Development and testing of a modified ground sediment trap
by Leslie Carol Bush

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
A modified version of a ground sediment trap was tested in a greenhouse study for its effectiveness in collecting overland flow and soil loss. Four degrees of slopes, three ground cover levels, varying rainfall and overland flow conditions, and one soil type were used in erosion studies to determine their interactions and influences on overland flow and soil loss. Overland flow and soil losses (a) increased with slope steepness, storm intensity, and storm duration; and (b) decreased with increasing ground cover. Rate of soil loss increased during the first 40 minutes and then decreased as overland flow continued while rate of overland flow increased during the first 40 minutes and then remained constant. The traps were more efficient and less variable in collecting overland flow and soil losses on slopes steeper than 10%. The traps worked more effectively under storms of moderate to high intensities, and with storms of 40 minutes to extended durations; consequently, they should function adequately during semi-arid and arid region natural precipitation events over rangelands in moderate to poor conditions.

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A thesis submitted in partial fulfillment
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Master of Science

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Range Science

MONTANA STATE UNIVERSITY
Bozeman, Montana

August, 1985

APPROVAL

of a thesis submitted by

Leslie Carol Bush

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

It is with deep gratitude that I acknowledge the help and advice given by Mr. Don Donham while the microsite was at Fort Ellis, my graduate committee, Mr. Dennis Neuman and the use of his lab facilities, my curriculum professors, friends, and family. I would like to especially thank Dr. Clayton Marlow for his moral and financial support, and advice; the United States Forest Service Intermountain Forest and Range Experiment Station for the use of their greenhouse facility; Ms. Gayle Barthel for her secretarial assistance; Ms. Linda Kisha for her assistance in obtaining literature; Mr. Terry Koral for his computer programing assistance; Dr. Richard Lund and Dr. Michael Huffman for their guidance in statistical analysis; Mr. Gene Kennon for his draftmanship; and Mr. Henry Tacon for his mathematical consultations and assistance. Lastly, I would like to particularly thank Mrs. Paula Ross for her word processing assistance.

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ABSTRACT

A modified version of a ground sediment trap was tested in a greenhouse study for its effectiveness in collecting overland flow and soil loss. Four degrees of slopes, three ground cover levels, varying rainfall and overland flow conditions, and one soil type were used in erosion studies to determine their interactions and influences on overland flow and soil loss. Overland flow and soil losses (a) increased with slope steepness, storm intensity, and storm duration; and (b) decreased with increasing ground cover. Rate of soil loss increased during the first 40 minutes and then decreased as overland flow continued while rate of overland flow increased during the first 40 minutes and then remained constant. The traps were more efficient and less variable in collecting overland flow and soil losses on slopes steeper than 10%. The traps worked more effectively under storms of moderate to high intensities, and with storms of 40 minutes to extended durations; consequently, they should function adequately during semi-arid and arid region natural precipitation events over rangelands in moderate to poor conditions.

INTRODUCTION

Soil erosion, "a process of detachment and transportation of soil materials by erosive agents" (Ellison 1947a), is "one of the three components in the overall sedimentation process (erosion, transport, and deposition)" (Ekern 1950). There are two basic categories of erosion (a) normal erosion, degradation of the soil at a rate equivalent to the geological normal, and (b) accelerated erosion, degradation of the soil at a rate greater than geologic normal (Croft et al. 1943). Accelerated erosion occurs through the destructive modification or removal of soil resulting from impairment of the protective influence exerted by the plant and litter cover (Croft et al. 1943). It has been recognized that erosion is a serious problem of farm- and rangelands over a large part of the earth (Smith and Wischmeier 1962). Consequently, proper land management practices are needed to reduce, rectify, and solve erosional problems on noncultivated and cultivated land bases. An important facet of these management practices is the evaluation of their effectiveness; consequently, there are demands for accurate means of quantitative erosion measurement and monitoring.

Ideally, methods of quantifying normal and accelerated erosion on semi-arid rangelands should alter natural ecosystem processes as little as possible. The use of ground sediment traps may be one way to meet this requirement. This study analyzed the feasibility and effectiveness of such traps. There were three primary objectives in this study:

(a) to design and develop a versatile ground sediment trap, (b) to test the effectiveness of prototype traps in controlled erosion studies and (c) to evaluate the influences of ground cover, slope and overland flow conditions on overland flow and soil loss. Hypothetically, sediment collection by in-situ traps varies with changes in slope, storm conditions, soil characteristics, and ground cover. Four slopes, three different ground covers, varying rainfall and overland flow conditions, and one soil type were used in the erosion study to determine their interactions and influences on overland flow and sediment production, and to analyze trap effectiveness.

The study was conducted in the United States Forest Service's Intermountain Forest and Range Experiment Station greenhouse on Montana State University's campus in Bozeman, Montana. Test dates were September 1983 through July 1984.

LITERATURE REVIEW

Erosion Analysis

Studies dealing with soil erosion problems need to take into account the four factor classes involving erosion. These factor classes are (a) pedologic; including texture, structure, and other soil characteristics involving erodibility; (b) physiographic; including slope, length of overland flow, surface roughness, depression storage, etc.; (c) hydrologic; including precipitation intensity and duration, infiltration capacity, and surface runoff characteristics; and (d) hydraulic; including fluid conductivity, routing and physical characteristics (Horton 1938). The physiographic and hydrologic factors operate indirectly through hydraulic factors and independent variables such as depth and velocity of overland flow, and type of overland flow. Erosion studies which simulate natural conditions need accurate representation of these factor classes in order to obtain results applicable to those expected from studies done under natural climatic and environmental conditions. Erosion studies also need runoff and soil loss collection apparatus which operate efficiently and accurately. Several methods have been developed to better understand the influences and interactions of factors influencing erosion.

Ellison (1944) developed devices that measured overland flow and splash erosion under natural and simulated storms. His overland flow sampler was adjustable for slope and could be carried around for use on random plots or used on permanent transects. Debris was troublesome in the collection slots, and erosion by overland flow only could not be determined if there was any raindrop erosion (Ellison 1944). Ellison's splash sampler was as portable as the overland flow sampler, and together they could help determine the distribution and nature of the erosional activity occurring over a watershed (Ellison 1944).

Numerous studies have been done under natural and/or simulated storm conditions through use of plots with barriers, troughs, flumes, recording gages, and collection containers for the collection and measurement of surface runoff (SRO) and soil loss. Erosion plots with wood barriers and wood catchment troughs of variable dimensions were used by Lowdermilk (1930), Marston (1952), Rowe and Reimann (1961), and Osborn et al. (1964). Natural rainfall events were used in all these studies. Troughs used by Marston and Rowe and Reimann did not have flumes, recording gages, or collection containers. Lowdermilk's plots (1930) had pipes which transported surface runoff and seepage water from the plots into tipping bucket gages to obtain rates of flow. Osborn et al.'s (1964) troughs had pipes which transferred runoff into silt tanks. Van Doren et al.'s (1940) plots had wood barriers and metal troughs with flumes from which iron pipes transported surface runoff of natural rainfall events into silt tanks. Various modifications of plots equipped with metal sidewalls and metal catchment troughs have been used by Pearse and Woolley (1936), Dunford (1954), Haupt (1967), and Orr (1970). Pearse and Woolley's plots (1936) were supplied by simulated overland flow. The overland flow was funneled through a metal spout into collection cans and jars placed beneath the downslope frame side. Dunford's plots (1954) were supplied by natural rainfall. Metal flumes were incorporated into Dunford's troughs from which pipes fed runoff into silt tanks. Haupt (1967) used plots with metal sidewalls and metal troughs on which natural and simulated precipitation was supplied. Orr (1970) used plots with metal sidewalls and troughs supplied by natural rainfall. Runoff was funneled from the troughs into buried pipes which emptied into collection tanks. Erosion plots equipped with concrete sidewalls and troughs have been used. Nichols and Sexton (1932) delineated plots with concrete sidewalls and applied simulated rainfall. Surface runoff was collected in concrete cisterns which fed into collection cans at the end of each slope. Leopold (1964) used plots equipped with concrete sidewalls and concrete troughs that fed natural rainfall runoff into collection tanks.

