Variability of Tillage Erosion Coefficient for Selected Tillage Tools

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Introduction

Tillage erosion through soil movement by tillage is a function of tillage intensity and slope gradient. The distance soil will move by tillage has been shown to be statistically correlated with slope gradient (Lindstrom et. al. 1992). Tillage erosion is the amount of mass soil loss or gain at any place on the landscape being governed by the change in slope gradients rather then the magnitude of the slope gradient. An interrelated process that occurs during tillage erosion is the direct transport of soil from one place to another and is referred to as Tillage Soil Translocation (Govers et.al. 1999). Lindstrom et. al. (1992) developed regression equations describing the distance soil moves both parallel and perpendicular to the direction of tillage for the moldboard plow. Tillage transport coefficients for different types of tillage equipment have since been documented by various researchers. A modified method for the development of tillage transport coefficients that permits a high retrieval rate of soil tracer is described in this poster.

Objective

Describe a method for estimating the movement of soil by tillage equipment that allows for a high retrieval rate of soil tracer for plot treatments.

Site Description

An agricultural field under no-till practices for fifteen years was selected as the research site. The field cropping practices during this time period consisted of a corn-soybean rotation. The soil was of a glacial till origin with a silt loam soil texture. The soil bulk density ranged from 1.20 to 1.37 g/cm^3. Field slopes ranged between 0% to 12%.

Methods

The measurement of soil displacement by tillage was based on the use of soil tracers (Lobb 2002), this method was modified utilizing metallic washers and a magnetic sweep for increased tracer retrieval. The metallic tracers were placed in dug trenches with dimensions of 0.2 meter wide by 1 meter length by 0.22 m height. A wood reference board (0.2 meter by 1 meter by 0.02 meter thick) was placed in the bottom of the pit.

The quantity of tracers placed in each plot was 3000 grams of 1.27 cm diameter metallic washers (approximately 5% of the soil mass), the tracer was uniformly mixed with the soil taken from the trench, and then repacked (minus the soil excavated for the board and metallic washer volume).

The plot locations were placed based on the slope topographic characteristic of the field, locations with slopes of 10%, 7%, 5%, 3% and 0% were identified for trench placement positioned transversally to the slope. Tillage runs for each tillage treatment were conducted in both the upslope and down-slope directions at each of the identified slopes.

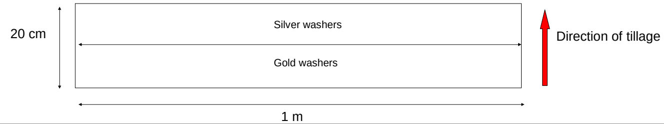
Soil Tracer Placement Retrieval

Upon tillage operation each trench area's 1m * 0.2 m block dimensions were excavated for metallic washer retrieval with the aid of a magnetic sweep and sieve. Washer retrieval rates from the buried washers were 98% - 99%. The movement of the metallic washers being a direct indication of soil movement.





Trials at ten plot areas for each tillage treatment were conducted at slope gradients (%) of 0 , 3 , -3 , 5 , -5 , 7 , -7 , 10 , -10. Tillage operations were performed in the upslope and down-slope directions (upslope gradient is positive; down-slope negative). After each tillage operation the buried washers were retrieved, cleaned and weighed for calculation of average washer (soil) translocation within each plot area. One aspect of this experiment is the use of two different colors of washers that were mixed with the repacked soil. Gold washers were mixed with soil and repacked into the first 10 cm of the trench and the silver into the second 10 cm of the trench. The division of the colored washers into separate sections of the trench was done in order to provide an internal estimate of translocation variability. This was examined at three plot locations: 10% upslope, -10% down-slope and 0% slope for the chisel plow treatment.



Results

Table 1. Site and Treatment Measurements for Chisel Plow

Plot #	Treatment	Tillage Direction	Avg. Tillage Depth cm	Dry Bulk Density g/cm3	Soil Moisture Content (w/w) kg/kg	Tractor Speed km/h	Washer Recovery Rate Ratio	Slope Gradient %	Soil Texture
1	Chisel Plow	7up	10.2	1.30	0.18	5.2	0.994	7	Silt Loam
2	Chisel Plow	7down	8.0	1.35	0.19	6.9	0.981	-7	Silt Loam
3	Chisel Plow	10up	8.9	1.38	0.15	6.0	0.987	10	Silt Loam
4	Chisel Plow	10down	8.5	1.34	0.16	6.9	0.922	-10	Silt Loam
5	Chisel Plow	0_slope	9.6	1.28	0.18	5.4	0.994	0	Silt Loam
6	Chisel Plow	0_slope	7.0	1.31	0.20	5.4	0.994	0	Silt Loam
7	Chisel Plow	3up	7.8	1.31	0.20	6.2	0.987	3	Silt Loam
8	Chisel Plow	3down	11	1.32	0.21	6.4	0.992	-3	Silt Loam
9	Chisel Plow	5up	9.8	1.34	0.19	5.4	0.990	5	Silt Loam
10	Chisel Plow	5down	12.2	1.31	0.18	6.6	0.988	-5	Silt Loam

