopted for the sieving of soils in the MRRS. The objectives of the study were modified to include a fourth objective:

(4) The development and testing of a methodology to evaluate aggregate comminution in the MRRS.

2.2 MATERIALS AND METHODS

A Rapid Rotary Sieve was constructed using the basic design by Fryrear (1985). Modifications to enable equal distribution of the sample on the sieve prior to sieving, and for ease of loading and cleaning were made.

The cylindrical sieve was split longitudinally and constructed in two unequal parts. They were hinged at one end and fastened with furniture catches at the other. Power was provided by a 12.8 RPM 1/15 HP gearmotor with a solid state variable speed reducer.

Clean sub-angular sand and gravel were used to test the sample size and sieving times recommended by Fryrear (1985). Forty five soil samples 3-4 kg in mass from the Two Hills area of Alberta were split into sub-samples of approximately equal mass, sieved separately, and the data employed to test the precision of soil sieving on the MRRS. Sieving data from 375 soil samples approximately 1.5 kg in mass were employed to develop and test a sieving model to estimate aggregate comminution. Samples were dominately chernozemic Ap horizons and ranged in texture from sand to heavy clay from the Oyen (Brown Soil Zone), Pincher Creek (Black Soil Zone), Vermilion and Flagstaff areas (both Black Soil Zone). Details of the soil sampling procedures are given in Chapter 3. A further 100 duplicate soil samples were sieved on a Rotary Sieve (Chepil and Bisal, 1943) to compare data from the two sieve designs.

The MRRS was set up over a top pan balance, material passing the sieve was collected by a funnel immediately under the sieve and conveyed by gravity to a weighing tray on the balance.

Samples were sieved at 4 RPM as recommended by Fryrear (1985), and the mass of material passing recorded for 30 second intervals until friable aggregates were estimated to have broken down; and then for at least one further increment. This stage of sieving was characterized by a large decrease in the rate of passage of material, and, in sandy samples by the noise of sand rolling in the sieve. Coarser soil samples occasionally required less than 30 seconds sieving to comminute friable aggregates whereas finer soils took up to 2.0 minutes.

2.3 RESULTS AND DEVELOPMENT OF THEORY

PRECISION OF SIEVING SAND AND SAND MIXTURES

In tests with mixtures of sand, and sand and gravel the sieve produced very consistent results (Table 2.1). Loadings up to 1.5 kg of <0.84 mm sand passed through the sieve within 30 seconds. Precision was excellent, the standard deviation of the percentage passing was less than 0.2%. Two kg of sand <0.84 mm did not pass within 30 seconds but was 99.9% sieved after 1 minute. The extra loading at 2 kg apparently caused interlocking of the particles; little blockage of the apertures was observed after sieving.

Mixtures of sand >0.84 mm with sand <0.84 mm reduced the rate of sieving with increasing ratios of coarse to fine sand. Only 53.4% of sand <0.84 mm from a 50:50 mixture totalling 1.5 kg passed through the sieve in the first 30 seconds of sieving; compared to 99.7% for 1.5 kg of sand <0.84 mm alone. Sand greater than mesh size apparently formed a barrier between the fine sand and the sieve mesh reducing the rate of passage.

Addition of sub-angular gravel up to 1 cm diameter to sand <0.84 mm tended to increase the rate of sieving. A mixture of 2.0 kg sand with 0.5 kg gravel allowed 99.7% of the sand to pass within 0.5 minutes compared to 91.4% when 2 kg of sand <.84 mm was sieved alone. Apparently the gravel caused agitation of the sand reducing interlocking of particles. Soil aggregates probably have a similar effect when whole soils are sieved.

From these data we concluded that soil sample sizes of 1.5 - 2 kg would be suitable for this sieve design.

2.4 DEVELOPMENT OF A METHOD TO ESTIMATE AGGREGATE COMMINUTION

The rate of breakdown of degradable aggregates to sub-mesh particles during sieving is assumed to be of the form:

$$\frac{dx}{dt} = -a(x-A)^m, \ a > 0, \ 0 < m < 1 \qquad (1)$$

where: x is the proportion of larger than mesh sized soil material retained by the sieve,

t is time in minutes,

A is the proportion of sieve-robust soil material,

a is a constant dependant mainly on the sieve geometry, sieve loading, particle size and denisty, and

m is a constant that characterizes the soil sample under consideration. (m is commonly assumed to be 1 (Whitby 1958), and in that case is known as the rate constant for the breakdown process).

For the puroses of simplicity in this discussion any sand whether loose in the original sample or released by aggregate breakdown is considered to be either sub-mesh material or is included with the sieve-robust aggregates.

A plot of the data for ln(x-A) against t did not result in a straight line, even after the original sub-mesh particles had passed the sieve (Figure 8.2). An argument for choosing $0<$ is given in Section 8.3.4, Appendix 3. The equation is [illegible] to obtain (Equation A12, Section 8.3.4):

$$(1 - [t/T)]^{\beta} \qquad (2)$$

ere: $y = \dfrac{x - A}{x_o - A}$ is the ratio of degradable aggregates present at time t to that present at time t = 0

T is the time at which the sieve contains only sieve-robust aggregates and sand >0.84 mm,

the parameter β is defined by $\beta = 1/1-m$.

Initially, the material on the sieve consists of sub-mesh particles, degradable aggregates, and sieve-robust aggregates in the propotions s_o, x_o-A, and A respectively. The sub-mesh material is assumed to pass the sieve at a constant rate that is large compared to the rate of breakdown of the aggregates (Equation A3, Section 8.3.4), a process that is assumed to be completed in about 0.5 minutes of sieving. The material passing through the sieve after 0.5 minutes is assumed to be sub-mesh material formed by breakdown of aggregates. This process will be completed in a finite time T, provided that Equation 1 with $0<m<1$ is correct. For $t>T$ the amount of material per minute passing through the sieve decreases dramatically, indicating that the aggregates of interest have been broken down into sub-mesh particles and sieve-robust material.

The percentage of sand >0.84 mm plus sieve-robust aggregates (A) at time T can be obtained by graphing the sieving data (Figure 2.2). The proportion of sand <0.84 mm and aggregates which break down during sieving (y) can be obtained form Equation 2.2 once the proportion of sieve-robust material (A) is subtracted. Since most material <0.84 mm passes sieve after 0.5 minutes of sieving, a plot of ln (100y) against ln [1-(t/T)] only using data from sieving times greater than 0.5 minutes will relate to aggregate breakdown. The plot will have a slope of β. The intercept with the abscissa (I) gives the total percentage of aggregates which break down in the sieve(degradable aggregates) and any near-mesh material remaining (Figure 2.3). Values of I are then adjusted to a whole soil basis (D). The summation of D and A gives an estimate of the total amount of sand and aggregates >0.84 mm which were present in the sample prior to sieving.

Calculations and graphical interpretations may be conveniently made using a computer spreadsheet. β and I may be readily calculated by regression analysis.

The average rate of aggregate breakdown during sieving (G) can be employed as an index of aggregate stability it is calculated as follows:

$$G = \frac{t}{T}\int_{0}^{T}\left[1-\frac{t}{T}\right]^{\beta} dt \qquad 2.4$$

Since $\beta = 1/(1-m)$ an evaluation of Equation 4 yields:

$$G = \frac{1-m}{(2-m)T} \qquad 2.5$$

G may be used to compare the mechanical stability of different soil samples sieved on the same sieve.

APPLICABILITY OF THE METHODOLOGY

The theory was applied to 375 soil samples from the Ap horizon of 75 fields representing a wide variety of soil properties. Table 2.2 contains typical sieving parameters. The applicability of the model is best demonstrated by column 10 which reports the correlation coefficients (r) for the relationship ln [1 -(t/T)] vs ln (100y). Despite the relatively few data points (3-5) coefficients are close to unity indicating a good fit of the data to the theory.

Coarse textured soils tended to have fewer sand+aggregates (sieve-robust and degradable) >0.84 mm than fine textured soils. Values for the full data set ranged from a low of 11% to a high of 52% for coarse soils, between 28% and 63% for fine textured soils, and between 36% and 68% for medium textured soils.

The estimate of aggregate comminution is most sensitive to a good estimate of T. Low values for r and negative estimates of m indicate inapplicability of the model, poor data, or, an improper interpretation of the sieving data curve. Data from 23 of the 375 samples were rejected due to negative values of m. All but six of the data sets rejected had inadequate data (insufficient sieving increments); the model was developed subsequent to the sieving. All r values of data sets retained were above 0.93.

Estimates of time T may be improved by increasing the number of data points obtained during sieving. At least 5 points are advisable requiring 2.5 minutes of sieving with most soils. Sieving in 15 second increments may be required for coarse textured soils.

To test the reproducibility of the method, 45 samples were divided into approximately equal portions and sieved separately. The total percentage of sand and aggregates

>0.84 mm was calculated using the method and results from the individual pairs randomized. A paired t test (Zar, 1974) indicated that the population means of the two sub-samples were not significantly different at the 95% level confirming that the method gives reproducible results.

COMPARISON OF THE MODIFIED RAPID ROTARY SIEVE TO A ROTARY SIEVE

One hundred soil samples were sieved on a Rotary Sieve (Chepil and Bisal 1943), duplicate samples were sieved on the Modified Rapid Rotary Sieve. The percentage of aggregates >0.84 mm retained in the Modified Rapid Rotary Sieve after the recommended sieving time of 0.5 minutes (Fryrear 1985) was compared to that fraction separated by the Rotary Sieve using a correlation analysis (Zar, 1974). A correlation coefficient (r) of 0.63 was obtained indicating a poor comparison between the results obtained using the two sieves.

A better correlation (r = 0.79) was obtained after employing the methodology developed in this paper to the data from the Modified Rapid Rotary Sieve (Figure 2.4). The shape of the scattergram in Figure 2.4 suggests that a logarithmic transformation of the Rotary Sieve data would give a better fit. However a plot of the residuals (Zar, 1974) indicated that the spread of the scattergram at higher percentage retained is due to the influence of unidentified variables and so a transformation is not appropriate. The relationship between the two sieves is:

$$RS = -0.21 + 0.80\ (MRRS) \qquad (5)$$

where: RS = Rotary Sieve estimated of material >0.84 mm

MRRS = Modified Rapid Rotary Sieve estimate of material >0.84 mm

This comparison shows that the application of the methodology proposed in this paper to data from the Modified Rapid Rotary Sieve will yield a larger percentage of aggregates and sand >0.84 mm than sieving with a Rotary Sieve.

DISCUSSION AND CONCLUSIONS

This study demonstrates that the Modified Rapid Rotary Sieve yields reproducible sieving data. The model developed to estimate the attrition of aggregates in the sieve gives consistent results between paired soil sub-samples and estimates a higher proportion of aggregates + sand >0.84 mm than a Rotary Sieve.

Current estimates of soil erodibility using rotary sieves are based solely on the proportion of aggregates >0.84 mm in soil samples after sieving; regardless of differing amounts of aggregate comminution in the sieve and regardless of aggregate stability. The methodology developed in this paper provides an estimate of, and correction for, aggregate attrition during sieving with the MRRS. A stability index based on this methodology is also proposed. Results should relate more closely to field conditions and allow a better estimate of soil erodibility than previously reported methods.

Table 2.1 The effects of various sand mixtures and sieve loadings on the performance of the Modified Rapid Rotary Sieve

SIEVE	CONTENTS	#REPS	MEAN * % PASSING	S	RANGE	MEAN % PASSING	S	RANGE	MEAN %PASSING	S	RANGE
			0.5 MIN			1.0 MIN			1.5 MIN		
250g <		10	99.9	0.19	99.6-100						
500g <		10	99.7	0.06	99.6-99.8						
1000g <		10	99.8	0.06	99.7-99.9						
1500g <		10	99.7	0.09	99.5-99.7	99.9	0.01	99.8-99.9			
2000g <		10	91.4	2.50	88.1-85.8	99.9	0.03	99.8-99.9			
1350g <	+150g >	10	99.2	0.47	98.4-99.6	100	0.04	99.9-100			
1200g <	+300g >	10	91.4	1.73	87.9-93.3	99.8	0.10	99.7-100			
1050g <	+450g >	5	73.4	1.79	71.1-75.9	99.6	0.15	99.4-99.8			
900g <	+600g >	5	61.2	2.41	58.9-64.8	93.8	1.88	92.3-96.7	99.3	0.31	98.9-99.6
750g <	+750g >	5	53.4	1.60	51.7-55.5	81.9	0.78	81.3-83.2	95.6	0.96	94.1-96.5
1500g <	+500g >	5	60.7	1.69	58.3-62.8	96.3	0.78	95.3-97.4	99.7	0.08	99.6-99.8
1750g <	+250g >	5	56.4	3.09	52.3-60.7	99.6	0.11	99.4-99.7	99.8	0.07	99.7-99.9
1350g <	+150g G	5	99.8	0.20	99.5-100						
1200g <	+300g G	5	99.9	0.11	99.7-100						
900g <	+600g G	5	99.7	0.30	99.4-100						
2000g <	+500g G	5	99.7	0.09	99.7-99.9						

* = mean % of total sand <0.84 mm passing the sieve
S = standard deviation
< = sand <0.84 mm
> = sand >0.84 mm
G = gravel

Table 2.2 Typical sieving parameters for soils from the Brown Soil Zone of Alberta

Sample#	Texture	T	100A	β	m	I	D	G	r	Tot%>0.84mm
1	SL	3.30	23.0	1.75	0.43	13.8	10.7	0.11	1.000	33.7
2	SL	2.55	29.5	2.38	0.58	30.2	21.3	0.12	1.000	50.8
3	SL	2.25	16.3	1.30	0.23	12.6	10.6	0.19	1.000	26.9
4	SL	2.55	27.0	1.31	0.24	17.9	13.1	0.17	0.999	40.1
5	SL	3.05	19.5	2.45	0.59	39.6	31.9	0.10	0.996	51.4
6	SL	3.15	26.5	1.81	0.45	31.5	23.1	0.11	0.999	49.7
7	LS	2.25	11.7	1.87	0.47	22.8	20.2	0.15	0.999	31.9
8	LS	2.01	12.0	1.92	0.48	13.3	11.7	0.17	0.995	23.7
9	LS	2.40	15.0	1.58	0.37	15.3	13.0	0.16	1.000	28.0
10	SL	2.20	17.0	2.27	0.56	29.6	24.6	0.14	0.997	41.6
11	SiL	2.70	30.0	2.18	0.54	27.3	19.2	0.12	0.999	49.2
12	L	2.75	35.0	1.91	0.48	33.7	22.0	0.12	0.999	57.0
13	L	2.55	28.0	1.44	0.31	28.5	20.5	0.16	0.999	48.5
14	SiL	3.00	16.0	2.05	0.51	34.4	29.0	0.11	0.989	45.0
15	L	2.25	23.0	1.67	0.40	31.8	24.5	0.17	1.000	47.5
16	C	2.55	13.0	2.00	0.50	17.6	15.4	0.13	1.000	28.3
17	CL	3.15	26.0	1.82	0.45	49.9	36.9	0.11	0.993	62.9
18	CL	2.60	29.8	1.81	0.45	50.9	35.7	0.14	0.996	65.5
19	CL	2.45	24.0	1.93	0.48	20.9	15.9	0.14	0.998	39.9
20	C	2.01	17.9	1.24	0.19	8.8	7.2	0.22	1.000	25.1
21	C	2.01	15.7	1.29	0.22	11.4	9.7	0.22	1.000	25.4
22	C	1.85	18.6	2.88	0.65	29.6	24.1	0.14	1.000	42.8
23	C	2.35	15.0	1.49	0.33	17.2	14.7	0.17	0.995	29.7
24	C	2.15	26.0	1.58	0.37	20.0	14.9	0.18	0.984	40.9
25	C	2.01	23.0	1.61	0.38	5.8	4.5	0.19	0.994	27.5
26	L	2.75	41.6	1.95	0.49	44.7	26.1	0.12	0.994	67.7
27	SL	3.6	22.0	1.76	0.43	38.4	30.0	0.10	0.999	52.0
28	LS	2.15	6.0	1.09	0.08	9.6	9.0	0.22	0.993	15.0
29	S	2.01	2.0	1.10	0.09	9.2	9.0	0.24	0.975	11.0
30	LS	2.10	8.0	2.26	0.56	14.1	13.0	0.15	0.990	21.1
31	L	2.75	30.0	1.13	0.12	20.4	14.3	0.17	0.998	44.3
32	SL	3.30	31.0	1.46	0.32	27.1	18.7	0.12	0.999	49.7
33	SL	3.15	22.0	1.77	0.44	32.7	25.6	0.11	0.999	47.6
34	SCL	2.45	25.0	1.10	0.09	15.9	12.0	0.19	0.994	37.0
35	L	3.00	32.0	1.14	0.12	26.3	17.9	0.16	0.996	49.9
36	L	2.85	23.0	1.18	0.15	17.4	13.4	0.16	0.996	36.4
37	CL	2.40	22.0	2.04	0.51	21.3	16.6	0.14	1.000	38.6
38	L	3.15	18.0	2.08	0.52	20.7	17.0	0.10	0.998	35.0
39	CL	2.85	18.0	2.16	0.54	22.6	18.6	0.11	0.998	36.6
40	L	3.30	26.0	1.43	0.30	27.1	20.1	0.12	0.985	46.1
41	CL	2.20	36.0	1.84	0.46	20.4	13.1	0.16	0.991	49.1
42	C	2.30	26.0	1.49	0.33	20.9	15.5	0.17	0.979	41.5
43	CL	1.95	39.0	2.18	0.54	21.9	13.4	0.16	1.000	52.4
44	C	1.75	31.0	1.05	0.05	13.6	9.4	0.28	0.985	40.4
45	CL	2.40	30.5	1.26	0.21	18.5	12.9	0.18	0.986	43.4
46	HC	2.30	21.0	1.97	0.49	16.6	13.1	0.15	0.995	34.1
47	HC	2.15	21.0	1.38	0.28	15.0	11.9	0.20	0.987	32.9
48	HC	2.05	37.0	1.40	0.29	19.4	12.3	0.20	0.975	49.3
49	HC	1.51	25.6	1.62	0.38	42.9	32.0	0.25	0.993	57.6
50	HC	2.05	40.0	1.91	0.48	17.9	10.8	0.17	1.000	50.8

T - time at which all friable aggregates comminuted
100A - % sand + sieve robust aggregates >0.84 mm remaining in the sieve at time T
β - a sieving constant
m - a sieving constant related to the mechanism of aggregate breakdown
I - % of degradible aggregates as a % of sample less 100A
D - I in relation to the total sample weight
G - an aggregate stability coefficient {(1-m)/(2-m)T}
r - correlation coefficient for the relationship ln (100Y)vs ln (1-[t/T])
Tot%>0.84 - sand + sieve-robust and degradable aggregates >0.84 mm in the whole soil sample

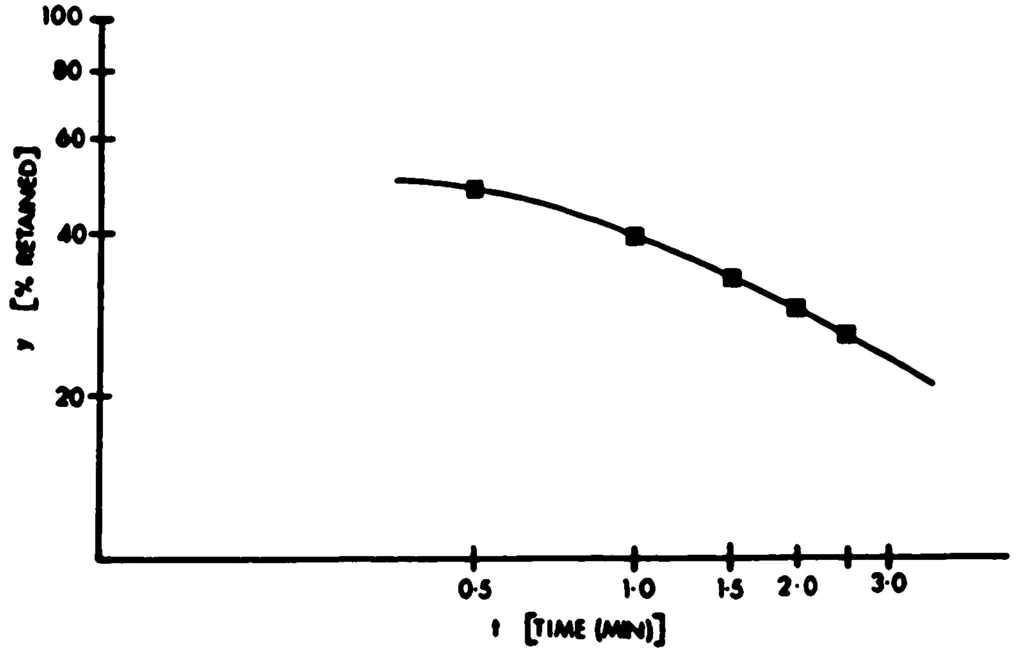

Figure 2.1 A typical soil sieving curve (from an Ap horizon of a Brown Chernozemic soil).

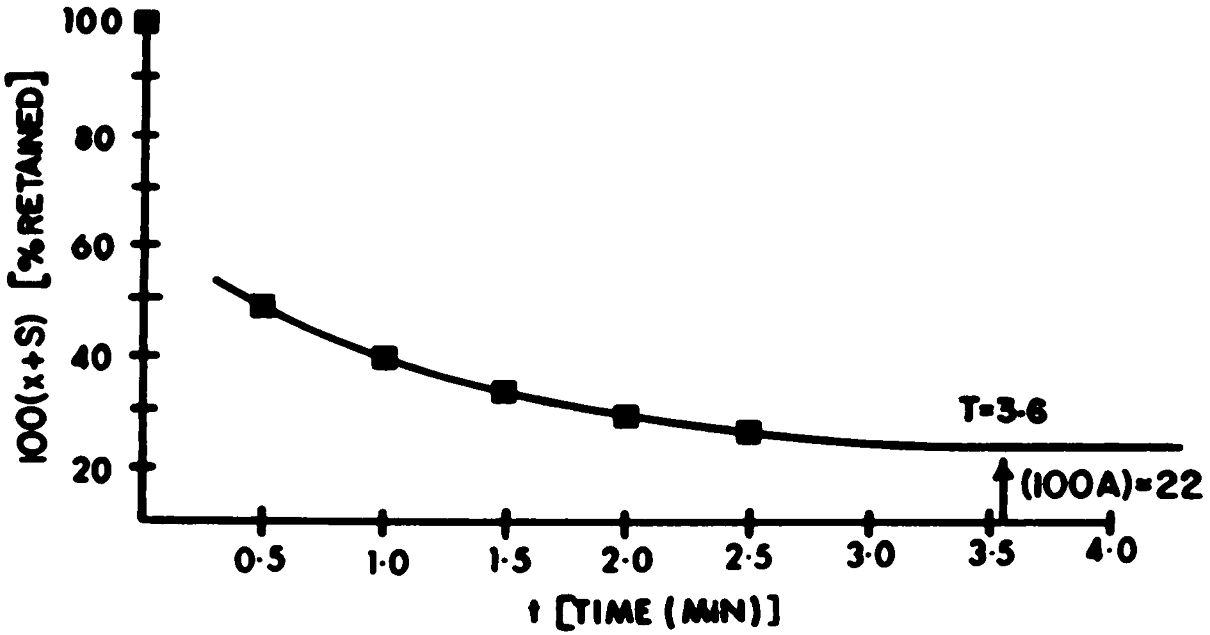

Figure 2.2 A representative plot of soil sieving data used to estimate T and A (from an Ap horizon of a Brown Chernozemic soil). [T = time at which no more material passes, 100A = % sand and sieve-robust aggregates >0.84 mm, 100x = % soil material >0.84 mm, 100S = % soil material <0.84 mm].

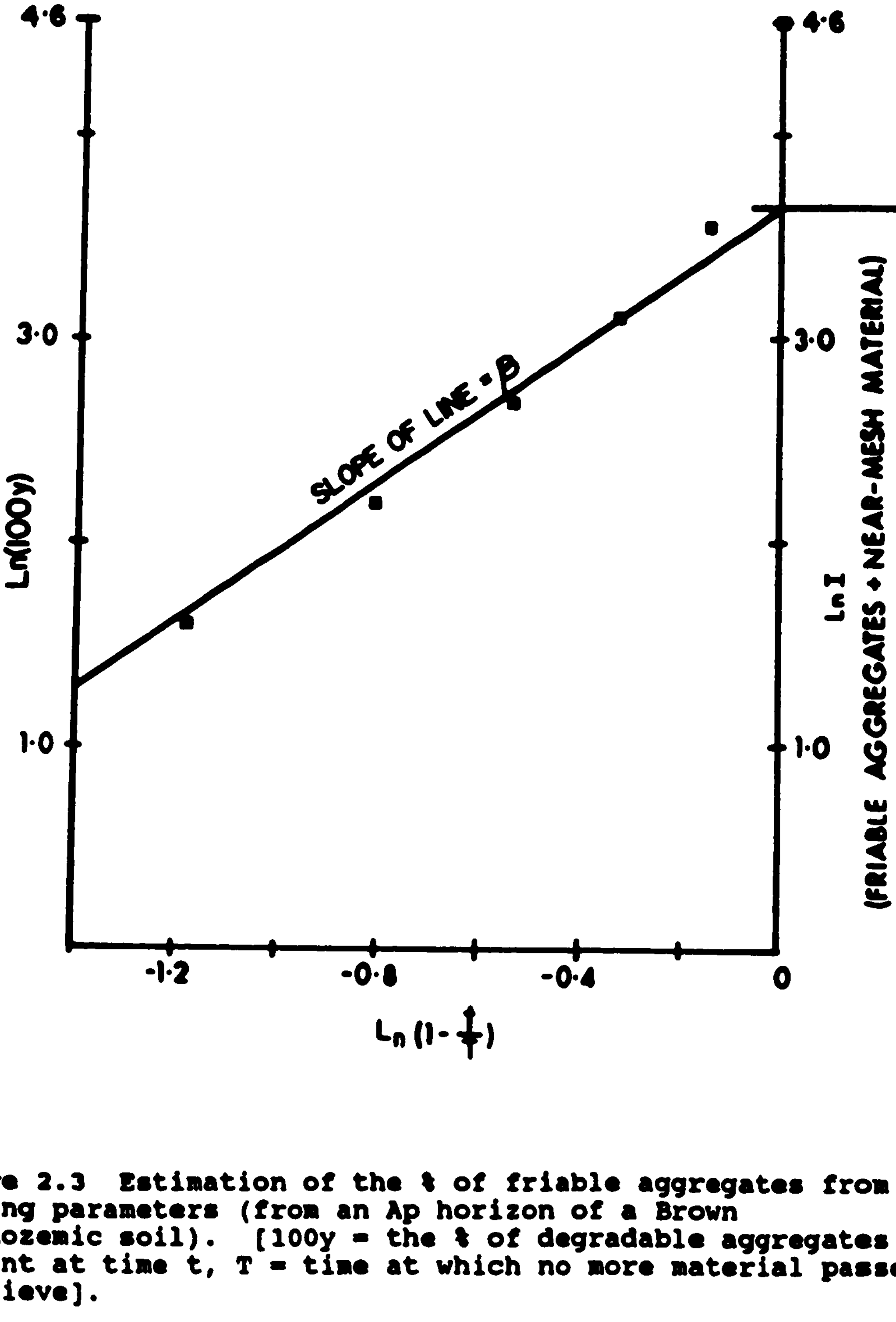

Figure 2.3 Estimation of the % of friable aggregates from sieving parameters (from an Ap horizon of a Brown Chernozemic soil). [100y = the % of degradable aggregates present at time t, T = time at which no more material passes the sieve].

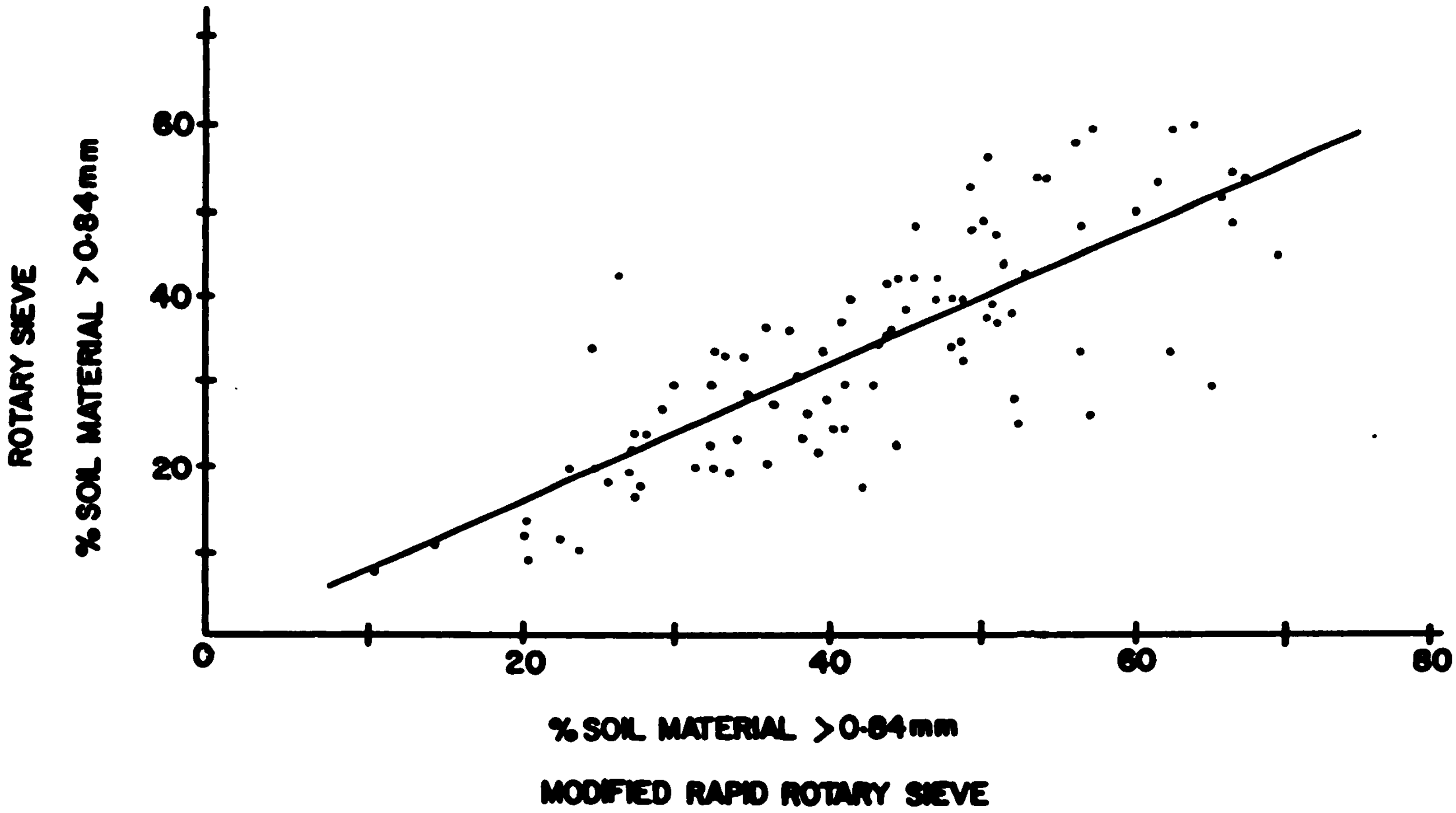

Figure 2.4 Comparison of soil aggregates + sand separated by a Rotary Sieve and the % calculated using the proposed methodology from data of duplicate samples sieved in a Modified Rapid Rotary Sieve (n = 99, r = 0.79).

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CHAPTER 3

THE WIND ERODIBILITY OF ALBERTA SOILS AFTER SEEDING

(1) AGGREGATION IN RELATION TO FIELD-OBTAINABLE PARAMETERS

3.1 INTRODUCTION

An appraisal of the wind erodibility of soils is central to estimates of annual soil loss for use in soil conservation planning. Wind erodibility is influenced by several interacting soil physical properties. These include the proportion and mechanical stability of non-erodible aggregates, the presence of soil surface crusts and their stability, and, the size of erodible fractions and their density (Chepil 1958; Dolgilevich et al. 1973 [as cited by Zachar 1983]).

Relatively little soil >0.84 mm diameter is moved by common erosive winds. Consequently, in the absence of crusting, the initial erodibility of a soil can be estimated by the proportion of soil material >0.84 mm as determined by dry sieving in a rotary sieve (Chepil 1958). Subsequent erosion is strongly dependent on the stability of non-erodible soil material >0.84 mm.

Chepil (1958) noted that soil erodibility is influenced by "basic soil properties" such as soil texture, calcium carbonate content, organic matter, the products of

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decomposition of plant residue and organic matter, water soluble salts, and the nature of soil colloids.

The problem of estimating wind erodibility is compounded by the fact that erodibility is a dynamic property; it is a function of the soil structure at the surface and is affected by environmental factors such as frost, snowcover, wetting and drying, and biological activity (Anderson and Bisal 1969; Smika and Greb 1975). Consequently, wind erodibility varies among seasons and among years (Chepil 1954a; Bisal and Ferguson 1968). Tillage, kinds of crops grown, and the previous erosional history of the field also affect the wind erodibility of soils (Chepil 1958; Lyles and Woodruff 1962; Chepil and Woodruff 1963; Armbrust et al. 1982).