Although there are many advantages of using delineated erosion plots, there are several disadvantages. Advantages are (a) controlled collection of runoff leading to accurate measures of SRO and soil loss; (b) simplified manipulation of vegetal and soil conditions; (c) capabilities for simulating precipitation events over controlled plot conditions resulting in regulated erosion events; and (d) potential correlation of plot erosion conditions to those expected on unaltered areas. Major disadvantages in using constructed erosion plots are (a) alteration of natural erosion patterns over areas where plots were placed; (b) alterations of vegetal and soil conditions which changed erosion patterns and potentials; (c) slow availability of data and variability of data under natural precipitation events; and (d) variability in control of simulated precipitation and other drawbacks with the use of precipitation simulators. Runoff and erosion data vary greatly due to dissimilar precipitation conditions (Martson 1952).

Simulated Rainfall Studies on Natural Terrain

Similar SRO and soil loss collection apparatus as those described in the proceeding section have been used in simulated rainfall studies on smaller erosion plots on natural terrain. Smaller erosion plots were used primarily due to the higher costs, more frequent inaccuracies of measurement, and greater disturbance to natural erosion patterns which were common with large erosion plots. Six infiltrometer models used often in studies on natural terrain are (1) Type-F infiltrometer, (2) Rocky Mountain infiltrometer, (3) modified North Fork equipment, (4) Pearse square foot apparatus, (5) "raindrop applicator", and (6) "rainulator" (Wilm 1941). Their predominant designs involved non-adjustable metal plot frames with metal troughs usually equipped with gages. Runoff may or may not be funneled from the troughs into collection jars and cans depending on the model. Precipitation was supplied by type-F nozzle sprinklers, or a suspended graduated container which fed into a perforated pipe. Dortignac's Rocky Mountain infiltrometer (1951) had a frame with troughs which were adjusted to slope and had fly screen trash collectors to prevent clogging of SRO flows. SRO and soil loss were then passed from each trough through garden hose and drain pipe into 1 gallon containers. Osborn (1952) and Rauzi (1960) used "raindrop applicators" and metal plot frames for erosion study. Osborn's (1952) frame had splash collection troughs on the left and right frame sides and a SRO collection jar positioned at the end of a metal spout on the downslope frame side. In contrast, Rauzi's (1960) frame had a metal spout covered with burlap which funneled runoff into a collection jar. Meyer and McCune (1958) and Meyer (1960) used a "rainulator" on plots with metal barriers. SRO was collected in metal troughs, measured by gages, and funneled into collection cans. Their trough flumes had water level recorders, and sampling wheels.

As mentioned in the proceeding section, there were advantages and disadvantages prevalent with the use of simulated rainfall. Many of these will be discussed in the following section.

Natural Rainfall Studies vs Simulated Rainfall Studies

There has been much debate over the need and use of natural vs simulated rainfall in erosion studies. Although natural rainfall studies provide the most direct means of correlating erosion and precipitation actions they also (a) are slow to yield results, (b) are less efficient than simulated rainfall studies, and (c) are less controlled than simulated rainfall studies (Mech 1965). Simulated rainfall studies have been found to yield SRO volumes comparable to those from natural rainfall of similar intensity and duration. However, simulated rainfall studies tend to yield underestimations of expected SRO and erosion from similar natural rainfall conditions (Mech 1965, and Barnett and Dooley 1972). There are other drawbacks to the use of simulated rain. Raindrop energy remains constant with changing simulated intensities while it changes with changes in natural rainfall intensities. There is variation in height of fall of raindrops, rate of delivery, and rainfall distribution (Dortignac 1951). Rainfall simulators have operational limitations due to their expense and operation complexities (Mech 1965, Young and Burwell 1972). There are limitations on the modeling of environmental and climatic condition constraints in simulated rainfall studies (Mech 1965, Young and Burwell 1972). Natural erosion patterns are altered by plot boundary construction. The results of simulated rainfall studies have also been found to be primarily qualitative (Meyer and McCune 1958). Consequently, there is a need for more effective and efficient erosion analysis methods to be used under natural rainfall conditions since simulated rainfall studies have numerous drawbacks.

Simulated Rainfall Studies on Constructed Microsites

The number and variation of factors affecting soil erosion are such that it is difficult to determine the importance of each individual factor. In order to determine the effect of any one factor, the other factors need to be held constant or measured while the variable being studied is altered (Neal 1937). The manipulation and control of factors affecting soil erosion is very difficult under natural conditions. Consequently, microsites have been used in erosion studies so factors affecting soil erosion could be controlled.

Neal (1937) constructed a wood soil tank to use in analyzing the interactions of various factors on SRO, soil loss, and infiltration. He studied (a) the influences that slope, precipitation intensity and duration, initial soil moisture, soil surface condition, and infiltration had on SRO and soil loss; and (b) the influences that slope, rainfall intensity, initial soil moisture, and rate of infiltration had on infiltration. No ground cover was used while Neal controlled soil conditions, slope, and precipitation intensities and durations. Six slopes were used. Five rainfall intensities and seven rainfall durations were provided with an oscillating nozzle sprinkler system. SRO was collected in a galvanized iron trough at the tank base which fed into collection cans. Soil loss per can was determined for each 10 minute period. Percolation water was collected in a can fed from a trough on the box bottom. Three infiltration cylinders placed in the soil surface were used for obtaining infiltration rates during each run.

Relative density of runoff material increased as slope and rainfall intensity increased (Neal 1937). Soil loss from a saturated soil increased as the 0.7 power of slope, the 2.2 power of rainfall intensity, and directly to rain duration. Neal concluded that rainfall intensity was the most important factor affecting runoff and soil loss in that it (a) had a greater effect on soil loss than on runoff, and (b) had a greater effect on soil loss than percent slope.

Meyer and Monke (1965) used a microsite to establish basic relationships between soil erosion and various factors influencing it: slope length, slope steepness, and soil particle size. No ground cover was used while they controlled soil and slope conditions, and rainfall intensities and durations. Four particle sizes of glass beads ranging from that of a very fine sand to a medium sand were dried and smoothed prior to each run. Six slope steepnesses and four slope lengths were used. Two rainfall intensities were supplied from a rainfall simulator for 30 minutes. SRO was collected in a metal trough at the plot base which drained into collection cans.

