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John E. Gilley
University of Nebraska-Lincoln, john.gilley@ars.usda.gov

S. C. Finkner
University of Nebraska-Lincoln

R. G. Spomer
United States Department of Agriculture

L. N. Mielke
University of Nebraska-Lincoln

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J. E. Gilley, S. C. Finkner, R. G. Spomer, L. N. Mielke
MEMBER ASAE ASSOC. MEMBER ASAE MEMBER ASAE AFFILIATE ASAE

ABSTRACT

SIZE distribution of sediment was measured under simulated rainfall conditions at selected downslope distances on plots with corn residue rates ranging from 0.00 to 6.73 t/ha. The formation of rills caused increases in the percentage of larger sized sediment material. Greater surface cover usually resulted in an increase in the percentage of smaller sized sediment.

Considerable variation in the size of sediment from both rill and interrill areas was found with downslope distance. On interrill regions, the presence of residue served to reduce sediment size along the entire plot length. Transport of aggregated sediment occurred on each of the residue treatments.

INTRODUCTION

The transportability of sediment produced from cultivated cropland during erosive rainstorms is largely dependent on sediment size (Meyer et al., 1980). The downslope transport of detached soil occurs primarily in concentrated flow channels. Both primary and aggregated particles are usually found in sediment eroded from cohesive soils.

Sediment may serve as the delivery mechanism for some agricultural chemicals to streams and reservoirs. The amount and type of clay present in sediment influences chemical transport capacity. Thus, not only the sediment itself but also the size distribution of eroded soil may be a water pollution concern.

Some sediment transport models consider the size distributions of eroded materials. These models can select, according to size classes, the amount of sediment available for deposition or transport. If the factors affecting size distributions of eroded soil can be better defined, existing transport models can be more efficiently utilized.

Weakly (1962) examined the degree of aggregation of sediment in rainfall-induced runoff from plots under varying degrees of slope, rainfall intensity and crop cover. Cogo et al. (1983) found a decrease in particle-size with increasing residue cover on smooth surfaces. However, the effect of cover on particle size was negligible on rough surfaces. The densities of wet aggregates that exist during fluvial transport of sediment from agricultural soils were measured by Rhoton et al. (1983). Alberts et al. (1983) studied the physical and chemical properties of aggregates eroded from two fertile agricultural soils in southwestern Iowa.

Statistically different particle size distributions were found by Swanson et al. (1965) between eroded sediment and surface soil. Gabriels and Moldenhauer (1978) compared the size distribution of aggregates and primary particles eroded from simulated rainfall on different textured soils. Much of the sediment from cohesive soils was found by Meyer et al. (1980) in the form of aggregates, and some of the aggregates were much larger than the primary particles of which the soils were composed. Alberts et al. (1980) measured large differences in the size of soil aggregates and primary particles of sediment originating from rill and interrill areas.

A laboratory study to reproduce size distributions of soil eroded from field plots during simulated rainstorms was conducted by Rhoton et al. (1982). Meyer et al. (1983) found that certain combinations of wetting and agitation of surface soil resulted in size distributions very similar to those obtained during field erosion studies. Three different commercial particle size analyzers were compared by Schiebe et al. (1983) with the conventional pipet technique for measuring size distribution of very fine sediments.

Young and Onstad (1976) developed a set of equations for predicting particle size distribution of eroded soil, based on soil surface area and texture and considering organic matter content and tendency of a soil to rill. General guidelines on the characteristics of eroded soil for use in sediment prediction models were suggested by Young (1980). Neibling et al. (1983) described the effects of storage time and method of analysis on size distribution of aggregated sediment.

In many of the previous investigations, size distribution of sediment was measured at a single discharge location. Information concerning sediment size distributions along a slope is limited. The objective of this study was to determine size distribution of sediment from rill and interrill areas as affected by varying amounts of corn residue.

PROCEDURE

The study was conducted in southwestern Iowa near Treynor. The Monona soil at the site (fine-silty, mixed mesic typic Hapludolls) developed on a deep loessal mantle overlying glacial till. Average slope at the location was 5.2%.