The relationship between the factors affecting wind erodibility listed above is shown in Figure 3.1. Soil erodibility is a function of the primary factors which in turn are influenced by basic soil factors, dynamic soil factors and soil management. With the possible exception of water soluble salts in saline soils, the basic soil factors change very little from year to year. They can be considered to have a static effect on soil erodibility. The dynamic factors reflect the influence of recent weather and the activities of soil organisms (including growing plants) on soil erodibility. They cause annual, seasonal, and short term fluctuations of soil erodibility. Soil management includes a complex set of factors. For example, the tillage factor encompasses the choice, design, setting, speed of operation, and number of passes made by tillage implements. Soil management can have an immediate effect on soil erodibility during tillage or longer term impacts through the effects of rotation, yields, and crop residue management. The many inter-relationships between factors which affect the wind erodibility of soils are symbolized by the dotted arrows on Figure 3.1.

The soil physical properties affecting erodibility have been incorporated into the soil erodibility factor (I) of the Wind Erosion Equation (Woodruff and Siddoway 1965) which is employed in soil conservation planning. The I factor relates soil erodibility to the long-term average percentage of soil material >0.84 mm (i.e. aggregates and loose sand) typically present at the soil surface. Standardization of sieving time and vigor is considered to accommodate differences in aggregate stability between soils (Chepil et al. 1963). Soil crusting is assumed to be transitory and is ignored in long-term estimates of erodibility for the I factor (Woodruff and Siddoway 1965).

Chepil (1962) introduced the concept of grouping soils of similar erodibility and using the average content of non-erodible soil material (>0.84 mm) before spring tillage for each group to estimate soil loss. These were subsequently entitled Wind Erodibility Groups (WEG) and were published in tabular form (Chepil et al. 1963; Hayes 1965). Currently soils are classified into nine WEG according to surface texture and carbonate content (Slevinsky 1983); e.g. non calcareous loams and silty clays are placed into WEG 5 and are estimated to have 40% aggregates >0.84 mm before spring seeding in North Dakota. Similarly all soils with carbonates are placed into WEG 4L with a tabulated estimate of 25% aggregates >0.84 mm (Slevinsky 1983).[1]

The grouping of soils into WEG only employs soil texture and the presence/absence of carbonates. It ignores the influence of the other basic soil properties and the long term effects of soil management. As a result, estimates of average long term soil erodibility using the WEG are unlikely to be precise within the Great Plains Region in which they were developed and may be incorrect in other regions where basic soil properties are different.

WEG currently employed in North Dakota are being used in Manitoba (Slevinsky 1983). However sieving data from Manitoba soils by Langman (1985) are at variance with the North Dakota WEG. For a Reinland loamy sand, Langman (1985) reported 2.7% soil material >0.84 mm before seeding; this compares to 10% estimated from the WEG. Figures for a Gervais clay loam and a Reinland very fine sandy loam were 19.8% and 4.6% respectively from sieving compared to WEG

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[1] The North Dakota WEG Table discussed by Slevinsky (1983) relates the WEG to "Percentage Aggregates >0.84 mm". This should read "Percentage soil material >0.84 mm" as stated by Chepil et al. 1963. The parameter is measured by dry sieving which does not separate aggregates and loose sand >0.84 mm.

estimates of 25% for each soil. After seeding most of the soils sampled were less erodible than predicted by the WEG.

Other dry aggregate sieving data for the Prairies bear little relationship to the WEG. Anderson and Wenhardt (1966) at Swift Current, Saskatchewan, found soil material in a clay loam before seeding to average 64% >0.84 mm over five years, compared to 25% as indicated by the WEG. Bisal and Ferguson (1968) also at Swift Current reported ten year averages of 60% soil material >0.84 mm for a loam, 45% for a clay and 22% for a fine sandy loam, these compared to estimates of 40%, 25% and 25% based on WEG.

For a given field, total soil loss tends to be dominated by a small number of major erosion events rather than a series of smaller incidents. Given the dynamics of soil aggregation and the modifying effects of soil management, the concept of long-term average erodibility must yield imprecise results when applied through an erosion equation.

It can be concluded that the WEG as currently used in North Dakota could be improved upon for the estimation of soil erodibility to wind on the Canadian Plains.

The objectives of this study were: (1) To compare the percentage soil material >0.84 mm determined by dry sieving to estimates based on the WEG for a wide variety of Southern Alberta soils. (2) To investigate some of the factors contributing to the proportion of aggregates >0.84 mm in Southern Alberta soils after seeding.

3.2 MATERIALS AND METHODS

Sampling areas containing a wide range of surface textures were chosen in the Oyen, Pincher Creek, and Vermilion/Flagstaff areas. Soils in the Oyen area are predominantly Brown Chernozem. Black Chernozemic soils are most common in the other sampling areas (Figure 3.2).

Five soil polygons of each soil texture, as identified from soil survey maps, were sampled. Representative fields within each polygon were chosen and five samples per field taken from midslope positions along a single transect. [Preliminary experiments (Appendices 1 and 2) had indicated that 5 samples per field would be required to estimate the proportion of soil material >0.84 mm with sufficient precision for use in the WEQ.] Transects were either parallel to grid roads or to strip-cropping direction, 20 m from field boundaries. Actual sampling sites were located by throwing a quadrat; 1.5 -2 kg samples were taken with a flat spade to 3 cm depth and gently placed in rigid trays. Samples were taken in the spring of 1986 after seeding and before crops were 10 cm high. In most cases sampling was within 5 days of seeding. A total of 375 samples representing 75 fields was taken.

Soils were textured by hand at most sites and an acid drop test (Alberta Soils Advisory Committee 1987) employed to rank samples according to their content of free $CaCO_3$. Site aspect was noted and crop residue levels estimated by comparison to photographs of crop residue (Manitoba

Agriculture 1984). Producers were interviewed regarding the rotation, tillage regime, and crop residue management practices employed on each parcel.

Samples were air-dried, their air-dry Munsell colour recorded, and passed through a Modified Rapid Rotary Sieve (MRRS) (Chapter 2). The mass of material <0.84 mm passing the sieve in 30 second increments was recorded. Sieving was continued until all friable aggregates were comminuted and then for a further 30 second increment. Stones and straw were removed whenever encountered. Sieving times varied from 1 minute to 2.5 minutes depending on the mechanical stability of the aggregates. The sieving data were analyzed using the methodology developed in Chapter 2 to estimate the amount of aggregate comminution in the sieve. The total amount of sand + aggregates (S+AG) >0.84 mm which was present before sieving was then calculated.

Following sieving by the MRRS, the samples were re-bulked, mixed and passed through a 2 mm sieve. Ten gram sub-samples were ground to pass a 100 mesh sieve for $CaCO_3$ determinations.

Particle size analysis using the hydrometer method (McKeague 1978) was conducted on sub-samples. Samples which had effervesced during the field acid drop test were pre-treated to remove carbonates, and samples which contained more than 5% organic matter were pre-treated with hydrogen peroxide. Sub-samples were passed through a 250 μm sieve to quantify the medium sand and fine sand fractions.

Soil pH in water was determined following procedures detailed by McKeague (1978). Inorganic C was determined using the method of Bundy and Bremner (1972) on samples which had effervesced in the field acid drop test and on samples which had a pH >7.5 in water and could therefore potentially contain carbonates (Bohn et al. 1979).

In order to assess the effects of factors affecting aggregate formation (or destruction) on aggregates alone, the percentage of sand >0.84 mm not contained in aggregates (% free sand, FS) was subtracted. This gives the percentage of true aggregates (TA) (Kemper 1965). Since particle size analysis was not conducted separately on aggregates, it was assumed that aggregates >0.84 mm have the same particle size distribution as the whole soil (Coughlan et al. 1978; Christensen 1986).

A general equation which allowed the estimation of N was developed by simultaneous solution of the following equations:

$$N + B = S \qquad 3.1$$

$$TA + N = J \qquad 3.2$$

$$\frac{100B}{TA} = S \qquad 3.3$$

Where:

N = % non aggregated sand >0.84 mm in the whole soil sample,

B = sand in TA expressed as a % of the whole soil sample,

S = % sand 0.84 mm in the whole sample,

TA = % aggregates >0.84 mm in the whole soil sample, and

J = % total soil material >0.84 mm.

J and S were obtained from sieving and particle size data. The general equation is:

$$100\ (S - N) + S*N = J*S \qquad 3.4$$

N was estimated from Equation 3.4 and TA was calculated from Equation 3.2.

A multiple regression analysis (Sokal and Rohlf 1981) was employed to examine the relationship between field estimated variables and true aggregates >0.84 mm. A stepwise procedure was employed. Variables were removed or re-grouped when found to be non-significant using a t test. The data were grouped into classes thereby necessitating the use of dummy variables (Draper and Smith 1981).

To avoid bias in the regression analysis samples were placed into the appropriate textural group (Agriculture Canada 1974) from particle size analysis. This simulated the results of "perfect" hand texturing. The same procedure was used for soils containing free carbonates. Laboratory analysis allowed soils containing carbonates to be allocated into four groups adapted from those suggested by the Alberta Soils Advisory Committee (1987). The groups were 0 - 0.4%, 0.4 - 5.00%, 5.01 - 10% and >10% $CaCO_3$. It was observed from the data that approximately 0.4% $CaCO_3$ was the minimum amount of free soil carbonates which could be detected by the acid drop test. Thus 0.4% $CaCO_3$ was then employed to discriminate between a non calcareous group and a weakly effervescent group (0.41-4.99%).

3.3 RESULTS AND DISCUSSION

The soils sampled had textures varying from sand to heavy clay (Table 3.1). Sand content ranged from 15% to 93%, clay from 3% to 69%, and silt from 4% to 50%. The number of soil samples falling into each texture class and the average percentage of sand and clay for each class is shown in Table 3.1.

The percentage of true aggregates as calculated from the sieving parameters and equations 3.1 and 3.2 had a wide range, from 93.4% in heavy clays to 2.9% in dune sand. The distribution of values was close to normal.

Inorganic carbonates were measured in 116 of the samples; 39, 74, and 3 from the Oyen, Pincher Creek and Flagstaff/Vermilion areas respectively. Content of $CaCO_3$ varied from a trace to 17.7%. Generally the Pincher Creek samples had a higher content of $CaCO_3$ than samples from other areas.

Crop residue levels on sampling varied from <100 kg/ha to >850 kg/ha. In the Oyen area (Brown Soil Zone) 19% of fields sampled had <100 kg/ha residues compared to 18% at Pincher Creek (Black Soil Zone) and 33% at Flagstaff/Vermilion (Black Soil Zone). Fields with >450 kg/ha residues comprised 23% of the total at Oyen, 9% at Pincher Creek, and 19% in the Flagstaff/Vermilion area.

It should be noted that tillage and cropping data are not necessarily representative of the practices in the sampling areas. Sampling in the Flagstaff/Vermilion area was intentionally biased to permit sampling of an equal number of fields seeded to oilseeds and small grains. This therefore precludes more than a cursory comparison of field data between areas.

Rotations were exclusively small grain-fallow in the Oyen areas. At Pincher Creek some 27% of the fields sampled were in small grain-fallow rotation, the remaining fields were in continuous small grain. In the Flagstaff/Vermilion area 15% of fields were in continuous small grain, 26% in continuous small grain-oilseed rotation, 26% in a small grain - oilseed rotation, and 33% in oilseed - small grain - summer fallow rotation.

The number of pre-seeding tillage operations varied from zero to four. In the Oyen, Pincher Creek, and Flagstaff/Vermilion areas 46%, 18%, and 7% of fields respectively received no tillage prior to seeding. The percentage of fields receiving one tillage operation was 50%, 18% and 48% respectively in the three areas. Only two fields received four pre-seeding operations.

Seeding implements were markedly different among areas. In the Oyen area 65% of fields were seeded with a disker, 23% with a hoe press drill, and the remainder with a disk press drill. The hoe press drill was used in 82% of fields with an air seeder and disk press drill each used in 9% of the fields sampled in the Pincher Creek area. In the Flagstaff/Vermilion area the figures were 70%, 19%, and 11% for the hoe press drill, airseeder, and disk press drill respectively.

No post-seeding tillage was employed in 58%, 95%, and 19% of fields in the Oyen, Pincher Creek, and Flagstaff/Vermilion areas respectively. A harrowpacker/ roller was used in 35%, 5%, and 19% of fields with harrows alone and rodweeders making up the remainder in the three areas respectively.

The method developed by Black et al. (Chapter 2) was applied to the soil sieving data to estimate and compensate for aggregate breakdown during sieving. As a result, estimates of the percentage of aggregates >0.84 mm and thus soil erodibility closely approximated field conditions. Data on 23 samples were insufficient to apply the method so these were rejected reducing the number of data sets to 352.

The percentage of soil material >0.84mm as estimated using the North Dakota WEG is compared to the sieving results in Table 3.2. Only a relative comparison is possible since the WEG were developed to estimate aggregation before spring tillage and seeding which generally result in a small increase in soil erodibility on the Canadian Plains (Anderson and Wenhardt 1966; Bisal and Ferguson 1968; Keyes et al. 1970). N.B. Langman (1985) found that tillage and seeding decreased erodibility, however, this may have been due to the high level of carbonates in the soils sampled.

A large discrepancy is apparent when comparing data from the 352 samples sieved on the Modified Rapid Rotary

Sieve (MRRS) after compensation for aggregate comminution to the WEG. For heavy clay, clay, silty clay, calcareous clayloam and loam, loamy sand, and sand textures the WEG estimate is less than half that from the MRRS (Table 3.2). For other textures the difference is between 9 and 18% except for silty clay loam which can have either 25% or 50% soil material >0.84 mm at 35% clay according to the WEG table. The correlation between % soil material >0.84 mm estimated by the two methods for the 352 samples was very poor, r = 0.33. This only explained 11% of the variability between the two estimates indicating no consistent relationship between them.

The WEG were developed from Rotary Sieve Data so the results from the MRRS were adjusted using the relationship developed in Chapter 2 to estimate the proportion of soil material >0.84 mm which a Rotary Sieve would have screened from these samples (Table 3.2). The Rotary Sieve estimate is 40 - 120% greater than the WEG estimate for the most erodible textural classes (Table 3.2).

These results, combined with previous data by Anderson and Wenhardt (1966) and Bisal and Ferguson (1968), suggest that in most cases the North Dakota WEG underestimate the percentage of material >0.84 mm obtained by dry sieving soils from the Canadian Plains both before and after seeding.

The relationship between % TA calculated from Equations 3.4 and 3.2, and the variables listed in Table 3.3

was examined using multiple regression.

Preliminary analysis during the step-down procedure employed suggested rejection of several variables which had non-significant t values at the 5% level. Before dropping a variable it was, if possible, re-grouped. For example, soil colour originally had 9 dummies representing value increments of 0.5 units, these were reduced to three groups and finally to one dummy (Munsell value > or <3.5) before being dropped as non-significant. Similarly, types of seeding implements were re-grouped before being dropped.

It was anticipated that a difference in aggregation would be apparent between fields seeded to oilseeds and those seeded to small grains because a finer seedbed is recommended for oilseeds (Hadas and Russo 1974; Canola Council of Canada 1984). However, a crop variable showed no difference in aggregation between fields seeded to the two different classes of crops. Similarly there was no significant difference detectable after post-seeding tillage (if any) in the proportion of aggregates >0.84 mm in fields seeded with different seeding equipment.

Site aspect was included in the experiment to investigate any microclimate effects on biological activity expressed in soil aggregates >0.84 mm. No significant differences due to aspect were detected.

Table 3.4 is the correlation matrix of the variables retained, the dummy variable representing sandy loam (D1) has the largest correlation with % TA ($r = -0.27$). A number of other variables (D9, D15, D17, and D18) had r values of between 0.20 and 0.26.

The multiple regression equation developed was:

$$\%TA = 10.1 + A + B + C + D \tag{3.3}$$

Where A = 0 when soil texture is sand or loamy sand
= 24.9 when texture is sandy loam
= 37.0 when texture is sandy clay loam
= 39.8 when texture is loam
= 41.3 when texture is silt loam
= 42.1 when texture is clay loam
= 54.1 when texture is silty clay
= 39.9 when texture is silty clay loam
= 44.5 when texture is clay
= 54.6 when texture is heavy clay

Where B = 0 when carbonates in the sample are 0 - 0.4%
= -7.2 when %$CaCO_3$ is 0.41 - 5.0%
= -3.1 when %$CaCO_3$ is 5.01 - 10%
= 3.8 when %$CaCO_3$ is >10%

Where C = 0 when no pre-seeding tillage operations are used
= 7.6 when 1 pre-seeding tillage operation is used
= 14.8 when 2 pre-seeding tillage operations are used
= 8.7 when 3 pre-seeding tillage operations are used
= 21.6 when 4 pre-seeding tillage operations are used

Where D = 0 when no post seeding tillage operations are used

= -6.5 when harrowpacker or roller used after seeding

= -5.5 when harrows alone are used after seeding

= 19.3 when rodweeded after seeding

The multiple correlation coefficient for the equation was 0.78 which explains 61% of the variability observed in the samples. Note that this multiple regression equation does not estimate the total proportion of material resisting wind erosion. This fraction consists of true aggregates as estimated by the relationship above together with free sand >0.84 mm not contained in aggregates.

The multiple regression coefficients, standard error of the variables and t values for the variables retained are listed in Table 3.5. At 334 degrees of freedom the t values for significance at 5% and 1% are 1.97 and 2.59 respectively (Zar 1974). All the variables except D11 and D12 are significant at the 5% level and most at the 0.1% level. D11 and D12 were retained since D10 the other dummy variable in the group was significant. Individual dummy variables from a group cannot be dropped in this type of analysis.

The multiple regression coefficients may be used to provide a relative comparison of the effects of the independent variables on true aggregates. A positive coefficient indicates in an increase in the percentage aggregates >0.84 mm (and therefore a reduction in soil erodibility).

Examination of the estimated regression coefficients for the soil textural classes (Table 3.5) shows that all the coefficients are positively correlated with %TA thus indicating that heavier-textured soils are less erodible than sand/loamy sand. The order of erodibility for the soils was: sand/loamy sand >sandy loam >sandy clay loam >loam, silty clay loam >silt loam, clay loam >clay >silty clay, heavy clay. This ranking generally agrees with findings by Chepil (1953), Shiyatyi (1972), and with the North Dakota WEG (Slevinsky, 1983).

It should be emphasised that soil erodibility is dynamic and that this ranking will not hold year-round. Clay soils may be extremely erodible before spring tillage due to overwinter breakdown of aggregates resulting from freeze-thaw conditions.

The multiple correlation coefficient for the texture variables was 0.67 indicating that soil texture alone explained approximately 45% of the variability in aggregation displayed by the samples.

The regression coefficients for carbonates showed that 0.4 - 5.00% and 5.01 - 10% $CaCO_3$ reduced the % TA resulting in the soil being more erodible. Soils containing >10% $CaCO_3$ gave the converse result by increasing %TA (but not significantly at the 5% level). Increasing quantities of $CaCO_3$ up to approximately 6% have been reported to increase the wind erodibility of soils. Beyond 6% $CaCO_3$ some soils became less erodible. (Canada Dept. of Agriculture 1949; Chepil 1954b).

The regression coefficients demonstrate that pre-seeding tillage decreased soil erodibility and that the effect tends to be greater as the number of operations increases. This is indicative of aggregates >0.84 mm being brought to the surface by seedbed preparations.

Conversely, post-seeding tillage with a harrowpacker, harrows alone, or a roller increased erodibility. This is compatible with field observations that rolling and harrowing tend to pulverize aggregates. The analysis, however, indicated that rodweeding after seeding, based unfortunately on the results of only one field, may decrease erodibility perhaps by bringing larger aggregates to the surface.

These results show that the effects of tillage on dry soil aggregates are not necessarily obliterated by subsequent field operations, thus confirming data by Fenster et al. (1965). The lack of significance between different types of seeding implements suggests that the effects of shallow tillage on aggregation are more readily erased by subsequent field operations than those of deep tillage.

3.4 THE EFFECT OF SOIL MANAGEMENT ON SOIL AGGREGATION

Two simple calculations employing the multiple regression equation (Equation 3.3) using typical field parameters illustrate the effect of soil management practices on true aggregates and thus on soil erodibility.

Consider a clay loam field in the Oyen area, containing no carbonates, no pre-seeding tillage is used but one post-seeding pass with a harrowpacker is employed. Using Equation (3.3) %TA after seeding can be calculated as follows (assuming identical conditions to those which prevailed in 1986):

$$\%TA = 10.1 + 42.1 - 6.5$$

$$\%TA = 45.7\%$$

Total material >0.84 mm = %TA + % Non aggregated sand (N)

The average % non aggregated sand in clay loam soils in the Oyen area is 1.7%.

Therefore total material >0.84 mm = 45.7 + 1.7%

= 47.4%

If the same field were instead to receive one preseeding tillage operation and no post-seeding packing:

$$\%TA = 10.1 + 42.1 + 7.6$$

$$= 59.8\%$$

Total material >0.84 mm = 59.8 + 1.7

= 61.5%

The change in management is equivalent to employing one pre-seeding pass with a cultivator and seeding with a press drill instead of seeding with a discer and packing with a harrowpacker. These are both common management strategies on clay loam soils in the Oyen area.

Chepil (1958) and Shyatyi (1965) [as cited by Zachar (1982)] reported that an unprotected soil containing more than 60% material in the 0.84-1 mm size range will not blow in most erosive winds. Therefore, in the absence of protective crop residues or other conservation practices these clay loam soils will be at risk to wind erosion when a discer harrowpacker combination is employed, but not when pre-seeding cultivation and a press-drill are used.

In the Flagstaff-Vermilion area a loam soil without carbonates had approximately 50% TA after seeding in 1986 when considering only the effects of basic soil properties. One pre-seeding tillage operation, seeding with an airseeder and packing with harrows after seeding has little effect on %TA leaving it at approximately 51%. A tillage regime employing two pre-seeding tillage operations seeding with a pressdrill with attached rodweeder would increase the %TA to approximately 80%. Again, soil management overrides the effect of the basic soil properties on soil erodibility and could have prevented loss from a bare soil in the event of an erosive wind. The effect of soil management is not recognized in the WEG which only considers basic soil factors.[2]

3.5 FIELD VARIABILITY OF TRUE AGGREGATES

The regression model presented in this paper does not explain all the variability in true aggregates encountered during sampling. One, or a number of influential variables are not considered e.g. moisture content at the time of tillage (Lyles and Woodruff 1962). Nevertheless,

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[2] It should be noted that these examples only consider the effect of tillage on soil aggregation. Soil management for wind erosion control must also take into account the effect on soil surface roughness and on crop residues.

calculations of %TA using the model come close to the average %TA of samples along transects where the basic soil properties are uniform. From Table 3.6, the %TA for samples B1 to B5 (Transect #1) ranges from 16.9 to 46.0 for individual samples; however, the average for the five samples (32.1) is similar to the average calculated using Equation 3 (35.0). The average %TA for transect #62 is considerably different from that calculated from Equation 3.3, 23.5% compared to 49.7%. The reasons for this discrepancy are not apparent but encourage caution in interpretation of these data. Most other transects show considerable variation in values for %TA for individual samples but have averages within 7% of the calculated figure using Equation 3.3. This apparent similarity between calculated and measured averages for %TA along a transect suggests that sampling strategies similar to soil testing procedures will yield acceptable results for the estimation of the wind erodibility of soils given a more complete model.

3.6 CONCLUSIONS

The WEG used in North Dakota did not successfully estimate the % soil material >0.84 mm in a wide range of Alberta soils sampled after seeding in 1986. Because of the dynamic nature of dry soil aggregation this may not be the case in all years; however, the spring of 1986 and the preceding winter were not climatically atypical.

The experiment has demonstrated that basic soil factors such as texture, and carbonate content play a significant role in dry soil aggregation. It also showed that tillage can have an overriding effect on these basic soil properties and therefore may determine soil erodibility after seeding. This latter result has significant implications for control of wind erosion.

Much remains to be elucidated about the effects of crop management, tillage, recent weather, and several other variables on dry soil aggregation before reliable estimates of the wind erodibility of soils can be made for soil conservation planning.

Table 3.1. Textures and average clay and sand content of the soils sampled.

Texture	#	%clay	s*	%sand	s*
Heavy clay	27	63.7	2.6	6.7	3.9
Clay	74	49.7	6.3	19.6	6.2
Silty clay	5	49.6	5.7	10.2	4.4
Silty clay loam	2	35.0	7.1	18.5	0.7
Silt loam	3	23.3	6.4	26.3	4.2
Clay loam	72	32.9	3.7	33.0	5.3
Loam	101	33.3	3.7	41.3	5.9
Sandy clay loam	11	23.4	2.7	53.3	4.1
Sandy loam	57	14.2	3.5	62.4	6.2
Loamy sand	21	6.5	2.0	81.1	3.7
Sand	2	5.0	2.8	90.0	2.8

\# - number of samples
S* - standard deviation

Table 3.2 Material >0.84 mm in soils sampled in relation to that estimated from the North Dakota WEG

Texture	%sand and aggregates >0.84 mm from MRRS sieve data(1)					Rotary Sieve(2)	WEG(3)
	#	Ave.	Max.	Min.	$	Estimate >0.84 mm	Estimate >0.84 mm
Heavy Clay	28	69.6	93.5	32.9	18.32	55.3	25
Clay	68	60.8	93.2	25.1	18.41	48.2	25
Silty Clay	5	79.1	92.9	62.4	16.62	62.8	25
Silty Clay Loam	2	43.8	51.4	36.2	10.69	34.7	50
Silt Loam	3	54.7	70.1	45.0	13.44	43.4	45
Sandy Clay Loam	8	56.2	71.4	37.0	12.76	44.6	40
Clay Loam (4)	48	57.9	86.0	26.2	12.45	46.0	45
Clay Loam (5)	28	56.5	80.4	25.4	16.46	44.9	25
Loam (4)	74	59.8	83.7	33.2	11.87	47.5	45
Loam (5)	11	57.5	80.3	36.4	14.42	45.7	25
Sandy Loam	54	43.7	83.7	26.9	12.44	34.6	25
Loamy Sand	18	21.5	38.8	7.2	7.6	16.9	10
Sand	5	7.0	8.3	5.8	1.41	5.3	3

(1) Calculated from Modified Rapid Rotary Sieve data (Black et al. [Chapter 2]). Includes aggregates which break down during sieving.
(2) Estimated from the regression relationship in Black et al. (Chapter 2).
(3) Estimate of sand and aggregates >0.84 mm from the North Dakota Wind Erodibility Groups
(4) Samples containing no $CaCO_3$
(5) Samples containing $CaCO_3$
\# Number of samples
S Standard deviation

Table 3.3. List of variables examined in the multiple regression analysis

Soil texture
Percentage free carbonate in soil samples
Soil pH
Soil colour (Munsell Value)
Aspect at sampling site (four compass points)
Crop rotation
Crop or summerfallow in the previous year
Type of crop seeded (small grains or oilseeds)
Number of pre-seeding tillage operations
Type of seeding implement
Type of post-seeding tillage
Crop residue levels on sampling

Table 3.4 Correlation matrix of the variables remaining after the multiple regression analysis

TA	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	
1	-.272	-.003	.138	.004	.097	.125	-.045	.152	.229	-.001	.108	.082	.046	.245	-.020	.176	-.260	-.222	.124	TA
	1	-.068	-.239	-.039	-.221	-.051	-.022	-.206	-.124	-.178	-.082	-.079	.068	-.017	-.036	-.072	-.011	-.237	.017	D1
		1	-.092	-.015	-.085	-.019	-.009	-.079	-.048	.005	-.032	.168	.098	-.067	.085	-.280	-.009	-.004	-.019	D2
			1	-.053	-.298	-.068	-.030	-.278	-.167	-.164	-.111	-.070	.160	-.085	.102	.102	.031	-.087	.155	D3
				1	-.049	-.011	-.005	-.045	-.027	-.048	-.018	-.017	-.008	-.061	-.027	-.016	-.046	-.034	-.011	D4
					1	-.063	-.028	-.257	-.154	-.017	-.103	.054	.007	-.058	.075	-.090	-.019	-.044	-.063	D5
						1	-.006	-.059	-.035	-.003	.104	-.023	.006	.078	-.035	-.021	-.060	-.044	-.014	D6
							1	-.026	-.016	.103	-.010	-.010	-.041	-.035	-.016	-.009	.107	-.020	-.006	D7
								1	-.144	.295	.248	-.013	-.082	.102	-.117	.133	-.009	-.136	-.059	D8
									1	.209	.109	.118	-.141	.150	-.086	-.050	.011	-.108	-.035	D9
										1	-.101	-.097	-.155	.102	-.100	-.088	.110	-.10[illegible]	-.062	D10
											1	-.037	-.089	.134	-.058	-.033	-.060	-.072	-.024	D11
												1	-.049	-.021	-.055	-.032	.063	-.069	-.023	D12
													1	-.508	-.228	-.132	.092	-.104	.155	D13
														1	-.193	-.112	-.249	-.236	-.079	D14
															1	-.050	-.015	.119	-.035	D15
																1	-.085	-.063	-.021	D16
																	1	-.183	-.060	D17
																		1	-.044	D18
																			1	D19

TA - True aggregates >0.84 mm.
D1 - Dummy variable comparing the effect of sand/loamy sand to sandy loam texture on true aggregates >0.84 mm.
D2 - As D1 compares the effect of sand/loamy sand to sandy clay loam.
D3 - As D1 compares the effect of sand/loamy sand to loam.
D4 - As D1 compares the effect of sand/loamy sand to silt loam.
D5 - As D1 compares the effect of sand/loamy sand to clay loam.
D6 - As D1 compares the effect of sand/loamy sand to silty clay.
D7 - As D1 compares the effect of sand/loamy sand to silty clay loam.
D8 - As D1 compares the effect of sand/loamy sand to clay.
D9 - As D1 compares the effect of sand/loamy sand to heavy clay.
D10 - Dummy variable comparing the difference in % true aggregates >0.84 mm between samples with 0-0.4% $CaCO_3$ and samples with 0.41-5% $CaCO_3$.
D11 - As D10 except D11 compares effect of 0-0.4% $CaCO_3$ to the effect of 5.01-10% $CaCO_3$.

Table 3.4 (continued)

D12 - As D10 except D12 compares effect of 0-0.4% $CaCO_3$ to the effect of >10% $CaCO_3$.
D13 - Dummy variable comparing the effects of no pre-seeding tillage to the effects of one tillage operation on true aggregates >0.84 mm.
D14 - As D13 comparing the effects of two operations to no pre-seeding operations.
D15 - As D13 comparing the effects of three operations to no pre-seeding tillage operations.
D16 - As D13 comparing the effects of four operations to no pre-seeding tillage operations.
D17 - Dummy variable comparing the effects of no post-seeding tillage to harrowpacking/rolling on true aggregates >0.84 mm.
D18 - As D17 comparing the effects of no post-seeding tillage to the use of harrows.
D19 - As D17 comparing the effects of no post-seeding tillage to the use of rodweeder (only five samples).

Table 3.5. Multiple regression coefficients and t values for variables retained in the model

Independent Variable	Estimated Coefficient	Standard Error	t Value
D1	24.9	3.354	7.42 ***
D2	37.0	5.525	6.69 ***
D3	39.8	3.434	11.60 ***
D4	41.3	8.024	5.15 ***
D5	42.1	3.359	12.54 ***
D6	54.1	6.710	8.07 ***
D7	39.9	13.428	2.97 **
D8	44.5	3.697	12.04 ***
D9	54.6	4.158	13.14 ***
D10	-7.2	2.064	3.50 ***
D11	-3.2	4.056	0.78 N.S.
D12	3.8	4.065	0.93 N.S.
D13	7.6	2.256	3.37 ***
D14	14.7	2.373	6.22 ***
D15	8.7	3.217	2.70 **
D16	21.5	4.792	4.50 ***
D17	-6.5	1.987	3.29 **
D18	-5.4	2.488	2.21 *
D19	19.2	5.974	3.22 **

*, **, *** $p = 0.05$, $p = 0.01$, $p = 0.001$ respectively.
N.S. = Non significant
D1 = Dummy variable comparing the effect of sand/loamy sand to that of sandy loam on true aggregates >0.84 mm.
D2 = Compares the effect of sand/loamy sand to that of sandy clay loam.
D3 = Compares the effect of sand/loamy sand to that of loam.
D4 = Compares the effect of sand/loamy sand to that of silt loam.
D5 = Compares the effect of sand/loamy sand to that of clay loam.
D6 = Compares the effect of sand/loamy sand to that of silty clay.
D7 = Compares the effect of sand/loamy sand to that of silty clay loam.
D8 = Compares the effect of sand/loamy sand to that of clay.
D9 = Compares the effect of sand/loamy sand to that of heavy clay.
D10 = Dummy variable comparing the difference between 0-0.4% $CaCO_3$ and 0.4-5% $CaCO_3$ on true aggregrates >0.84 mm.
D11 = As D10 except compares 0-0.4% $CaCO_3$ and 5-10% $CaCO_3$.
D12 = As D10 except compares 0-0.4% $CaCO_3$ and >10% $CaCO_3$.
D13 = Dummy variable comparing the difference between no preseeding tillage and 1 pass on true aggregates >0.84 mm.
D14 = As D13 compares effect of no pre-seeding tillage to 2 passes.
D15 = As D13 compares no pre-seeding tillage to 3 passes.
D16 = As D13 compares no pre-seeding tillage to 4 passes.
D17 = Dummy variable comparing the difference between no post-seeding tillage & harrowpacker/roller on % true aggregates >0.84 mm.
D18 = As D17 compares no post-seeding tillage to harrows alone.
D19 = As D17 compares no post-seeding tillage to attached rod weeder.