Runoff erosion was found to increase with slope length and steepness except at small steepnesses and lengths where essentially no erosion occurred (Meyer and Monke 1965). Rainfall plus runoff increased erosion of smaller particle sizes but decreased erosion of larger sizes as compared with runoff alone. Meyer and Monke (1965) determined that increased sediment availability and runoff carrying capacity were dominant for more easily transported small particles whereas decreased carrying capacity of runoff was dominant for larger particles.

Farmer and Van Haveren (1971) used a wood constructed microsite to (a) develop information about the effects of soil, slope, and rainfall variables on the erodibility of bare soil; (b) determine the magnitude of these effects; and (c) identify relationships between these variables. Three surface soil samples were tested. Three slopes were used. Two rainfall intensities were provided from F-type nozzles for 30 minute runs. Soil splash was collected on four concentric interlocking trays on the plot perimeter, and on a large unsegmented pan on the floor at the plot base. All SRO was collected into cans and weighed. One pint SRO samples were periodically collected during the runs to find the concentration of soil material.

Farmer and Van Haveren (1971) found that rainfall intensity, slope steepness, and percent by weight of soil particles greater than 2 mm had the greatest effects on erosion by overland flow (OLF). Slope steepness and rainfall intensity strongly interacted to influence soil erosion by OLF. The interactive strength of slope and rainfall intensity was at least a full order of magnitude greater than any soil variable.

Although information yielded from these studies are very accurate and reliable sources of soil erosion behavior explanation, more information on rainfall patterns and characteristics, and topographic effects needs to be assembled before real expertise can be developed in explaining soil erosion behavior. These studies and others of similar principle could be used as a basis in future erosion studies under more natural conditions, and to provide increased understanding of the soil-erosion process. For this study, various equipment designs used by formerly discussed researchers were incorporated into a modified ground sediment trap that can be used under natural precipitation events. A rectangular metal frame to be left buried with its surface at ground level and to serve as a support for a removable trough was incorporated from Ellison's (1944) and Dortignac's (1951) designs. Trough or trap shapes used by Dortignac (1951), Meyer and McCune (1958), Haupt (1967) and Orr (1970) were combined into a removable metal-trap design. The trap has its downslope rim slide into a lip of the frame and its upslope rim lie over the frame rim. A metal baffle for reducing downslope overflow potentials was installed on the downslope trap side. Modifications of overflow system designs used by Lowdermilk (1930), Pearse and Woolley (1936), Ellison (1944), Meyer and McCune (1958), Rowe and Reimann (1961) and Orr (1970) were incorporated into trap overflow systems in which collection containers would be placed (a) within the frame beneath the trap for low runoff yielding storms, and

(b) downslope of the traps for high runoff volume yielding storms. Prototype traps were tested on a constructed microsite (Neal 1937, Farmer and Van Haveren 1971) with three ground cover levels and various simulated rainfall and overland flow conditions.

METHODS AND MATERIALS

Wood Box and Sediment Trap Construction

Wood Box. An adjustable 2.4 m x 1.2 m x 24.8 cm box was constructed to contain soil and vegetation (Figure 1). The box sides were tapered to facilitate drainage. Four steel braces were nailed to the box front for support. Finally, burlap was placed over the front opening to prevent soil loss. Caulking was added to inner box seams.

Drainage holes were made to facilitate soil drainage (Figure 1). Twenty 0.5 cm holes were made through the front sides and covered on the inside with burlap. Very coarse sand was then spread at a depth of 4.1 cm on the box bottom to further facilitate drainage.

Ground Sediment Trap. A general trap design is shown in Figure 2 with a top view of the removable trap shown in Figure 3. The traps were made of sheet metal with i x 0.3i x 0.4i (i = frame length) dimensions for the stationary frame and i' X 0.2i' X 0.3i' (i' = trap length) dimensions for the removable trap where i' = 0.95i. The frame is designed to be left buried with the surface rim being even with the soil surface. Length of frame, i, should be the same as desired sample plot width. Three prototype removable traps were used in the greenhouse study in which i' = 30.5 cm. Trap frames were not used in the study due to their expense. Surface runoff (SRO) was manually removed from the traps with pipettes, a handpump, and/or siphons.

FIGURE 1. Diagram of Microsite Wood Box.

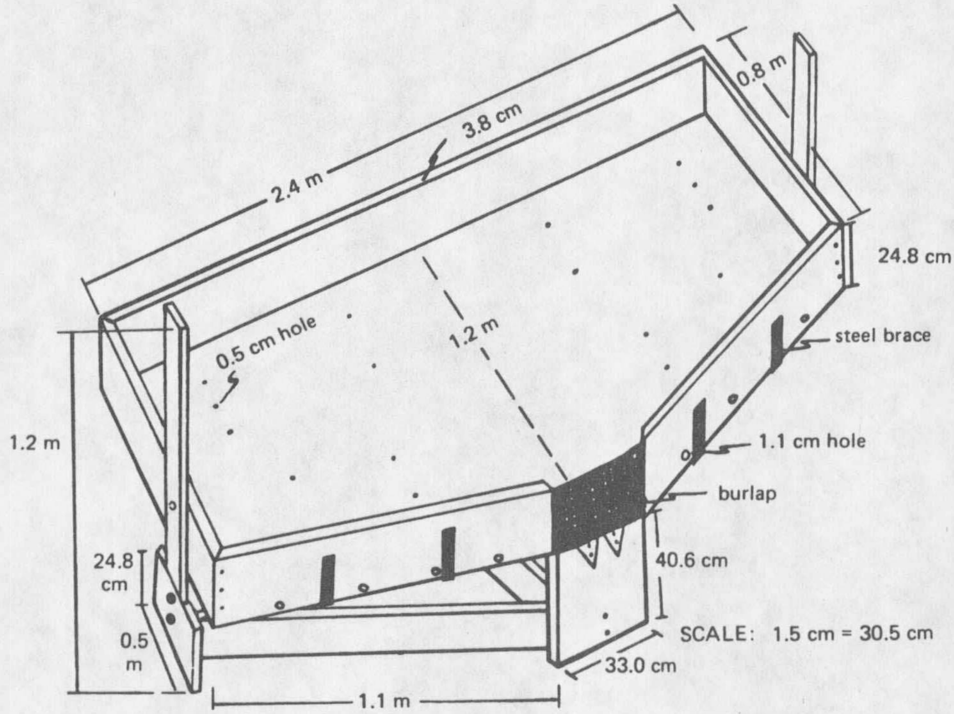
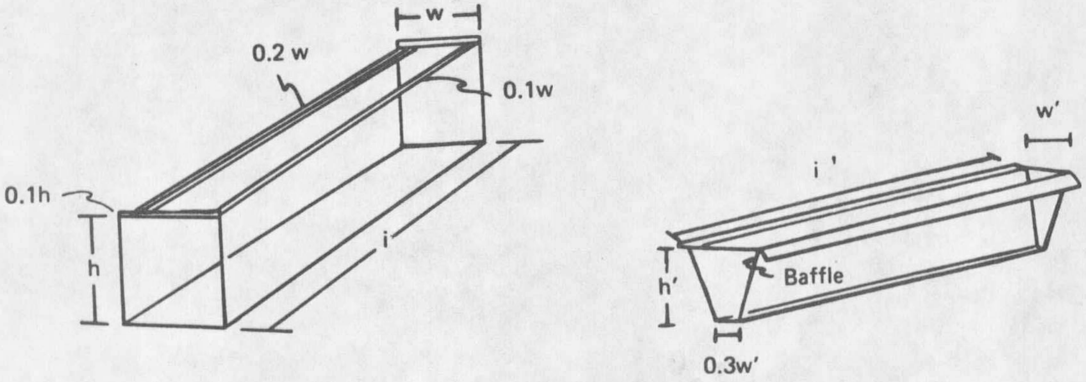


FIGURE 2. General Ground Sediment Trap Design (a) Support Frame, and (b) Removable Trap.

