Potential for Wind Erosion in Alternative Cropping Systems.

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Abstract

The potential for wind erosion in agricultural soils is a function of the distribution of aggregates at the surface, soil structure and moisture, and crop residue. These properties were measured in a cropping systems study designed to determine the effect of input level and crop diversity on sustainability and the potential for wind erosion. The experiment was established on a sandy loam soil in the Dark Brown Soil Zone at Scott Saskatchewan. Input levels were organic, reduced and high, while cropping-diversity levels were low diversity, diverse annual and diverse annual perennial. Differences in residue were attributed to the effect of tillage and the relative levels of productivity in the systems. Spring and fall tillage in organic systems reduced the amount of residue compared to reduced input systems. Levels of crop residue were low at the beginning of this study, and crop residue cover should be measured in future years to determine potential for erosion. Crop residue levels may not reflect the system's potential for soil erosion until two rotation cycles are complete. Relative treatment differences observed in the study, were similar to those calculated with of the Douglas-Rickman decomposition equation and tillage coefficients.

Introduction

The objective of this study was to determine the potential for soil erosion in components of cropping systems. Residue cover and aggregate size distribution are two key factors, which affect the potential for wind erosion (Morgan 1986). Current guidelines for residue related to control of wind erosion are from information provided by the Prairie Farm Rehabilitation Administration (1998).

Table 1. Residue cover required for erosion control and critical levels of bare ground (PFRA, 1998).

Wind Erosion	Residue cover (%)	Bare ground (%)[z]
Soil texture		
Medium (loam)	45	55
Fine (clay)	60	40
Coarse (sandy)	75	25

[z] Bare ground calculated from residue cover.

Critical values for aggregate size distribution (Table 2) are based on the information from Morgan (1986).

Table 2. Assessments of soil erodibility by wind (after Dolgilevich, Sofronova and Mayevskaya (1973) in Morgan 1986).

% dry stable aggregates < 0.84 mm	<20	20-50	50-70	70-80	>80
Erodibility (t ha^{-1} y^{-1})	<0.5	0.5-1.5	1.5-5	5-15	>15

The Residue Tillage Decision Support System (RTDS) was used to simulate production of crop residues in the Alternative Cropping Systems Study at Scott Saskatchewan. The program includes an empirical equation for decomposition of crop residue, effects of tillage on residue, and costs based on field operations in Western Canada. The program calculates changes in residue mass due to decomposition, based on an equation developed by Douglas and Rickman (1992). In the program, decomposition of residues is based on cumulative degree days (CDD), location of residue at the surface or in soil, in crop or fallow. The Douglas Rickman model has been evaluated for a number of cereals and broadleaf crops in chemical and tillage fallow systems at the Melfort Research Farm (Moulin et al 1995). Over winter losses of residue are based on coefficients calculated from field data. Decreases in residue due to tillage are calculated with a series of coefficients specific to different implements and residue classes.

Methods

Experimental Design

The study is designed to evaluate to evaluate input and diversity of cropping systems on a sandy loam soil at Scott, Saskatchewan. The study was initiated in 1994 with a baseline study followed by cropping systems treatments in 1995 to 1997. Three levels of input were assigned to main plots in a split-split-plot factorial design. Three levels of cropping diversity were assigned to sub-plots within each main plot to enhance detection of diversity level differences. Input levels were organic, reduced and high, while cropping-diversity levels were low diversity wheat, diverse annual and diverse annual perennial. Ulrich (2001) describes details of tillage and crop management for the study.

Data reported in this study were collected in 1997. Calculations of residue mass and cover are based on tillage operations conducted in 1996. In 1996, fallow treatments in organic and high input systems were tilled in the fall and spring with a heavy-duty cultivator. Plots were prepared for seeding in organic and high input systems with a heavy-duty cultivator with mounted tine harrows followed by a heavy-duty cultivator. Fallow treatments were not tilled in reduced input systems. Plots were direct seeded in reduced input systems.