Table 3.6 Variability of % True Aggregates along transects within fields having the same static soil properties

Transect#	Sample#	Texture	$CaCO_3$ (1)	Pre-Seed Tillage (2)	Post-Seed Tillage (3)	Sample %TA	Field Avg. %TA	Field Calc (4)
1	B1	SL	nil	nil	nil	25.5	32.1	35.0
	B2	SL	nil	nil	nil	38.6		
	B3	SL	nil	nil	nil	16.9		
	B4	SL	nil	nil	nil	33.5		
	B5	SL	nil	nil	nil	46.0		
5	B22	C	W/E	nil	HP	42.2	34.4	40.9
	B23	C	W/E	nil	HP	28.3		
	B24	C	W/E	nil	HP	40.3		
	B25	C	W/E	nil	HP	26.7		
10	B46	HC	W/E	nil	HP	34.1	44.9	51.0
	B47	HC	W/E	nil	HP	32.9		
	B48	HC	W/E	nil	HP	49.3		
	B49	HC	W/E	nil	HP	57.6		
	B50	HC	W/E	nil	HP	50.8		
12	B56	L	nil	1	nil	41.0	46.3	57.5
	B57	L	nil	1	nil	56.6		
	B58	L	nil	1	nil	50.1		
	B59	L	nil	1	nil	42.0		
	B60	L	nil	1	nil	41.7		
16	B76	LS	nil	nil	nil	14.6	15.8	10.1
	B77	LS	nil	nil	nil	12.2		
	B78	LS	nil	nil	nil	17.8		
	B79	LS	nil	nil	nil	24.5		
	B80	LS	nil	nil	nil	10.1		
23	B111	SL	nil	1	nil	37.6	37.5	42.6
	B112	SL	nil	1	nil	30.8		
	B113	SL	nil	1	nil	27.7		
	B114	SL	nil	1	nil	49.6		
	B115	SL	nil	1	nil	42.0		
30	P16	CL	W/E	nil	nil	66.4	55.7	45.0
	P17	CL	W/E	nil	nil	40.2		
	P18	CL	W/E	nil	nil	41.4		
	P19	CL	W/E	nil	nil	74.8		
39	P61	HC	W/E	2	nil	72.2	74.4	72.3
	P62	HC	W/E	2	nil	83.6		
	P63	HC	W/E	2	nil	65.0		
	P64	HC	W/E	2	nil	76.8		

Table 3.6 (continued)

Transect#	Sample	Texture	$CaCO_3$ (1)	Pre-Seed Tillage (2)	Post-Seed Tillage (3)	Sample %TA	Field Avg.%TA	Field Calc (4)
55	F31	L	nil	2	nil	60.5	71.5	64.7
	F32	L	nil	2	nil	68.1		
	F33	L	nil	2	nil	75.3		
	F34	L	nil	2	nil	82.1		
62	F66	SL	nil	2	nil	22.4	23.5	49.8
	F67	SL	nil	2	nil	24.0		
	F68	SL	nil	2	nil	21.5		
	F69	SL	nil	2	nil	26.1		
65	F81	L	nil	4	nil	71.4	71.3	71.4
	F82	L	nil	4	nil	76.0		
	F83	L	nil	4	nil	75.2		
	F84	L	nil	4	nil	60.7		
	F85	L	nil	4	nil	67.1		
66	V1	L	nil	2	nil	47.9	53.8	64.6
	V2	L	nil	2	nil	41.4		
	V3	L	nil	2	nil	71.3		
	V4	L	nil	2	nil	59.4		
	V5	L	nil	2	nil	49.0		

(1) W/E = Weakly effervescent

(2) = Number of pre-seeding tillage operations

(3) HP = harrow-packer

(4) Calculated using Equation 3

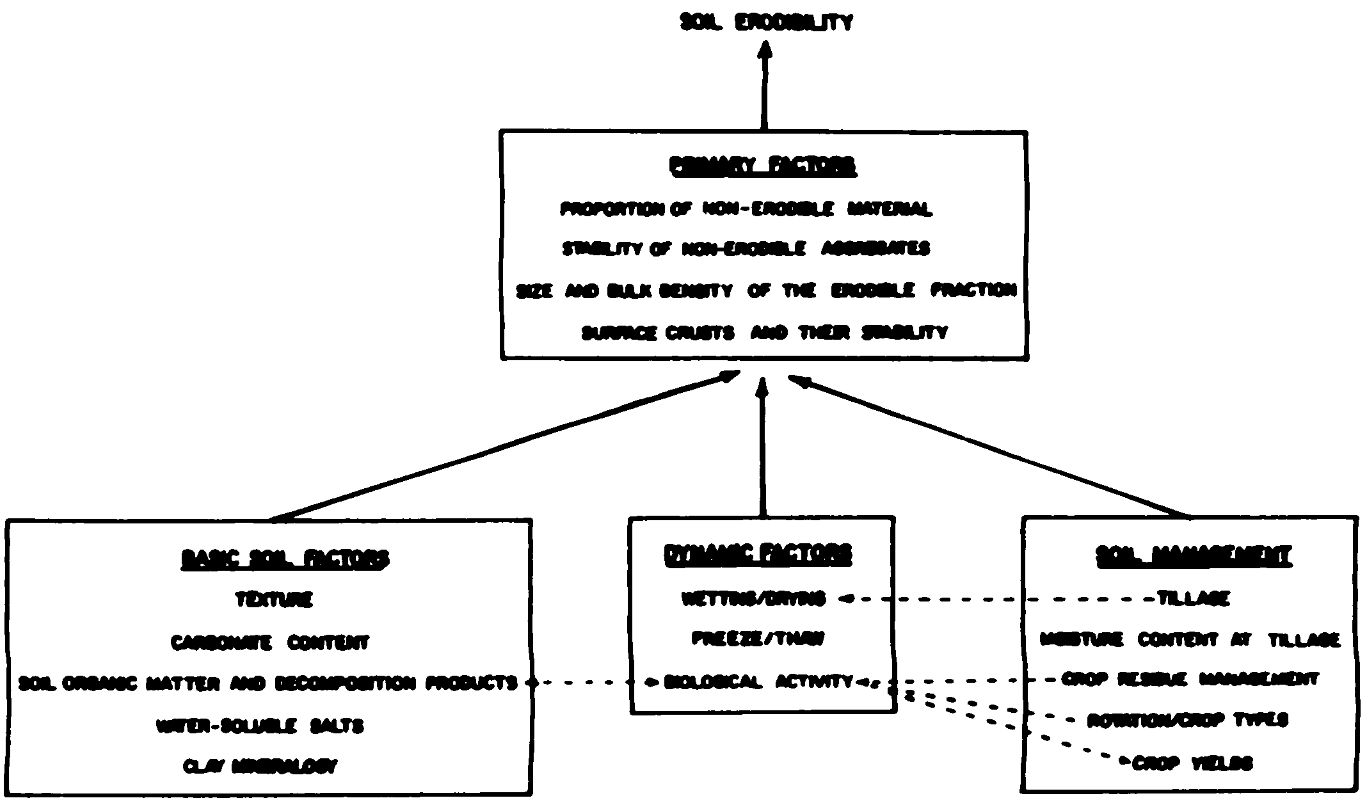

Figure 3.1 A conceptual grouping of the factors affecting the wind erodibility of soils.

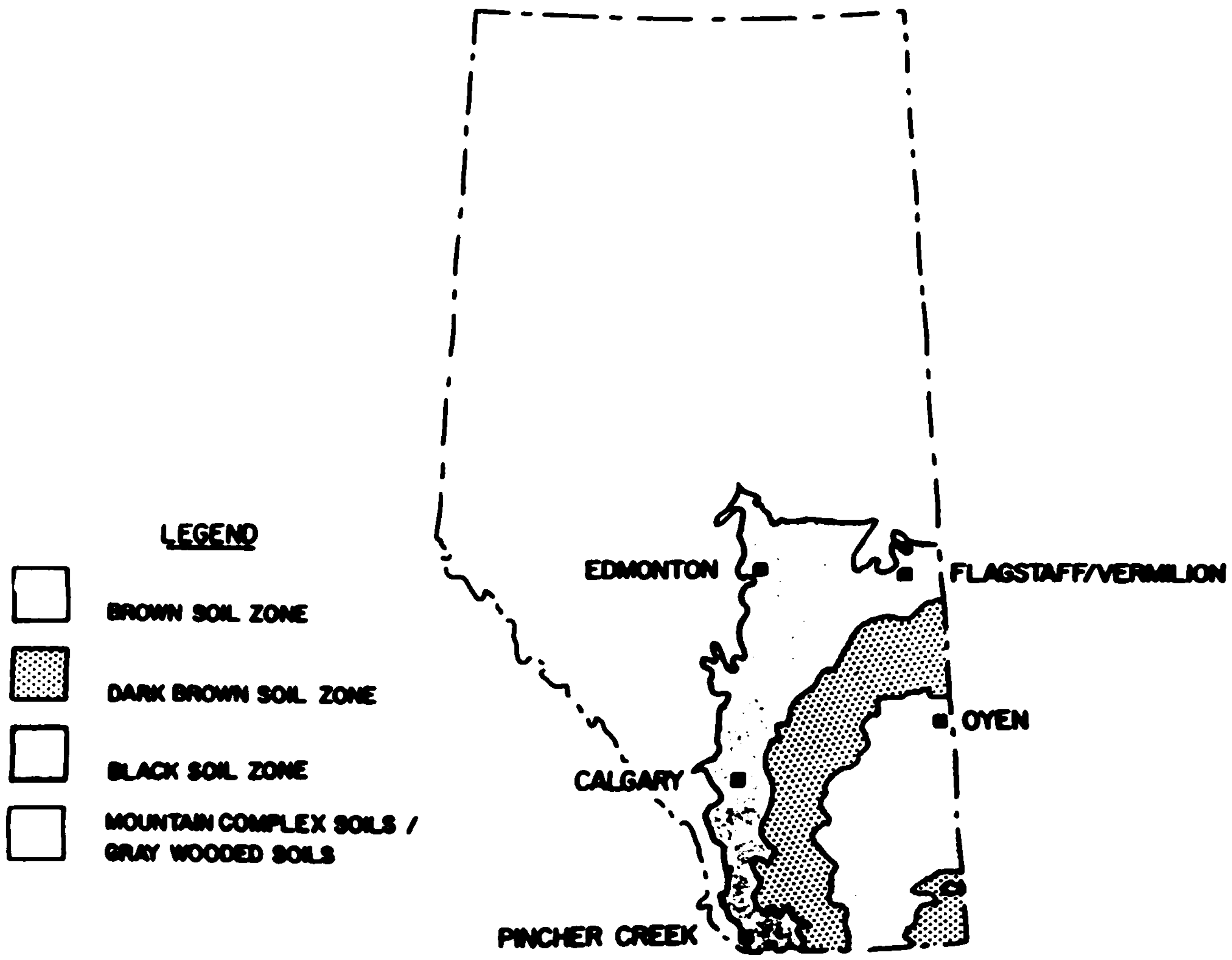

Figure 3.2 Location of the sampling areas.

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CHAPTER 4

THE WIND ERODIBILITY OF ALBERTA SOILS AFTER SEEDING

(2) AGGREGATION IN RELATION TO BASIC SOIL PROPERTIES

4.1 INTRODUCTION

The wind erodibility of soil is governed by the state and stability of soil aggregation at the surface. Soil material >0.84 mm has been shown to be resistant to movement by most erosive winds (Chepil and Bisal 1943; Zingg 1951).

The proportion of soil material >0.84 mm (i.e. aggregates and sand particles) may be determined by either wet or dry sieving. However, Chepil (1943, 1953a) has shown by wind tunnel studies that the proportion of soil material >0.84 mm which remains stable during wet sieving bears no simple or consistent relationship to the wind erodibility of soils. In contrast the proportion of soil material >0.84 mm as determined by dry sieving has been demonstrated to be a satisfactory index of the initial erodibility of uncrusted soils (Chepil 1958). Subsequent soil erodibility during an erosion event is primarily determined by aggregate stability, aggregation at depth, and soil sorting.

Much research has been devoted to understanding the mechanisms of, and factors contributing to, wet stable aggregation (Harris et al. 1966; Lynch and Bragg 1985). By comparison, the factors contributing to dry soil aggregation have received little attention.

Dry soil aggregates at the soil surface are readily disrupted by rain (Lyles and Schrandt 1972) and hail, particularly during windy conditions (Hagen et al. 1975). They are also susceptible to breakdown by freeze-thaw cycles during winter conditions when unprotected by snow (Anderson and Bisal 1969.). Tillage, crop rotations, and kinds of crop grown also affect dry soil aggregation (Siddoway 1963; Armbrust et al. 1982).

The factors affecting dry soil aggregation have been categorized into three groups (Chapter 3). The static soil variables such as soil texture and organic matter content which can be considered to provide soil with an inherent level of dry aggregation are termed "basic soil factors" (Chepil 1958). "Dynamic factors" such as weather and the effects of biological activity and; "soil management factors" such as tillage, rotations, etc. interact with the basic soil factors to determine the final proportion of dry aggregates in a soil. This paper concentrates on the effect of the basic soil factors on dry soil aggregation.

Chepil (1953b, 1955a) reported complex relationships between soil particle size fractions and soil erodibility of artificial soils in a wind tunnel. Soil erodibility decreased with increasing clay and silt content with the first 5% of each being equally effective. Beyond 5%, silt was 1.5 times more effective in reducing erodibility than clay. The least erosive Canadian prairie soils had 20% clay, 38% silt and 42% sand, whilst the least erosive soils from Kansas and Nebraska had 27% clay, 51% silt and 22% sand. The differences between these figures were tentatively attributed to the size distribution of silt and the nature and amount of soil organic matter (Chepil 1955a).

The addition of straw to soils increased the amount of aggregates >0.84 mm in soils in proportion to the quantity applied (C.D.A. 1949; Chepil 1955b; Black 1973). The consequent reduction in erodibility (following weathering of the straw) decreased with time and was reversed after approximately 2-3 years, causing the soils to become more erodible than they had been before the straw was added (Chepil 1955b). Smika and Greb (1975) attributed the reduction of erodibility after additions of straw to fats, waxes, and resins released by straw breakdown. They obtained a high correlation (r=0.86) between dry soil aggregation and these compounds. The increase of erodibility with time was postulated to be a result of breakdown or replacement of the cementing agents causing formation of erodible aggregates (Chepil 1955b).

Soils high in calcium carbonate appear to be susceptible to wind erosion (Hopkins 1935). The addition of up to 3% $CaCO_3$ increased the erodibility for most soils (C.D.A. 1949; Chepil 1954). Further additions up to 10% increased erodibility in some soils but caused a decrease in others (Chepil 1954). A synergistic effect, due to an interaction between decomposed plant material and calcium carbonate, was reported by Chepil (1954) to substantially increase the wind erodibility of Kansas soils.

The effect of water soluble salts and adsorbed cations on dry soil aggregation has received little attention in the literature, although intuitively they would seem to be important considering their effect on the hydration of colloids. Chepil (1943) reported that a saline Val Marie Clay from Saskatchewan was particularly resistant to wind erosion. Lyles and Schrandt (1972) reported decreased erodibility on soil treated with NaCl to an electrical conductivity of 12 mS/cm. Similar additions of a 1:1 ratio of $CaCl_2$ -$MgCl_2$ and a 1:1:1: ratio of NaCl - $CaCl_2$ - $MgCl_2$ slightly increased erodibility but not significantly.

A number of researchers have attempted to fit the basic soil factors affecting dry soil aggregation into simple models to estimate soil erodibility. Shiyatyi (1972) [as reported by Zahar 1982] developed a simple equation relating resistance to wind erosion of Russian soils to soil texture, and carbonate content (which was considered to reduce erodibility). Dolgilevich et al. (1973) [as reported by Zahar 1982] reported that soil erodibility was reduced by increasing proportions of clay and by the total quantity of Ca+Mg in the soil. Briggs and France (1982) correlated dry stable aggregates in soils from England with soil properties tabulated in soil survey reports. Factors investigated were soil texture, stoniness, organic matter, and $CaCO_3$ content. The best correlation with dry stable aggregates obtained was for coarse sand, and stones (r = 0.62). In contrast, Simmons and Dotzenko (1974) obtained hig correlations (r = 0.95) between dry aggregates >0.84 mm and (1) CEC; and (2) 15 bar moisture percentage, for 14 irrigated soils in Colorado. The correlations between clay; silt; and silt and clay; and dry aggregates >0.84 mm were also excellent (r = >0.89).

Soils in North America have been categorized into Wind Erodibility Groups (WEG) based only on soil texture and carbonate content (Chepil et al. 1963; Hayes 1965). The effects of soil organic matter, adsorbed cations, and CEC are ignored. The WEG have been used extensively for soil conservation planning in the U.S.A. (Troeth et al. 1980) and are being used in Canada (Slevinsky 1983).

No published attempt has been made to integrate the basic soil factors reported to affect aggregation into a simple model for the assessment of the wind erodibility of Canadian soils. The objectives of this study were to develop such a model from the types of information typically available in soil survey reports, and in so doing, to investigate the relationship between various basic soil parameters and dry soil aggregation.

4.2 MATERIALS AND METHODS

Three hundred and seventy five samples from the Ap horizon of soils displaying a wide range of texture were taken from the Oyen, Pincher Creek and Vermilion/Flagstaff areas in the Brown, and Black soil zones of Alberta. Samples were taken in 1986 after seeding but before approximately 25% ground cover was achieved by the growing crop. Sampling procedures have been reported elsewhere (Chapter 3). Samples were air-dried, passed through a Modified Rapid Rotary Sieve (MRRS), and the proportion of soil material >0.84 mm estimated using the method described in Chapter 2.

After sieving through the MRRS, samples were re-bulked, mixed, and passed through a 2 mm sieve. Ten gram sub-samples were ground to pass a 100 mesh sieve for measurement of inorganic carbon content and total carbon.

Particle size and soil pH in water were determined following procedures detailed by McKeague (1978). The method of Bundy and Bremner (1972) was employed to determine inorganic carbon on samples which had effervesced in an acid drop test and on samples with a pH of >7.5.

Total carbon was determined by oxidation at 1300°C an oxygen stream using a resistance furnace (Leco Carbon Determinator CR12). Organic carbon was calculated by the difference between the total carbon and inorganic carbon data.

Adsorbed cations from soils containing inorganic C were extracted with barium chloride - triethanolamine using the method recommended by Thomas (1982). Soils containing no inorganic C were leached with ammonium acetate (McKeague 1978) to extract the cations. Exchangeable Ca^{++} and Mg^{++} were determined by flame photometry, Na^{+} and K^{+} by atomic absorption. Total extractable cations (TEC) were calculated by summation of individual cations.

The proportion of sand particles >0.84 mm was calculated and subtracted from the sieving data in order to assess the effects of factors affecting dry aggregation on aggregates alone (Chapter 3). This gives the percentage of true aggregates (%TA) (Kemper 1965).

A multiple stepwise regression analysis (SAS Institute Inc. 1987) was employed to investigate the relationship between %TA >0.84 mm and several laboratory variables (Table 4.1). Residuals were plotted as a function of each variable to test for homoscedastictity of the variable and to indicate the necessity for data transformations (Draper and Smith 1981). Variables, if significant using an F test, were retained in the model up to the number suggested by a Mallows Cp test (SAS Institute Inc. 1987).

Data sets for multiple regression must be complete for each variable. Since not all samples contained soil carbonates, the data from the samples was split into two groups, those containing carbonates and those without. The method developed in Chapter 2 to estimate the proportion of soil material >0.84 mm was applied to the sieving data for each sample. Insufficient data were obtained for 23 samples; these samples were rejected. Of the 352 samples remaining, 116 samples contained carbonates.

4.3 RESULTS AND DISCUSSION

The soil samples had textures ranging from heavy clay to sand (Table 4.2). Clay content varied from 3% to 69%, sand content from 15% to 93%, and silt from 4% to 53%. TA calculated from the sieving data varied from 2.9 to 93.4%. Loose sand >0.84 mm was estimated at between 0.0 to 17.3%.

Total carbon ranged from 0.6% to 7.9%. Inorganic carbon was measured in 116 of the samples; content ranged from a trace to 2.12% (equivalent to 17.7% $CaCO_3$). Generally, soils in the Pincher Creek Area had a higher content of carbonates than soils from the other sampling areas due to the effects of previous erosion.

Exchangeable calcium varied from 2.7 to 46.4 meq/100 g, magnesium varied from 0.7 to 33.9 meq/100 g, and sodium and potassium varied from 0.04 to 2.5 meq/100 g and from 0.4 to 4.5 meq/100 g respectively. Total exchangeable cations varied from 5.2 to 79.3 meq/100 g and pH from 4.6 to 8.3.

The relationship between %TA estimated for the soils containing carbonates and the variables listed in Table 2 was determined using multiple regression and correlation. Variables representing soil carbonates in linear and parabolic relationships were not significant. In addition compound variables employed to search for synergism in the effects of $CaCO_3$ combined with organic matter were not significant. These results indicated, for the 116 soils containing $CaCO_3$, that soil carbonates had no effect on soil erodibility. Consequently the relationship between %TA and the remaining variables was examined for the full data set (352 samples).

The rejection of carbonates as non significant appears to be inconsistent with the field-obtained results in Chapter 3 which displayed a decrease in %TA due to the presence of carbonates. The inconsistency is an artifact resulting from the method of statistical analysis. In Chapter 3 the carbonate data was grouped and treated as three dummy variables using all 352 samples. In this paper, the carbonate data are treated as a continuous variable; as a result the regression analysis could only consider the effects of carbonates on TA for the 116 samples containing carbonates. These samples represented soils predominantly from the Pincher Creek and Oyen areas which were generally medium to heavy in texture. The results reported in Chapter 3 are similar to those reported by CDA (1949) and Chepil (1954). The effect of carbonates in the 116 soils containing $CaCO_3$ may be confounded by other variables; a controlled experiment is required to elucidate these results.

In contrast to the results of Simmons and Dotzenko (1974), the variable TEC had a low simple correlation ($r = 0.46$) with %TA. TEC was highly correlated ($r = - 0.72$) with medium + coarse sand; the variable which had the highest correlation with %TA. Exchangeable Ca and % clay were also highly correlated with TEC ($r = 0.97$ and 0.87 respectively). TEC therefore exhibited multicollinearity with its influence on %TA being duplicated by the correlated variables. Consequently TEC was dropped from the analysis. The effect on the multiple regression coefficient was minor, confirming that the variable made no significant contribution to the model.

Dry aggregation in the soils studied was dominated by the effects of soil texture (Table 4.3). Medium + coarse sand had the highest simple correlation with %TA ($r = -0.64$), followed by total sand, organic carbon and adsorbed potassium ($r = -0.60$, $+0.40$, $+0.23$ respectively).

An arcsin transformation which is sometimes recommended for percentage data did not improve the multiple correlation coefficient and so was not employed. A plot of the residuals against the independent variables was homoscedastic confirming that transformation was not required (Draper and Smith 1981).

The multiple regression equation developed was:

$$\%TA = 70.1 - 1.05A - 0.73B + 4.23C - 5.67D$$

where; A = % medium and coarse sand

B = % very fine sand

C = % organic carbon

D = meq K/100 g soil

The multiple correlation coefficient for the relationship was 0.71 which explains 50% of the variability measured in the samples.

All variables retained were very highly significant ($p = 0.001$). An examination of the regression coefficients showed that increasing proportions of medium and coarse sand, very fine sand, and of adsorbed potassium reduced the % TA >0.84 mm thereby increasing soil erodibility.

The effect for medium and coarse sand and very fine sand is similar to that reported by Chepil (1955a), Shiyatyi (1972) [as reported by Zahar 1982], and Briggs and France (1982). Homoscedasticity of a plot of the residuals (Draper and Smith 1981) for medium and coarse sand and for very fine sand against each independent variable suggests a linear relationship with % TA, rather than the curvilinear dependence reported by Chepil (1955a) for artificial soils. Interactions with other variables in whole soils probably have a confounding influence.

The effect of potassium on soil erodibility appears to be large in relation to the other variables and has not been reported previously. This could be particularly significant with regard to the wind erodibility of Prairie Soils which generally have a high potassium content (Beaton 1980). The mechanism causing the effect of potassium on TA requires elucidation. It is probably not due to the effect of potassium on the hydration of colloids since the exchange complex is dominated by calcium in all samples. The non significance of Ca/K and (Ca+Mg)/(Na+K) variables would tend to confirm this hypothesis. Martin and Aldrich (1955) reported that the binding action of polymers with uronic acid groups to soil particles decreased with increasing base saturation in the presence of K^+ and Ca^{++} ions. This indicates that potassium may have some effect on the bonding between polysaccharides and soil particles and thus on dry aggregates.

Increasing quantities of organic carbon increase % TA thereby reducing soil erodibility. In light of the results by Chepil (1955b) discussed previously, this suggests that the effect of the relatively fresh decomposition products from straw breakdown dominates the effects of the more highly decomposed fraction of the organic matter in the soils studied.

The relationship obtained explains only 50% of the variability in %TA. Not all of the basic soil factors which have been reported to affect dry soil aggregation were investigated. The inclusion of clay mineralogy and water soluble salts may have improved the relationship. However, the effects of soil management and the dynamic factors affecting aggregation are also significant (Chapter 3). The effects of rotations, crop residue management, and crop yields will be reflected in the types and quantity of cementing compounds in the rhizosphere and of crop residue breakdown products. These compounds are dynamic and make up a small proportion of the total organic matter (Smika and Grebb 1975, Baldock et al. 1987). Therefore, a variable representing total % organic carbon may underestimate the importance of these compounds. Further research in this area is necessary.

4.4 CONCLUSIONS

The relationship developed to predict TA from basic soil factors explained only 50% of the variability in the samples investigated. This is probably due to the influence of dynamic and soil management factors which were not investigated. Attempts to estimate %TA using analytical data from soil reports rather than from analysis of samples collected specifically for this purpose would be less successful due to the additional effects of soil variability. A model to estimate TA from field obtainable parameters has better potential since it can include factors representing soil management and can accommodate field variability through a suitable sampling strategy.

The compounds released from plant roots and by decomposition of straw which affect the dry aggregation of Canadian soils require further identification and evaluation. In addition the effects of $CaCO_3$ and adsorbed K^+ require further quantification. Clearly much remains to be elucidated about the effects of soil factors responsible for dry soil aggregation.

Table 4.1. List of variables examined in the multiple regression analyses.

Total % sand
% medium+coarse sand (>250 µm)
% fine sand (100-250 µm)
% very fine sand (50-100 µm)
Total % silt
% coarse silt (50-10 µm)
% medium silt (5-10 µm)
% fine silt (5-2 µm)
Total % clay
pH
% inorganic carbon (IC)*
% organic carbon (OC)
IC^2
OC^2
1/IC
$1/IC^2$
IC+OC
IC*OC
$(IC+OC)^2$
Adsorbed Ca (meq/100g)
Adsorbed Mg (meq/100g)
Adsorbed Na (meq/100g)
Adsorbed K (meq/100g)
Total extractable cations (T.E.C.)
Adsorbed Ca/K
Adsorbed Na+K (meq/100g)
Adsorbed Ca+Mg (meq/100g)
Adsorbed Ca+Mg+Na (meq/100g)
Adsorbed Ca+Mg/Na+K

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* Variables containing IC alone and combinations with OC were only examined in the exploratory model investigating the effects of inorganic carbonates on %TA.

Table 4.2 Textures and average clay and sand content of the soils sampled

Texture	#	%Clay	s*	%Sand	s*
Heavy clay	27	63.7	2.6	6.7	3.9
Clay	74	49.7	6.3	19.6	6.2
Silty clay	5	49.6	5.7	10.2	4.4
Silty clay loam	2	35.0	7.1	18.5	0.7
Silt loam	3	23.3	6.4	26.3	4.2
Clay loam	72	32.9	3.7	33.0	5.3
Loam	101	23.3	3.7	41.3	5.9
Sandy clay loam	11	23.4	2.7	53.3	4.1
Sandy loam	57	14.2	3.5	62.4	6.2
Loamy sand	21	6.5	2.0	81.1	3.7
Sand	2	5.0	2.8	90.0	2.8

# = number of samples
s = standard deviation

Table 4.3. Correlation matrix of the variables remaining after multiple regression analysis.

TA	M+CS	VFS	OC	K	
1.0	-.64	-.36	.40	.24	TA
	1.0	.35	-.27	-.56	M+CS
		1.0	-.13	-.29	VFS
			1.0	.09	OC
				1.0	K

TA = % true aggregates
M+CS = % medium+coarse sand
VFS = % very fine sand
OC = % organic carbon
K = adsorbed potassium (meq/100g)

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CHAPTER 5

THE EFFECT OF FIELD AND LABORATORY ESTIMATED PARAMETERS ON THE DRY AGGREGATE STABILITY OF ALBERTA SOILS AFTER SEEDING

5.1 INTRODUCTION

The proportion of dry soil aggregates >0.84 mm and the mechanical stability of those aggregates have been reported to be the most important factors affecting the wind erodibility of dry soils (Chepil 1958; Skidmore and Powers 1982). The relative importance of aggregate stability varies with the surface roughness and the area of the field. For small fields the proportion of aggregates >0.84 mm has a dominant effect on subsequent erosion. For large fields the stability of aggregates >0.84 mm is the more important factor due to the abrasion caused by saltating particles (Chepil 1951; Chepil and Woodruff 1963; Hagen 1983). Field sizes on the Canadian Prairies are generally increasing to accommodate wider farm equipment (Coote et al. 1981; PFRA 1983); consequently the effects of aggregate stability in controlling wind erosion must be increasing in importance.

Chepil (1953) reported that aggregates large enough to resist movement by most erosive winds are predominantly compound soil units. These "secondary aggregates" were reported to consist of a number of water stable aggregates bound together by water dispersible cements. Grossman and Cline (1957) and Rogowski et al. (1968) reported that dry aggregate strength, as measured by crushing, increased as the proportion of clay in samples increased. Powers and Skidmore (1984) crushed dry aggregates and, using electron microscopy, identified organic and soluble clay bonds as being responsible for dry aggregate strength in Typic Argiudolls from Kansas. Hadas (1986) stated that the strength of dry aggregates is dependent on the specific surface area of the soil, and that $CaCO_3$, organic matter, and Fe_2O_3 bonds maintain the integrity of aggregates.

Aggregate stability to the effects of sandblast by saltating particles may not be directly related to the crushing resistance of dry aggregates, particularly when the aggregates are considerably larger than the impacting particle. Nevertheless, the results discussed above may provide some insight to the factors contributing to the wind erodibility of larger fields.

Chepil (1951) reported that the resistance of dry soil aggregates to abrasion in a wind tunnel varied with soil textures in the order SiC>SiL>L>FSL. Chepil (1951, 1953) compared repeated sieving of aggregates in a rotary sieve to abrasion in a wind tunnel and concluded that repeated sieving was a good measure of aggregate stability to abrasion.

Repeated sieving was used by Toogood (1978) to investigate the stability of dry aggregates 1-2 mm diameter from a wide range of Alberta soils. Simple correlation coefficients for clay, sand, and organic matter were 0.55,

-0.46, and 0.32 respectively. Arshad and Mermut (1988) used Toogood's methodology to investigate the factors contributing to the stability of aggregates from surface crusts from six soils from the Peace River Region of Alberta. Simple correlation coefficients (r) of 0.80 and 0.78 were obtained between aggregate stability and, Al_o extracted by NH_4 - oxolate, and, pH in $CaCl_2$ respectively. The correlations for clay and sand were 0.72 and -0.48 respectively which corresponded well with Toogood's (1978) results.

Dry aggregate stability is a dynamic property; it is affected by recent weather, cropping, and tillage. Chepil (1958) reported that aggregate stability is generally greater in the fall than in the spring. Langman (1985) found that spring tillage reduced aggregate stability for sandy soils but not for a clay loam. Armbrust et al. (1982) reported that aggregates from Kansas soils under continuous wheat were more stable than those under continuous sorghum; and that those under continuous soybeans were the least stable of the three crops. Aggregates in tilled soils were more stable than those when herbicides were used alone or in combination with tillage.

The objectives of this study were to evaluate the effects of: (1) field obtainable parameters and (2) static soil properties on soil aggregate stability as estimated using dry sieving.

5.2 MATERIALS AND METHODS

Soils displaying a wide range of properties were sampled in the Oyen; Pincher Creek and Vermilion/Sedgewick areas in the Brown, and Black soil zones respectively of Alberta during the spring of 1986. Sampling procedures have been reported elsewhere (Chapter 3). Rotation, tillage and crop residue management information was obtained for each parcel from the respective producers. After airdrying, samples were sieved in a Modified Rapid Rotary Sieve and the weight of material passing recorded for 30 second increments until 30 seconds after region 2 sieving (Whitby 1958) was attained (Chapter 2).

Particle size analysis, pH, organic carbon, inorganic carbon, and adsorbed cations were determined using standard procedures as described previously (Chapter 4).