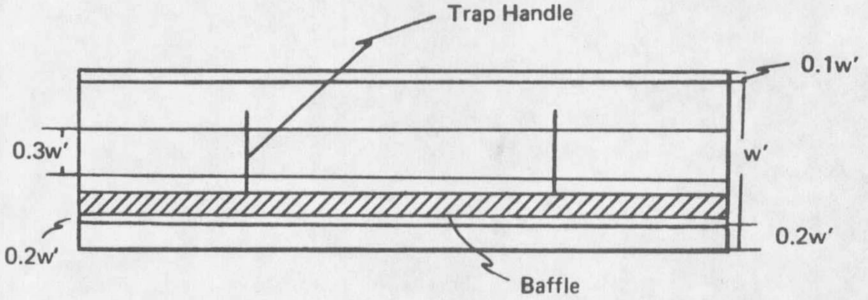


(a) (b)

Ground Cover

Seeding. The box was filled with clay loam topsoil from nearby garden plots, and saturated with water. A 62 X 62 cm frame with 9 20 X 20 cm internally welded quadrats was placed in the upper right corner of the box. Twelve 0.5 cm deep holes per quadrat were randomly made and filled with Garrison Creeping Foxtail (Alopercurus pratensis L.) seed. Garrison Creeping Foxtail was choosen due to its water tolerance and its being a common species on subirrigated soils. The frame was moved to consecutive areas and seeds planted until the entire surface was planted.

FIGURE 3. Top View of Removable Trap.



Monitoring. Three cover conditions were used to evaluate vegetal influences on sediment and overland flow under variable overland flow and slope conditions. These cover conditions and their mean coverage were (a) heavy, 64%, (b) medium, 48%, and (c) bare ground, 0%. The latter two cover conditions were achieved by thinning after all heavy and medium cover tests were completed respectively. Only heavy coverage averaging 51% was used during the rainfall simulator study.

Seedling counts were obtained after shoot emergence with the 62 X 62 cm frame. Plant numbers were obtained with the frame at the initiation of each cover condition for a density estimation. The canopy cover method (Daubenmire 1959) was used to obtain initial percent canopy cover and final percent canopy cover estimates for each cover condition.

Thinning. Number of plants per quadrat was determined with the 62 X 62 cm frame after completion of heavy cover tests. One-third of the plants per quadrat were randomly removed by clipping their crown tissue out and discarding their leaves. This provided the medium cover.

All plants were removed from the microsite in the same manner as before after all medium cover tests were completed. Soil clods and root systems were removed, and the surface raked. A superconcentrated solution of the herbicide, Spike[1], was poured on the microsite to insure vegetation removal. The soil surface was then graded to an uniform condition with a fine-toothed handsaw.

Sediment Collection and Surface Runoff Determination via Rainfall Simulator

The microsite was divided into three plots 0.75 m in width (Figure 4). A ground sediment trap was installed in the center of each plot. Slope lengths were 77 cm for plots 1 and 3, and 82.5 cm for plot 2. Traps 1 and 3 had shorter slope lengths due to the box tapering.

A 62 X 62 cm rainfall simulator was suspended on two parallel greased steel pipes 2 m above the microsite (Figure 5). Tap water entered the simulator through a plastic tube fed from a garden hose and was regulated by a Gilmont 100 ml flowmeter. The simulator was rotated at a constant speed by an electrical engine and drive chain. The simulator regulation was achieved by (1) placing plastic over the microsite, (2) centering the simulator over the plot to be tested, (3) adjusting water flow to the desired volume, (4) spacing three large

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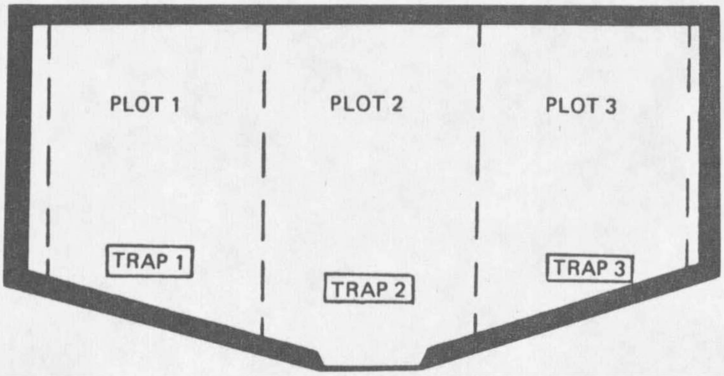
[1] Tebuthiuron manufactured by Lanco, Indianapolis, Indiana.

cans under the simulator, and (5) measuring volume output per can during one-minute trials and reregulating the flowmeter until a constant average volume was maintained. It was noted that water volume delivered from the simulator was not consistent. The front third of the simulator consistently delivered twice as much water as the rear third, and three times as much water than the middle third (Figure 6). The location of raindrop delivery also varied as slope was altered (Figure 7) because of the pipes' location being stationary for all tests. Raindrop delivery was directly behind trap #2 at 0% slope; near the box's back side at 15% slope; and proportionally placed between the traps and box back at the 5% and 10% slopes.

FIGURE 4. Top View of Microsite Plot and Ground Sediment Trap Positions.



The soil was then supersaturated with water and allowed to drain to near field capacity if not pre-moistened from prior tests. The sediment traps were drained and cleaned. The simulator was regulated and plot runs performed while the flowmeter was monitored and reregulated between runs if necessary. Four intensities (0.2, 0.9,

FIGURE 5. Photo of 62 X 62 cm Rainfall Simulator.

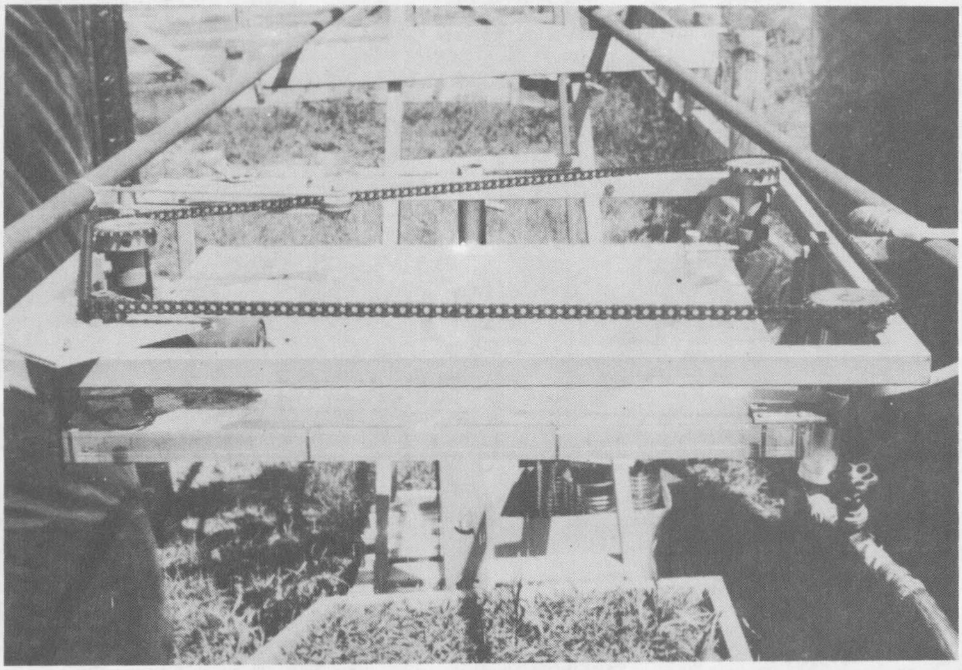


FIGURE 6. Mean Rainfall Simulator Volume Distribution.