Residue

Residue cover and bare soil were measured with a grid count of 144 points per quadrat (1 m^2) at two locations per plot. Percent cover was calculated from the number of points, which intersected soil, standing and fallen crop residue. Data were collected from the second and sixth phase of all treatments.

Aggregates and soil moisture

Aggregates, bulk density and soil moisture were sampled from the 0 to 5 cm depth increment shortly after seeding in 1997. Aggregate samples weighing approximately 2.5 kg were dry sieved with a rotary sieve. Bulk density and oven dry soil moisture were measured in a soil core taken at the same time. Samples were collected from the second and sixth phase of all treatments.

Statistical analyses
Statistical analyses were conducted for the soil and crop variables in each year of the study. A general linear model was calculated for phases 2 and 6 of the treatments with diversity nested within input. Error bars represent one least significant difference for significant effects specified in the appendices.

Residue Simulation
Residue cover was simulated with inputs based on harvest index, decomposition with the Douglas-Rickman Equation and tillage coefficients as described previously (Moulin et al 1995). Residue mass was converted to cover with the equation developed by Gregory (1982). Tillage operations and dates are based on those for the study in 1996 while air temperatures are the 30 means for air temperature at the Scott meteorological station.

Results

Residue simulation
Simulation of crop residue cover, as percent bare ground, showed the impact of low residue inputs and frequent tillage. Organic inputs with low diversity had the highest proportion of bare ground over the longest period of time (Figure 1). This was attributed to frequency of cultivation particularly use of heavy-duty cultivators in fall and spring. Significant losses were also calculated for operations with hoe drills. Lentil green manure also increased bare ground relative to other rotations. Reduction of cultivation and increased production of residue reduced bare ground and the potential for wind erosion in reduced input systems for low diversity rotations (Figure 2)

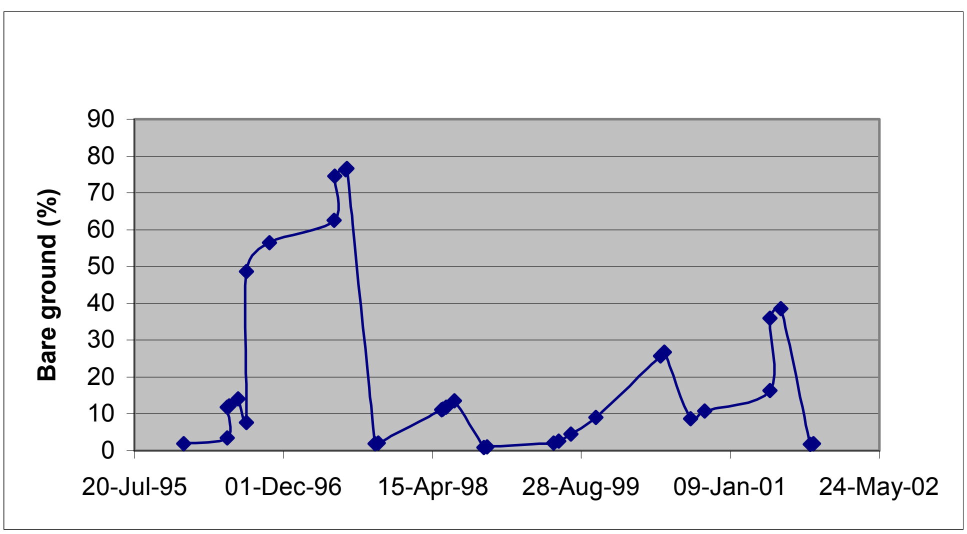

Figure 1. Simulated bare soil (%) for organic input and low diversity.