An index representing the average rate of aggregate breakdown in the sieve (G) was calculated for each sample using the method developed in Chapter 2:

The equation to estimate G is:

$$G = \frac{1-m}{(2-m)T} \qquad (1)$$

where: m is a sieving parameter which varies with the rate of aggregate breakdown in the sieve, and

T is the time at which no more material is estimated to pass through the sieve.

Samples with low values of G have more stable aggregates than those with higher values of G, Multiple stepwise regression analysis (SAS Institute. Inc. 1987) was used to investigate the relationship between the stability index (G) and: (1) field variables (2) laboratory variables. The variables investigated in each model are listed in Table 5.1.

5.3 RESULTS AND DISCUSSION

A total of 375 samples was taken from the three sampling areas; of these, 23 samples had insufficient data to apply the model developed by Black et al. (a) [Chapter 2] which estimates the average rate of aggregate comminution during sieving. A wide range of soil textures was sampled; as a result field and laboratory measured parameters displayed the variability requisite for multivariate analysis. (Black and Chanasyk; Black et al. (b) (Chapters 2 and 3).

Values for the index G varied between 0.32 and 0.06 g/min. The relationship developed from the field variables had a multiple correlation coefficient (R) of 0.50. Although this relationship was significant at the 1% level using an F test (Zar,1974) it explained only 25% of the variability in G suggesting that untested variables play a significant role in aggregate stability. The results of Lyles and Woodruff (1962) indicate that moisture content at tillage may be important.

The regression equation relating aggregate stability to the field variables was:

$G = 0.256 + TEXT + CARB + ROT + POST$

Where:

TEXT = 0.000 for soils with a texture of dune sand

-0.058 for loamy sand

-0.108 for sandy loam

-0.127 for sandy clay loam

-0.112 for loam

-0.142 for silt loam

-0.101 for clay loam

-0.154 for silty clay

-0.166 for silty clay loam

-0.097 for clay

-0.099 for heavy clay

CARB = 0.000 for soils with 0 -0.4% $CaCO_3$

+0.019 for soils with 0.41 - 5% $CaCO_3$

+0.013 for soils with >5% $CaCO_3$

ROT = 0.000 for fields cropped in a small grain-fallow rotation

+0.017 for fields in a continuous small grain rotation

+0.053 for fields in a continuous small grain-oilseed rotation

+0.010 for fields in a small grain-small grain-oilseed rotation

+0.012 for fields in an oilseed-small grain-summerfallow rotation.

POST = 0.000 for fields with no separate post-seeding packing operations

-0.045 for fields with separate post-seeding

packing operations.

Table 5.2 is a correlation matrix of the variables which were retained after the analysis. The highest simple correlation coefficient (r) between G and an individual variable was for the effect of continuous small grain-oilseed versus small grain-fallow rotations on aggregate stability (r = 0.23). The effect of loamy sand versus dune sand and, post-seeding packing versus no post-seeding packing had the next largest r values (r = 0.172 and -0.161 respectively). Correlation between independent variables was low, indicating a desired lack of bias in the multiple regression coefficients (Weslowski, 1976).

The index G represents the average rate of aggregate breakdown during sieving. Consequently low values of G indicate stable aggregates. Examination of the estimated regression coefficients (listed above) shows that soil texture had the largest effect on aggregate stability compared to the other significant variables. Soil textures fell into four groups in relation to aggregate stability: SiCL, SiC, SiL>SCL, SL, L CL, HC, C > LS> DS. This result is almost identical to that reported by Chepil (1951 and 1958) and is very similar to that reported by Chepil (1945).

Carbonates in samples displaying weak effervescence ($CaCO_3$ content 0.04 - 5%) and those with a stronger reaction had a small but significant effect in decreasing aggregation as indicated by low positive regression coefficients. This result is similar to that reported by Chepil (1954) who reported decreased stability of aggregates up to approximately 3% $CaCO_3$.

Extended rotations in relation to small grain-fallow rotations reduced aggregate stabilities but the effect was small in relation to the effects of soil texture.

The regression coefficient for post-seeding packing operations suggests a slight increase in aggregate stability. Packing could be expected to pulverize friable aggregates so that those remaining would be on average more stable than the average if a packing operation not been used.

Preliminary analysis examining the relationship between laboratory parameters and G indicated that soil carbonates in the 116 samples containing carbonates had no effect on aggregate stability. This apparent contradiction between the effects of carbonates in a field model and a laboratory model is similar to that found earlier for the proportion of aggregates >0.84 mm (Chapter 4). The discrepancy can be attributed to the different statistical techniques used in the field versus the laboratory models and, to confounding effects due to other unmeasured variables (Black et al.(b). [Chapter 4). Chepil (1954) reported that aggregates from high-lime soils were less stable than low-lime soils thus tending to confirm the field model.

The relationship obtained between aggregate stability for all 352 samples and laboratory-measured variables was also low. The multiple correlation coefficient was 0.31 which explained only 10% of the variability in aggregate stability. The variables retained were total sand and total silt, both of which had a small effect of increasing aggregate stability as evidenced by small negative low multiple correlation coefficients.

The poor correlation between aggregate stability and the results of particle size analysis is consistent with the model developed for field parameters. The complex relationship between soil mineral fractions and soil texture render it unlikely that a good relationship could be obtained between individual size fractions and stability of aggregates from whole soils. In addition, secondary aggregates are composed of assemblages of water stable aggregates. It is probable that only a small proportion of the total organic matter content and clay in any soil will be responsible for linking water stable aggregates together into dry aggregates. Consequently it is not surprising that the model based on laboratory parameters was unsuccessful in explaining the observed variability of aggregate stability.

Toogood (1978) and Arshad and Mermut (1988) obtained good correlation between aggregate stability and, various soil mineral size fractions, pH, and soil organic matter. These results were for aggregates of 1-2 mm diameter for a limited number of soils. Toogood (1978) noted that the mechanisms of aggregate stability may vary between soil types, soil management systems, and between regions. The mechanisms may also vary with aggregate size. If these hypotheses are correct, it is not surprising that the results of this experiment were inconclusive since all aggregates >0.84 mm from a wide range of soils were studied. A scanning electron microscope study such as that employed by Toogood (1978) may help to resolve the factors responsible for aggregate stability.

5.4 CONCLUSIONS

The stability of dry aggregates >0.84 mm to dry sieving in the soils examined is strongly related to soil texture and is affected by soil carbonates, crop rotations and post-seeding packing operations. Other unmeasured variables such as moisture content at time of tillage and the content of Alox may also significantly effect dry aggregate stability.

It is likely that dry aggregate stability in Canadian Chernozemic soils may be related to a small proportion of the clay and organic matter present, rather than the total content.

Given the importance of aggregate stability in determining the wind erodibility of large fields, further research in this area is required.

Table 5.1. List of variables investigated in the field and laboratory models.

Field Model	Laboratory Model
Soil texture	Total % sand
Coarse sand (>250 µm)	% Medium and coarse sand (>250 µm)
Soil Colour (Munsell Value)	% Fine sand (100-200 µm)
Aspect (4 compass points)	% Very fine sand (50-100 µm)
Crop - s/f previous year	Total % silt
Residue type	% Coarse silt (50-10 µm)
Residue quantity	% Medium silt (5-10 µm)
# preseed tillage operations	% Fine silt (5-2 µm)
Seeding implement	Total % clay
Post seed tillage implement	pH
	% Inorganic carbon (IC)*
	% Organic carbon (OC)
	IC + OC
	$(IC + OC)^2$
	(IC * OC)
	OC/IC
	Adsorbed Ca (meq/100g)
	Adsorbed Mg (meq/100g)
	Adsorbed Na (meq/100g)
	Adsorbed K (meq/100g)
	Total extractable cations
	Geometric mean diameter of the mineral fraction

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* Variables containing IC alone and in combination with OC were only examined in the exploratory model investigating the effects of inorganic carbonates on the index G.

Table 5.2 Correlation matrix for stability index Vs field variables remaining after the multiple regression analysis

G	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	
1.0	.17	-.08	-.07	-.12	-.10	-.01	-.10	-.06	.08	.06	.10	.05	.14	.23	-.04	-.05	-.16	G
	1.0	-.10	-.04	-.13	-.02	-.12	-.03	-.01	-.11	-.07	-.12	-.07	-.08	.03	-.05	-.09	-.03	D1
		1.0	-.07	-.23	-.04	-.22	-.05	-.02	-.20	-.13	-.18	-.12	-.10	.08	.15	-.14	.02	D2
			1.0	-.09	-.02	-.09	-.02	-.01	-.08	-.05	.01	.10	.07	-.05	-.05	.10	-.02	D3
				1.0	-.05	-.30	-.06	-.03	-.28	-.17	-.17	-.13	-.24	.22	.10	.04	.15	D4
					1.0	-.05	-.01	-.01	-.05	-.03	-.05	-.03	-.05	-.03	-.03	-.04	-.01	D5
						1.0	-.06	-.03	-.25	-.16	-.02	-.04	-.04	-.13	-.02	.25	-.06	D6
							1.0	-.01	-.05	-.03	.01	.07	.12	-.03	-.04	-.04	-.01	D7
								1.0	-.26	-.02	.10	-.01	-.03	-.02	-.02	-.02	-.01	D8
									1.0	-.14	.31	.18	.20	-.14	-.14	-.10	-.06	D9
										1.0	.21	.16	.27	-.09	-.10	-.11	-.04	D10
											1.0	-.15	.2	-.15	-.17	-.20	-.06	D11
												1.0	.30	-.08	-.10	-.11	-.03	D12
													1.0	-.17	-.10	-.11	-.04	D13
														1.0	-1.0	-.11	-.04	D14
															1.0	-.13	-.04	D15
																1.0	-.05	D16
																	1.0	D17

G = Stability index
D1 = Dummy variable comparing the effect of loamy sand to sand on G.
D2 = Dummy variable comparing the effect of sandy loam to sand on G.
D3 = Dummy variable comparing the effect of sandy clay loam to sand on G.
D4 = Dummy variable comparing the effect of loam to sand on G.
D5 = Dummy variable comparing the effect of silt loam to sand on G.
D6 = Dummy variable comparing the effect of clay loam to sand on G.
D7 = Dummy variable comparing the effect of silty clay to sand on G.
D8 = Dummy variable comparing the effect of silty clay loam to sand on G.
D9 = Dummy variable comparing the effect of clay to sand on G.
D10 = Dummy variable comparing the effect of heavy clay to sand on G.
D11 = Dummy variable comparing the effect of 0.41-5% $CaCO_3$ to the effect of 0-0.4% $CaCO_3$ on G.
D12 = Dummy variable comparing the effect of >5.01% $CaCO_3$ to the effects of 0-0.4% $CaCO_3$ on G.
D13 = Dummy variable comparing the effect of a continuous small grain rotation to a small grain-fallow rotation on G.
D14 = Dummy variable comparing the effect of a small grain-oilseed rotation to a small grain-fallow rotation on G.
D15 = Dummy variable comparing the effect of a small grain grain-oilseed rotation to a small grain-fallow rotation on G.
D16 = Dummy variable comparing the effect of a oilseed-small grain fallow rotation to a small grain-fallow rotation on G.
D17 = Dummy variable comparing the effect of post seeding packing to no post seeding packing on G.

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CHAPTER 6

6.1 DISCUSSION OF PROJECT RESULTS

Chapters 2-5 explored specific objectives which were established in order to address the project goals listed in Chapter 1. This chapter discusses the project results in relation to these goals, it also examines some of the broader implications of the results.

GOAL #5

To develop a method to evaluate aggregate comminution during sieving in the MRRS.

A model to estimate aggregate comminution during sieving was developed which successfully fitted the sieving curves of 98% of the samples tested. This model is an improvement over previous methods because it separates the sieving from the milling process during soil sieving. Utilization of the model will provide a better estimate of actual field aggregation than previous methods and will result in better estimates of soil erodibility.

GOAL #1

To compare the proportion of material >0.84 mm from a wide variety of Alberta soils to estimates made using the North Dakota Wind Erodibility Groups.

The WEG were tested for a large number of Alberta soils and were found to provide a poor estimate of soil aggregation after seeding. This result is consistent with most reported results for soils of the Canadian Plains and confirms that another method to estimate the material resisting wind erosion is required for these soils. The result has very significant implications for soil conservation planning using the WEQ. A poor estimation of soil erodibility based on the WEG could result in the recommendation of inappropriate conservation practices and in inaccurate resource monitoring data.

GOAL #2

To develop a regression model to predict the proportion of dry aggregates >0.84 mm in Alberta soils from field-obtainable parameters with sufficient precision for use in the Wind Erosion Equation.

A regression model using field-obtainable parameters explained 60% of the variability of the proportion of dry aggregates in soil samples. Soil texture, carbonate content and tillage variables were identified as important determinants of dry aggregation. The results were obtained from a wide variety of Alberta soils after seeding in 1986. Thus it is possible to use regression models to estimate dry soil aggregation with sufficient precision for use in the Wind Erosion Equation. This approach is therefore a viable replacement for the WEG.

The regression model quantifies the importance of soil management in determining dry aggregation and thereby the erodibility of soil by wind. The effect of soil management on large wet-stable aggregates has been well accepted (Tisdall and Oades 1982) but has received little attention for dry soil aggregation. Consequently it will be possible to suggest management alternatives which will increase soil aggregation in situations where crop residues are insufficient to control erosion.

GOAL #3

To develop a regression model to predict the proportion of aggregates >0.84 mm in Alberta soils from the analytical information typically obtainable in soil survey reports.

A regression model employing the type of analytical data typically available from soil survey reports was successful in explaining 50% of the variability of the proportion of dry aggregates in the soils studied. The model isolated sand as the most important soil component in the determination of dry aggregation, thereby confirming the field model.

After further evaluation, this type of regression model could be used to replace the WEG in the estimation of wind erosion potential for inventory and planning purposes.

GOAL #4

To build a regression model to predict the stability of aggregates >0.84 mm in Alberta soils from soil, and soil management factors.

The relationship between aggregate stability; and field and laboratory parameters was investigated. The stability of aggregates was not well explained by the regression models developed, suggesting that soil management has less effect on aggregate stability than on the proportion of dry aggregates >0.84 mm in soils. Conservation strategies on exhibiting low aggregate stability must therefore concentrate on preventing the initiation of wind erosion rather than relying on the presence of stable aggregates to minimize soil loss as an event progresses. Such practices would include the maintenance of adequate crop cover and the adoption of annual or perennial barriers. Strip cropping will not be beneficial on such soils since this practice relies on stable aggregation to minimize erosion. Implements designed to form large aggregates will also be of minimal utility on soils which do not form stable aggregates.

The project results provide a number of suggestions for further research; these are discussed in Chapter 7.

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CHAPTER 7

7.1 CONCLUSIONS

(1) The 0.5 minute sieving time recommended by Fryrear (1985) for sieving of soils in the MRRS was not suitable for the samples studied. This was due to the mechanics of the sieving process and due to differences in the behaviour of soils during sieving.

(2) The method developed to estimate and compensate for aggregate comminution in the MRRS was successful and provides a better estimate of field conditions than previous methods.

(3) The WEG used in North Dakota do not successfully estimate the proportion of soil material resisting wind erosion in Alberta soils.

(4) Although soil texture and $CaCO_3$ content strongly influence the proportion of soil aggregates >0.84 mm the superposition of tillage operations may have an overriding effect on soil erodibility.

(5) A comprehensive model could be developed from field estimated parameters to evaluate the proportion of aggregates >0.84 mm in soils from the Canadian Plains with sufficient precision for soil conservation planning.

(6) A model to estimate the proportion of dry soil aggregates >0.84 mm solely from data published in soil survey reports would have insufficient precision for on-farm soil conservation planning due to the large spatial

variability of this parameter. Program planning would require less precision; however, soil survey coverage at an adequate scale to employs the type of model proposed is incomplete for large areas of the Canadian Plains.

(7) The basic soil factors correlated to dry aggregation are, medium and coarse sand, very fine sand, organic matter, and adsorbed K^+.

(8) The stability of dry aggregates >0.84 mm is not well defined by the total amount of particular soil constituents or by soil management.

(9) The role of $CaCO_3$ in dry soil aggregation and in the stability of aggregates is not well defined due to the interactions of other unknown factors.

7.2 SUGGESTIONS FOR FURTHER RESEARCH

In order to provide an accurate appraisal of the wind erodibility of soils for on-farm soil conservation planning, inventory, and monitoring, all the significant factors affecting dry soil aggregation must be included into a comprehensive model. A schematic conceptualization of the factors reported to contribute to the wind erodibility of soils was presented in Chapter 3. Time constraints dictated that several of the listed factors could not be investigated in this project. Basic soil factors such as clay species, Al and Fe Ox content, and the specific plant decomposition products responsible for dry soil aggregation remain to be investigated thoroughly. The effects of wetting and drying, and the interaction of clay quantity and speciation with soil moisture content as it affects the over-winter breakdown of dry aggregates should be integrated into any model predicting the wind erodibility of soils from the Canadian Plains.

Other aspects of soil management may have a large effect on dry soil aggregation. The setting, speed, depth of operation, and sequence of tillage implements employed may be particularly important, together with the soil moisture content at which tillage takes place. The effects of crop types and yields on dry soil aggregation require further investigation. Controlled experiments are requied to clarify the effects of soil management so that improved conservation strategies can be developed.

A wind tunnel study is required to relate the sieving data using the method developed in Chapter 2 to that developed using previous methods. This is required since the aggregates >0.84 mm estimated using the new method are more fragile than those which are identified using existing sieving techniques. As a result erosion from a soil with a given proportion of materials >0.84 mm will be greater when this fraction is estimated by the new method.

The role of $CaCO_3$ in dry soil aggregation requires further evaluation. Chepil (1954) suggested that the effect of $CaCO_3$ is largely a physical effect due to the size of the $CaCO_3$ crystals (silt-sized). If this is correct, an investigation of any interaction between $CaCO_3$

and silt in soils may be revealing. Such a correlation was not observed in the samples but may have been confounded by other interactions. The synergistic effects of $CaCO_3$ with organic matter reported by Chepil (1954) were not detected in the analysis reported in Chapter 3. A series of controlled experiments is required to explore the effects of $CaCO_3$ and these other soil constituents on dry soil aggregation.

The laboratory model identified adsorbed K^+ as having significant effect on dry aggregation. If confirmed in a controlled experiment this result may help explain why soils from the Canadian Plains are more erodible than soils of similar texture in the USA (Chepil 1955).

A thorough examination of dry soil aggregates at a microscopic scale is required to elucidate the precise physical and chemical relationship between soil constituents contributing to the proportion and stability of dry aggregates in soils. Only a fraction of the total quantity of a particular component may be involved in bonding the primary water stable aggregates into secondary units. Further work is required to elucidate the relationships suggested by this project.

Toogood (1978) suggested that the mechanisms responsible for aggregation and aggregate stability may be different for each soil type, region, and management system. If he was correct, a considerable amount of work remains to be done on dry soil aggregation.

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8.1 APPENDIX 1

A study of the effect of different amounts of soil material >0.84 mm on soil loss estimated using the Wind Erosion Equation.

In order to design a sampling strategy to investigate the effects of soil properties and management on dry soil aggregation, it was necessary to gain an appreciation of the effect of different amounts of aggregation on estimated soil loss.

Estimates of soil loss were made using the Wind Erosion Equation (WEQ) [Woodruff and Siddoway, 1965] which is the only model in common use in North America for the estimation of wind erosion. The equation is:

$$E = f(I,K,C,L,V)$$

Where E = estimated long term average annual soil loss (tons/ac)

I = a soil erodibility factor

K = a surface roughness factor

C = a climatic factor

L = an unsheltered fieldwidth factor

V = a vegetative factor

The factors in the equation are discussed by Woodruff and Siddoway (1965). Only the soil erodibility (I) factor is of importance to this discussion. The I factor represents the average annual soil loss from a wide, bare, non-crusted soil surface at Garden City, Kansas. The factor was derived from wind tunnel studies and is directly related to the proportion of soil material >0.84 mm in a soil sample (Chepil, 1958). The I factor is modified by topography for use in the WEQ. In the equation, the I factor is established first and modified by the other factors in order to estimate soil loss for a field under consideration.

The WEQ has not yet been converted to metric units. Consequently, in this appendix calculations have been made using imperial units and converted to their metric equivalents.

A sensitivity analysis was conducted holding L constant at 182.9 m (600 ft) and V constant at 1136.4 kg ha^{-1} (1000 lb/ac) of flat small grain residue. Three separate sets of calculations were made with C set at 100, 80 and 60 respectively. The I factor was varied to correspond with soil material >0.84 mm from 5 to 50% and appropriate K factors were taken from Table 1.1.

The results of the analysis are shown in Figure 7.1. As anticipated a C factor of 100, representing the most erosive climate, resulted in larger estimated soil losses than the other two C factors. The break-points in each curve between 20 and 25% soil material >0.84 mm and between 45 and 50% are due to the changes in the K factor which occur at these points. Those break-points are spurious and could be removed by a more precise estimate of soil roughness. Estimated soil loss is high at low percentages of soil material >0.84 mm and low when percentages are higher. The curves are exponential showing a reduced sensitivity to changes in aggregation as the proportion of aggregates in the soil increases.

Soil erosion tolerances have been developed which relate soil loss to long term soil productivity. In the U.S.A. these are set at between 4.4 and 11.2 tonnes ha^{-1} (2-5 tons/ac) and are used to design soil conservation practices using the WEQ (PFRA, 1983). The precision of soil loss estimates thus becomes more important below approximately 22 tonnes ha^{-1}. (Any practice which results in estimated soil losses larger than 11.2 tonnes ha^{-1} is inadequate for erosion control. For soil conservation planning precise estimates of soil loss much above this figure are not necessary). From Figure 8.1 it is apparent for soil losses below 22 t/ac that a precision in estimating aggregation to 10% would estimate soil loss within 3.6 tonnes ha^{-1} and a 5% precision would estimate soil losses to within 2.0 tonnes ha^{-1} . It was concluded that estimating soil material >0.84 mm to a precision of 5% to 7% would be adequate for soil conservation planning purposes.

8.2 APPENDIX 2

A study to investigate the field variability of dry soil material >0.84 mm.

Wind Erodibility Groups (WEG) are commonly used to estimate the proportion of dry soil material for use in the Wind Erosion Equation. Soils are placed into groups having a similar proportion of dry soil aggregates according to their texture and carbonate content (Table 1.1). Since surface soil texture may vary within a short distance due to factors such as topography, erosion, and variations in soil parent material it was anticipated that dry soil material >0.84 mm would also vary accordingly.

The objectives of the experiment were (1) to investigate the variability of dry soil material (>0.84 mm) within one soil map polygon in relation to soil texture and (2) to use the results of this experiment to design a sampling program for the main project. A Black Chernozemic Loamy Sand polygon derived from fluvial material located 10 km north of Two Hills, Alberta was sampled. The Two Hills area was chosen because it is close to Edmonton and because the Alberta Soil Survey was working in the area. A loamy sand polygon was chosen because these soils tend to be very variable in soil properties due to past erosion.

Within the polygon three fields were sampled on a 100 m grid in September 1985. A total of 48, 3-4 kg samples were taken at a 0-4 cm depth and placed in rigid trays. The adjoining soil was hand textured. Samples were air-dried and passed through the Modified Rapid Rotary Sieve. The amount of material passing the sieve was recorded at 0.5 minute intervals. Samples were sieved to one increment beyond the beginning of Region 2 (Whitby 1958) which was identified by a marked reduction in the rate of passage of material. The material retained at the beginning of region 2 sieving was taken to be sand + aggregates >0.84 mm. Samples were grouped into textural classes and the mean and standard deviation for the population calculated (Table 8.2). From this data the number of samples required to estimate the mean proportion of material (>0.84 mm to 5% and 7% with a 95% probability of being correct) was calculated using:

$$n = \frac{4\,s^2}{L^2}$$ Equation 8.2.1 (Zalik 1983)

Where n = number of samples required

s = standard deviation, and

L = desired level of precision (5 or 7%).

Hand texturing revealed some variability within the soil polygon as anticipated. Only half of the 48 samples were loamy sand corresponding to the dominant soil texture in the soil polygon. The remainder were sandy loam and [illegible] loam (Table 8.1). The sieving results displayed a wide range within soil textural groupings with loamy sand [illegible] largest variability in aggregation, ranging from [illegible] 4.5%; sandy loam and light loam soils had similar but lesser variability (Table 8.1). This is reflected in (relatively) large values for the respective standard deviations. The mean percentage of material >0.84 mm was greater than the WEG value for loamy sands (15.2% compared to 10%) and, smaller for the sandy loam and light loam soils (20.3 and 31.8% for the samples compared to 25 and 40% respectively from the WEG [see Table 1.1]). It should be noted that the WEG are intended to estimate soil aggregation in spring before seeding and the samples were taken in the fall. As a result the comparison is of general interest only.

The number of samples required to estimate the mean percentage of material >0.84 mm for each textural group +/-5% and +/-7% is detailed in Table 8.2. The larger variability of aggregation in the loamy sand group is reflected in the larger number of samples required to estimate dry soil aggregation with either precision (11 at +/-5% and 5 at +/-7%). From Table 7.2 it was deduced that no less than 10 samples per soil textural grouping would be required to estimate mean aggregation +/-5% and that 5 samples would be sufficient for a precision of +/-7%.

On reviewing the data in Table 8.2 whilst planning the sampling program for the main project, it was anticipated that four or five different surface soil textures would be encountered in each sampling area. Imposing a requirement to estimate aggregation +/- 5% would require 10 samples per polygon. With three sampling areas, five soil textures, ten samples per polygon and sampling 5 polygons/texture the total number of samples required would be approximately 750.

By relaxing this goal to 7% only 375 samples would be required. It was concluded that this was a more realistic number of samples to take and analyse within the time available.

8.3 APPENDIX 3

8.3.1 PROJECT INITIATION

This project was initiated after a comparison between soil sieving data for Manitoba soils reported by Langman (1985) and the WEG used in North Dakota (Slevinsky 1984) revealed large differences between dry soil aggregation predicted by the WEG and actual sieving results (Table 1.2). A subsequent literature review found little comparison between WEG estimated aggregation and reported sieving data for a large number of experiments conducted on Prairie soils (Table 8.3).

Fryrear (1985) described the design and calibration of a Rapid Rotary Sieve which he reported to be cheap and easy to construct and gave results comparable to conventional rotary sieves used in dry aggregate analysis. Fryrear (1985) recommended a 0.5 minute sieving time for all soils. A sieve was constructed for this project by PFRA. Slight modifications to the design were made, to allow better sample distribution and easier cleaning of the sieve. These changes would not have altered the performance of the sieve from those reported by Fryrear. During sieving the first soil sample in the Modified Rapid Rotary Sieve, it was observed that a considerable quantity of fine material remained in the sieve after the 0.5 minute time recommended by Fryrear (1985). This raised a major question: when is a sample finished sieving? A considerable amount of time and thought was devoted to finding a solution to this critical question.

A review of literature which discusses the theory of sieving provided little assistance. Whitby (1958) identified two "regions" of sieving through the graphing of sieving data. In region 1, at the commencement of sieving, the rate of passage of material is high due to the high proportion of material smaller than sieve size on the screen. Region 1 grades into region 2 which is characterized by low rates of passage. In region 2 there remains a low proportion of particles which are just smaller than sieve size and which must be correctly oriented in order to pass through the screen.

As an interim solution it was decided to sieve all samples in half minute increments until region 2 was reached and for one further increment. It was understood that some breakdown of aggregates would result by extending sieving times. However, the rotary sieves commonly used in dry aggregate analysis are designed to sieve into region 2 (Lyles et al. 1970).

A careful review of the paper by Fryrear (1985) revealed one potentially misleading statement. In calibrating the sieve, mixtures of sand less than sieve size and gravel larger than sieve size were used. The results (Table 8.4) reported only the proportion of gravel retained on the sieve after sieving. Obviously, material larger than sieve size would be retained! The statistic of real interest is proportion of material smaller than sieve size retained on the sieve after 0.5 minute sieving; however this was not reported. This statement confirmed the necessity to calibrate the MRRS and to compare it to a rotary sieve [see: Chapter 2].

8.3.2 SAMPLING STRATEGY

A preliminary experiment on field variability of aggregates >0.84 mm and a sensitivity analysis performed on the WEQ were used to design a sampling program (See Appendices 8.2 and 8.3). The objectives of sampling for the main project were:

(1) to collect a large number of samples for optimal use of multiple regression analysis.

(2) to sample a wide variety of surface textures in order to ensure wide applicability of any predictive model developed from the data.

(3) to sample between seeding and significant crop emergence in order to minimise the temporal effects of climate on soil aggregation.

Samples were taken after seeding since wind erosion is at a maximum during this period.

From previously published data it was anticipated that dry soil aggregation of Alberta soils could be affected by soil properties such as soil texture, soil organic matter levels and $CaCO_3$ content. Soil management factors including crop rotations, tillage practices, type of crop seeded, crop yields and crop residue management were also considered to potentially affect dry soil aggregation. It was decided to sample in the Oyen, Pincher Creek and Flagstaff/Vermilion areas since good soil survey information was available and since these areas would provide a good range of soils, climate, and management variables. Brown Chernozemic soils are predominant in the Oyen area, moisture is generally limiting to crop production resulting in lower crop yields and a higher proportion of summerfallow than in other areas. The Pincher Creek area contains predominantly Black Chernozem soils many of which are calcareous at the surface due to past erosion. There is less summerfallow in the Pincher Creek area than around Oyen due to better moisture conditions. The Vermilion/Flagstaff areas are in the Black Soil Zone and have a smaller moisture deficit than the Pincher Creek area, rotations are generally longer and often contain oilseeds.

The basic sampling unit was taken to be a soil polygon as delineated on the soil map. A dominant soil type and corresponding surface texture is reported for each polygon. Polygons containing similar soil types are designated by the same map unit but may have different proportions of dominant and sub dominant soils. For this reason it was decided to sample five polygons of each map unit representing each of the dominant soil surface textures in each sampling area. Five samples were taken from one representative field selected from each polygon for a total of 25 samples representing each soil texture in an area. Fields which had recently been seeded and which had typical crop residue levels and topography for the soil polygon were selected. Samples were taken in midslope positions to minimize soil variability due to topography.

Field sampling procedures are discussed in Chapter 3. Field hand-texturing and subsequent particle size analysis revealed a much greater variability in surface texture along transects than had been anticipated. As a result, unequal numbers of soil samples of the various soil textures were taken, this did not affect the data analysis.

8.3.3 DEVELOPMENT OF THEORY TO ESTIMATE AGGREGATE COMMINUTION IN THE MRRS.

Soil material within the MRRS is subjected to both sieving and milling processes[1]. Ideally, in order to describe the conditions at the soil surface prior to the initiation of soil movement, it is necessary to separate and quantify the non-erodible soil material without subjecting it to any milling. A review of the literature on particle separation revealed that the mechanisms of sieving and milling have seldom been considered in conjunction; particularly for material as friable as soil aggregates. The equation for passage of material through a sieve is:

$$\frac{dy}{dt} = - a y^{m} \qquad \text{Equation 2.1 (Whitby 1958)}$$

Where:

y is the proportion of material retained on the sieve,

t is time,

a is a sieving rate constant, and

m is a constant commonly considered to be unity

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[1] Sieving is a separating process whereby loose material is sorted into two size fractions by agitating it on a screen of suitable aperture size. Milling, with reference to sieving, is the process by which material is reduced in size due to mechanical forces during sieving. The occurrence of milling is undesirable if the objective of sieving is to obtain information on the original particle size distribution of a sample.

Gupta et al. (1975) developed a complex function based on Equation 2.1 to explain the combined milling and sieving of iron pyrites. They assumed that the exponent in Equation 2.1 was unity i.e. that the rate of comminution of the material was constant. This would be correct in a screening process during which fresh material is being added at a constant rate. This is not the case with the MRRS; consequently, the model of Gupta et al. (1975) was unsuccessful in explaining the processes taking place. A method to estimate aggregate comminution during sieving in the MRRS was developed with considerable help from Dr. F. A. Baragar, Department of Mathematics, University of Alberta. The development and application of the methodology is explained in mathematical language in Section 8.3.4.

The method first removes the sand and sieve-robust aggregates >0.84 mm, then seeks to explain the passage of material beyond 0.5 minutes by fitting an expression to the sieving curve. At 0.5 minutes virtually all the original soil material smaller than sieve size has passed through the sieve, the majority of material passing beyond this time results from aggregate breakdown. The model is then used to project the aggregate breakdown curve back to the commencement of sieving in order to estimate the percentage of aggregates >0.84 mm present in the sample prior to sieving. Figures 8.2 and 8.3 depict possible sieving curves of the material <0.84 mm resulting from aggregate comminution. In Figure 8.2 the rate of aggregate breakdown increases as the quantity of aggregates remaining in the sieve decreases. This implies that the milling process increases in severity as sieving progresses. This would be an incorrect assumption for the MRRS since the sieving action does not change as the sample size decreases. In Figure 8.3 the rate of production of sub-mesh material (i.e. material smaller than sieve size) is still large when no more friable aggregates remain in the sieve. This is also an incorrect assumption for the conditions experienced. An expression is required to fit Figure 8.4 where the rate of passage of material falls asymptotically to the abscissa. This was resolved by evaluating the exponent m in the Equation 2.1 from which Equation 2.2 was derived.

$$y = \left[1 - \frac{t}{T}\right]^{\left(\frac{1}{1-m}\right)} \qquad \text{Equation 2.2}$$

where y is the proportion of degradable aggregates retained on the sieve at time t,

t is time in minutes,

T is the time at which no more material passes the sieve, and

m is a sieving parameter which varies with the rate of breakdown of aggregates in the sieve.