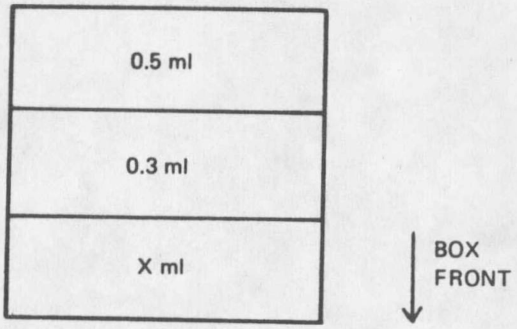
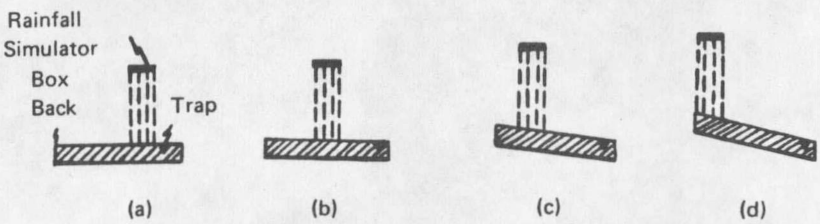


FIGURE 7. Raindrop Delivery Position at (a) 0% Slope, (b) 5% Slope, (c) 10% Slope, and (d) 15% Slope.



2.4, and 4.4 mm/minute) were run for five durations (10, 20, 40, 60, and 80 minutes) on each of four slopes (0%, 5%, 10%, and 15%). Six runs, 2 per plot, were performed at all intensities for the 10 and 20 minute durations. Three runs, 1 per plot, were performed at all intensities for the other durations. Only three runs were done at the longer durations due to time constraints. A total of 336 runs were done in a progressive order of intensity and duration with pre-set box draining periods. Plots #1, #2, and #3 were done in a successive order. Draining periods (Table 1) were based on those used in infiltration studies by Rauzi and Hanson (1966) and Gifford et al. (1970).

Surface runoff (SRO) containing sediment was withdrawn from the traps with a handpump or pipettes during and after each run and placed in cups. SRO volume per plot and mean SRO per intensity/duration was determined by noting the number of cups collected. Collected sediment from each plot was drained through a 230 μm mesh seive and then into a nickel crucible. The crucibles were dried at 105°C for 16-18 hours and allowed to cool completely. Net sediment masses were determined by weighing each crucible to the nearest hundred thousandth gram. Mean dry sediment mass per intensity/duration was calculated from the averages of sediment collected from all three plots. The box was raised with hydraulic jacks to the next slope desired for testing and the process repeated. Box weight support was supplied through a steel pipe, cinder blocks and wood.

TABLE 1. Box Draining Period Prior to Each Rainfall Simulation Run.

RAINFALL DURATION (minutes)	RAINFALL INTENSITY (mm/min)	DRAINING PERIOD (time after prior intensity's run completion)
10	0.2	First runs of the day
10	0.9	1.5 hours
10	2.4	First runs of the day
10	4.4	2.5 hours
20	0.2	First runs of the day
20	0.9	2.5 hours
20	2.4	First runs of the day
20	4.4	4 hours
40	0.2	First runs of the day
40	0.9	5 hours
40	2.4	First runs of the day
40	4.4	7 hours
60	0.2	First runs of the day
60	0.9	8 hours
60	2.4	18 hours
60	4.4	20 hours
80	0.2	20 hrs after 43 mm/min for 60 minutes
80	0.9	20 hours
80	2.4	20 hours
80	4.4	20 hours

Sediment Collection and Overland Flow Determination via Overland Flow Mechanism

Due to irregularities in simulated rainfall application, it was decided to discontinue this portion of the study after heavy cover tests were completed. Instead, a modified version of an overland flow mechanism used by Tsai (1983) was built for use on the microsite (Figure 8). Forty-seven 0.2 cm diameter holes were made 5 cm apart on a PVC pipe. A metal elbow and a metal valve were glued on opposite pipe ends. Water was supplied to the pipe from a garden hose. The overland flow mechanism was regulated by (1) turning the pipe to flow onto the greenhouse floor; (2) filling the pipe with water voiding it of all air; (3) setting up six food cans (2 pipe holes per can) under the pipe flow line; and (4) measuring volume output per can during one-minute trials until a constant average volume was maintained. Although water volume delivered from the pipe was consistent there was a pressure head loss from the water inlet to the end valve. The pressure head loss resulted in a mean decrease of 15 ml output from the water source to the valve.

The same plot and trap positions were used as in the rainfall simulator tests. The soil was supersaturated with water and allowed to drain to approximate field capacity if not moistened from previous tests. The traps were drained and cleaned, and trap overflow siphon systems set up. The overland flow mechanism was regulated and turned onto the microsite making sure all holes were flowing without obstruction (Figure 9). Three intensities (7, 12, and 19 mm/minute) were run for five durations (10, 20, 40, 60, and 80 minutes) on each slope (0%, 5%, 10%, and 15%). One run was performed for all intensities and durations resulting in a total of 60 runs. The tests were done in a progressive order of intensity and duration with pre-set draining periods. Draining periods (Table 2) were determined from the mean time it took the microsite to drain to near field capacity between each intensity/duration run. Overland flow (OLF) with sediment was withdrawn from the traps during and after the runs. OLF volume per plot and mean OLF per run were determined. Collected sediment was transferred into nickel crucibles as done in the rainfall simulator study. The crucibles were dried at 105°C for 16-18 hours and allowed to cool completely. Net dry sediment mass per intensity/duration was calculated from the averages of sediment collected per plot. The box was raised to the next slope after all tests were complete. The same procedures were followed for all cover treatments; however, the soil surface was graded with a fine-toothed handsaw to an uniform surface condition after each bare ground run.

Statistical Analysis

Ground sediment masses and surface runoff volumes for the rainfall simulator and overland flow treatments were analyzed with the Analysis of Variance for Multiple Factors (AVMF) program at a P = 0.05 level[2]. Treatment factor means, treatment combination means, and multiple comparisons using the least significant difference (t-test) for all factors were obtained.

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[2] Lund, R. 1983. MSUSTAT. A statistical package. Mont. State Univ., Bozeman, MT.

FIGURE 8. Diagram of Overland Flow Mechanism (modification of Tsai design, 1983).