Crop residue on the soil surface was first removed and stored for future use. The area was then disked and

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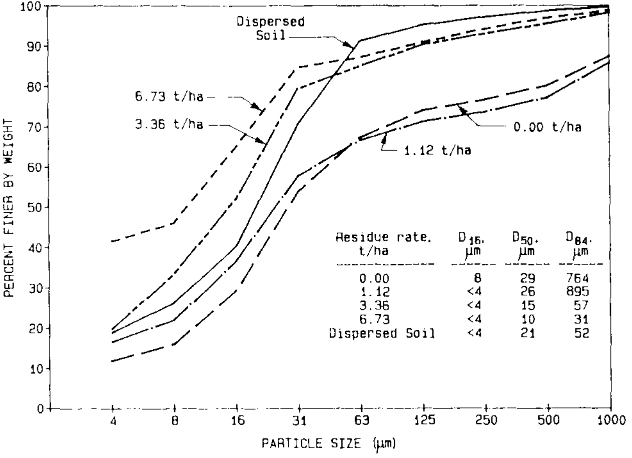
The authors are: J. E. GILLEY, Agricultural Engineer, USDA-ARS, and S. C. Finkner, Research Engineer, Agricultural Engineering Dept., University of Nebraska, Lincoln; R. G. SPOMER, Agricultural Engineer, USDA-ARS, Council Bluffs, IA; and L. N. MIELKE, Soil Scientist, USDA-ARS, University of Nebraska, Lincoln.



Residue rate, t/ha	D_{16}, μm	D_{50}, μm	D_{84}, μm
0.00	8	29	764
1.12	<4	26	895
3.36	<4	15	57
6.73	<4	10	31
Dispersed Soil	<4	21	52

Fig. 1—Size distributions of eroded sediment for four corn residue treatments and of dispersed soil. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.

rototilled to depths of approximately 150 and 80 mm, respectively. Following tillage, plots 3.7 m across the slope by 22.1 m long were established. The plots were covered with plastic to maintain similarity in soil water conditions.

A sample of the top 25 mm of surface soil was collected prior to simulation testing. The primary particle size distribution of this soil after dispersing (Day, 1965) was determined and is shown in Fig. 1. The soil, classified as a silt loam, consisted of 9% sand, 72% silt, and 19% clay.

Previously stored residue was returned to the plot surface in a random orientation. Residue was applied at 0.00, 1.12, 3.36 and 6.73 t/ha, which covered 10, 31, 51 and 83% of the surface, respectively. There were two replications of each residue rate. Residue coverage was measured using the point quadrant method (Mannering and Meyer, 1963).

A portable rainfall simulator designed by Schulz and Yevjevich (1970) was used to apply rainfall for one hour at a design intensity of approxinately 28 mm/h. The first rainfall application (initial run) occurred at existing soil water conditions while the wet and very wet runs were conducted approximately 24 and 48 h later, respectively. Standard procedures were used to measure average rainfall intensity and total runoff (Meyer, 1960).

Samples for determining sediment size distribution were obtained once steady-state runoff conditions had become established during the very wet simulation run. A stage recorder mounted on an HS flume was used to determine steady-state runoff conditions. Samples, approximately 800 ml in size, were collected in polyethylene bags at the flume discharge location.

Runoff samples were also obtained at the point where each rill (flow area in which soil scouring had occurred) or overland flow channel (flow area in which soil scouring had not occurred) discharged into the collection trough. Additional upstream samples were collected along two of the channels on each plot at approximately 6-m intervals. A 800 mL runoff sample was obtained by placing a polyethylene bag across the channel cross section. A platform which extended over the entire plot width was used to prevent plot disturbance during sample collection.

Once runoff samples had been obtained from the rills, liquid paraffin was placed along the wetted perimeter of any rill in which scouring had occurred, preventing future rill development. Additional rainfall was then applied and samples for determining sediment size distribution were collected at the locations used previously. Since the rill networks were sealed and therefore could no longer serve as source areas for soil detachment, sediment moving along the rills originated primarily from interrill regions.

The runoff samples were immediately wet sieved as suggested by Meyer and Scott (1983). Sand sized sediment fractions were determined by washing the runoff samples through sieves with 1000, 500, 250, 125 and 63 μm openings. Each sieve was gently and thoroughly washed. The material passing through the 63 μm sieve was then stored for future analyses.

Sediment sizes of 31, 16, 8 and 4 μm were determined using pipette withdrawal procedures proposed by Guy (1969). Guy (1969) suggested that particles greater than 62 μm be classified as sand, that silt-sized particles range from 4 to 62 μm, and that particles less than 4 μm be classified as clay. Use of a special 25 mL pipette (Day, 1965) greatly facilitated withdrawal and dispensing of the sample.