In order to solve the equation, T and two additional parameters A and I must be evaluated. [A is the proportion of sand and sieve robust aggregates >0.84 mm in the sample and I is the proportion of degradable aggregates >0.84 mm]. Values for A and T may be obtained from interpolation of soil sieving curves (Figure 2.2). I can be calculated by regression analysis. Dependent variables (Y) are calculated as follows:

If t = 1.0 and the proportion retained at t = 1.0 is P

$$\text{Ln } Y = \frac{[P - A]*100}{[100 - (A)} \qquad \text{Equation 8.3.1}$$

Independent variables (X) can be calculated as follows:

If t = 1.0 min

$$\text{Ln } X = 1-(1.0/T) \qquad \text{Equation 8.3.2}$$

The regression analysis yields Ln intercept (I) and m. The percentage of aggregates which break down in the sieve expressed in terms of total sample weight (D) is calculated as follows:

$$D = \frac{I * [100 - A]}{100} \qquad \text{Equation 8.3.3}$$

Finally to estimate the total percentage of material >0.84 mm:

$$\text{Total } \% > 0.84 \text{ mm} = D + A. \qquad \text{Equation 8.3.4}$$

The assumptions made in developing Equation 2.2 were:

(1) Very little near mesh material remains in the sieve after 0.5 minutes.

(2) The breakdown of aggregates is quickly followed by passage of any resultant sub-mesh material through

the sieve.

(3) The rate of aggregate breakdown follows an exponential decay curve similar to Figure 2.7.

The validity of assumption (1) is discussed in Chapter 2. Assumption (2) is reasonable since the mass of near mesh particles produced by aggregate comminution present in the sieve at any time is small in relation to the sample mass. Assumption (3) is not entirely true since a plot of ln 100Y - A Vs ln (1-t/T) is not always a straight line (Figure 2.3 in Chapter 2). However, the use of a more complicated expression is not justified since the correlation coefficients obtained for this relationship are invariably adequate for all practical purposes (see Table 2.2 in Chapter 2).

One weakness imposed by the method is that very soft aggregates cannot be accommodated if they are broken down during the first 0.5 minutes of sieving. During this period, sub mesh and near mesh material are also passing through the sieve. This deficiency could be overcome if samples were re-sieved and the results compared. This was not attempted since the method was developed subsequent to the samples being ground to pass a 2 mm sieve for particle size analysis. The benefits derived from sieving each sample twice would probably not be justified in relation to the extra time required for sieving and data analysis.

8.3.4 A MATHEMATICAL DERIVATION OF EQUATION 2.2

There are in general three types of material in any soil sample:

1) particles which are less than mesh size,
2) aggregates that are initially greater than mesh size, but break into smaller pieces due to interactions with the sieve surface and other particles in the sample, and
3) aggregates and sand that are sieve-robust, i.e. particles that do not contribute any sub-mesh particles during the time interval over which sieving takes place.

It will be assumed that the rate of aggregate breakdown is a function of the proportion of degradeable aggregate in the sample, irrespective of the size of the sample.

Let S_0 represent the proportion of sub-mesh material originally present in the sample, and $S(t)$ that which is retained by the sieve at time t after the commencement of sieving. Let $x(t)$ be the proportion of the original sample composed of larger than mesh size material still in the sieve at time t, and $x_0=x(0)$. Then $x_0+S_0=1$ and $p(t)=1-S(t)-x(t)$ is the proportion of the soil that has passed through the sieve at time t. It is $p(t)$ that is measured directly. Note that $x_0-x(t)$ is the proportion of the sample that is sub-mesh material formed from the aggregate by the sieving operation.

Let us first assume that the sample contains no degradeable aggregates. The particles with diameters less than the mesh size pass through at a rate proportional to the number at the sieve surface, a rate that should be roughly constant. When the sieve is heavily loaded, the pressure at the sieve surface may tend to increase this rate, but some interlocking of particles to form larger particles may decrease the rate. Whether or not these effects cancel one another or not depends upon the properties of the material. A reasonable equation for S,

$$dS/dt=-C \qquad C>0 \tag{A1}$$

has the solution

$$S(t)=S_0-Ct \tag{A2}$$

This material has all passed through the sieve at time $\tau=S_0/C$. For particles near mesh size, C would be expected to be small relative to the value of C for smaller particles. Thus, for particles of diameter d we would have

$$S^d(t)=S^d{}_0-C(d)t \tag{A3}$$

where the rate of passage C(d) is a decreasing function of d. The presence of aggregates that are relatively stable over time intervals comparable to τ will be expected to increase the effective value of C and so decrease τ.

The soil sample will usually contain aggregates with particle sizes significantly larger than mesh size. Due to the interaction with the sieve and the other material, these aggregates will tend to break down into smaller pieces, some of which have diameters less than mesh size.

This process generally takes a time $T \gg \tau$ to go to completion and there is generally some material remaining that will not break down into sub-mesh pieces. Let it be initially assumed that $S_0=0$. A model that might be expected to describe the rate at which sub-mesh particles are created from aggregate is, if x represents the proportion of aggregates in the original sample and $A>0$ the proportion of sieve-robust material in the sample,

$$dx/dt=-C-\alpha(x-A)$$

$$=-\alpha(x+X) \qquad \text{A4}$$

where α is the proportional rate of breakdown of aggregate and $X=-A+C/\alpha$. The sign of α may be either positive or negative. Thus, if $\alpha>0$, we must have $X>0$ (so $-\alpha(x+X)<0$ when $x=0$) while for $\alpha<0$, $X<-x_0$ (so that $-\alpha(x+X)<0$ when $x=x_0$. The solution to A4 that satisfies $x(0)=x_0$ is

$$x=[(x_0+X)\exp(-\alpha t)]-X \qquad \text{A5}$$

for $0 \le t \le -(1/\alpha)\ln[X/(x_0+X)]$. The solution for $X<-x_0$ and $\alpha<0$ and the solution for for $X>0$ and $\alpha>0$ are sketched in Figs. A1 and A2 respectively. In both these equations, $dx/dt<0$ when $x=A$ (because $C \neq 0$), a condition that does not appear to be satisfied by the soil samples examined in this study. The problem may be resolved in the following way.

First, we observe that the equation A4 with $C=0$ has the solution

$$x=(x_0-A)\exp(-\alpha t)+A \qquad \text{A6}$$

where x_0-A is the proportion of the original sample that is degradable aggregate and A the proportion of the material that does not break up (sieve-robust aggregates and sand). This implies that there are always some particles with diameters less than the mesh size being formed. This is not observed. The degradeable aggregates of interest complete their breakdown in a finite time, leaving only sieve-robust material which breaks down much more slowly, if at all.

We want a function of x that is larger than ax but less than a constant for x near 0 to represent the rate of breakdown of aggregate (Fig. A3). A simple equation that satisfies these conditions is

$$dx/dt=-\alpha(x-A)^m, \quad \alpha>0, \quad 0<m<1 \qquad \text{A7}$$

The solution to this equation with $x(0)=x_0$ that contains a proportion x_0-A of degradable aggregate is

$$(x-A)^{1-m}/(1-m)= [(x_0-A)^{1-m}/(1-m)] -\alpha t \qquad \text{A8}$$

or

$$x= [(x_0-A)^{1-m}-\alpha(1-m)t]^{\beta} +A \qquad \text{A9}$$

where $\beta=1/(1-m)$.

If $x=A$ at $t=T$, then

$$x=[\alpha(1-m)]^{\beta} (T-t)^{\beta} +A \qquad \text{A10}$$

where

$$T=(x_0-A)^{1-m}/\alpha(1-m) \qquad \text{A11}$$

The proportion of degradable aggregate present at time t is

$$y=(x-A)/(x_0-A)=(1-t/T)^{\beta} . \qquad \text{A12}$$

Most samples contain the three types of material. In practice, most of the sub-mesh material originally present passes through the sieve before the degradable aggregates have been broken down. Thus, as $T>>\tau$, there is a time interval in which the sub-mesh particles passing through the sieve arose from aggregate breakdown.

8.3.5 ESTIMATES OF T AND ITS EFFECT ON D

The estimation of aggregate comminution during sieving is dependent on a good evaluation of T. Values of T and A are obtained by interpolation of the soil sieving data. This may be achieved graphically or by employing a curve fitting program on a computer. The estimation of T is improved as the number of sieving data points increases, a minimum of four being preferable. In order to consider aggregate comminution only, the analysis avoids region 1 sieving.

Mathematical curve fitting is less time consuming than graphical interpolation but accuracy of the estimation of T is vulnerable to incorrect data points. These may be identified during graphical interpolation of sieving data. When using mathematical curve fitting, in the absence of a visual inspection of the sieving curve, it must be assumed that region 1 sieving is complete after 0.5 minutes sieving. This is not always the case (see Figure 8.3) thereby introducing some error into the estimates of T and A.

Graphical interpolation of the sieving data was used for the project. The soil sieving data was plotted on a computer screen using a spreadsheet. A curve was fitted to the points using an acetate overlay allowing the estimation of A to within +/-1% and T to within +/-0.1 minute. Occasionally more than one curve could be fitted to the data. In these instances the value for T closest to the final sieving data point was taken since this required less extrapolation of the data.

The proportion of friable aggregates (D) was calculated from estimates of T and A. The sensitivity of D to T is dependent on the sieving characteristics of the sample and on the fit of the regression relationship to the sieving data. Figure 8.6 is a typical graph to illustrate the sensitivity of D to T. The curvilinear relationship shows the values of D increase as estimates of T increase. The slope of the curve is dependent on the friability of the aggregates in the sieve. Sample B42 is a clay; a clay loam or loam would have a steeper curve indicating more rapid breakdown of aggregates in the sieve. A 10% overestimation of T increases values of D by approximately 0.5%. Underestimation of T has a slightly larger effect but is constrained by the sieving data. Estimates of T must be greater than the final sieving time. In this example they cannot be less than 70% of the interpolated estimate. In addition points 1 and 2 are not good estimates of T since m (the exponent of Equation 2.2) becomes negative for these points, indicating a poor fit of the model to the data. This is supported by smaller correlation coefficients for the relationship.

The analysis of this and several other sets of data chosen at random indicated that D was estimated with a precision of +/-3% using graphical interpolation.

Table 8.1. Sieving data for Two Hills (Alberta) soil samples

Texture	#	% Material >0.84 mm Mean	Range	s
LS	24	15.2	4.9 - 34.5	8.10
SL	18	20.3	10.6 - 28.8	6.24
LL	6	31.8	23.0 - 42.3	6.88

# = number of samples
s = standard deviation

Table 8.2. The number of samples required to estimate average soil material >0.84 mm in several soil textural classes to within 5 and 7% based on sampling at Two Hills, Alberta

Texture	# Required @ 5%	7
LS	11	[illegible]
SL	6	3
LL	8	4

Table 8.3 Comparison of dry soil material >0.84 mm reported from Canadian Prairie Soils with estimates from the North Dakota Wind Erodibility Groups

	#Years/	Spring/	Samp			W.E.G.	
Reference	Start	Fall	Code	Zone	Texture	%>.84	%>.84 mm
C.D.A.	4	F		Brown	HvC	56.4	25
(1949)	1941				SiCL	57.0	25
					CL	33.7	25
					L	18.3	40
					FSL	11.8	25
				Dark	HvC	73	25
				Brown	SiCL	23.4	25
					SiL	28.9	45
					L	19.5	40
					FSL	12.6	25
				Black	SiCL	27.5	50
					CL	26.4	25
					SiL	17.4	40
					L	19.5	40
					FSL	6.5	25
Anderson	5	S	BT	Brown	CL	66.0	25
Wenhardt	1955	S	AS		CL	52.0	25
(1966)							
Bisal &	10	S	BT	Brown	L	60.0	40
Ferguson	1955				C	45.0	25
(1968)					FSL	22.0	25
		S	AS		L	60.0	40
					C	44.0	25
					FSL	27.0	25

Table 8.3 (continued)

Reference	#Years/ Start	Spring/ Fall	Samp Code	Zone	Texture	%>.84	W.E.G. %>.84 mm
Wenhardt.A.	3	S	BT	Brown	CL	60.5	25
(1962)	1958	S	AS		CL	53.0	25
		F			CL	56.7	25
Keys et al	3	S	BT	Black	L	51.6	40
(1970)	1960				SiCL	62.4	25
				Brown	L	53.6	40
					L	76.3	40
		S	AS	Black	L	43.0	40
					SiCL	56.0	25
				Black	L	42.3	40
					L	55.2	40
Dew,D.A.	5	S	AT	Black	L	54.2	40
(1967)	1961						
Lindwall &	7	S	BT	Brown	CL	47.0	25
Anderson	1969	F			CL	50.6	25
(1981)							
Nuttall et al	6	S	BT?	Black	SiC	49.8	25
(1984)							

* BT - Before Tillage
AT - After tillage but before seeding
AS - After seeding

Table 8.4. Comparison of compact rotary sieve and rapid rotary sieve with various percentages of gravel <2 mm; median diameter, 6 mm) and washed blow sand less than 0.84 mm.

Actual % gravel >8.84 mm	% gravel by sieving* Compact rotary sieve	 Rapid rotary sieve
95	93.92	95.05
90	88.87	89.94
85	84.18	84.79
80	79.06	79.85
75	74.02	74.55
62.5	61.61	61.93
50	49.17	49.27
25	24.51	24.53
Average 70.31	Average 69.41	Average 69.98

* Remaining in the sieve (aperture 0.84 mm) after 0.5 min sieving. Adapted from Fryrear (1985).

TABLE 8.5 OYEN SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
1	SE-5-22-17 W4	SL	0	4.5	SE	0	HPD	0	WHEAT	F	<100	SG-F
2	SE-5-22-17 W4	SL	0	4.5	S	0	HPD	0	WHEAT	F	<100	SG-F
3	SE-5-22-17 W4	SL	0	4.5	S	0	HPD	0	WHEAT	F	<100	SG-F
4	SE-5-22-17 W4	SL	0	4.5	S	0	HPD	0	WHEAT	F	<100	SG-F
5	SE-5-22-17 W4	SL	0	3.5	S	0	HPD	0	WHEAT	F	<100	SG-F
6	SW29-18-15 W4	SL	0	4.5	S	0	0	0	WHEAT	F	<100	SG-F
7	SW29-18-15 W4	LS	0	4.5	S	0	0	0	WHEAT	F	<100	SG-F
8	SW29-18-15 W4	LS	0	4.5	S	0	0	0	WHEAT	F	<100	SG-F
9	SW29-18-15 W4	LS	0	4	S	0	0	0	WHEAT	F	<100	SG-F
10	SW29-18-15 W4	SL	0	4.5	S	0	0	0	WHEAT	F	<100	SG-F
11	SW13-25-3 W4	SiL	0	4.5	0	0	DPD	0	WHEAT	F	200	SG-F
12	SW13-25-3 W4	L	0	5	0	0	DPD	0	WHEAT	F	200	SG-F
13	SW13-25-3 W4	L	0	5	S	0	DPD	0	WHEAT	F	200	SG-F
14	SW13-25-3 W4	SiL	0	5	S	0	DPD	0	WHEAT	F	200	SG-F
15	SW13-25-3 W4	L	0	4.5	S	0	DPD	0	WHEAT	F	200	SG-F
16	NE2-25-2 W4	C	0	5	N	0	D	HRP	WHEAT	F	350	SG-F
17	NE2-25-2 W4	CL	VWE	5.5	N	0	D	HRP	WHEAT	F	350	SG-F
18	NE2-25-2 W4	CL	0	4.5	N	0	D	HRP	WHEAT	F	350	SG-F
19	NE2-25-2 W4	CL	0	4.5	N	0	D	HRP	WHEAT	F	350	SG-F
20	NE2-25-2 W4	C	0	4.5	N	0	D	HRP	WHEAT	F	350	SG-F
21	SW14-24-1 W4	C	0	4.5	S	0	D	HRP	WHEAT	F	350	SG-F
22	SW14-24-1 W4	C	0	5	0	0	D	HRP	WHEAT	F	350	SG-F
23	SW14-24-1 W4	C	0	5	0	0	D	HRP	WHEAT	F	350	SG-F
24	SW14-24-1 W4	C	0	4.5	0	0	D	HRP	WHEAT	F	350	SG-F
25	SW14-24-1 W4	C	0	4.5	0	0	D	HRP	WHEAT	F	350	SG-F
26	NE15-29-1 W4	L	0	4.5	S	0	HDR	HRP	WHEAT	F	350	SG-F
27	NE15-29-1 W4	SL	0	4.5	S	0	HDR	HRP	WHEAT	F	350	SG-F
28	NE15-29-1 W4	LS	0	4	S	0	HDR	HRP	WHEAT	F	350	SG-F
29	NE15-29-1 W4	S	0	4	S	0	HDR	HRP	WHEAT	F	350	SG-F
30	NE15-29-1 W4	LS	0	4.5	N	0	HDR	HRP	WHEAT	F	350	SG-F
31	SE33-29-2 W4	L	0	4	N	CT	HPD	0	WHEAT	F	600	SG-F
32	SE33-29-2 W4	SL	0	4.5	S	CT	HPD	0	WHEAT	F	600	SG-F
33	SE33-29-2 W4	SL	0	4.5	S	CT	HPD	0	WHEAT	F	600	SG-F
34	SE33-29-2 W4	SCL	0	4	S	CT	HPD	0	WHEAT	F	600	SG-F
35	SE33-29-2 W4	L	0	4	N	CT	HPD	0	WHEAT	F	600	SG-F
36	NE31-25-2 W4	L	ME	4.5	N	3CT	HPD	0	WHEAT	F	200	SG-F
37	NE31-25-2 W4	CL	0	5	N	3CT	HPD	0	WHEAT	F	200	SG-F
38	NE31-25-2 W4	L	0	4.5	N	3CT	HPD	0	WHEAT	F	200	SG-F
39	NE31-25-2 W4	CL	0	5	N	3CT	HPD	0	WHEAT	F	200	SG-F
40	NE31-25-2 W4	L	0	4.5	N	3CT	HPD	0	WHEAT	F	200	SG-F
41	NE1-25-3 W4	CL	ME	5.5	N	0	D	HRP	WHEAT	F	600	SG-F
42	NE1-25-3 W4	C	0	5	N	0	D	HRP	WHEAT	F	600	SG-F
43	NE1-25-3 W4	CL	ME	5.5	N	0	D	HRP	WHEAT	F	600	SG-F
44	NE1-25-3 W4	C	ME	5.5	S	0	D	HRP	WHEAT	F	600	SG-F
45	NE1-25-3 W4	CL	WE	5	N	0	D	HRP	WHEAT	F	600	SG-F
46	NE12-24-2 W4	HC	0	4.5	N	0	D	HRP	WHEAT	F	600	SG-F
47	NE12-24-2 W4	HC	0	4.5	N	0	D	HRP	WHEAT	F	600	SG-F
48	NE12-24-2 W4	HC	0	5	N	0	D	HRP	WHEAT	F	600	SG-F
49	NE12-24-2 W4	HC	0	5	N	0	D	HRP	WHEAT	F	600	SG-F
50	NE12-24-2 W4	HC	0	5	N	0	D	HRP	WHEAT	F	600	SG-F

TABLE 8.5 (cont) OYEN SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
51	SW17-24-1 W4	CL	0	5	0	0	D	NRP	WHEAT	F	600	SG-F
52	SW17-24-1 W4	SiCL	0	5.5	0	0	D	NRP	WHEAT	F	600	SG-F
53	SW17-24-1 W4	CL	0	5	0	0	D	NRP	WHEAT	F	600	SG-F
54	SW17-24-1 W4	C	0	4.5	0	0	D	NRP	WHEAT	F	600	SG-F
55	SW17-24-1 W4	C	0	4.5	0	0	D	NRP	WHEAT	F	600	SG-F
56	NE15-25-3 W4	L	S	6.5	0	CT	DP	0	WHEAT	F	600	SG-F
57	NE15-25-3 W4	L	E	6.5	0	CT	DP	0	WHEAT	F	600	SG-F
58	NE15-25-3 W4	L	E	6.5	0	CT	DP	0	WHEAT	F	600	SG-F
59	NE15-25-3 W4	L	E	6	0	CT	DP	0	WHEAT	F	600	SG-F
60	NE15-25-3 W4	L	E	6.5	0	CT	DP	0	WHEAT	F	600	SG-F
61	SE3-25-2 W4	CL	0	5.5	0	0	D	NRP	WHEAT	F	200	SG-F
62	SE3-25-2 W4	L	0	5.5	0	0	D	NRP	WHEAT	F	200	SG-F
63	SE3-25-2 W4	L	0	5.5	E	0	D	NRP	WHEAT	F	200	SG-F
64	SE3-25-2 W4	CL	0	5.5	E	0	D	NRP	WHEAT	F	200	SG-F
65	SE3-25-2 W4	C	0	5.5	W	0	D	NRP	WHEAT	F	200	SG-F
66	SE13-24-3 W4	CL	0	5	0	RW	DP	N	WHEAT	F	350	SG-F
67	SE13-24-3 W4	L	0	5.5	0	RW	DP	N	WHEAT	F	350	SG-F
68	SE13-24-3 W4	CL	0	5.5	0	RW	DP	N	WHEAT	F	350	SG-F
69	SE13-24-3 W4	C	0	5.5	0	RW	DP	N	WHEAT	F	350	SG-F
70	SE13-24-3 W4	C	0	5	W	RW	DP	N	WHEAT	F	350	SG-F
71	SW27-25-3 W4	SL	0	5	0	0	D	NRP	WHEAT	F	200	SG-F
72	SW27-25-3 W4	SL	0	5	N	0	D	NRP	WHEAT	F	200	SG-F
73	SW27-25-3 W4	LS	0	5	N	0	D	NRP	WHEAT	F	200	SG-F
74	SW27-25-3 W4	SL	WE	5	N	0	D	NRP	WHEAT	F	200	SG-F
75	SW27-25-3 W4	LS	0	4.5	0	0	D	NRP	WHEAT	F	200	SG-F
76	SE13-29-2 W4	LS	0	4.5	0	0	DP	0	WHEAT	F	<100	SG-F
77	SE13-29-2 W4	LS	0	4.5	0	0	DP	0	WHEAT	F	<100	SG-F
78	SE13-29-2 W4	LS	0	4.5	0	0	DP	0	WHEAT	F	<100	SG-F
79	SE13-29-2 W4	LS	0	4.5	0	0	DP	0	WHEAT	F	<100	SG-F
80	SE13-29-2 W4	LS	0	4	0	0	DP	0	WHEAT	F	<100	SG-F
81	SE13-29-2 W4	SL	0	4.5	0	C	DP	0	WHEAT	F	450	SG-F
82	SW4-30-1 W4	SL	0	4.5	S	C	DP	0	WHEAT	F	450	SG-F
83	SW4-30-1 W4	SiCL	SE	4.5	SW	C	DP	0	WHEAT	F	450	SG-F
84	SW4-30-1 W4	L	0	4.5	N	C	DP	0	WHEAT	F	450	SG-F
85	SW4-30-1 W4	SL	0	4.5	N	C	DP	0	WHEAT	F	450	SG-F
86	NE22-29-1 W4	L	0	4	0	C	HPD	0	WHEAT	F	600	SG-F
87	NE22-29-1 W4	L	0	4	S	C	HPD	0	WHEAT	F	600	SG-F
88	NE22-29-1 W4	SL	0	4.5	NW	C	HPD	0	WHEAT	F	600	SG-F
89	NE22-29-1 W4	L	0	4.5	N	C	HPD	0	WHEAT	F	600	SG-F
90	NE22-29-1 W4	L	0	4	N	C	HPD	0	WHEAT	F	600	SG-F
91	SE30-25-2 W4	C	0	5	0	CR	DP	0	WHEAT	F	100	SG-F
92	SE30-25-2 W4	CL	0	4.5	0	CR	DP	0	WHEAT	F	100	SG-F
93	SE30-25-2 W4	CL	0	4.5	0	CR	DP	0	WHEAT	F	100	SG-F
94	SE30-25-2 W4	CL	0	4.5	0	CR	DP	0	WHEAT	F	100	SG-F
95	SE30-25-2 W4	C	0	4.5	0	CR	DP	0	WHEAT	F	100	SG-F
96	SE30-25-2 W4	L	0	4.5	N	RW	DP	0	WHEAT	F	100	SG-F
97	SE30-25-2 W4	L	0	4.5	N	RW	DP	0	WHEAT	F	100	SG-F
98	SE30-25-2 W4	SL	0	4.5	N	RW	DP	0	WHEAT	F	100	SG-F
99	SE30-25-2 W4	SL	0	4.5	N	RW	DP	0	WHEAT	F	100	SG-F
100	SE30-25-2 W4	SL	0	4	N	RW	DP	0	WHEAT	F	100	SG-F

TABLE 8.5 (cont) OYEN SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
101	SW26-27-3 W4	L	0	4.5	0	CR	DPD	0	WHEAT	F	200	SG-F
102	SW26-27-3 W4	L	0	4.5	W	CR	DPD	0	WHEAT	F	200	SG-F
103	SW26-27-3 W4	SiL	0	4.5	0	CR	DPD	0	WHEAT	F	200	SG-F
104	SW26-27-3 W4	L	0	4.5	W	CR	DPD	0	WHEAT	F	200	SG-F
105	SW26-27-3 W4	L	0	4.5	0	CR	DPD	0	WHEAT	F	200	SG-F
106	SW14-29-3 W4	L	0	4	E	CT	D	CP	WHEAT	F	200	SG-F
107	SW14-29-3 W4	SL	0	5	E	CT	D	CP	WHEAT	F	200	SG-F
108	SW14-29-3 W4	L	0	4.5	E	CT	D	CP	WHEAT	F	200	SG-F
109	SW14-29-3 W4	L	0	5	E	CT	D	CP	WHEAT	F	200	SG-F
110	SW14-29-3 W4	L	0	4.5	E	CT	D	CP	WHEAT	F	200	SG-F
111	NW29-29-1 W4	SL	0	4	N	C	HPD	0	WHEAT	F	100	SG-F
112	NW29-29-1 W4	SL	0	4	N	C	HPD	0	WHEAT	F	100	SG-F
113	NW29-29-1 W4	SL	0	4.5	0	C	HPD	0	WHEAT	F	100	SG-F
114	NW29-29-1 W4	SL	0	4	0	C	HPD	0	WHEAT	F	100	SG-F
115	NW29-29-1 W4	SL	0	4.5	N	C	HPD	0	WHEAT	F	100	SG-F
116	NE35-28-1 W4	L	0	4.5	S	C	DP	0	WHEAT	F	<100	SG-F
117	NE35-28-1 W4	L	WE	5	S	C	DP	0	WHEAT	F	<100	SG-F
118	NE35-28-1 W4	L	0	5	NE	C	DP	0	WHEAT	F	<100	SG-F
119	NE35-28-1 W4	SL	0	5	E	C	DP	0	WHEAT	F	<100	SG-F
120	NE35-28-1 W4	L	0	5	W	C	DP	0	WHEAT	F	<100	SG-F
121	SE36-28-2 W4	L	0	4.5	W	CT	D	HRPCR	WHEAT	F	100	SG-F
122	SE36-28-2 W4	L	0	5	E	CT	D	HRPCR	WHEAT	F	100	SG-F
123	SE36-28-2 W4	SL	0	5	W	CT	D	HRPCR	WHEAT	F	100	SG-F
124	SE36-28-2 W4	L	0	5	E	CT	D	HRPCR	WHEAT	F	100	SG-F
125	SE36-28-2 W4	L	0	4.5	E	CT	D	HRPCR	WHEAT	F	100	SG-F
126	NE13-28-2 W4	CL	0	4	N	CT	DP	0	WHEAT	F	<100	SG-F
127	NE13-28-2 W4	CL	0	4.5	N	CT	DP	0	WHEAT	F	<100	SG-F
128	NE13-28-2 W4	CL	0	5	N	CT	DP	0	WHEAT	F	<100	SG-F
129	NE13-28-2 W4	L	0	4.5	N	CT	DP	0	WHEAT	F	<100	SG-F
130	NE13-28-2 W4	CL	0	4.5	N	CT	DP	0	WHEAT	F	<100	SG-F

TEXT = soil texture
CARB = soil carbonates from field HCl test
VWE = very weakly effervescent
WE = weakly effervescent
ME = moderately effervescent
SE = strongly effervescent
VSE = very strongly effervescent
ASPECT = site aspect, 4 compass points
PST = preseeding tillage, impliment and number of passes
SEED = seeding impliment
PS = post seeding impliment
C = canola
SG = small grains
F = fallow
TILLAGE AND SEEDING EQUIPMENT
AS = air seeder
ASTP = airseeder + tine harrows + packer
C = cultivator
CDRH = cultivator + deadrod + harrows

TABLE 8.5 (cont) OYEN SOILS - FIELD DATA

CHP = cultivator with harrowpackers
CP = crowfoot packer
CR = cultivator with rodweeder
CS = cultivator (sweeps)
CT = cultivator with tine harrows
D = discer
DP = discer with attached packer wheels
DPD = disk press drill
DT = deep tiller
H = drag harrows
HDR = hoe drill with rodweeder
HDT = hoe drill with tine harrows
HP = harrowpacker
HPD = hoe press drill
K = knife
P = packed with seed drill
RW = rodweeder
TD = tandem disks
TH = tine harrows
V = vibrashank

TABLE 8.6. PINCHER CREEK SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
1	NE12-8-1 W5	C	SE	4	N	2CR	HPD	0	WHEAT	WHEAT	350	CONT-SG
2	NE12-8-1 W5	HC	SE	4	N	2CR	HPD	0	WHEAT	WHEAT	350	CONT-SG
3	NE12-8-1 W5	C	ME	3.5	N	2CR	HPD	0	WHEAT	WHEAT	350	CONT-SG
4	NE12-8-1 W5	C	SE	4	S	2CR	HPD	0	WHEAT	WHEAT	350	CONT-SG
5	NE12-8-1 W5	C	ME	3	N	2CR	HPD	0	WHEAT	WHEAT	350	CONT-SG
6	SE21-8-29 W4	CL	SE	6.5	N	2CR	HPD	0	BARLEY	F	200	SG-F
7	SE21-8-29 W4	CL	ME	3	N	2CR	HPD	0	BARLEY	F	200	SG-F
8	SE21-8-29 W4	CL	0	3.5	N	2CR	HPD	0	BARLEY	F	200	SG-F
9	SE21-8-29 W4	CL	0	3.5	S	2CR	HPD	0	BARLEY	F	200	SG-F
10	SE21-8-29 W4	CL	0	3.5	S	2CR	HPD	0	BARLEY	F	200	SG-F
11	NE13-8-30 W4	CL	0	3	E	0	ASTH	0	WHEAT	WHEAT	200	CONT-SG
12	NE13-8-30 W4	CL	0	3	E	0	ASTH	0	WHEAT	WHEAT	200	CONT-SG
13	NE13-8-30 W4	CL	SE	3	E	0	ASTH	0	WHEAT	WHEAT	200	CONT-SG
14	NE13-8-30 W4	CL	SE	5.5	E	0	ASTH	0	WHEAT	WHEAT	200	CONT-SG
15	NE13-8-30 W4	CL	SE	5.5	E	0	ASTH	0	WHEAT	WHEAT	200	CONT-SG
16	SW18-8-29 W4	CL	SE	4	S	0	ASTH	0	WHEAT	WHEAT	100	CONT-SG
17	SW18-8-29 W4	CL	SE	3.5	S	0	ASTH	0	WHEAT	WHEAT	100	CONT-SG
18	SW18-8-29 W4	CL	SE	3.5	S	0	ASTH	0	WHEAT	WHEAT	100	CONT-SG
19	SW18-8-29 W4	CL	ME	3.5	S	0	ASTH	0	WHEAT	WHEAT	100	CONT-SG
20	SW18-8-29 W4	C	SE	3.5	S	0	ASTH	0	WHEAT	WHEAT	100	CONT-SG
21	NW5-8-29 W4	C	0	3.5	0	2CT	HPD	0	BARLEY	F	100	SG-F
22	NW5-8-29 W4	C	0	3.5	0	2CT	HPD	0	BARLEY	F	100	SG-F
23	NW5-8-29 W4	C	ME	4	0	2CT	HPD	0	BARLEY	F	100	SG-F
24	NW5-8-29 W4	C	WE	3.5	0	2CT	HPD	0	BARLEY	F	100	SG-F
25	NW5-8-29 W4	C	0	3.5	0	2CT	HPD	0	BARLEY	F	100	SG-F
26	NW9-8-29 W4	C	ME	3	S	CT	HPD	0	WHEAT	WHEAT	<100	CONT-SG
27	NW9-8-29 W4	C	ME	3	S	CT	HPD	0	WHEAT	WHEAT	<100	CONT-SG
28	NW9-8-29 W4	C	ME	3.5	S	CT	HPD	0	WHEAT	WHEAT	<100	CONT-SG
29	NW9-8-29 W4	C	WE	3.5	S	CT	HPD	0	WHEAT	WHEAT	<100	CONT-SG
30	NW9-8-29 W4	L	WE	3.5	S	CT	HPD	0	WHEAT	WHEAT	<100	CONT-SG
31	NE4-9-1 W5	L	0	3	S	2C	HPD	0	OATS	SOD	100	SG-SG-HAY
32	NE4-9-1 W5	CL	0	3	S	2C	HPD	0	OATS	SOD	100	SG-SG-HAY
33	NE4-9-1 W5	L	VWE	3.5	S	2C	HPD	0	OATS	SOD	100	SG-SG-HAY
34	NE4-9-1 W5	C	0	3	S	2C	HPD	0	OATS	SOD	100	SG-SG-HAY
35	NE4-9-1 W5	CL	VWE	3.5	S	2C	HPD	0	OATS	SOD	100	SG-SG-HAY
36	SE30-8-1 W5	L	VWE	4	S	C	DPDR	0	BARLEY	OATS	300	CONT-SG
37	SE30-8-1 W5	L	SE	4.5	S	C	DPDR	0	BARLEY	OATS	300	CONT-SG
38	SE30-8-1 W5	SCL	SE	5	N	C	DPDR	0	BARLEY	OATS	300	CONT-SG
39	SE30-8-1 W5	SCL	VSE	4	N	C	DPDR	0	BARLEY	OATS	300	CONT-SG
40	SE30-8-1 W5	HC	VSE	3.5	N	C	DPDR	0	BARLEY	OATS	300	CONT-SG
41	SW2-8-1 W5	C	SE	4.5	S	CH	HPD	0	OATS	BARLEY	100	CONT-SG
42	SW2-8-1 W5	C	ME	4	S	CH	HPD	0	OATS	BARLEY	100	CONT-SG
43	SW2-8-1 W5	C	0	3	E	CH	HPD	0	OATS	BARLEY	100	CONT-SG
44	SW2-8-1 W5	CL	0	3.5	E	CH	HPD	0	OATS	BARLEY	100	CONT-SG
45	SW2-8-1 W5	C	0	3.5	E	CH	HPD	0	OATS	BARLEY	100	CONT-SG
46	NW35-7-1 W5	C	SE	5.5	W	0	HPD	0	BARLEY	F	<100	SG-SG-HAY
47	NW35-7-1 W5	HC	SE	4	W	0	HPD	0	BARLEY	F	<100	SG-SG-HAY
48	NW35-7-1 W5	HC	SE	5	W	0	HPD	0	BARLEY	F	<100	SG-SG-HAY
49	NW35-7-1 W5	CL	SE	5	W	0	HPD	0	BARLEY	F	<100	SG-SG-HAY
50	NW35-7-1 W5	HC	SE	4.5	W	0	HPD	0	BARLEY	F	<100	SG-SG-HAY