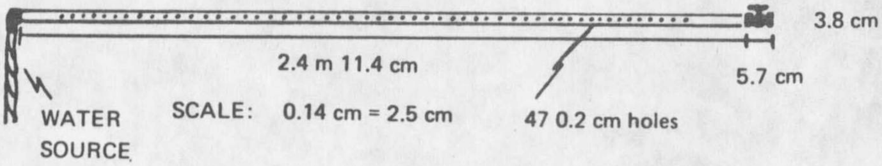


FIGURE 9. Overland Flow Mechanism Positioned on Microsite.

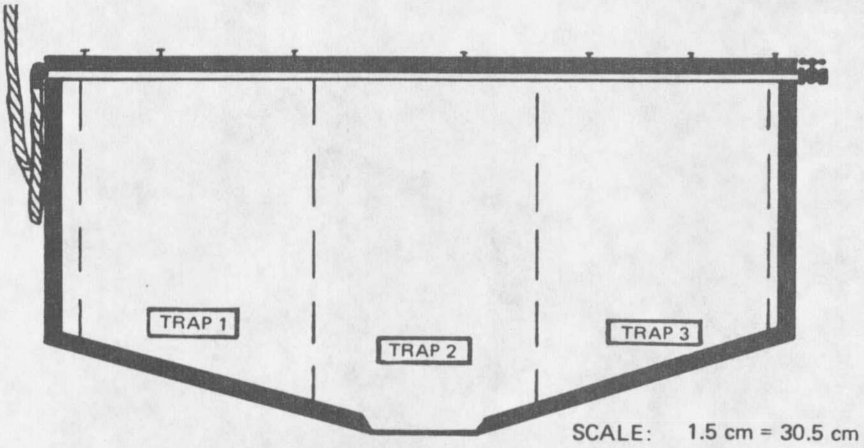


TABLE 2. Box Draining Period Prior to Each Overland Flow Run.

OVERLAND FLOW DURATION (minutes)	OVERLAND FLOW INTENSITY (mm/minute)	DRAINING PERIOD (time after prior intensity's run)
10	7	First run of the day
10	12	45 minutes
10	19	45 minutes
20	7	2 hrs after 70 mm/min for 10 minutes
20	12	1.5 hours
20	19	2 hours
40	7	First run of the day
40	12	1 hr 15 minutes
40	19	1.5 hours
60	7	First run of the day
60	12	2 hours
60	19	3 hours
80	50	First run of the day
80	60	2.5 hours
80	70	3.5 hours

RESULTS AND DISCUSSION

Ground Sediment Trap Performance

Resulting magnitudes of standard deviation were too great to effectively compare treatments because of the very large overland flow volumes and very small sediment loads. Sediment loads per trap ranged from 0.0000 g to 0.0908 g in the overland flow portion of the study. Therefore, the coefficient of variability (CV) was used instead of standard deviations for comparing trap difference [where CV equals treatment standard deviation divided by treatment mean (n = no. of samples for each run) times one-hundred]. Overland flow (OLF) and soil loss per plot, microsite means, and coefficient of variability for all cover types on all slopes during 20 and 40 minutes of overland flow at 7, 12, and 19 mm/min intensities are shown in Appendix A. Coefficient of variability ranged from 72 to 176% for OLF, and from 0.0010 to 0.1732% for soil loss except for medium cover which had a CV of 231% for its 40 minute OLF on 10% slope. Dortignac (1951) found the CV of a single vegetation-soil complex varied between 25 and 70% for areas as small as 5 to 10 acres in size. Lower CV indicated less variation about sample mean.

Ground Cover Influences on Overland Flow and Soil Loss

Average OLF over the microsite generally increased as canopy cover decreased (Figures 10, 11 and 12). Mean soil loss from the microsite shown in Figures 13, 14, and 15 also generally increased as canopy

FIGURE 10. Overland Flow Vs Overland Flow Intensity for Heavy Cover at 15% Slope.

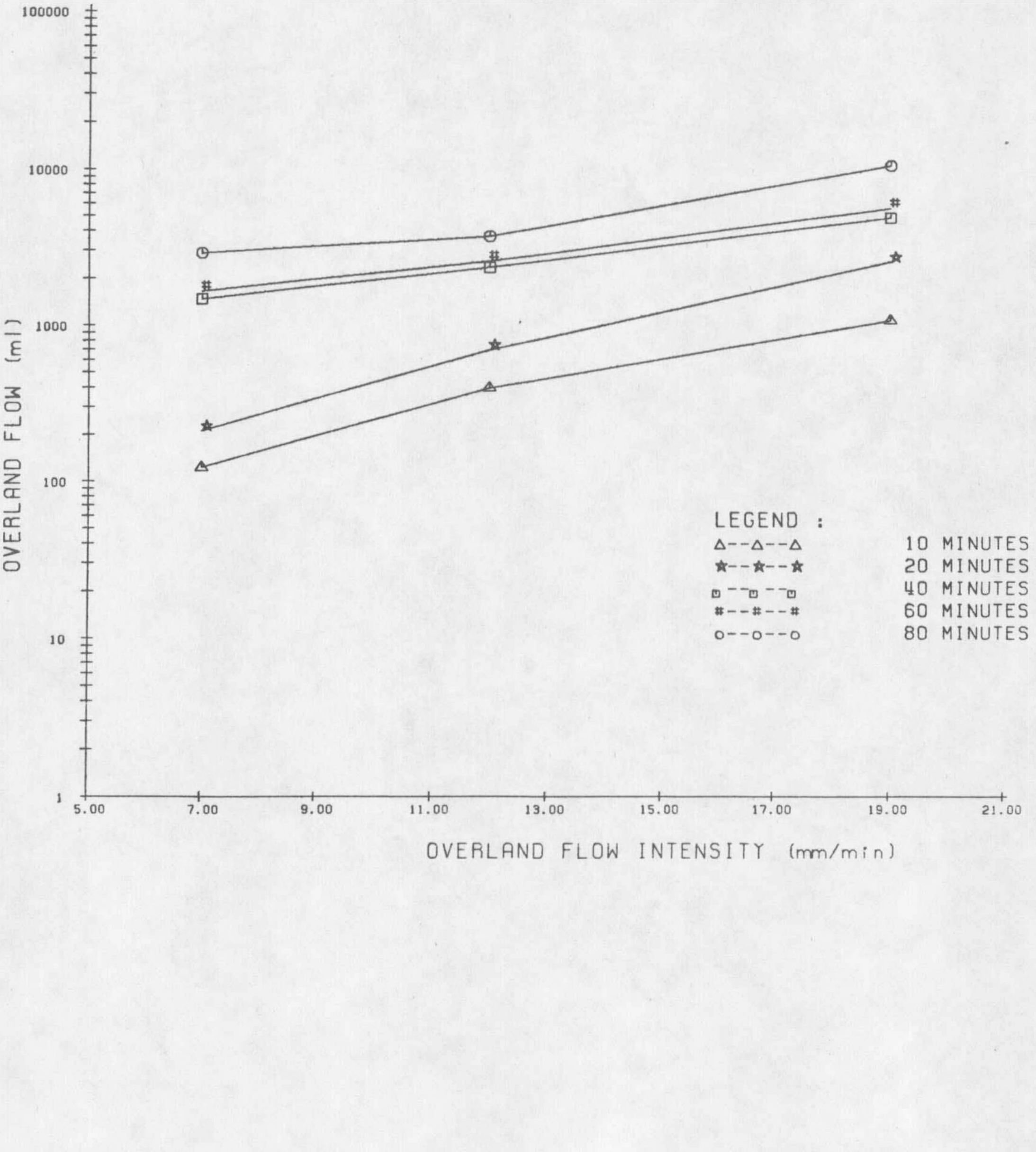


FIGURE 11. Overland Flow Vs Overland Flow Intensity for Medium Cover at 15% Slope.