Effective depth of the soil being displaced from the initial trench is calculated from the total plot average of the mass of the metallic washers that were moved outside the boundary of the initial trench box area (1028 g). The effective depth is then estimated as (1028/ 3000 * 20 = 6.85 cm). (Total washers=3000 g, Washers moved outside trench= 1028 g, Trench Box Depth =20 cm)

Table 2. Chisel Plow Washer Displacement

Chisel Plow Washer Translocation Distance	Plot 1 (Slope Up 7%)		
Trench center line to block center lines	All Washer Mass (g)	Block washer mass / Mass recovered outside trench	Weighted Washer Displacement
Distance (0) Trench Box	1920.60	Washer Ratio (g/g)	Distance * Ratio
15	341.40	0.32	4.82
25	126.20	0.12	2.97
35	95.90	0.09	3.16
45	92.10	0.09	3.90
55	63.00	0.06	3.26
65	74.60	0.07	4.56
75	60.90	0.06	4.30
85	60.70	0.06	4.86
95	51.30	0.05	4.59
105	19.50	0.02	1.93
115	17.30	0.02	1.87
125	16.20	0.02	1.91
135	14.20	0.01	1.80
145	10.90	0.01	1.49
155	2.20	0.00	0.32
165	6.50	0.01	1.01
175	7.60	0.01	1.25
185	1.10	0.00	0.19
195	0.00	0.00	0.00
205	0.00	0.00	0.00
215	1.10	0.00	0.22
225	0.00	0.00	0.00
235	0.00	0.00	0.00
245	0.00	0.00	0.00
255		0.00	0.00
265		0.00	0.00
275		0.00	0.00
285		0.00	0.00
295		0.00	0.00
305		0.00	0.00
315		0.00	0.00
325		0.00	0.00
335		0.00	0.00
345		0.00	0.00
355		0.00	0.00
370			
	Outside Trench 1062.70	Totalized 1.00	Average Weighted Distance 48.40
	Total Washer 2983.30		

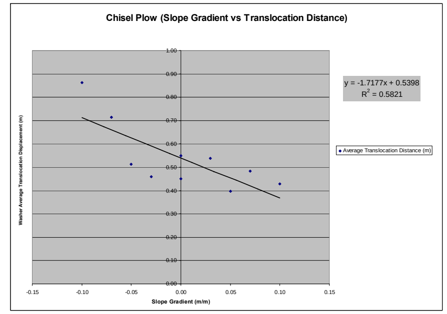
Table 3. Mean Weighted Translocation Distance (MTWD) for All Tracers and Tracers Separated by Initial Position

Plot	Slope (m/m)	All	Silver (m)	Gold
1	0.07	0.48	--	--
2	-0.07	0.72	--	--
3	0.10	0.43	0.35	0.41
4	-0.10	0.86	0.79	0.79
5	0.00	0.55	0.48	0.50
6	0.00	0.45	--	--
7	0.03	0.54	--	--
8	-0.03	0.46	--	--
9	0.05	0.40	--	--
10	-0.05	0.51	--	--

A line running through the middle of the trench box was set at 0 cm to represent the center of initial tracer mass. Distance to the center of the first excavated box area was 15 cm with each subsequent increment being increased by 10 cm.

Three plots were used to demonstrate the internal estimate of soil translocation variability using silver and gold washers grouped separately within the trench box. The center line of the silver and gold washer box was 10 cm and 20 cm from the first excavated box area center line respectively. The mass of the first 10 cm displacement for the gold washers was approximately using the silver washer mass recovered for the first 10 cm box area.

Single estimates were lower than grouped estimates of MWTD. The ability to reduce the initial center line distances from the main trench box leads to improved estimates of MWTD used to develop tillage erosion coefficients.



The empirical equation for soil displacement by tillage is of the form: L=b(S) + a (i.e.. Y=-1.71x +0.54)

The tillage transport coefficient (k) is defined as k=-D*ρb*β
Tillage transport coefficient (Chisel Plow): D=.0685 m,
Average ρb=1320 kg m-3, β=-1.71 m

k= (-1)*(.0685)*(1320)*(-1.71)= 154.4 kg/m

Summary

- High rates of in-field tracer retrieval (98%) were obtained using metallic washers and a magnetic sweep.

- The tillage translocation coefficient for the chisel plow was estimated to be 154 kg/m.

- Estimates of internal sampling error were measured at three plot locations. Similar values were found between duplicate measurements for each sampling location tested.

-The results from this initial test indicate that the average translocation estimate of the tracer (soil) movement could be refined by using both gold and silver washers to estimate translocation distance.

- **The initial center line distances from the trench box to the excavation box areas can be reduced leading to a refinement in the estimation process while still maintaining an adequate number of tracers for recovery operations. In this indicator study.**

-Between plot variability is expected to be higher than within plot variability. These sources of variability include: tillage depth, tillage implement contact with the soil medium, the randomness of the tracer disbursed in the soil medium, tillage field history, tillage speed, moisture content at tillage, tillage implement settings.

- **High labor and time requirements make measurements of between plot variability difficult.**

References

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