TABLE 8.6. (cont) PINCHER CREEK SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
51	NE11-8-1 W5	C	ME	4	0	2CN	NPD	0	BARLEY	F	<100	SG-SG-HAY
52	NE11-8-1 W5	C	SE	4	S	2CN	NPD	0	BARLEY	F	<100	SG-SG-HAY
53	NE11-8-1 W5	C	SE	5	S	2CN	NPD	0	BARLEY	F	<100	SG-SG-HAY
54	NE11-8-1 W5	C	SE	4	S	2CN	NPD	0	BARLEY	F	<100	SG-SG-HAY
55	NE11-8-1 W5	C	SE	4	S	2CN	NPD	0	BARLEY	F	<100	SG-SG-HAY
56	E1/2 4-8 29 W4	C	SE	4	S	0	NPD	0	WHEAT	F	350	SG-F
57	E1/2 4-8 29 W4	C	SE	4	SE	0	NPD	0	WHEAT	F	350	SG-F
58	E1/2 4-8 29 W4	C	SE	4	E	0	NPD	0	WHEAT	F	350	SG-F
59	E1/2 4-8 29 W4	CL	SE	4.5	E	0	NPD	0	WHEAT	F	350	SG-F
60	E1/2 4-8 29 W4	HC	SE	4	E	0	NPD	0	WHEAT	F	350	SG-F
61	SE27-7-1 W5	HC	SE	4	S	2CT	DPD	0	WHEAT	F	<100	SG-F
62	SE27-7-1 W5	HC	SE	4	S	2CT	DPD	0	WHEAT	F	<100	SG-F
63	SE27-7-1 W5	HC	SE	3.5	S	2CT	DPD	0	WHEAT	F	<100	SG-F
64	SE27-7-1 W5	HC	SE	3.5	S	2CT	DPD	0	WHEAT	F	<100	SG-F
65	SE27-7-1 W5	C	SE	4.5	S	2CT	DPD	0	WHEAT	F	<100	SG-F
66	NE7-9-1 W5	C	SE	3.5	S	D+CT	NPD	0	BARLEY	F	100	SG-SG-HAY
67	NE7-9-1 W5	C	SE	3.5	S	D+CT	NPD	0	BARLEY	F	100	SG-SG-HAY
68	NE7-9-1 W5	C	SE	3.5	N	D+CT	NPD	0	BARLEY	F	100	SG-SG-HAY
69	NE7-9-1 W5	C	SE	4	S	D+CT	NPD	0	BARLEY	F	100	SG-SG-HAY
70	NE7-9-1 W5	SiC	SE	3.5	S	D+CT	NPD	0	BARLEY	F	100	SG-SG-HAY
71	NE30-9-1 W5	CL	SE	4	N	2C	NPD	0	OATS	OATS	100	CONT-SG
72	NE30-9-1 W5	C	VWE	3	N	2C	NPD	0	OATS	OATS	100	CONT-SG
73	NE30-9-1 W5	CL	ME	4	N	2C	NPD	0	OATS	OATS	100	CONT-SG
74	NE30-9-1 W5	CL	WE	3.5	S	2C	NPD	0	OATS	OATS	100	CONT-SG
75	NE30-9-1 W5	C	0	3	S	2C	NPD	0	OATS	OATS	100	CONT-SG
76	NE12-6-30 W4	C	0	3	0	2CDRN	NPD	0	OATS	F	350	SG-F
77	NE12-6-30 W4	C	0	4	0	2CDRN	NPD	0	OATS	F	350	SG-F
78	NE12-6-30 W4	C	0	3	0	2CDRN	NPD	0	OATS	F	350	SG-F
79	NE12-6-30 W4	SiC	0	3.5	0	2CDRN	NPD	0	OATS	F	350	SG-F
80	NE12-6-30 W4	C	0	3	0	2CDRN	NPD	0	OATS	F	350	SG-F
81	NW9-6-29 W4	SiC	SE	5	0	2C	NPD	0	WHEAT	WHEAT	450	CONT-SG
82	NW9-6-29 W4	C	SE	4	0	2C	NPD	0	WHEAT	WHEAT	450	CONT-SG
83	NW9-6-29 W4	HC	ME	3.5	0	2C	NPD	0	WHEAT	WHEAT	450	CONT-SG
84	NW9-6-29 W4	L	ME	3.5	0	2C	NPD	0	WHEAT	WHEAT	450	CONT-SG
85	NW9-6-29 W4	HC	ME	3	0	2C	NPD	0	WHEAT	WHEAT	450	CONT-SG
86	SW1-6-29 W4	HC	0	3	0	C+RW	NPD	0	WHEAT	WHEAT	350	CONT-SG
87	SW1-6-29 W4	SiC	0	3	0	C+RW	NPD	0	WHEAT	WHEAT	350	CONT-SG
88	SW1-6-29 W4	HC	0	3	0	C+RW	NPD	0	WHEAT	WHEAT	350	CONT-SG
89	SW1-6-29 W4	C	0	3	0	C+RW	NPD	0	WHEAT	WHEAT	350	CONT-SG
90	SW1-6-29 W4	HC	0	3	0	C+RW	NPD	0	WHEAT	WHEAT	350	CONT-SG
91	SW26-5-27 W4	CL	0	3	0	2CT	NPD	0	WHEAT	WHEAT	100	CONT-SG
92	SW26-5-27 W4	CL	0	3	0	2CT	NPD	0	WHEAT	WHEAT	100	CONT-SG
93	SW26-5-27 W4	CL	0	2.5	W	2CT	NPD	0	WHEAT	WHEAT	100	CONT-SG
94	SW26-5-27 W4	CL	VWE	2.5	W	2CT	NPD	0	WHEAT	WHEAT	100	CONT-SG
95	SW26-5-27 W4	CL	0	2.5	W	2CT	NPD	0	WHEAT	WHEAT	100	CONT-SG
96	NW26-5-27 W4	HC	0	3	0	2CT	NPD	0	WHEAT	WHEAT	700	CONT-SG
97	NW26-5-27 W4	HC	0	2	0	2CT	NPD	0	WHEAT	WHEAT	700	CONT-SG
98	NW26-5-27 W4	HC	VWE	3.5	0	2CT	NPD	0	WHEAT	WHEAT	700	CONT-SG
99	NW26-5-27 W4	C	0	2.5	0	2CT	NPD	0	WHEAT	WHEAT	700	CONT-SG
100	NW26-5-27 W4	HC	0	3	W	2CT	NPD	0	WHEAT	WHEAT	700	CONT-SG

TABLE 8.6. (cont) PINCHER CREEK SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
101	SE5-6-28 W4	HC	ME	4	0	2CTR	HPD	0	BARLEY	WHEAT	350	CONT-SG
102	SE5-6-28 W4	HC	ME	4	0	2CTR	HPD	0	BARLEY	WHEAT	350	CONT-SG
103	SE5-6-28 W4	HC	ME	2.5	0	2CTR	HPD	0	BARLEY	WHEAT	350	CONT-SG
104	SE5-6-28 W4	HC	ME	2.5	0	2CTR	HPD	0	BARLEY	WHEAT	350	CONT-SG
105	SE5-6-28 W4	HC	ME	2.5	0	2CTR	HPD	0	BARLEY	WHEAT	350	CONT-SG
106	SE18-6-28 W4	C	0	3	0	2C+2H	HPD	0	WHEAT	F	100	SG-F
107	SE18-6-28 W4	C	0	3.5	N	2C+2H	HPD	0	WHEAT	F	100	SG-F
108	SE18-6-28 W4	C	0	3.5	0	2C+2H	HPD	0	WHEAT	F	100	SG-F
109	SE18-6-28 W4	C	0	3	S	2C+2H	HPD	0	WHEAT	F	100	SG-F
110	SE18-6-28 W4	C	0	3	0	2C+2H	HPD	0	WHEAT	F	100	SG-F

TEXT = soil texture
CARB = soil carbonates from field HCl test
VWE = very weakly effervescent
WE = weakly effervescent
ME = moderately effervescent
SE = strongly effervescent
VSE = very strongly effervescent
ASPECT = site aspect,
PST = preseeding tilla
SEED = seeding implime
PS = post seeding impl
C = canola
SG = small grains
F = fallow
TILLAGE AND SEEDING EQUIPMENT
AS = air seeder
ASTP = airseeder + tine harrows + packer
C = cultivator
CDRH = cultivator + deadrod + harrows
CHP = cultivator with harrowpackers
CP = crowfoot packer
CR = cultivator with rodweeder
CS = cultivator (sweeps)
CT = cultivator with tine harrows
D = discer
DP = discer with attached packer wheels
DPD = disk press drill
DT = deep tiller
H = drag harrows
HDR = hoe drill with rodweeder
HDT = hoe drill with tine harrows
HP = harrowpacker
HPD = hoe press drill
K = knife
P = packed with seed drill
RW = rodweeder
TD = tandem disks
TH = tine harrows
V = vibrashank

TABLE 8.7 FLAGSTAFF SOILS - FIELD DATA

SAMP #	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
1	NW23-44-12 W4	CL	0	3	W	CT	AS	NP	WHEAT	CANOLA	450	SG-C
2	NW23-44-12 W4	L	0	4.5	E	CT	AS	NP	WHEAT	CANOLA	450	SG-C
3	NW23-44-12 W4	L	0	4.5	W	CT	AS	NP	WHEAT	CANOLA	450	SG-C
4	NW23-44-12 W4	L	0	3	W	CT	AS	NP	WHEAT	CANOLA	450	SG-C
5	NW23-44-12 W4	L	0	3	W	CT	AS	NP	WHEAT	CANOLA	450	SG-C
6	SW6-45-12 W4	L	0	3.5	S	CT	AS	NP	WHEAT	CANOLA	600	SG-C
7	SW6-45-12 W4	L	VWE	3	S	CT	AS	NP	WHEAT	CANOLA	600	SG-C
8	SW6-45-12 W4	L	0	3	S	CT	AS	NP	WHEAT	CANOLA	600	SG-C
9	SW6-45-12 W4	SCL	VWE	2.5	S	CT	AS	NP	WHEAT	CANOLA	600	SG-C
10	SW6-45-12 W4	SL	0	3	W	CT	AS	NP	WHEAT	CANOLA	600	F-C-SG-C
11	SE25-43-12 W4	LS	0	3	N	2C	ND	TN	WHEAT	CANOLA	350	F-C-SG-C
12	SE25-43-12 W4	SL	0	3	N	2C	ND	TN	WHEAT	CANOLA	350	F-C-SG-C
13	SE25-43-12 W4	LS	0	3	N	2C	ND	TN	WHEAT	CANOLA	350	F-C-SG-C
14	SE25-43-12 W4	S	0	3	N	2C	ND	TN	WHEAT	CANOLA	350	F-C-SG-C
15	SE25-43-12 W4	S	0	3	W	2C	ND	TN	WHEAT	CANOLA	350	F-C-SG-C
16	SW22-43-13 W4	L	0	3	W	CT	NPD	0	CANOLA	F	<100	F-C-SG-C
17	SW22-43-13 W4	SL	0	3	W	CT	NPD	0	CANOLA	F	<100	F-C-SG-C
18	SW22-43-13 W4	L	0	3	W	CT	NPD	0	CANOLA	F	<100	F-C-SG-C
19	SW22-43-13 W4	L	0	3	W	CT	NPD	0	CANOLA	F	<100	F-C-SG-C
20	SW22-43-13 W4	L	0	3	W	CT	NPD	0	CANOLA	F	<100	F-C-SG-C
21	NW15-43-13 W4	L	0	2.5	0	CS.NP	AS	NP	WHEAT	CANOLA	100	SG-SG-C
22	NW15-43-13 W4	L	0	2.5	0	CS.NP	AS	NP	WHEAT	CANOLA	100	SG-SG-C
23	NW15-43-13 W4	CL	0	2.5	0	CS.NP	AS	NP	WHEAT	CANOLA	100	SG-SG-C
24	NW15-43-13 W4	L	0	4	0	CS.NP	AS	NP	WHEAT	CANOLA	100	SG-SG-C
25	NW15-43-13 W4	L	0	3	E	CS.NP	AS	NP	WHEAT	CANOLA	100	SG-SG-C
26	NE16-43-13 W4	L	0	3.5	E	CS.NP.	AS	NP	CANOLA	BARLEY	450	SG-SG-C
27	NE16-43-13 W4	L	0	3.5	E	CS.NP.	AS	NP	CANOLA	BARLEY	450	SG-SG-C
28	NE16-43-13 W4	C	0	3.5	E	CS.NP.	AS	NP	CANOLA	BARLEY	450	SG-SG-C
29	NE16-43-13 W4	CL	0	4	E	CS.NP.	AS	NP	CANOLA	BARLEY	450	SG-SG-C
30	NE16-43-13 W4	CL	0	4	E	CS.NP.	AS	NP	CANOLA	BARLEY	450	SG-SG-C
31	NE30-43-13 W4	L	0	3.5	W	2CR	NPD	0	CANOLA	F	<100	F-C-SG-SG
32	NE30-43-13 W4	L	0	3.5	E	2CR	NPD	0	CANOLA	F	<100	F-C-SG-SG
33	NE30-43-13 W4	L	0	3.5	E	2CR	NPD	0	CANOLA	F	<100	F-C-SG-SG
34	NE30-43-13 W4	L	0	3.5	N	2CR	NPD	0	CANOLA	F	<100	F-C-SG-SG
35	NE30-43-13 W4	L	0	3	N	2CR	NPD	0	CANOLA	F	<100	F-C-SG-SG
36	SW5-44-13 W4	L	0	3	0	2CR	NPD	N	WHEAT	CANOLA	100	F-C-SG-SG
37	SW5-44-13 W4	SL	0	3	0	2CR	NPD	N	WHEAT	CANOLA	100	F-C-SG-SG
38	SW5-44-13 W4	CL	0	2.5	S	2CR	NPD	N	WHEAT	CANOLA	100	F-C-SG-SG
39	SW5-44-13 W4	CL	0	3	S	2CR	NPD	N	WHEAT	CANOLA	100	F-C-SG-SG
40	SW5-44-13 W4	CL	0	3	S	2CR	NPD	N	WHEAT	CANOLA	100	F-C-SG-SG
41	NE4-44-13 W4	S	0	4	N	3C	DPD	N	WHEAT	WHEAT	350	CONT SG
42	NE4-44-13 W4	S	0	3	N	3C	DPD	N	WHEAT	WHEAT	350	CONT SG
43	NE4-44-13 W4	S	0	3	S	3C	DPD	N	WHEAT	WHEAT	350	CONT SG
44	NE4-44-13 W4	S	0	3	S	3C	DPD	N	WHEAT	WHEAT	350	CONT SG
45	NE4-44-13 W4	SL	0	2.5	S	3C	DPD	N	WHEAT	WHEAT	350	CONT SG
46	NE9-44-13 W4	SL	0	3	0	2CR.KT	DPD	N	CANOLA	BARLEY	600	SG-SG-C
47	NE9-44-13 W4	SL	0	3	0	2CR.KT	DPD	N	CANOLA	BARLEY	600	SG-SG-C
48	NE9-44-13 W4	CL	0	3	0	2CR.KT	DPD	N	CANOLA	BARLEY	600	SG-SG-C
49	NE9-44-13 W4	L	0	3	N	2CR.KT	DPD	N	CANOLA	BARLEY	600	SG-SG-C
50	NE9-44-13 W4	SL	0	2.5	N	2CR.KT	DPD	N	CANOLA	BARLEY	600	SG-SG-C

TABLE 8.7 (cont) FLAGSTAFF SOILS - FIELD DATA

SAMP #	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
51	SE16-44-13 W6	SL	0	2.5	0	2CT	DPD	N	WHEAT	CANOLA	<100	SG-SG-C
52	SE16-44 13 W6	SL	0	2.5	0	2CT	DPD	N	WHEAT	CANOLA	<100	SG-SG-C
53	SE16-44-13 W6	SL	0	3	S	2CT	DPD	N	WHEAT	CANOLA	<100	SG-SG-C
54	SE16-44-13 W6	LS	0	3	S	2CT	DPD	N	WHEAT	CANOLA	<100	SG-SG-C
55	SE16-44-13 W6	LS	0	3	S	2CT	DPD	N	WHEAT	CANOLA	<100	SG-SG-C
56	SW28-44-13 W6	LS	0	3	E	C	D	N	WHEAT	WHEAT	200	CONT SG
57	SW28-44-13 W6	SL	0	3	W	C	D	N	WHEAT	WHEAT	200	CONT SG
58	SW28-44-13 W6	SL	0	3	E	C	D	N	WHEAT	WHEAT	200	CONT SG
59	SW28-44-13 W6	SL	0	3	E	C	D	N	WHEAT	WHEAT	200	CONT SG
60	SW28-44-13 W6	LS	0	3	E	C	D	N	WHEAT	WHEAT	200	CONT SG
61	SE2-44-13 W6	SL	0	3	N	2C	HD	TH	WHEAT	WHEAT	100	SG-SG-C
62	SE2-44-13 W6	SL	0	3	N	2C	HD	TH	WHEAT	WHEAT	100	SG-SG-C
63	SE2-44-13 W6	SL	0	3	S	2C	HD	TH	WHEAT	WHEAT	100	SG-SG-C
64	SE2-44-13 W6	SL	0	3	N	2C	HD	TH	WHEAT	WHEAT	100	SG-SG-C
65	SE2-44-13 W6	SL	0	3	S	2C	HD	TH	WHEAT	WHEAT	100	SG-SG-C
66	SW5-44-12 W6	SL	0	3	0	2C.H	HPD	0	CANOLA	WHEAT	100	SG-SG-SG-C
67	SW5-44-12 W6	SL	0	3	S	2C.H	HPD	0	CANOLA	WHEAT	100	SG-SG-SG-C
68	SW5-44-12 W6	SL	0	3	W	2C.H	HPD	0	CANOLA	WHEAT	100	SG-SG-SG-C
69	SW5-44-12 W6	SL	0	3	W	2C.H	HPD	0	CANOLA	WHEAT	100	SG-SG-SG-C
70	SW5-44-12 W6	SL	0	3.5	W	2C.H	HPD	0	CANOLA	WHEAT	100	SG-SG-SG-C
71	SW11-44-12 W6	SL	0	3.5	N	CT	AS	HP	WHEAT	CANOLA	<100	SG-C
72	SW11-44-12 W6	SL	0	3.5	N	CT	AS	HP	WHEAT	CANOLA	<100	SG-C
73	SW11-44-12 W6	SL	0	3	0	CT	AS	HP	WHEAT	CANOLA	<100	SG-C
74	SW11-44-12 W6	SL	0	3	N	CT	AS	HP	WHEAT	CANOLA	<100	SG-C
75	SW11-44-12 W6	SL	0	3	W	CT	AS	HP	WHEAT	CANOLA	<100	SG-C
76	NW23-43-14 W6	L	0	3.5	N	2CT.R	HPD	0	WHEAT	CANOLA	100	SG-C
77	NW23-43-14 W6	L	0	3	N	2CT.R	HPD	0	WHEAT	CANOLA	100	SG-C
78	NW23-43-14 W6	L	0	3.5	S	2CT.R	HPD	0	WHEAT	CANOLA	100	SG-C
79	NW23-43-14 W6	L	0	4	S	2CT.R	HPD	0	WHEAT	CANOLA	100	SG-C
80	NW23-43-14 W6	L	0	3	S	2CT.R	HPD	0	WHEAT	CANOLA	100	SG-C
81	SE22-43-14 W6	L	0	3	W	2CT.R.	HPD	0	CANOLA	WHEAT	200	SG-C
82	SE22-43-14 W6	L	0	3	W	2CT.R.	HPD	0	CANOLA	WHEAT	200	SG-C
83	SE22-43-14 W6	L	0	3	W	2CT.R.	HPD	0	CANOLA	WHEAT	200	SG-C
84	SE22-43-14 W6	L	0	3	W	2CT.R.	HPD	0	CANOLA	WHEAT	200	SG-C
85	SE22-43-14 W6	L	0	3	W	2CT R.	HPD	0	CANOLA	WHEAT	200	SG-C

TEXT = soil texture
CARB = soil carbonates from field HCl test
VWE = very weakly effervescent
WE = weakly effervescent
ME = moderately effervescent
SE = strongly effervescent
VSE = very strongly effervescent
ASPECT = site aspect, 4 compass points
PST = preseeding tillage, impliment and number of passes
SEED = seeding impliment
PS = post seeding impliment
C = canola
SG = small grains
F = fallow

TABLE 8.7 (cont) FLAGSTAFF SOILS - FIELD DATA

TILLAGE AND SEEDING EQUIPMENT
AS = air seeder
ASTP = airseeder + tine harrows + packer
C = cultivator
CDRH = cultivator + deadrod + harrows
CHP = cultivator with harrowpackers
CP = crowfoot packer
CR = cultivator with rodweeder
CS = cultivator (sweeps)
CT = cultivator with tine harrows
D = discer
DP = discer with attached packer wheels
DPD = disk press drill
DT = deep tiller
H = drag harrows
HDR = hoe drill with rodweeder
HDT = hoe drill with tine harrows
HP = harrowpacker
HPD = hoe press drill
K = knife
P = packed with seed drill
RW = rodweeder
TD = tandem disks
TH = tine harrows
V = vibrashank

TABLE 8.8 VERMILION SOILS - FIELD DATA

SAMP#	LAND LOCATION	TEXT	CARB	MUNSELL VALUE	ASPECT	PST	SEED	PS	CROP SEEDED	1985 CROP	RESIDUE kg/ha	ROTATION
1	NE1-52-4 W4	L	0	3	E	CNP	NPD	0	CANOLA	F	100	F-C-SG
2	NE1-52-4 W4	L	0	2.5	0	CNP	NPD	0	CANOLA	F	100	F-C-SG
3	NE1-52-4 W4	L	0	3	0	CNP	NPD	0	CANOLA	F	100	F-C-SG
4	NE1-52-4 W4	L	0	3	N	CNP	NPD	0	CANOLA	F	100	F-C-SG
5	NE1-52-4 W4	SL	0	3	N	CNP	NPD	0	CANOLA	F	100	F-C-SG
6	SW2-52-4 W4	CL	VSE	3.5	W	CT	NPD	0	BARLEY	CANOLA	100	F-C-SG
7	SW2-52-4 W4	CL	0	2	E	CT	NPD	0	BARLEY	CANOLA	100	F-C-SG
8	SW2-52-4 W4	CL	0	3	E	CT	NPD	0	BARLEY	CANOLA	100	F-C-SG
9	SW2-52-4 W4	CL	0	2	N	CT	NPD	0	BARLEY	CANOLA	100	F-C-SG
10	SW2-52-4 W4	C	0	2.5	0	CT	NPD	0	BARLEY	CANOLA	100	F-C-SG
11	NE9-52-6 W4	CL	0	2	E	CTN	NPD	0	CANOLA	F	<100	F-SG-C
12	NE9-52-6 W4	L	0	2.5	0	CTN	NPD	0	CANOLA	F	<100	F-SG-C
13	NE9-52-6 W4	CL	0	2	W	CTN	NPD	0	CANOLA	F	<100	F-SG-C
14	NE9-52-6 W4	CL	0	3	N	CTN	NPD	0	CANOLA	F	<100	F-SG-C
15	NE9-52-6 W4	CL	0	3	E	CTN	NPD	0	CANOLA	F	<100	F-SG-C
16	SW10-52-6 W4	SCL	0	3	N	TD,2CT	NPD	0	WHEAT	WHEAT	>850	SG-SG-F
17	SW10-52-6 W4	SCL	VSE	2	N	TD,2CT	NPD	0	WHEAT	WHEAT	>850	SG-SG-F
18	SW10-52-6 W4	SCL	VSE	2	N	TD,2CT	NPD	0	WHEAT	WHEAT	>850	SG-SG-F
19	SW10-52-6 W4	SCL	0	3	N	TD,2CT	NPD	0	WHEAT	WHEAT	>850	SG-SG-F
20	SW10-52-6 W4	CL	0	3	E	TD,2CT	NPD	0	WHEAT	WHEAT	>850	SG-SG-F
21	NE35-52-6 W4	C	0	2	E	V	DPD	0	WHEAT	WHEAT	<100	SG-SG-SG-F
22	NE35-52-6 W4	C	0	2.5	E	V	DPD	0	WHEAT	WHEAT	<100	SG-SG-SG-F
23	NE35-52-6 W4	C	0	2	0	V	DPD	0	WHEAT	WHEAT	<100	SG-SG-SG-F
24	NE35-52-6 W4	SCL	0	2.5	N	V	DPD	0	WHEAT	WHEAT	<100	SG-SG-SG-F
25	NE35-52-6 W4	SCL	0	2.5	N	V	DPD	0	WHEAT	WHEAT	<100	SG-SG-SG-F
26	NE11-52-6 W4	CL	0	3	S	V	DPD	0	CANOLA	WHEAT	350	F-SG-C
27	NE11-52-6 W4	L	0	3	E	V	DPD	0	CANOLA	WHEAT	350	F-SG-C
28	NE11-52-6 W4	CL	0	2.5	N	V	DPD	0	CANOLA	WHEAT	350	F-SG-C
29	NE11-52-6 W4	CL	0	3	E	V	DPD	0	CANOLA	WHEAT	350	F-SG-C
30	NE11-52-6 W4	L	0	2.5	E	V	DPD	0	CANOLA	WHEAT	350	F-SG-C
31	SW7-48-5 W4	CL	0	4	0	CTN	NPD	0	WHEAT	CANOLA	100	F-C-SG
32	SW7-48-5 W4	CL	0	3.5	S	CTN	NPD	0	WHEAT	CANOLA	100	F-C-SG
33	SW7-48-5 W4	CL	0	3	0	CTN	NPD	0	WHEAT	CANOLA	100	F-C-SG
34	SW7-48-5 W4	CL	0	3	S	CTN	NPD	0	WHEAT	CANOLA	100	F-C-SG
35	SW7-48-5 W4	CL	0	4	S	CTN	NPD	0	WHEAT	CANOLA	100	F-C-SG
36	SE7-48-5 W4	L	0	2	0	3C	NPD	0	CANOLA	F	<100	F-SG-SG
37	SE7-48-5 W4	L	0	3	0	3C	NPD	0	CANOLA	F	<100	F-SG-SG
38	SE7-48-5 W4	L	0	3	0	3C	NPD	0	CANOLA	F	<100	F-SG-SG
39	SE7-48-5 W4	CL	0	3	0	3C	NPD	0	CANOLA	F	<100	F-SG-SG
40	SE7-48-5 W4	CL	0	3.5	N	3C	NPD	0	CANOLA	F	<100	F-SG-SG
41	NW21-49-4 W4	CL	0	3	S	CNP	NPD+TN	CT	CANOLA	F	<100	F-C-SG
42	NW21-49-4 W4	SCL	0	3	W	CNP	NPD+TN	CT	CANOLA	F	<100	F-C-SG
43	NW21-49-4 W4	L	0	3	S	CNP	NPD+TN	CT	CANOLA	F	<100	F-C-SG
44	NW21-49-4 W4	L	0	3	N	CNP	NPD+TN	CT	CANOLA	F	<100	F-C-SG
45	NW21-49-4 W4	L	0	3	N	CNP	NPD+TN	CT	CANOLA	F	<100	F-C-SG
46	SE29-49-4 W4	CL	0	3	E	CT	NPD	0	WHEAT	CANOLA	<100	F-C-SG
47	SE29-49-4 W4	L	0	3	S	CT	NPD	0	WHEAT	CANOLA	<100	F-C-SG
48	SE29-49-4 W4	L	0	3	E	CT	NPD	0	WHEAT	CANOLA	<100	F-C-SG
49	SE29-49-4 W4	L	0	3	E	CT	NPD	0	WHEAT	CANOLA	<100	F-C-SG
50	SE29-49-4 W4	CL	0	2.5	S	CT	NPD	0	WHEAT	CANOLA	<100	F-C-SG

TABLE 8 (cont) VERMILION SOILS - FIELD DATA

TEXT = soil texture
CARB = soil carbonates from field HCl test
VWE = very weakly effervescent
WE = weakly effervescent
ME = moderately effervescent
SE = strongly effervescent
VSE = very strongly effervescent
ASPECT = site aspect, 4 compass points
PST = preseeding tillage, impliment and number of passes
SEED = seeding impliment
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HP = harrowpacker
HPD = hoe press drill
K = knife
P = packed with seed drill
RW = rodweeder
TD = tandem disks
TH = tine harrows
V = vibrashank