RESULTS AND DISCUSSION

Consistent reductions in total runoff and erosion resulted from increased residue application (Gilley et al., 1986a). The rate of runoff and erosion may have a major affect on the size distribution of sediment. Runoff and soil loss rates were measured by Gilley et al. (1986b) at the same locations at which samples for identification of sediment size distribution were collected. However, only data on size distributions of sediment are reported here.

Rills formed during the wet rainfall simulation run on the 0.00 and 1.12 t/ha residue treatments. Formation of rills did not occur on the plots with residue rates of 3.36 or 6.73 t/ha, but well defined overland flow channels were present. It was within the rills or overland flow channels that runoff samples for determination of sediment size distribution were collected.

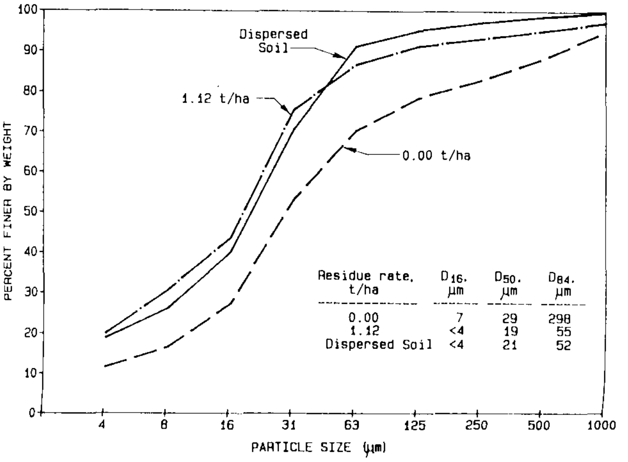
The area contributing runoff increases with downslope distance. Thus, larger runoff rates may result at greater slope length. Variations in runoff rates and associated water depth and velocity may affect soil detachment, deposition and sediment transport.

In the following discussion, the effects of surface cover on sediment size are examined. The size of sediment from interrill areas is reported and the effect of downslope distance on sediment size is described. The size of interrill sediment as affected by downslope distance is also discussed.

Surface Cover Effects on Sediment Size

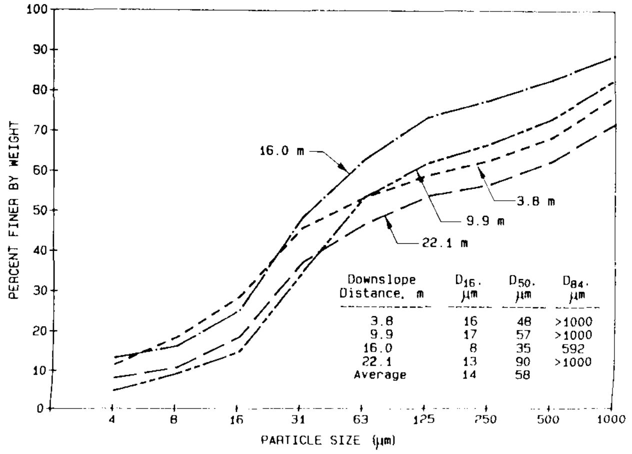
The size distributions of sediment from four corn residue treatments are shown in Fig. 1. Each of the reported values was obtained from runoff samples collected during the very wet simulation run on duplicated plots at the flume discharge location. These values represent sediment measurements of eroded soil originating from both rill and interrill areas.

Little variation in the size distribution of sediment was found between the 0.00 and 1.12 t/ha residue treatments. Rills formed on these plots. The percentage



Residue rate, t/ha	D_{16}, μm	D_{50}, μm	D_{84}, μm
0.00	7	29	298
1.12	<4	19	55
Dispersed Soil	<4	21	52

Fig. 2—Size distributions of eroded sediment from interrill areas for two corn residue treatments and of dispersed soil. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.



Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	16	48	>1000
9.9	17	57	>1000
16.0	8	35	592
22.1	13	90	>1000
Average	14	58	

Fig. 3—Size distributions of eroded sediment of selected downslope distances for corn residue rate of 0.00 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.

of sediment larger than 500 μm was greater on the 0.00 and 1.12 t/ha residue treatments than was found on the other plots. Correspondingly, the largest percentage of clay-sized particles eroded from the 3.36 and 6.73 t/ha residue treatments. Values of D_{50} and D_{84} were larger on those plots subject to rilling.