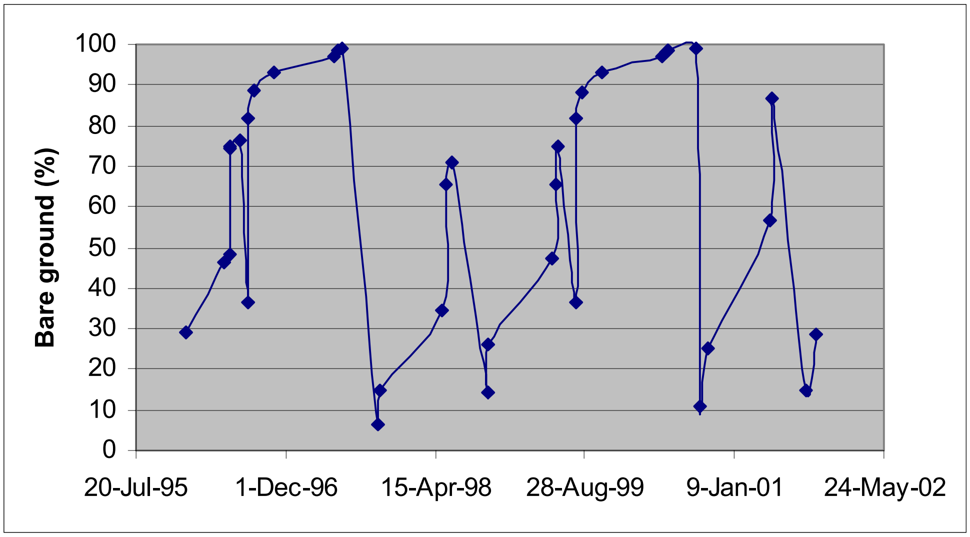

Figure 2. Simulated bare soil (%) for reduced input and low diversity

Systems with diverse annual grains showed similar trends with respect to organic and reduced inputs (Figure 3 and 4). The diverse annual grains rotation under organic inputs had less bare ground than the low diverse rotation due to the fourth phase with barley under-seeded to sweet clover.