TABLE 8.9 OYEN SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
1	25.5	66	23	29	14	23	12	6	5	11	7	0	1.23	9.46	2.41	0.17	1.07	13.11
2	38.6	57	21	22	15	30	16	7	7	13	6.3	0	1.85	10.02	2.48	1.38	1.99	15.87
3	16.9	64	29	22	13	25	13	5	7	11	6.3	0	1.40	8.10	2.18	0.31	1.23	11.82
4	33.5	59	24	22	13	30	17	4	9	11	5.5	0	2.30	9.34	2.07	0.34	1.56	13.30
5	46	63	21	27	15	27	14	5	8	10	5.7	0	2.14	9.41	2.13	0.28	1.64	13.46
6	47.6	64	12	32	20	26	15	6	5	10	6.1	0	2.10	8.65	2.55	0.62	1.22	13.04
7	25.2	77	18	41	18	15	5	6	4	8	5.8	0	1.88	7.21	1.65	0.82	1.22	10.90
8	16.2	78	18	42	18	14	7	3	4	8	6	0	1.38	7.23	1.78	0.11	0.85	9.97
9	19.1	77	26	34	17	17	7	5	5	6	5.3	0	1.92	8.00	1.98	0.68	1.10	11.77
10	35.1	73	23	31	19	19	8	7	4	8	5.3	0	2.31	8.48	1.94	0.55	2.06	13.02
11	48.7	25	5	10	10	48	27	9	12	27	6.3	0	2.13	9.40	7.71	1.99	2.85	21.95
12	55.2	38	10	17	11	45	27	8	10	17	6.5	0	2.46	10.48	4.99	0.37	2.97	18.80
13	47.5	33	8	13	12	48	30	9	9	19	6.4	0	2.39	12.16	6.99	0.48	2.85	22.48
14	43.8	31	7	13	11	53	31	9	13	16	6.6	0	2.66	12.98	5.54	0.28	4.49	23.29
15	44.7	41	13	17	11	44	29	5	10	15	6.8	0	2.15	11.75	5.37	0.28	2.36	19.76
16	27.6	18	4	6	8	34	14	7	13	48	7.8	0.05	1.54	28.52	10.52	0.43	2.45	41.92
17	62.6	20	4	7	9	40	19	8	13	40	6.5	0	1.82	16.90	9.58	0.73	2.41	29.62
18	64.8	30	6	13	11	38	20	8	10	32	6.6	0	1.70	14.72	7.94	0.22	1.87	24.74
19	39.3	25	5	10	10	36	16	9	11	39	7.1	0	1.86	20.03	9.78	1.04	2.39	33.23
20	24.3	22	5	9	8	33	16	3	14	45	7.9	0.01	1.61	34.14	10.09	0.27	2.19	46.69
21	23.8	23	8	12	4	37	17	9	11	40	7.8	0.03	1.24	24.57	12.54	0.50	2.22	39.83
22	42.2	17	3	7	7	30	14	7	9	53	8.1	0.16	1.22	59.00	12.77	2.25	1.93	75.95
23	28.3	26	6	13	7	30	13	7	10	44	8	0.1	1.41	53.06	10.15	1.16	2.34	66.72
24	40.3	19	4	7	8	23	10	5	8	58	8.2	0.14	1.29	56.90	11.01	3.11	2.29	73.31
25	26.7	22	4	9	9	30	14	6	10	48	8.1	0.07	1.47	39.55	9.52	1.23	2.14	52.44
26	65.6	40	13	17	10	35	22	6	7	25	6.5	0	1.36	12.38	7.45	0.43	1.07	21.32
27	44.8	62	33	16	14	24	16	3	5	14	6.1	0	1.47	6.40	2.43	1.05	0.90	10.78
28	9.1	79	55	16	8	13	6	3	4	8	6.4	0	1.26	5.90	1.65	0.86	0.94	9.36
29	7.2	89	67	14	8	5	1	1	3	6	6.8	0	0.59	4.42	1.35	0.74	0.39	6.91
30	13.4	85	57	20	8	9	5	1	3	6	6.2	0	0.90	4.43	0.99	0.61	0.39	6.42
31	39.5	47	18	17	12	33	18	7	8	20	7.4	0	1.64	14.94	5.02	0.62	1.06	21.63
32	43.5	60	26	20	14	27	13	7	7	13	6.6	0	2.01	9.80	2.41	1.84	1.13	15.17
33	41.8	63	23	25	15	22	11	5	6	15	7	0	1.32	10.28	3.32	0.45	0.60	14.65
34	30.7	52	19	21	12	27	14	6	7	21	6.4	0	1.27	10.57	4.11	1.42	0.81	16.91
35	45.5	46	17	16	13	30	16	8	6	24	6.1	0	1.40	11.14	4.93	1.64	0.67	18.39
36	30.9	47	16	18	13	29	15	7	7	24	8.1	0.4	1.39	36.79	5.95	0.39	1.20	44.34
37	37.4	35	6	17	12	35	21	9	5	30	7.8	0	1.58	38.37	7.80	0.37	1.27	47.81
38	32.3	39	12	16	11	42	31	1	10	19	6.1	0	2.29	19.36	4.47	1.87	1.60	27.30
39	34.6	31	9	12	11	42	27	6	9	27	6.5	0	1.90	11.08	6.71	0.28	1.46	19.54
40	43.2	38	12	15	11	41	23	9	9	21	6.3	0	2.28	16.36	4.74	0.45	1.56	23.11
41	45.9	31	13	10	8	33	15	6	12	36	8.2	0.47	1.22	43.26	8.13	0.25	1.67	53.31
42	40.9	10	4	2	4	32	15	6	11	58	8.2	0.12	1.07	49.20	10.16	0.52	1.94	61.82
43	49.4	41	13	17	11	29	15	4	10	30	8.3	1.2	0.86	44.44	7.03	0.15	1.19	52.80
44	37.9	30	10	11	9	25	11	6	8	45	8.2	0.42	1.06	47.46	9.15	0.17	1.45	58.23
45	39.1	34	14	13	7	33	16	6	11	33	8.2	0.19	1.23	39.90	7.73	0.16	1.67	49.46
46	34.1	10	1	5	4	30	9	6	15	60	7.9	0.05	1.50	50.70	9.78	0.51	2.65	63.65
47	32.9	1	1	0	0	32	10	6	16	67	8	0.1	1.42	51.22	10.99	0.91	2.54	65.66
48	49.3	12	2	7	3	23	8	4	11	65	8	0.12	1.23	58.47	11.05	0.96	2.29	72.77
49	57.6	11	1	7	3	29	10	7	12	60	8	0.07	1.42	50.25	8.97	0.29	2.56	62.06
50	50.8	10	1	3	6	27	9	7	11	63	8	0.13	1.30	60.19	10.29	0.40	2.30	73.18
51	24.7	27	6	13	8	39	19	7	13	34	7.8	0	1.72	24.90	9.98	0.32	2.90	38.10

TABLE 8.9 cont OYEN SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
52	36.2	18	3	8	8	42	16	9	17	40	7.8	0.03	1.73	31.17	11.34	0.50	3.70	46.70
53	31.8	31	12	10	9	35	16	8	11	34	8.2	0.4	1.56	48.15	8.38	0.31	1.71	58.55
54	32.2	26	5	13	8	24	14	5	5	50	8	0.05	1.23	30.10	12.32	2.19	2.08	46.69
55	27	21	3	11	7	31	17	5	9	48	8.1	0.16	1.37	48.67	10.91	2.34	1.95	63.87
56	41	37	13	16	8	41	23	5	13	22	7.3	0	1.42	16.65	7.47	0.50	1.57	26.19
57	56.6	36	11	13	12	42	25	9	8	22	6.2	0	1.85	9.86	5.55	0.61	1.72	17.75
58	50.1	38	12	14	12	41	22	7	12	21	6.4	0	1.89	12.96	6.29	0.13	1.62	21.00
59	42	32	7	12	13	50	31	8	11	18	6.1	0	2.07	10.45	4.44	0.15	2.10	17.14
60	41.7	34	8	13	13	47	29	9	9	19	6.1	0	2.03	9.85	4.64	0.86	1.91	17.26
61	34	35	9	17	9	35	17	8	10	30	7.7	0.03	1.39	20.64	8.19	2.23	1.88	32.93
62	42.7	35	12	13	10	38	18	6	14	27	7.5	0	1.37	16.61	7.25	0.48	1.72	26.07
63	62.7	42	19	14	9	32	16	7	9	26	7.4	0	1.27	16.14	6.46	1.88	1.56	26.04
64	38.2	32	10	12	10	37	18	8	11	31	7.1	0	1.34	15.05	8.28	0.57	1.71	25.61
65	36.3	20	3	9	8	35	18	6	11	45	8	0	1.55	26.95	12.68	0.96	2.04	42.63
66	29	31	6	14	11	37	19	7	11	32	8	0.07	1.40	29.08	7.84	2.25	1.81	40.98
67	62.8	38	8	19	11	36	20	7	9	26	8	0.05	1.54	22.52	7.63	1.75	1.53	33.43
68	61.2	30	6	14	10	30	15	8	7	40	7.5	0.01	1.49	18.24	12.90	2.30	1.49	34.93
69	52	28	6	14	8	25	12	6	7	47	8.3	0.18	1.13	45.37	13.98	1.37	1.45	62.16
70	48	18	3	8	7	25	13	6	6	57	8.2	0.5	0.94	53.56	11.36	1.33	1.34	67.60
71	22.2	76	33	26	17	16	10	3	3	8	6.7	0	1.34	5.56	1.64	0.21	1.05	8.47
72	31.6	61	25	24	12	28	17	5	6	11	6.2	0	1.80	7.77	2.56	0.35	1.21	11.89
73	5.2	80	55	16	9	14	9	2	3	6	6.7	0	1.05	4.73	1.36	0.81	0.63	7.52
74	14.5	74	43	21	11	16	11	3	2	10	7.9	0.04	0.56	11.92	1.34	0.19	0.28	13.73
75	17.1	81	48	22	11	13	9	1	3	6	6.8	0	0.91	4.86	1.53	0.31	0.60	7.29
76	14.6	76	44	23	9	20	13	2	5	4	6.5	0	2.07	8.19	1.80	0.41	1.11	11.51
77	12.2	80	48	22	10	16	8	3	5	4	6.3	0	1.71	7.53	1.54	0.63	0.83	10.52
78	17.8	81	49	23	9	15	9	1	5	4	6.2	0	1.73	6.30	1.31	0.66	0.74	9.01
79	24.5	78	44	26	9	18	9	4	5	4	6.4	0	1.58	7.11	1.60	0.19	0.52	9.42
80	10.1	82	44	28	10	14	8	1	5	4	6.9	0	1.38	6.55	1.67	0.82	0.58	9.63
81	39.5	63	10	35	18	24	14	3	7	13	7	0	1.29	11.81	3.95	0.18	1.18	17.12
82	44.9	58	3	36	19	28	15	6	7	14	6.4	0	1.68	9.55	3.50	0.71	1.67	15.43
83	51.4	19	1	8	10	51	34	9	8	30	7.9	0.26	1.56	30.68	7.81	0.16	1.65	40.29
84	54.7	39	2	21	16	41	26	7	8	20	6.3	0	2.01	11.79	5.33	0.64	2.12	19.89
85	50.6	52	2	31	19	33	21	6	6	15	6	0	1.95	8.37	3.17	0.59	2.13	14.27
86	57.7	38	2	20	16	42	25	9	8	20	5.6	0	2.24	10.10	4.49	0.27	2.35	17.20
87	56	48	3	28	17	35	21	5	9	17	6.1	0	2.06	12.55	4.29	0.16	1.07	18.07
88	32.5	52	4	32	16	31	20	4	7	17	7	0	1.42	14.15	3.89	0.28	1.39	19.73
89	37.4	46	4	26	16	36	23	5	8	18	7.1	0	1.66	16.00	4.36	0.55	1.45	22.36
90	60.5	41	2	24	15	40	28	4	8	19	6.3	0	2.34	14.94	4.63	0.26	2.19	22.02
92	69.3	26	7	10	9	35	15	8	12	39	7.3	0	1.48	17.99	10.04	0.65	2.20	30.88
93	66.1	25	7	10	8	37	15	6	16	38	7.3	0	1.42	18.50	10.66	0.28	2.09	31.52
94	66.2	26	7	10	9	37	15	9	13	37	7.4	0	1.39	19.50	9.84	0.38	2.23	31.95
95	50.2	20	7	6	7	33	13	6	14	47	7.8	0.01	1.20	24.17	12.28	1.30	1.98	39.73
96	45	50	7	25	18	39	24	5	10	11	7.5	0.02	1.74	11.29	5.53	2.89	1.75	21.47
97	62.5	49	3	27	19	40	23	7	10	11	7	0	1.98	10.25	3.62	0.90	2.48	17.25
98	37.3	55	5	28	22	32	22	5	5	13	7.6	0.04	1.57	13.75	4.20	0.26	1.69	19.90
99	53.7	52	5	31	16	38	27	2	9	10	7	0	1.80	10.05	3.02	0.24	1.69	15.00
100	51.8	54	9	30	15	35	19	8	8	11	7.4	0	1.63	11.35	3.45	0.24	1.70	16.73
101	62.1	50	19	21	10	33	20	4	9	17	6.7	0	2.04	10.48	4.45	1.94	1.42	18.29
102	50.7	50	18	20	12	32	18	5	9	18	7.3	0	1.64	14.21	4.97	0.48	1.04	20.70
103	69.4	23	7	9	7	50	27	11	12	27	6.7	0	1.83	13.40	6.28	0.57	1.55	21.79

TABLE 8.9 cont OYEN SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
104	60.1	41	16	15	10	38	20	9	9	21	7.3	0	1.95	13.27	4.86	0.79	1.40	20.32
105	58.4	51	25	15	11	37	21	7	9	12	7.3	0	1.96	12.09	5.22	2.08	1.49	20.89
106	38.1	49	16	21	12	32	19	6	7	19	5.8	0	1.76	8.32	4.16	0.56	1.13	14.16
107	29.7	66	23	28	15	23	11	4	8	11	6.4	0	1.58	8.79	2.67	0.58	1.04	13.08
108	43.4	46	16	17	13	34	18	7	9	20	7.5	0	1.99	16.57	5.27	0.96	1.37	24.17
109	70.9	33	7	15	11	47	25	12	10	20	5.6	0	2.46	11.27	3.93	0.86	1.85	17.90
110	50.2	50	15	22	13	34	20	6	8	16	6	0	1.94	7.85	2.71	0.55	1.41	12.52
111	37.6	63	14	31	18	23	13	4	6	14	6.4	0	1.46	11.44	3.63	0.54	0.67	16.28
112	30.9	75	25	33	17	15	7	4	4	10	6	0	1.35	7.29	1.85	0.88	0.65	10.68
113	27.7	71	24	29	18	19	10	4	5	10	6.2	0	1.53	6.59	2.06	0.27	1.16	10.08
114	49.6	58	19	23	16	23	13	5	5	19	6	0	1.94	10.15	3.05	0.78	1.01	14.99
115	42	65	24	26	15	25	15	3	7	10	5.8	0	1.77	6.74	1.98	0.25	1.35	10.32
116	51.8	51	2	29	20	31	19	4	8	18	6.5	0	1.51	10.92	3.63	0.30	2.08	16.94
117	42.1	31	3	16	13	42	26	8	8	27	7.9	0.2	1.38	31.30	6.01	0.33	1.54	39.18
118	77.2	39	8	19	12	34	16	7	11	27	7.6	0	1.50	18.40	7.05	0.15	2.00	27.60
119	51	70	28	29	13	18	11	3	4	12	7.9	0.02	0.81	15.14	2.39	0.16	0.94	18.64
120	56.2	30	2	16	12	46	27	8	11	24	5.5	0	2.24	10.54	5.92	0.24	1.58	18.28
121	83.3	43	6	21	16	38	26	3	9	19	6.3	0	1.76	10.63	4.54	0.97	1.90	18.05
122	77	49	8	24	17	30	21	3	6	21	6.3	0	1.20	13.71	5.41	0.16	1.34	20.62
123	73.6	55	7	30	18	27	17	4	6	18	7.5	0	1.06	13.39	4.18	0.13	0.99	18.70
124	66.4	50	7	27	17	30	20	3	7	20	6.7	0	1.24	11.99	4.87	0.85	1.31	19.02
125	68.8	51	9	27	15	31	20	3	8	18	6.3	0	1.41	10.12	4.61	0.13	1.26	16.13
126	45.5	29	1	18	10	41	23	9	9	30	7.3	0	1.27	16.84	6.96	0.38	1.42	25.60
127	51.5	30	1	19	10	43	23	8	12	27	7.5	0	1.32	20.18	6.84	1.01	1.55	29.57
129	80.3	29	1	16	12	45	29	10	6	26	7.9	0.02	1.56	21.37	7.60	1.15	2.10	32.22
130	51.9	27	1	14	12	43	26	8	9	30	7.9	0.11	1.44	30.85	6.99	0.50	1.60	39.94

SAMP = sample number
%TA = percentage true aggregates
S = total % sand
M+CS = % medium and coarse sand (>250 μm)
FS = % fine sand (100-250 μm)
VFS = % very fine sand (50 -100 μm)
Z = total % silt
CZ = % coarse silt (10-50 μm)
MZ = % medium silt (5-10 μm)
FZ = % fine silt (2-5 μm)
C = total % clay
inoC = % inorganic carbon
orgC = % organic carbon
Ca = adsorbed calcium (meq/100g)
Mg = adsorbed magnesium (meq/100g)
Na = adsorbed sodium (meq/100g)
K = adsorbed potassium (meq/100g)
TEC = total adsorbed cations (meq/100g)

TABLE 8.10. PINCHER SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
1	69.7	14	3	8	3	28	16	3	9	58	8	0.95	1.57	66.36	7.83	0.47	1.48	76.14
2	67.6	14	3	10	2	24	10	3	11	62	8	0.91	1.59	57.11	9.93	0.34	1.55	68.93
3	57.9	17	4	9	5	30	15	6	9	53	7.9	0.16	2.18	42.70	7.28	0.28	1.96	52.22
4	64	17	3	9	5	26	12	5	9	57	8.1	1.35	1.35	52.13	9.91	0.31	1.20	63.56
5	48.6	33	6	21	7	23	8	6	9	44	7.9	0.38	2.10	53.07	5.71	0.25	1.78	60.82
6	67.4	31	6	20	5	32	15	4	13	37	8.2	1.99	1.00	56.46	4.97	0.33	0.50	62.27
9	54	29	7	13	9	33	12	9	12	38	7.4	0	2.58	31.24	4.51	0.47	1.22	37.44
10	50.3	32	8	14	11	32	12	8	12	36	7.1	0	2.80	26.61	4.96	0.45	1.50	33.52
11	55.6	40	7	26	7	32	15	6	11	28	6	0	3.86	25.37	4.07	0.48	1.27	31.20
12	35.1	39	7	24	8	33	14	7	12	28	6.2	0	4.07	24.01	4.41	0.17	1.12	29.70
13	37.1	33	7	20	6	39	19	8	12	28	7.8	0.53	2.71	62.01	3.44	0.21	1.32	66.98
14	44.7	37	5	26	6	36	19	5	12	27	7.8	1.78	2.77	47.91	4.71	0.41	1.47	54.51
16	66.4	34	8	20	6	31	15	8	8	35	7.9	0.53	2.72	45.97	3.86	0.31	1.45	51.58
17	40.2	33	9	20	4	34	17	6	11	33	7.9	0.38	3.38	45.00	3.82	0.10	1.48	50.39
18	41.4	33	7	21	5	30	15	4	11	37	7.9	0.47	2.42	48.08	4.85	0.41	1.38	54.72
19	74.8	32	9	18	5	31	16	4	11	37	7.9	0.24	2.35	41.24	5.61	0.48	1.67	49.00
20	48.2	16	10	2	4	31	15	5	11	53	7.9	0.35	2.24	45.11	5.91	0.31	1.60	52.93
21	74.3	16	3	7	6	30	13	6	11	54	6.8	0	2.52	28.84	7.34	0.29	2.18	38.65
23	54.3	21	4	13	4	29	14	5	10	50	7.9	0.17	2.24	46.70	6.16	0.28	1.81	54.94
24	54.5	16	5	5	6	31	15	5	11	53	7.8	0.15	2.38	40.58	5.52	0.21	1.80	48.11
25	46.6	22	4	11	7	28	11	7	10	50	7.8	0.09	2.44	39.79	6.90	0.88	2.35	49.93
26	43.2	12	5	5	3	29	16	8	5	59	8	0.56	2.52	56.72	5.75	0.31	2.03	64.80
27	53.7	14	5	5	4	28	12	9	7	58	7.8	0.45	2.51	56.58	7.25	0.19	2.35	66.36
28	35.4	20	8	4	8	34	15	7	12	46	7.8	0.16	2.42	38.38	5.01	0.36	2.07	45.82
29	54.2	16	6	6	5	33	14	6	13	51	6.9	0.01	2.64	31.06	6.50	0.90	2.63	41.10
30	70	45	3	33	9	32	17	6	9	23	7.9	0.11	2.48	41.11	6.33	0.15	1.93	49.52
31	68.6	50	6	26	18	28	17	3	8	22	7.6	0.06	2.93	33.10	4.27	0.62	1.47	39.45
32	69.3	41	6	26	9	29	15	5	9	30	7.3	0.04	2.86	28.06	5.00	0.09	1.29	34.44
33	70.5	48	6	33	9	29	15	7	7	23	6.9	0.02	3.03	23.66	5.37	0.24	1.67	30.93
34	62.3	30	6	23	1	22	8	6	8	48	6.3	0.01	3.20	20.83	4.70	0.34	1.21	27.07
35	80	36	6	21	9	30	15	7	8	34	6.9	0.01	3.04	24.04	5.11	0.36	1.24	30.75
36	51.8	30	18	3	9	45	27	8	10	25	7.6	0.09	3.28	39.54	4.49	0.57	1.81	46.40
37	42.6	50	3	36	11	31	20	6	5	19	7.8	1.6	3.26	55.20	4.26	0.12	1.43	61.01
38	44.7	52	4	39	9	26	13	5	8	22	7.9	2.12	2.19	50.00	3.39	0.62	0.97	54.98
39	69.9	60	15	36	9	20	10	4	6	20	8	1.5	2.71	55.35	2.56	0.17	1.11	59.19
40	33.3	11	9	0	2	29	11	8	10	60	7.9	0.64	2.43	44.62	2.81	0.15	0.98	48.56
41	62.2	13	3	7	3	32	16	4	12	55	7.9	1.19	2.06	64.36	8.89	0.45	1.50	75.20
42	68.7	12	3	7	2	33	12	7	14	55	7.9	0.26	2.14	55.37	5.88	0.41	1.60	63.26
43	66.5	28	5	14	9	29	11	7	11	43	5.9	0	2.84	21.75	6.86	0.64	1.46	30.71
44	73.5	43	18	16	9	26	10	7	9	31	5.9	0.01	2.58	17.95	4.53	0.13	1.43	24.05
45	69.2	25	5	11	9	25	11	4	10	50	7.8	0.1	2.46	40.65	5.51	0.48	1.50	48.15
47	88.3	8	1	5	2	29	8	9	12	63	7.9	0.96	2.12	64.54	8.17	0.17	1.26	74.14
48	76.7	10	1	8	1	29	10	9	10	61	7.9	1.51	1.82	56.09	8.94	0.49	1.02	66.54
49	76.3	26	1	19	6	37	17	12	8	37	7.9	1.52	1.84	57.80	7.66	0.23	1.19	66.88
50	84.9	11	2	5	4	29	9	9	11	60	7.9	1.31	2.01	64.34	8.05	0.27	1.41	74.07
51	66.5	27	4	17	6	33	17	8	8	40	7.7	0.38	3.30	49.22	7.27	0.13	1.58	58.21
52	87.6	20	6	10	4	39	20	9	10	41	7.8	0.49	2.50	49.82	4.29	0.54	1.56	56.21
53	88.8	24	3	17	4	30	15	7	8	46	7.9	1.33	2.01	54.82	4.55	0.33	1.14	60.84
54	81.1	30	6	16	8	30	15	5	10	40	7.9	0.69	2.40	57.71	5.78	0.10	1.16	64.75
55	80.6	18	8	6	4	32	17	6	9	50	7.7	0.56	2.36	53.91	4.71	0.14	0.95	59.70
56	51.4	21	2	16	3	33	18	6	9	46	8.1	0.79	2.28	57.00	4.19	0.13	1.85	63.17

TABLE 8.10 cont. PINCHER SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
57	35.1	21	1	11	9	38	17	7	14	41	8	0.91	2.52	66.30	5.73	0.19	1.74	73.95
60	33.3	3	2	0	1	34	13	9	12	63	8	1.33	2.49	54.03	3.48	0.10	1.25	58.86
61	72.2	1	1	0	0	32	11	9	12	67	7.9	0.51	3.01	60.38	5.36	0.69	2.10	68.54
62	83.6	2	0	1	1	33	11	10	12	65	8	0.31	2.86	61.26	5.37	0.19	1.91	68.73
63	65	3	0	1	2	33	10	10	13	64	8	0.52	2.66	70.03	5.71	0.34	1.85	77.93
64	76.8	1	1	0	0	39	11	10	18	60	7.9	0.52	2.85	65.04	5.23	0.16	2.30	72.73
65	85.9	21	1	17	3	29	12	7	10	50	8	1.16	2.13	62.47	7.16	0.15	1.51	71.29
66	73.3	22	2	16	4	28	14	7	7	50	8	0.59	2.43	58.07	6.28	0.28	1.16	65.78
67	75.3	26	2	20	4	27	10	7	10	47	7.9	0.43	2.67	57.26	5.24	0.32	1.18	64.01
68	70.8	31	2	24	5	27	10	8	9	42	8	0.32	2.80	52.43	6.58	0.36	1.48	60.86
69	73.4	31	2	26	3	27	10	8	9	42	8	0.9	2.30	59.33	5.03	0.46	1.18	66.00
70	62.4	7	2	4	1	42	13	13	16	51	8.1	0.59	2.76	54.41	5.90	0.29	1.06	61.66
71	69.4	9	1	7	1	35	10	11	14	56	7.9	0.7	2.87	59.16	4.64	0.52	0.84	65.16
72	60.5	30	3	19	9	30	16	7	7	40	7.6	0.07	3.15	40.51	7.23	0.21	1.16	49.10
73	69.3	28	2	21	6	37	15	10	12	35	7.8	0.14	3.17	53.16	4.86	0.25	0.88	59.15
74	73	31	5	16	10	40	18	9	13	29	6.7	0.2	4.74	33.87	6.34	0.22	1.72	42.14
75	62.1	16	3	10	4	26	9	8	9	58	7.1	0	4.29	39.16	5.98	0.19	1.38	46.71
76	89.8	18	5	6	7	31	13	7	11	51	7.1	0	3.62	30.16	9.34	0.53	1.60	41.63
77	91.9	21	5	7	9	38	15	9	14	41	6.7	0	3.78	29.97	7.35	0.21	1.78	39.31
78	93	15	4	8	3	27	12	8	7	58	7	0	3.80	35.29	7.75	0.23	1.85	45.12
79	92.9	10	3	5	3	40	16	7	17	50	7.5	0	3.58	39.53	6.56	0.19	1.98	48.25
80	91.9	9	2	4	3	32	13	9	10	59	7.3	0.04	3.66	36.34	6.85	0.45	1.93	45.57
81	59.7	16	2	10	4	43	22	11	10	41	7.9	0.66	2.45	49.71	4.44	0.29	1.42	55.86
82	58.2	21	1	17	3	38	18	9	11	41	7.9	0.73	2.32	49.96	3.78	0.73	1.68	56.16
83	53.6	10	2	6	2	29	11	9	9	61	7.8	0.4	2.62	48.62	5.17	0.57	1.83	56.20
84	65.7	42	2	34	7	34	20	7	7	24	8	0.16	2.41	57.31	6.78	0.64	2.09	66.82
85	62.3	11	2	8	1	24	8	6	10	65	7.8	0.22	3.00	55.71	5.77	0.19	2.18	63.84
86	91.7	3	2	0	1	37	13	10	14	60	7.2	0	3.97	37.27	7.06	0.23	1.99	46.55
87	92.7	5	1	1	3	38	14	8	16	57	6.9	0	4.24	35.30	8.00	0.77	2.16	46.22
88	87.3	7	1	4	2	32	14	9	9	61	7.1	0	3.69	37.60	8.41	0.93	2.08	49.03
89	66.4	11	2	7	2	33	13	11	9	56	7.1	0	4.02	40.23	9.65	0.23	2.15	52.26
90	76	8	1	4	3	29	10	9	10	63	7.1	0	3.45	44.78	6.75	0.88	2.03	54.44
91	60.7	38	5	27	6	31	21	5	5	31	6.9	0	3.47	24.52	6.46	0.72	1.99	33.68
92	45.9	32	4	24	4	32	19	7	6	36	6.7	0	3.83	29.52	5.78	0.80	1.84	37.95
93	52.7	33	3	25	5	30	20	5	5	37	6.7	0	3.26	25.58	6.76	0.43	1.48	34.26
94	63.3	39	4	20	15	32	19	4	9	29	7.7	0.14	2.76	36.63	3.80	0.23	1.19	41.85
95	60.1	31	6	15	11	37	19	7	11	32	7	0.02	3.36	27.98	6.39	0.22	1.85	36.44
96	85.8	12	2	9	1	26	10	8	8	62	7.4	0	3.76	40.12	9.98	0.84	2.26	53.20
97	73.8	7	2	3	2	24	10	6	8	69	7.4	0	3.49	42.84	10.43	0.60	2.26	56.14
98	75.1	5	1	1	3	29	11	7	11	66	7.7	0.14	2.92	65.92	8.88	0.78	2.26	77.84
99	72.4	18	2	9	7	31	12	8	11	51	7.7	0.1	2.77	52.39	7.59	0.28	2.14	62.40
100	89.7	6	2	0	4	30	12	6	12	64	7.2	0	3.28	37.86	8.15	0.18	2.19	48.37
101	93.5	4	1	1	2	31	10	7	14	65	7.7	0.41	2.41	67.50	8.25	0.24	1.88	77.88
102	64.5	4	1	1	2	32	11	8	13	64	7.8	0.21	2.56	69.11	7.38	0.69	2.10	79.27
103	91.4	5	2	0	3	27	9	9	9	68	7.2	0.02	2.95	43.38	9.99	0.57	2.46	56.41
104	74.6	9	2	6	1	26	0	17	9	65	6.2	0	4.10	34.00	7.48	0.55	2.75	44.77
106	84.8	12	4	6	2	30	13	8	9	58	6.3	0	2.74	30.68	6.87	0.86	1.79	40.20
107	87.5	13	3	5	5	38	16	9	13	49	6.1	0	3.60	27.18	6.11	0.85	2.21	36.35
108	88.2	16	3	6	7	37	15	9	13	47	6.2	0	3.37	26.62	6.63	0.68	2.26	36.19
109	75.2	10	4	5	2	31	13	10	8	59	6.5	0	3.21	28.56	6.44	0.24	2.03	37.27
110	45.8	15	5	6	5	29	14	7	8	56	7.1	0	3.14	34.87	5.30	0.60	1.60	42.37

TABLE 8.10 cont. PINCHER SOILS - LABORATORY DATA

SAMP = sample number
%TA = percentage true aggregates
S = total % sand
M+CS = % medium and coarse sand (>250 μm)
FS = % fine sand (100-250 μm)
VFS = % very fine sand (50 -100 μm)
Z = total % silt
CZ = % coarse silt (10-50 μm)
MZ = % medium silt (5-10 μm)
FZ = % fine silt (2-5 μm)
C = total % clay
inoC = % inorganic carbon
orgC = % organic carbon
Ca = adsorbed calcium (meq/100g)
Mg = adsorbed magnesium (meq/100g)
Na = adsorbed sodium (meq/100g)
K = adsorbed potassium (meq/100g)
TEC = total adsorbed cations (meq/100g)

TABLE 8.11. FLAGSTAFF SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
1	58.5	39	12	17	10	32	14	7	11	29	7.3	0	2.75	24.06	6.10	1.34	1.33	32.83
2	59.3	40	13	17	10	36	20	6	10	24	5.8	0	2.74	13.09	5.69	1.70	1.33	21.82
4	60.9	41	14	16	11	37	23	7	7	22	5.7	0	3.26	14.93	3.91	1.16	1.96	21.97
5	52.6	46	14	19	13	32	18	7	7	22	5.9	0	3.59	15.81	4.90	1.03	1.64	23.38
6	42.9	43	12	19	12	38	23	7	8	19	5.6	0	3.67	15.30	3.25	1.45	1.69	21.70
11	17	83	39	31	13	10	7	1	2	7	5.5	0	2.10	7.11	0.82	1.13	0.70	9.75
12	32	67	29	22	16	22	12	3	7	11	5.7	0	2.67	10.73	2.37	0.83	0.77	14.71
13	9.1	80	36	31	13	11	7	2	2	9	5.6	0	1.89	7.21	1.46	0.87	0.35	9.90
14	4.4	89	46	32	12	7	1	2	4	4	5.9	0	1.33	4.49	0.86	1.26	0.47	7.08
15	3.5	88	41	32	15	5	2	1	2	7	6	0	1.54	4.34	0.73	1.26	0.55	6.88
16	64.1	40	12	17	11	38	21	9	8	22	5.5	0	2.66	13.87	4.51	1.86	0.72	20.96
17	64.2	59	12	29	18	25	14	4	7	16	5.2	0	3.40	13.30	3.40	2.25	1.00	19.96
18	60.1	45	13	21	12	35	20	8	7	20	5.7	0	2.85	16.30	3.79	1.83	0.84	22.75
19	66.6	41	10	20	11	36	20	9	7	23	5.6	0	3.13	15.95	3.79	1.96	0.84	22.54
21	50.1	39	10	18	11	38	21	10	7	23	5.3	0	5.59	17.89	5.12	2.30	2.02	27.33
22	52.2	40	11	19	10	37	21	9	7	23	5.4	0	5.24	20.22	3.34	1.63	1.35	26.53
23	58	25	9	8	8	43	20	12	11	32	5.3	0	5.68	19.73	4.00	1.82	1.65	27.20
24	63.6	33	7	14	12	46	26	9	11	21	6	0	6.88	27.62	4.47	2.26	3.02	37.36
25	48.2	38	11	18	9	38	22	7	9	24	5.3	0	5.87	21.91	4.19	2.05	1.38	29.53
26	70.9	45	13	20	12	34	19	8	7	21	5.3	0	2.99	12.82	3.38	1.96	1.17	19.33
27	49.4	46	15	21	10	33	23	2	8	21	5.7	0	2.84	14.62	3.18	1.61	0.61	20.03
28	71.5	15	11	0	4	36	21	7	8	49	5.7	0	2.47	16.51	5.29	2.24	0.78	24.82
29	53.8	26	13	6	7	36	20	7	9	38	5.2	0	2.67	11.84	3.12	1.63	0.84	17.44
30	82.6	23	11	7	5	37	20	8	9	40	5.4	0	3.17	14.73	3.19	1.60	1.02	20.55
31	60.5	50	15	23	12	31	20	6	5	19	5	0	3.24	11.86	2.15	2.13	0.76	16.90
32	68.1	50	17	20	13	30	16	7	7	20	5.3	0	2.69	11.49	3.72	1.69	0.87	17.77
33	75.3	43	13	19	11	32	18	8	6	25	6.2	0	2.75	16.36	4.51	1.86	1.02	23.75
34	82.1	39	12	17	10	37	20	9	8	24	7.2	0	2.81	22.29	5.23	2.31	1.10	30.93
35	70.3	40	13	18	9	37	21	9	7	23	5.5	0	3.28	16.86	3.92	2.19	1.34	24.31
36	80.7	37	11	16	10	38	22	9	7	25	6	0	3.71	18.56	4.32	2.14	1.37	26.40
37	70.6	55	12	28	16	37	20	9	8	8	6.3	0	3.85	19.04	4.26	2.22	1.32	26.83
38	85.2	36	13	14	9	35	19	10	6	29	5.6	0	3.31	14.89	3.40	2.26	1.03	21.59
39	73.9	38	14	15	9	35	19	9	7	27	5.3	0	3.37	13.26	2.80	1.86	0.71	18.63
40	78.2	37	10	17	10	34	18	8	8	29	5.7	0	3.50	18.68	4.58	2.27	0.63	26.15
43	2.9	92	53	31	9	5	2	2	1	3	6.2	0	1.11	2.69	0.87	1.01	0.64	5.20
44	4.6	87	44	31	12	7	4	0	3	6	5.8	0	1.57	4.17	1.25	1.15	0.68	7.25
45	25.3	70	33	23	14	18	10	2	6	12	5.7	0	2.22	9.97	1.69	1.89	0.71	14.26
46	81.9	57	22	23	12	25	14	6	5	18	5.6	0	3.03	12.67	2.80	1.82	0.96	18.24
48	54	39	20	11	8	29	15	7	7	32	5.6	0	3.48	13.73	2.54	1.82	1.35	19.43
49	63.4	50	18	21	11	30	18	4	8	20	5.7	0	3.61	14.50	3.13	1.69	1.44	20.75
50	48.8	61	28	20	13	23	14	4	5	16	5.9	0	2.90	12.66	2.53	1.67	0.92	17.78
51	52.3	53	23	17	13	28	18	5	5	19	5.4	0	4.10	12.62	2.54	1.70	1.37	18.23
52	41.3	60	22	21	17	24	15	4	5	16	5.7	0	2.91	12.14	2.40	1.75	1.02	17.30
53	46.6	61	23	26	13	21	12	4	5	18	5.4	0	2.71	11.07	2.60	1.72	0.69	16.08
54	8.1	80	38	30	12	11	8	1	2	9	5.6	0	1.92	6.45	1.38	0.87	0.73	9.43
55	4.8	82	47	26	10	10	6	1	3	8	5.9	0	1.51	5.52	1.48	0.84	0.62	8.46
56	6.2	81	39	31	11	10	7	1	2	9	5.3	0	1.82	4.29	0.90	0.99	0.65	6.83
57	21.3	74	35	25	14	16	7	5	4	10	5.2	0	2.69	7.21	1.42	0.84	0.78	10.25
58	33.1	70	30	26	14	19	9	3	7	11	5.4	0	2.41	7.10	2.10	0.84	0.81	10.85
59	37.8	64	33	18	13	20	11	4	5	16	5.2	0	2.86	6.97	2.07	0.87	1.39	11.31
60	13.4	79	43	27	9	11	5	4	2	10	5.4	0	1.83	4.71	1.36	0.83	0.90	7.80