When the size distribution of dispersed surface soil was compared with distribution curves for the 0.00 and 1.12 t/ha residue treatments, a substantial percentage of sand sized soil aggregates were apparent. A much smaller percentage of sand sized material was eroded from the 3.36 and 6.73 t/ha residue treatments. However, an increased percentage of silt and clay size particles eroded from the higher residue treatments.

Sediment Size from Interrill Areas

Fig. 2 shows sediment sizes from interrill areas on the 0.00 and 1.12 t/ha residue treatments. The samples used for determining sediment size distributions were collected at the flume discharge locations after stabilization of the rills with liquid paraffin. The values represent measurements of size distributions of sediment originating from along the entire plot length.

It can be seen from Fig. 2 that the application of surface residue served to reduce D_{50} and D_{84} of sediment originating from interrill areas. The percentage of sediment in size group 31 μm and larger was consistently greater for the no residue treatment while the percentage of sediment in size groups less than 31 μm was greatest on the plot with 1.12 t/ha of residue. Surface residue served to reduce the size of eroded material transported from interrill areas.

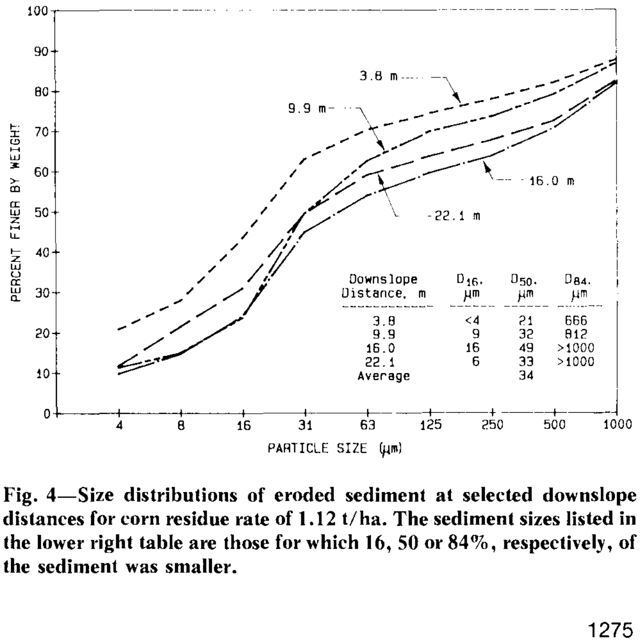
On the no residue treatment, sediment size distributions as shown in Figs. 1 and 2 were similar for each of the size classes except that >1000 μm. The percentage of sediment >500 μm originating from interrill areas for the 1.12 t/ha residue treatment (Fig. 2) was smaller than corresponding values for total eroded sediment (Fig. 1). Thus, the existence of rills served to increase the percentage of sediment found in the largest size classes.

Movement of sand-sized soil aggregates from interrill areas occurred for the no residue treatment. On the 1.12 t/ha residue treatment, size distribution of sediment was similar to dispersed surface soil. The dispersed surface soil and sediment originating from interrill areas on the 1.12 t/ha residue treatment had smaller D_{50} and D_{84} values.

Effect of Downslope Distance on Sediment Size

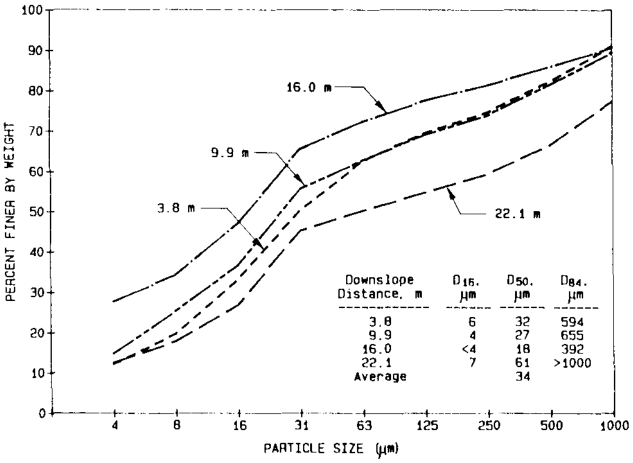
Sediment size distributions at selected downslope distances for residue rates of 0.00, 1.12, 3.36 and 6.73 t/ha are shown in Figs. 3, 4, 5 and 6, respectively. Runoff samples for determination of size distribution of sediment were collected at approximately 6-m intervals along the entire plot length. On the 0.00 and 1.12 t/ha residue treatments, sediment found in rills was a composite of soil material eroded from both rill and interrill areas.