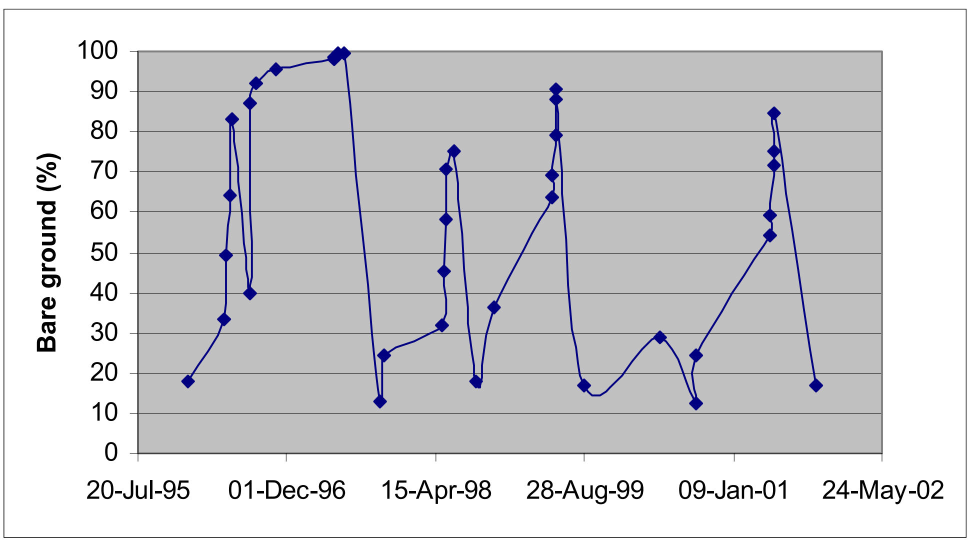

Figure 3. Simulated bare soil (%) for organic input and diverse annual grains

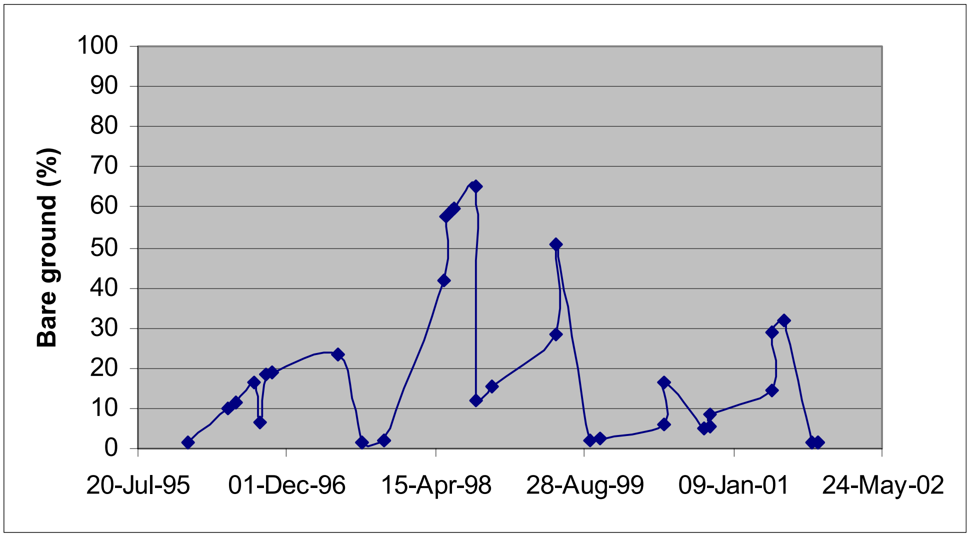

Figure 4. Simulated bare soil (%) for reduced input and diverse annual grains

Residue, experimental data

Residue and plant cover following spring seeding was significantly higher in the second phase of canola-fall rye-pea-barley-flax-wheat under reduced and high input management due to the presence of fall rye in diverse annual and diverse annual perennial in 1997 (Figure 5). Low residue cover following spring seeding in the second phase of fallow-wheat-wheat-fallow-canola-wheat under organic and high inputs was attributed to the burial of residue during tillage operations.

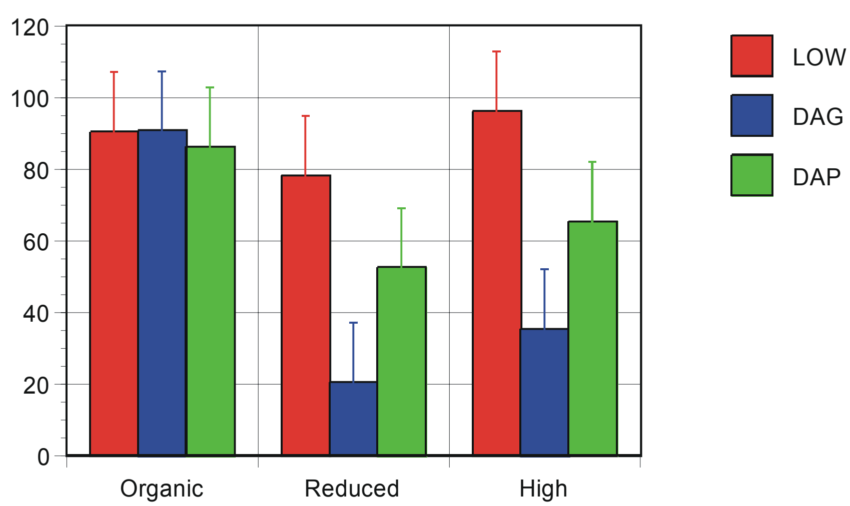

Figure 5. Bare soil (%) in second phase of rotations, spring 1997.