TABLE 8.11 cont. FLAGSTAFF SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
61	34.8	61	20	26	15	23	13	4	6	16	6	0	2.14	11.70	2.72	1.66	0.81	16.90
62	52.7	60	21	27	12	23	13	4	6	17	5.6	0	2.64	12.88	2.12	1.69	1.03	17.71
63	36.5	72	23	35	14	13	7	1	5	15	5.7	0	2.50	9.76	2.17	0.91	0.96	13.80
64	44.4	63	22	28	13	20	10	4	6	17	6.7	0	2.17	13.52	3.11	0.83	0.60	18.06
65	49.3	60	23	26	11	21	11	5	5	19	6.8	0	2.43	15.41	3.05	1.05	0.68	20.19
66	22.4	68	30	23	15	17	8	3	6	15	6.4	0	1.88	9.70	3.04	0.95	0.70	14.39
67	24	61	25	25	11	22	12	4	6	17	5.9	0	2.22	9.94	2.59	0.85	0.76	14.14
68	21.5	63	25	25	13	20	9	6	5	17	5.8	0	2.81	9.78	2.24	0.90	0.99	13.90
69	26.1	68	28	27	13	16	7	4	5	16	5.7	0	1.81	7.40	2.36	0.92	0.54	11.22
71	36.5	60	20	25	15	20	11	3	6	20	7.2	0	2.63	17.97	2.63	0.91	1.08	22.59
72	36.6	54	19	21	14	26	16	3	7	20	7.2	0	2.69	18.75	3.12	1.11	1.32	24.30
73	24.5	52	15	22	15	28	18	3	7	20	6.6	0	3.28	14.96	3.93	1.11	2.27	22.28
74	61.5	60	17	28	15	23	14	4	5	17	5.7	0	2.77	11.90	2.17	0.99	0.83	15.90
75	72	60	19	27	14	23	13	5	5	17	5.8	0	2.63	10.56	2.66	1.14	1.15	15.51
76	67.8	43	15	18	10	33	18	7	8	24	5.9	0	2.70	13.53	3.84	0.87	0.79	19.03
77	60.6	41	13	18	10	36	20	7	9	23	5.5	0	3.12	12.35	3.55	0.87	1.03	17.80
79	56	43	13	18	12	34	21	5	8	23	5	0	2.79	10.75	2.60	0.94	0.84	15.13
80	61.1	41	12	19	10	35	20	8	7	24	5.3	0	3.13	9.48	2.91	0.97	1.14	14.49
81	71.4	43	11	22	10	35	19	8	8	22	5.7	0	3.54	11.51	2.97	0.44	1.46	16.38
82	76	36	10	16	10	40	23	8	9	26	5.8	0	3.64	12.52	3.57	0.28	1.25	17.62
83	75.2	42	12	20	11	35	20	8	7	23	5.8	0	3.14	13.97	33.90	0.28	1.20	49.34
84	67	40	10	19	11	33	18	6	9	27	5.6	0	3.16	12.21	4.02	0.35	1.29	17.88
85	67.1	40	12	19	10	36	20	6	10	24	6	0	3.25	16.24	3.79	0.15	1.22	21.41

SAMP = sample number
%TA = percentage true aggregates
S = total % sand
M+CS = % medium and coarse sand (>250 µm)
FS = % fine sand (100-250 µm)
VFS = % very fine sand (50 -100 µm)
Z = total % silt
CZ = % coarse silt (10-50 µm)
MZ = % medium silt (5-10 µm)
FZ = % fine silt (2-5 µm)
C = total % clay
inoC = % inorganic carbon
orgC = % organic carbon
Ca = adsorbed calcium (meq/100g)
Mg = adsorbed magnesium (meq/100g)
Na = adsorbed sodium (meq/100g)
K = adsorbed potassium (meq/100g)
TEC = total adsorbed cations (meq/100g)

TABLE 8.12. VERMILION SOILS - LABORATORY DATA

SAMP#	%TA	S	M+CS	FS	VFS	Z	CZ	MZ	FZ	C	pH	inoC	orgC	Ca	Mg	Na	K	TEC
1	47.9	40	7	19	14	35	21	9	5	25	5.7	0	4.65	19.41	4.80	2.47	1.21	27.89
2	41.6	41	8	22	11	35	19	8	8	24	6	0	5.06	23.07	4.82	0.53	1.34	29.76
3	71.3	40	9	20	11	35	19	7	9	25	6	0	4.39	22.81	4.47	0.65	0.80	28.73
4	59.4	43	11	19	13	33	17	8	8	24	6.2	0	4.02	22.47	4.54	0.59	0.64	28.24
5	49	58	5	33	20	23	12	6	5	19	6.2	0	3.55	16.94	3.76	1.58	1.13	23.41
6	77.6	39	12	16	11	32	19	4	9	29	7.8	0.15	3.06	27.98	8.93	0.68	1.30	38.90
7	50.2	43	21	14	8	27	10	9	8	30	6.6	0.01	3.30	26.72	7.14	1.98	0.99	36.83
8	46.6	34	12	13	9	31	12	5	14	35	6.1	0.01	2.59	16.26	8.31	1.92	0.89	27.38
9	47	30	8	12	10	33	13	7	13	37	5.7	0	3.90	20.95	7.97	0.78	1.05	30.75
10	59.1	12	3	4	5	38	18	8	12	50	5.9	0	4.98	35.25	11.23	0.85	1.83	49.15
11	59.3	28	6	13	9	35	13	8	14	37	6.3	0	5.34	33.85	11.99	1.50	1.62	48.96
12	74.7	25	5	12	8	45	15	11	19	30	5.4	0	7.50	30.97	8.22	2.12	3.67	44.98
13	59.9	31	6	16	9	38	18	7	13	31	5.6	0	5.26	24.68	7.39	2.42	0.95	35.43
14	41.3	39	7	20	12	31	13	8	10	30	5.4	0	4.86	21.33	6.02	2.42	1.29	31.06
15	59.8	40	8	22	10	23	9	4	10	37	6.2	0	2.74	21.56	8.35	1.99	0.78	32.68
16	67.4	56	8	30	18	21	7	6	8	23	6.7	0	4.10	23.54	5.60	0.91	1.19	31.24
18	65.3	50	8	29	14	23	12	4	7	27	7.8	0.1	4.60	46.33	6.95	1.76	1.58	56.62
21	55.3	30	10	12	9	28	9	7	12	42	5.4	0	4.39	18.17	9.06	1.41	0.94	29.59
22	65.6	20	6	7	7	27	9	6	12	53	5.5	0	4.78	26.43	11.92	2.06	1.09	41.51
23	52.5	21	4	10	8	39	18	7	14	40	6	0	4.78	31.47	7.40	0.84	1.34	41.05
24	44.4	52	19	21	12	23	9	7	7	25	4.6	0	4.39	9.61	4.93	1.14	0.95	16.63
25	61.3	49	18	18	13	23	10	4	9	28	5.7	0	3.52	14.20	6.25	1.48	1.13	23.07
26	59.7	40	4	22	14	27	11	7	9	33	5.9	0	3.40	19.27	7.08	0.62	0.96	27.92
27	45.7	45	3	26	16	31	16	6	9	24	5.6	0	4.38	18.00	4.59	0.74	0.68	24.02
28	45.7	36	4	16	16	34	15	6	13	30	5.7	0	5.19	23.77	6.43	0.42	0.88	31.49
29	61.6	41	5	24	12	31	15	5	11	28	5.6	0	4.02	16.88	5.74	0.26	0.87	23.74
30	51.7	39	7	19	13	35	18	6	11	26	5.5	0	4.36	16.00	5.61	0.40	0.84	22.85
31	70.2	40	16	15	9	31	18	3	10	29	6.2	0	2.24	15.26	5.75	0.98	0.81	22.81
32	66	40	13	16	11	31	17	5	9	29	5.5	0	3.21	14.16	5.44	0.53	1.19	21.32
33	66.5	30	8	13	10	34	15	8	11	36	5.6	0	4.61	19.64	7.37	0.57	1.82	29.40
34	57.2	32	8	14	10	38	18	8	12	30	5.3	0	3.76	14.50	6.08	0.21	1.60	22.39
35	79.4	31	11	11	9	40	21	8	11	29	4.9	0	3.43	12.12	5.14	0.25	1.27	18.78
36	57.9	37	9	17	11	37	21	5	11	26	5.4	0	5.25	23.51	4.98	0.19	0.77	29.45
37	50.9	34	10	14	10	36	19	7	10	30	5.6	0	4.11	20.93	5.26	0.19	1.91	28.29
38	53.6	30	8	13	9	43	24	8	11	27	5.3	0	5.27	19.76	5.55	0.25	1.91	27.47
39	55.4	24	6	10	8	44	21	9	14	32	5.4	0	4.60	15.28	7.13	0.33	2.20	24.94
40	67.5	30	7	13	10	32	12	8	12	38	4.9	0	3.46	11.27	7.34	0.59	1.24	20.45
41	61	39	15	15	9	31	13	8	10	30	6	0	2.85	16.78	5.90	0.24	0.86	23.78
42	40.7	60	31	18	11	17	8	3	6	23	6	0	2.07	13.86	4.48	0.50	0.75	19.60
43	66.7	40	13	18	9	35	20	6	9	25	6	0	3.37	18.99	3.93	0.63	0.79	24.33
44	45.7	41	14	18	9	35	19	9	7	24	5.6	0	3.30	12.92	4.96	0.73	0.89	19.50
45	43	41	15	17	9	34	18	5	11	25	5.5	0	3.46	15.63	5.03	0.63	1.22	22.51
46	65.6	37	13	14	10	32	13	8	11	31	6.5	0	2.26	15.18	7.99	0.24	0.97	24.37
47	71.3	40	12	18	10	34	18	7	9	26	6.4	0	4.03	17.79	7.76	0.74	1.39	27.68
48	69.4	37	10	17	10	36	20	6	10	27	6.7	0	3.86	21.91	9.26	0.92	1.24	33.32
49	68.7	39	13	17	10	34	17	5	12	27	6	0	3.20	16.89	5.70	0.69	1.00	26.27
50	52.5	32	8	14	10	38	19	9	10	30	6.4	0	4.18	24.60	7.18	0.33	1.14	33.25

SAMP = sample number

%TA = percentage true aggregates

S = total % sand

TABLE 8.12 cont. VERMILION SOILS - LABORATORY DATA

M+CS = % medium and coarse sand (>250 µm)
FS = % fine sand (100-250 µm)
VFS = % very fine sand (50 -100 µm)
Z = total % silt
CZ = % coarse silt (10-50 µm)
MZ = % medium silt (5-10 µm)
FZ = % fine silt (2-5 µm)
C = total % clay
inoC = % inorganic carbon
orgC = % organic carbon
Ca = adsorbed calcium (meq/100g)
Mg = adsorbed magnesium (meq/100g)
Na = adsorbed sodium (meq/100g)
K = adsorbed potassium (meq/100g)
TEC = total adsorbed cations (meq/100g)

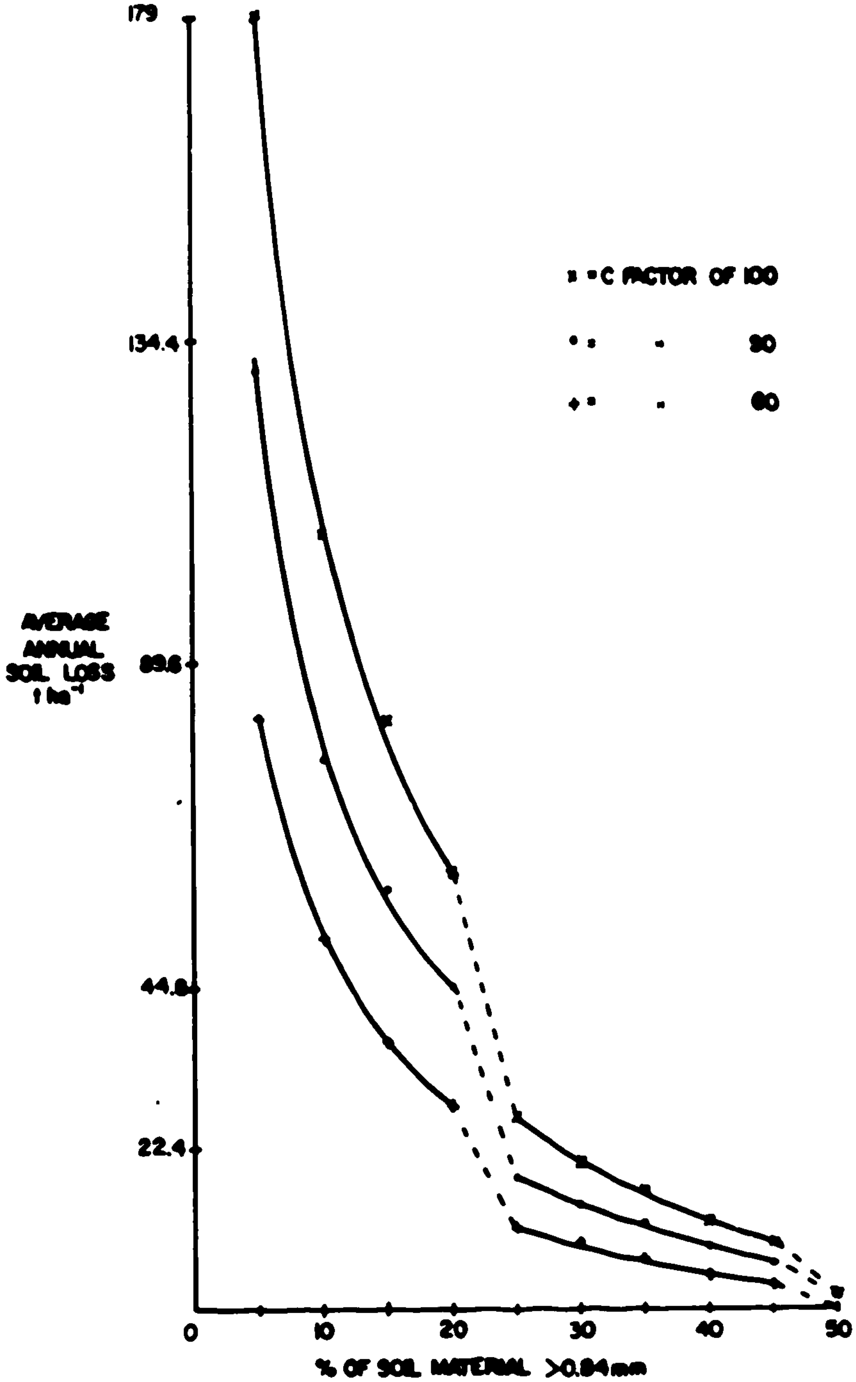

Figure 8.1 The sensitivity of average annual soil loss to wind erosion to changes in the proportion of soil material >0.84 mm. (Surface roughness values are taken from table 1.1, unsheltered fieldwidth is held constant at 182.9 m, vegetative cover is held constant at 1136.4 kg ha^{-1} small grain equivalent.)

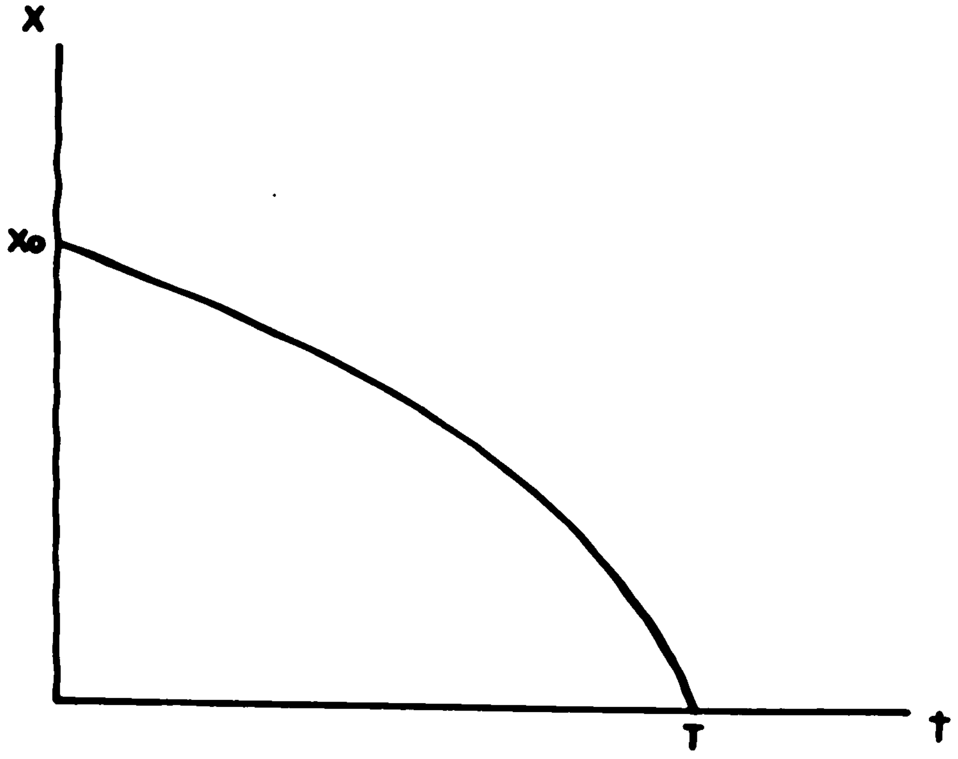

Figure 8.2 Sketch graph of a typical solution to Equation A4 for a<0.

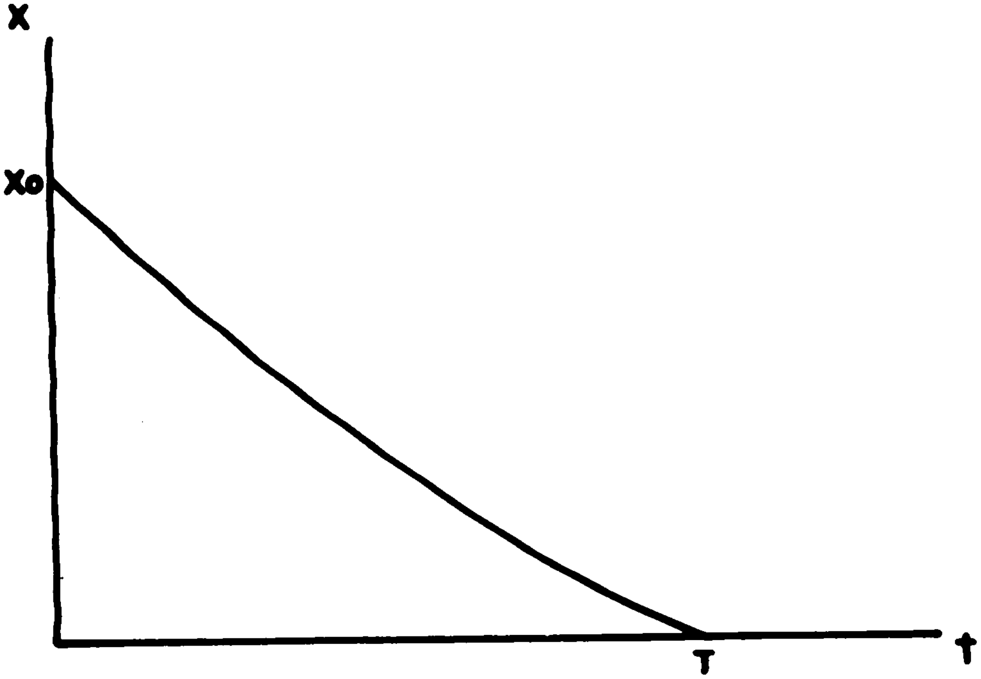

Figure 8.3 Sketch graph of a typical solution to Equation A4 for $\alpha > 0$.

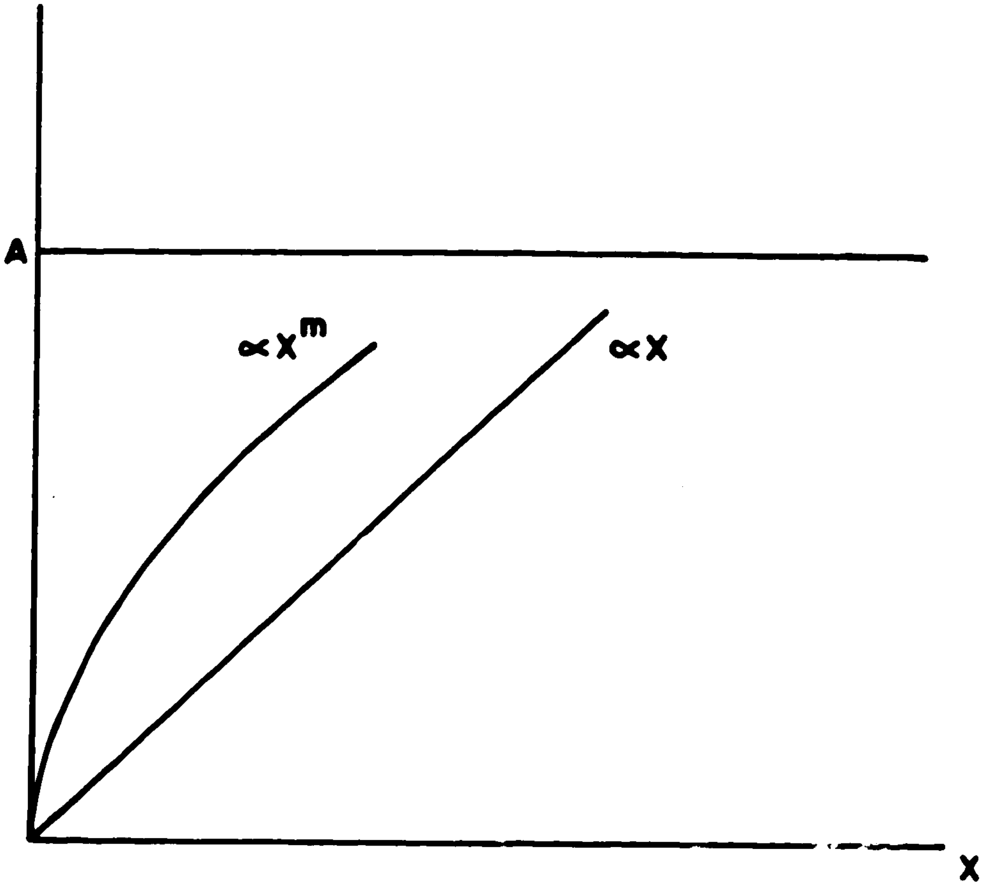

Figure 8.4 Sketch graph of the functions $f(x) = A$, $f(x) = \alpha x^m$, $0<m>1$, and $f(x) = \alpha x$ for $\alpha > 0$. The equations considered that may govern the breakdown of aggregate are $dx/dt = -A - \alpha(x-x_1)$ and $dy/dy = -\alpha(x-x_1)^m$.

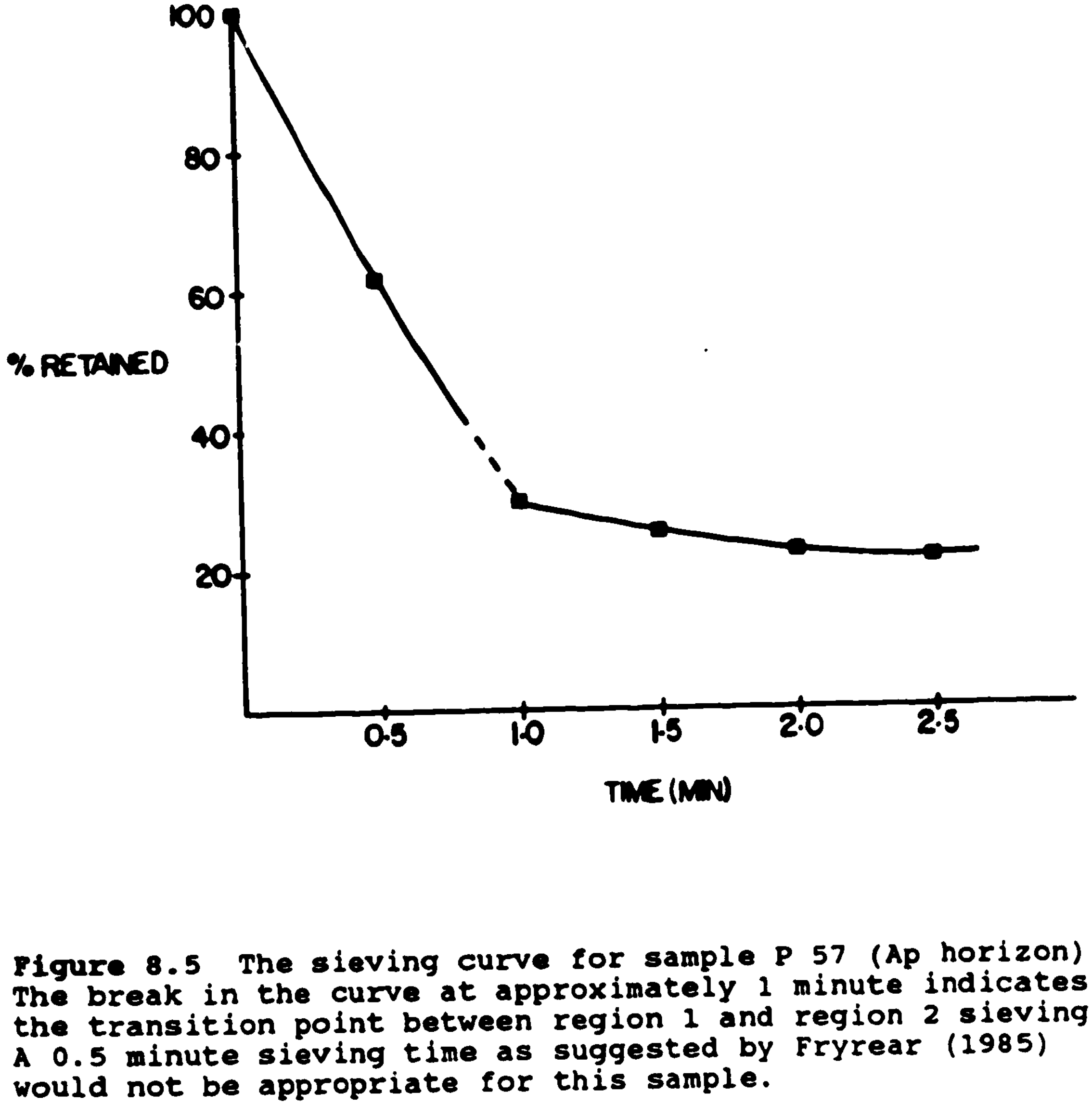

Figure 8.5 The sieving curve for sample P 57 (Ap horizon). The break in the curve at approximately 1 minute indicates the transition point between region 1 and region 2 sieving. A 0.5 minute sieving time as suggested by Fryrear (1985) would not be appropriate for this sample.

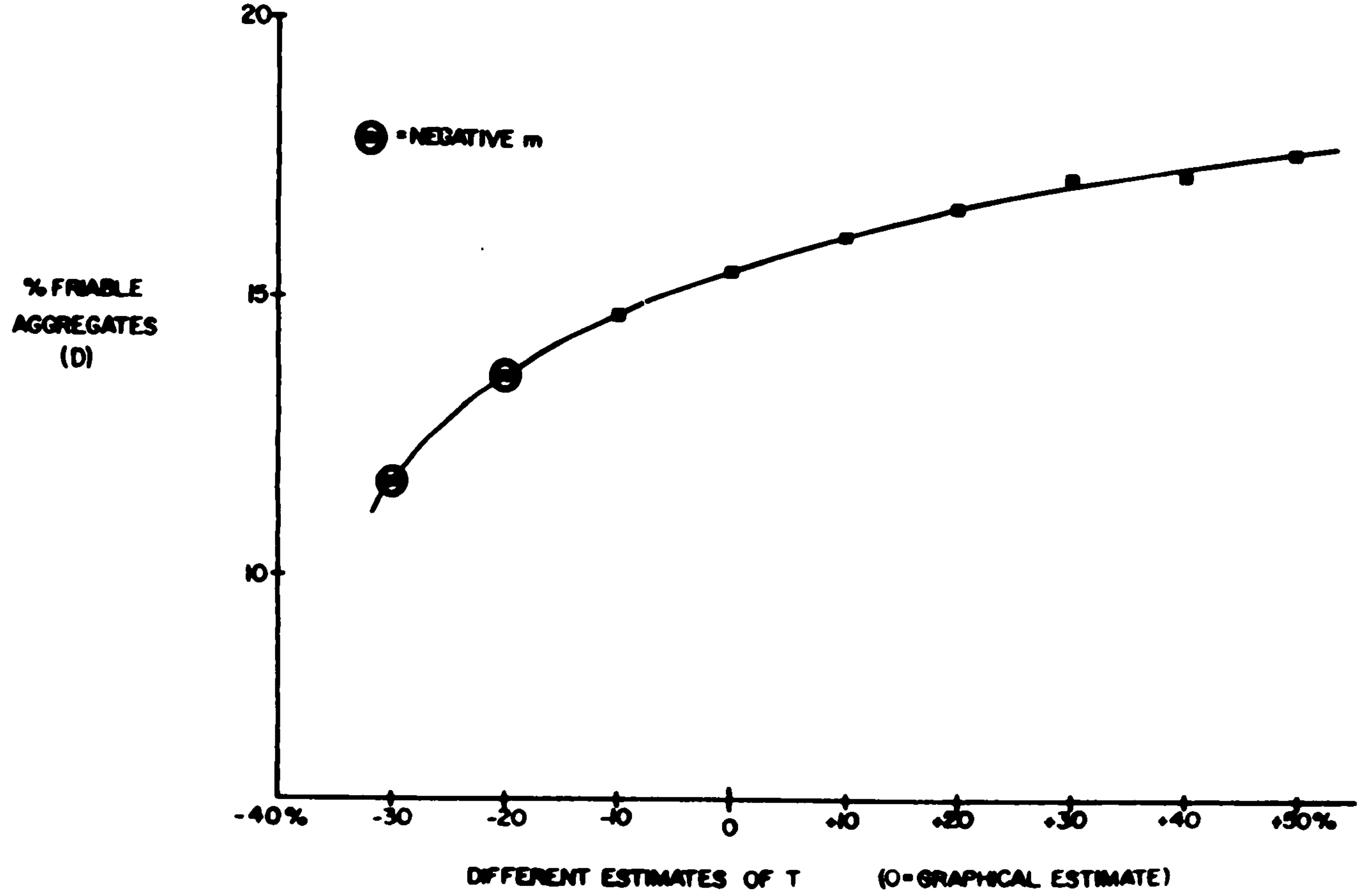

Figure 8.6 The sensitivity of index D (the proportion of friable aggregates on a whole soil basis) to changes in the estimation of T (the time at which no more material passes the sieve).

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