For those plots on which rilling occurred (0.00 and 1.12 t/ha residue treatments) D_{50} values averaged for all downslope distances decreased as a result of residue application. On the 3.36 nd 6.73 t/ha residue treatments, where interrill soil loss predominated, values of D_{50} averaged for all downslope distances were similar. On the 3.36 and 6.73 t/ha residue treatments, little



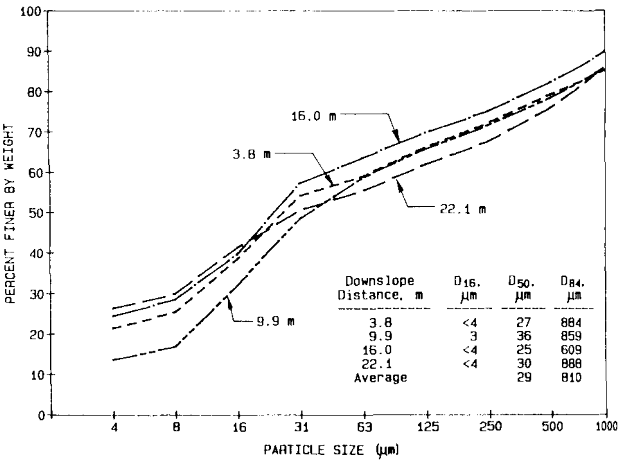
Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	<4	21	666
9.9	9	32	812
16.0	16	49	>1000
22.1	6	33	>1000
Average		34	

Fig. 4—Size distributions of eroded sediment at selected downslope distances for corn residue rate of 1.12 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.



Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	6	32	594
9.9	4	27	655
16.0	<4	18	392
22.1	7	61	>1000
Average		34	

Fig. 5—Size distributions of eroded sediment at selected downslope distances for corn residue rate of 3.36 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.



Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	<4	27	884
9.9	3	36	859
16.0	<4	25	609
22.1	<4	30	888
Average		29	810

Fig. 6—Size distributions of eroded sediment at selected downslope distances for corn residue rate of 6.73 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.

variation was found in the percentage of sediment in each of the size classes when averages for all distances were considered.

Considerable variation in the size of sediment occurred with downslope distance of each of the residue treatments. These fluctuations could be attributed to variations in runoff rate, runoff velocity, sediment concentration, slope and other factors. Information on changes in these parameters with downslope distance could aid in the estimation of size distribution of sediment.

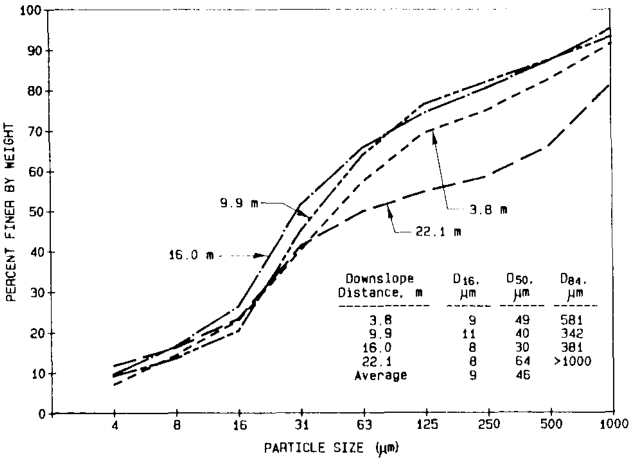
When sediment size distributions were averaged for all distances, the size classes with the largest amounts of sediment on both the 0.00 and 1.12 t/ha residue treatments were 16-31 and >1000 μm. In comparison, the largest average percentage of sediment on both the 3.36 and 6.73 t/ha residue treatments was for size fractions <4 and 16-31 μm. The flow occurring in the rills on the 0.00 and 1.12 t/ha residue treatments carried aggregates >1000 μm. On those plots with larger amounts of residue, an increased percentage of clay particles occurred.