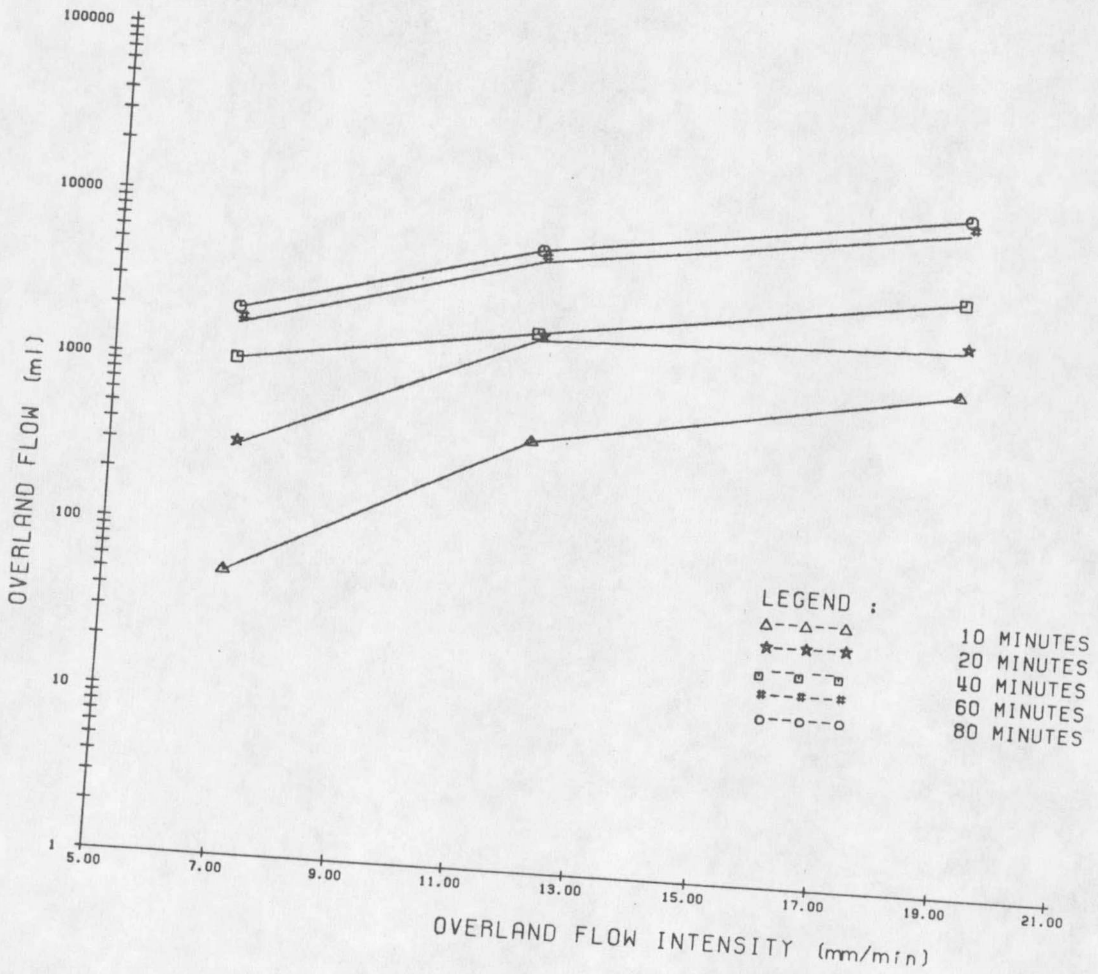


FIGURE 12. Overland Flow Vs Overland Flow Intensity for Bare Ground at 15% Slope.

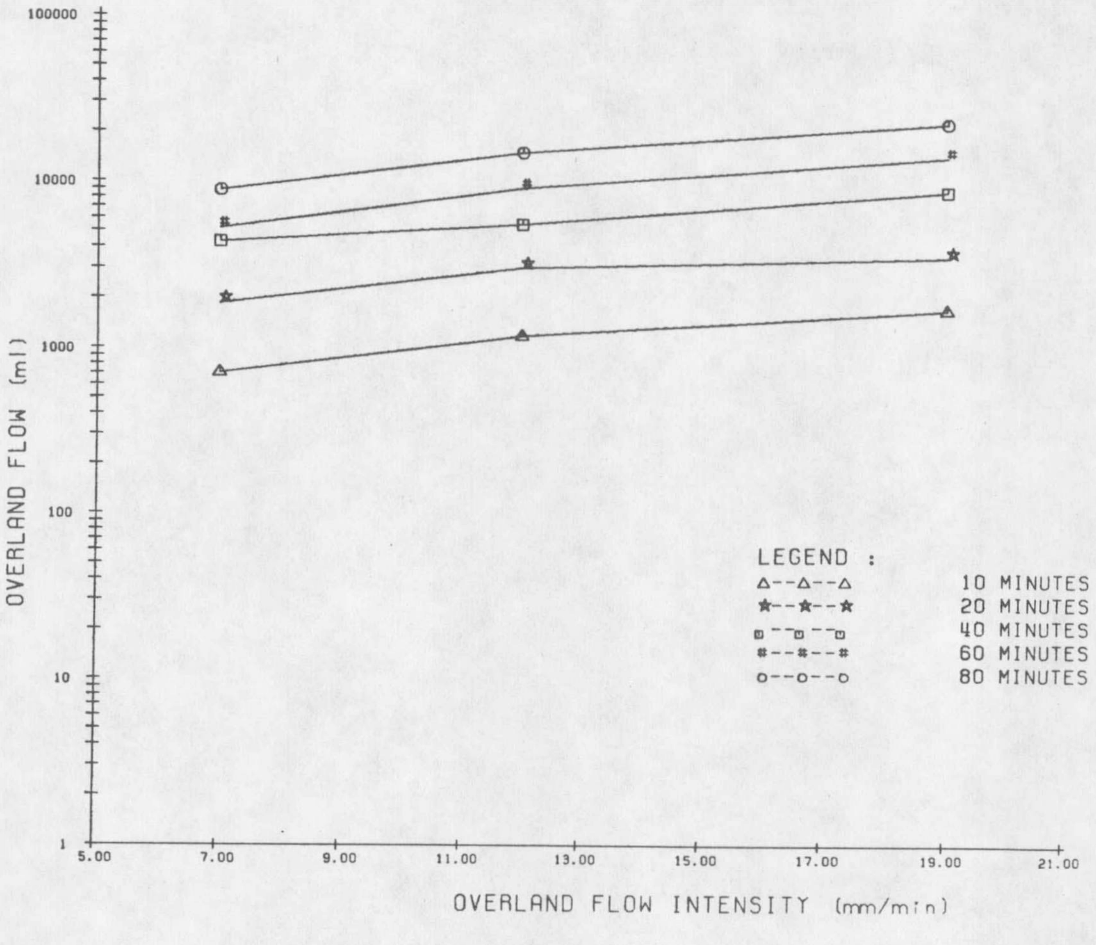


FIGURE 13. Soil Loss Vs Overland Flow Intensity for Heavy Cover at 15% Slope.