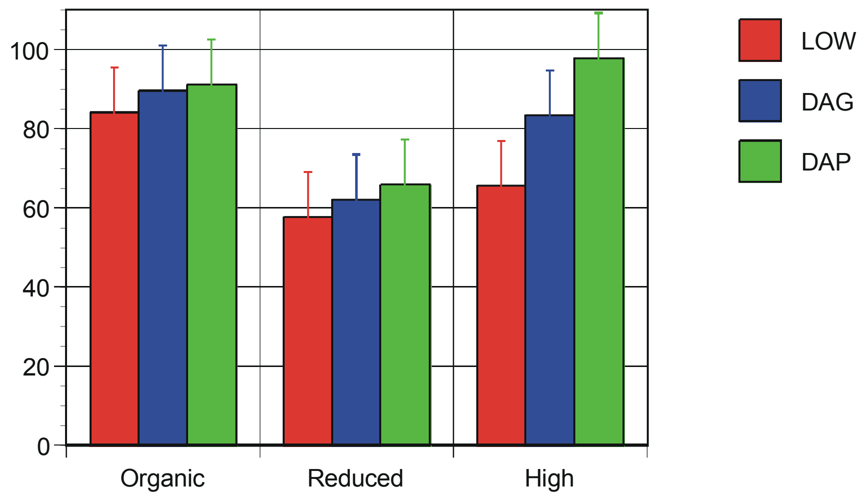

Figure 6. Bare soil (%) in sixth phase of rotations, spring 1997.

Residue cover was lower following spring seeding in the sixth phase in organic compared to reduced-input diversity. High-input systems in the sixth phase of fallow-wheat-wheat-fallow-canola-wheat had higher residue cover than organic systems (Figure 6) due to relatively higher crop production (Figure 7). Residue cover was less than required for control of wind erosion of sandy loam (Table 1). Cover was low in the hay phase of the diverse annual perennial rotation for 1997 due to difficulty of establishing brome/alfalfa.

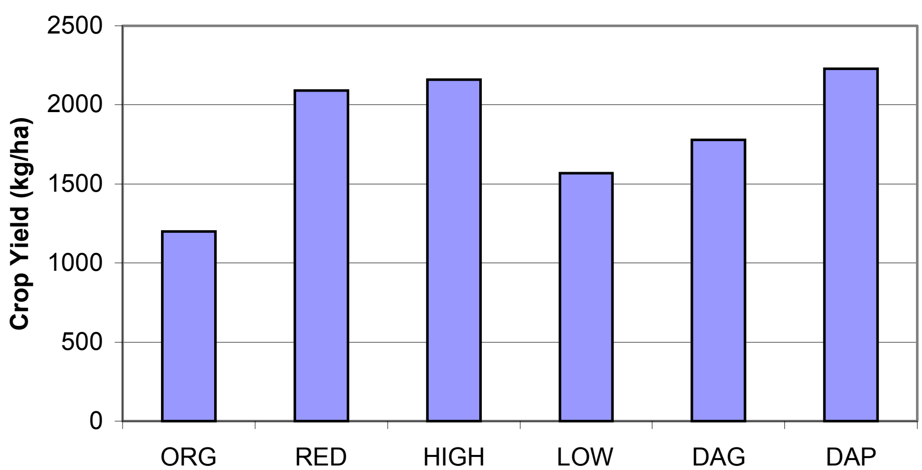

Figure 7. Yield of all crops as influenced by input and diversity for 1996 (kg ha^{-1})

Aggregate size distribution

The proportion of aggregates in the fraction with the lowest sieve opening (<0.5 mm diameter) varied considerably, though it was significantly higher following fallow in the second phase of rotation for high-input systems in fallow-wheat-wheat-fallow-canola-wheat compared to the high and reduced-input diverse annual grain rotation (Figure 8). This was attributed to fall rye. Small aggregates (< 0.5 mm diameter) make up a large proportion of erodible aggregates (<0.84 mm).