Interrill Sediment Size as Affected By Downslope Distance

Size distributions of eroded sediment from interrill areas at selected downslope distances for residue rates of 0.00 and 1.12 t/ha are shown in Figs. 7 and 8, respectively. Runoff samples for determination of sediment size distribution were collected along the entire plot length after stabilization of the rills with liquid paraffin. At a particular sampling location, transported sediment originated from upstream areas and adjoining interrill regions.

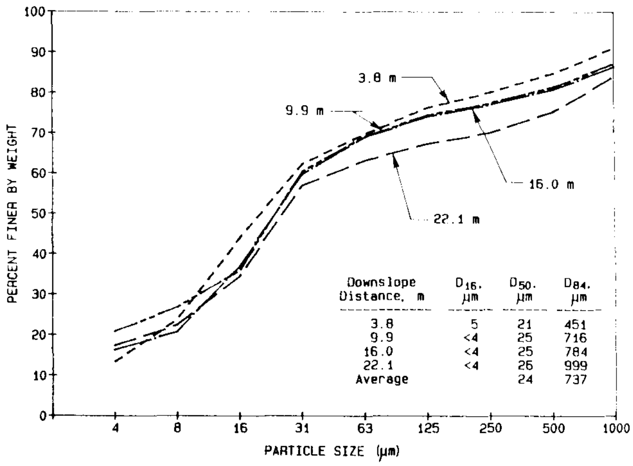
Values of D_{50} for the interrill areas at each of the downslope distances were greatest on the no residue treatment. The presence of residue served to reduce the size of sediment along the entire plot length. The largest percentage of sediment for both residue treatments was found in the 16-31 μm size class, the same as that found for dispersed surface soil.

For the no residue treatment, the percentages of sediment averaged for all distances in each of the size classes except that >1000 μm was similar for total and interrill eroded sediment as shown in Figs. 3 and 7,



Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	9	49	581
9.9	11	40	342
16.0	8	30	381
22.1	8	64	>1000
Average	9	46	

Fig. 7—Size distributions of eroded sediment from interrill areas at selected downslope distances for corn residue rate of 0.00 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.



Downslope Distance, m	D_{16}, μm	D_{50}, μm	D_{84}, μm
3.8	5	21	451
9.9	<4	25	716
16.0	<4	25	784
22.1	<4	26	999
Average		24	737

Fig. 8—Size distributions of eroded sediment from interrill areas at selected downslope distances for corn residue rate of 1.12 t/ha. The sediment sizes listed in the lower right table are those for which 16, 50 or 84%, respectively, of the sediment was smaller.

respectively. Rilling substantially increased the percentage of sediment in the largest size class. Average D_{16} and D_{50} values for interrill sediment (Fig. 7) were slightly less than corresponding measurements for total eroded sediment (Fig. 3) on the no residue treatment.

For size classes 31 μm and greater, percentages of total sediment averaged for all distances on the 1.12 t/ha residue treatment (Fig. 4) were larger than corresponding values for interrill areas (Fig. 8). Similarly, increased percentages of sediment <31 μm were found on interrill areas as compared to total eroded sediment. For the 1.12 t/ha residue treatment (Fig. 4), total D_{50} values for each of the downslope distances were larger than corresponding measurements from interrill areas (Fig. 8). Increased sediment size occurred along the entire slope length on the 1.12 t/ha residue treatment as a result of rill formation.

SUMMARY AND CONCLUSION

Simulated rainfall was applied to a Monona silt loam soil located in southwestern Iowa on which residue was placed at rates varying from 0.00 to 6.73 t/ha. The percentages of eroded sediment over 10 size classes ranging from 4 to 1000 μm were measured. Sediment size distribution was determined from both rill and interrill areas at selected downslope distances.

In general, surface residue served to reduce the size of eroded material transported from both rill and interrill areas. The percentage of sediment found in the largest size class usually increased on those plots subject to rilling, as compared to the treatments without rills. Correspondingly, as the amount of residue became greater, the percentage of sediment found in the smallest size class usually increased.

The size of sediment from interrill areas was reduced along the entire plot length as a result of residue application. Sediment size distribution of both rill and interrill discharge varied substantially with downslope distance. Transport of sediment in the form of aggregates occurred on each of the treatments.

Detachment, deposition and sediment transport mechanisms are frequently included in many upland erosion models. For the simulation models to function properly, estimates of runoff, size distribution of sediment and soil loss must be made. Downslope routing of water and sediment may be possible if these variables can be accurately predicted at a particular downslope distance.

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