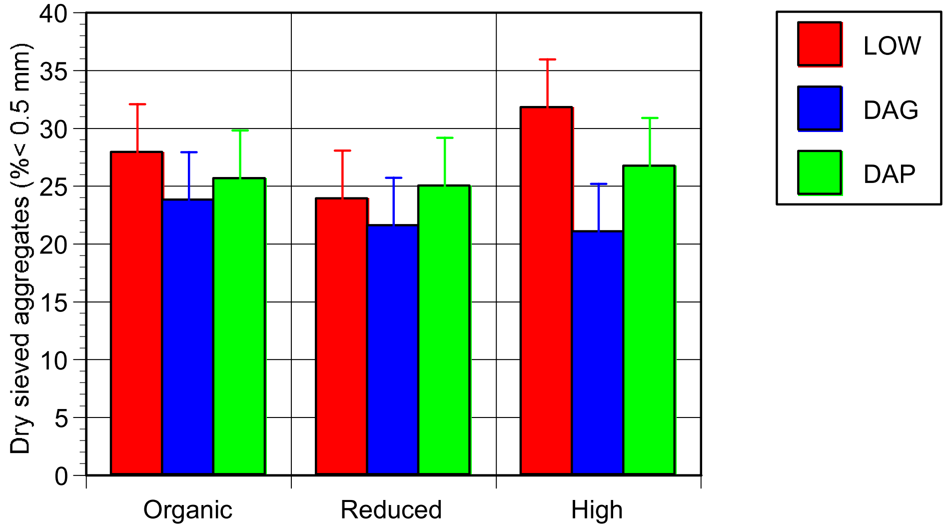

Figure 8. Dry sieved aggregates (%<0.5 mm) in second phase of rotations, spring 1997.

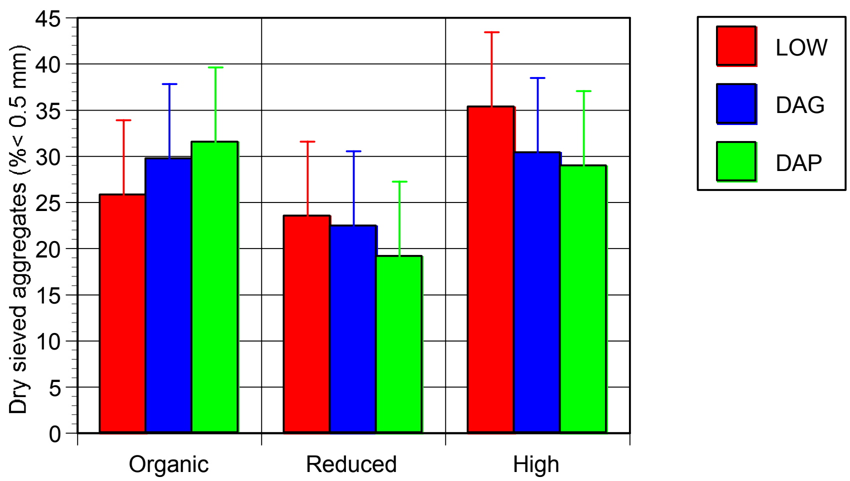

Figure 9. Dry sieved aggregates (%<0.5 mm) in sixth phase of rotations, spring 1997.

Discussion

The potential for erosion was significantly higher in spring following fallow in fallow wheat-wheat-fallow-canola-wheat compared to other rotations. Potential was lowest in the second phase with fall rye in canola-fall rye-pea-barley-flax-wheat. High input systems following canola in the sixth phase of fallow-wheat-wheat-fallow-canola-wheat had higher residue cover than organic systems following crop due to increased production. These effects were attributed to the effect of tillage and the relative levels of productivity in the systems. Spring and fall tillage in organic systems reduced the amount of residue compared to reduced input systems.
The experimental data also reflected the relative differences calculated with the Douglas-Rickman equation and tillage coefficients. Bare ground observed in 1997 varied from those predicted for input and diversity treatments, as 30-year means of air temperature were used in the simulations.

Amounts of residue cover required for erosion control vary depending on soil texture (Table 1). Levels of crop residue were low at the beginning of this study, and crop residue cover should be measured in future years to determine potential for erosion. Crop residue levels may not reflect the system's potential for soil erosion until two rotation cycles are complete.
High amounts of aggregates in the erodible fraction will also contribute to significant levels of soil erosion (Table 2). Inclusion of fall rye in rotation for diverse annual systems significantly decreases the potential for erosion.

Conclusions

Further research is required to confirm if residue cover is sufficient for erosion control for these production systems. Residue cover is lower under organic and high input relative to reduced systems, particularly following years of low productivity for broadleaf crops. Low residue cover was also attributed to higher frequency of tillage in organic and high input compared to reduced systems. Fall rye in diverse annual systems significantly decreased the amount of bare soil and potential for erosion in the spring.

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