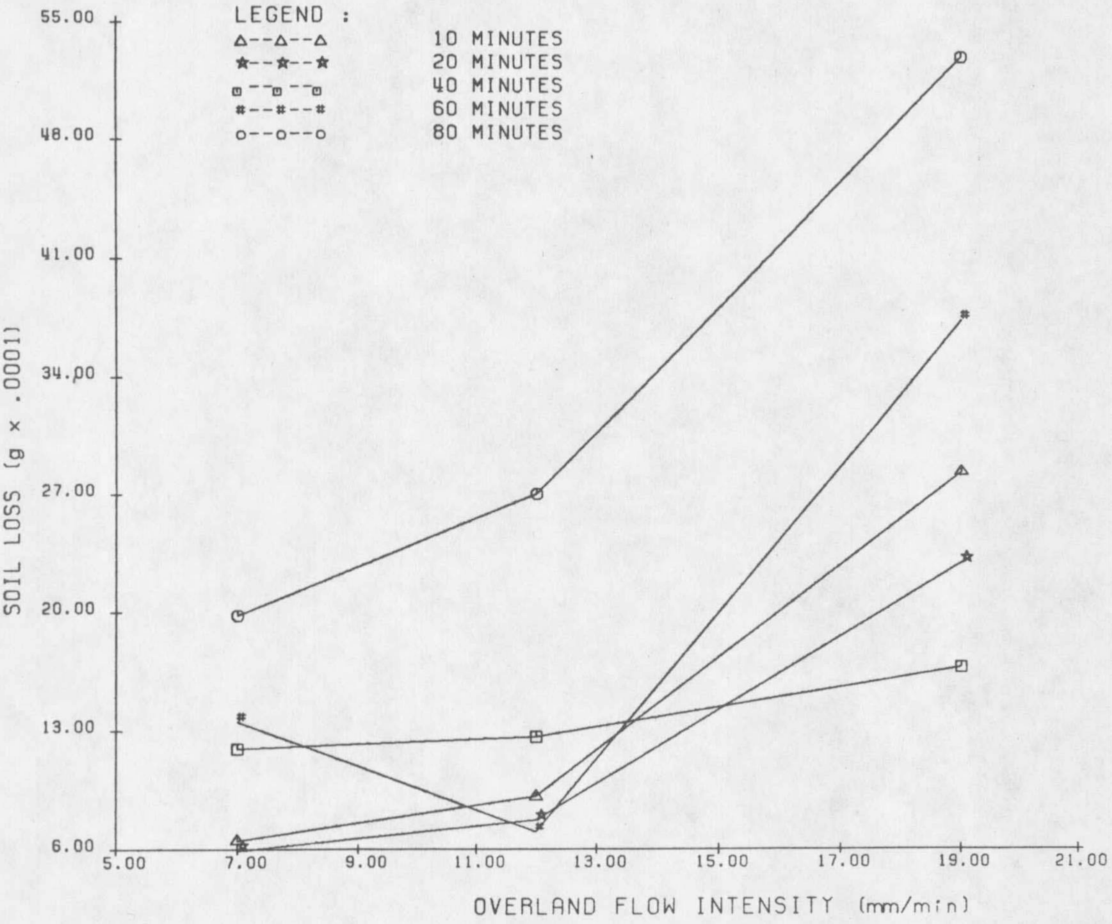


FIGURE 14. Soil Loss Vs Overland Flow Intensity for Medium Cover at 15% Slope.

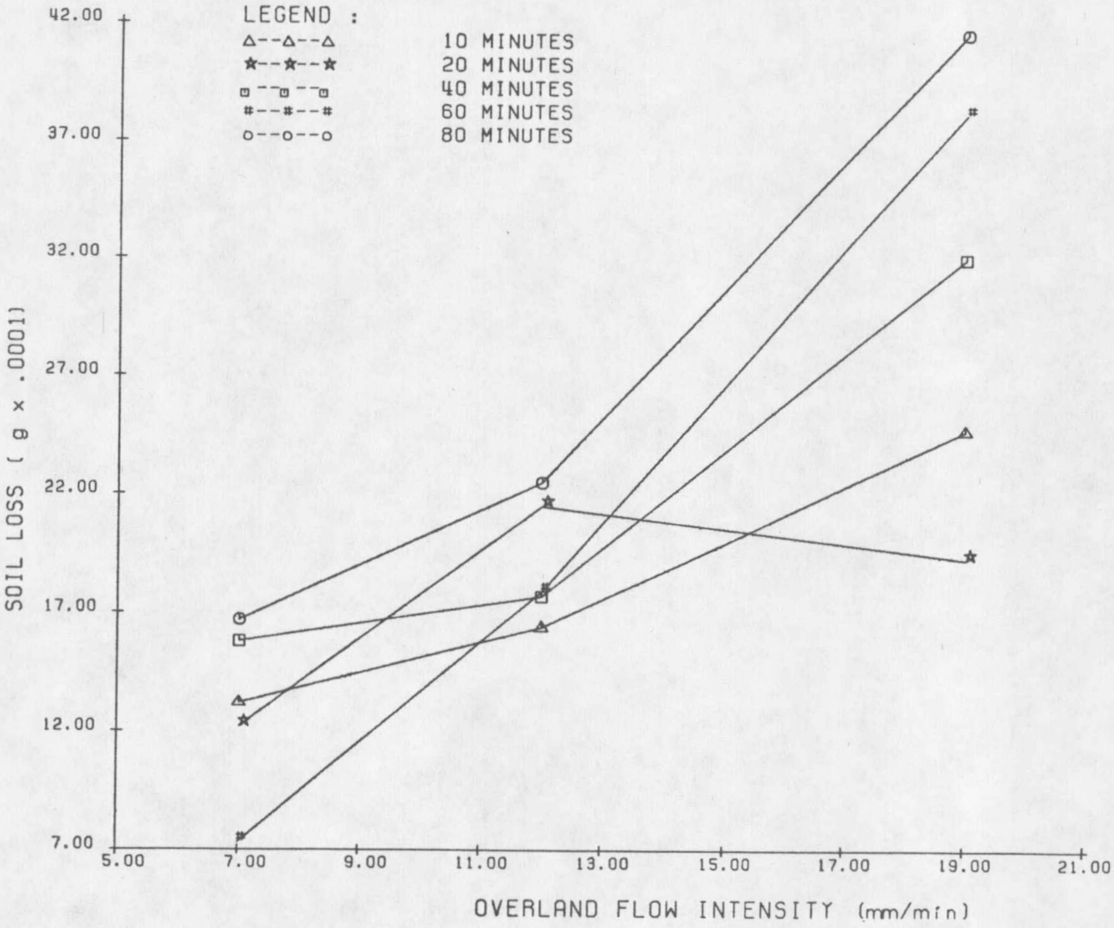
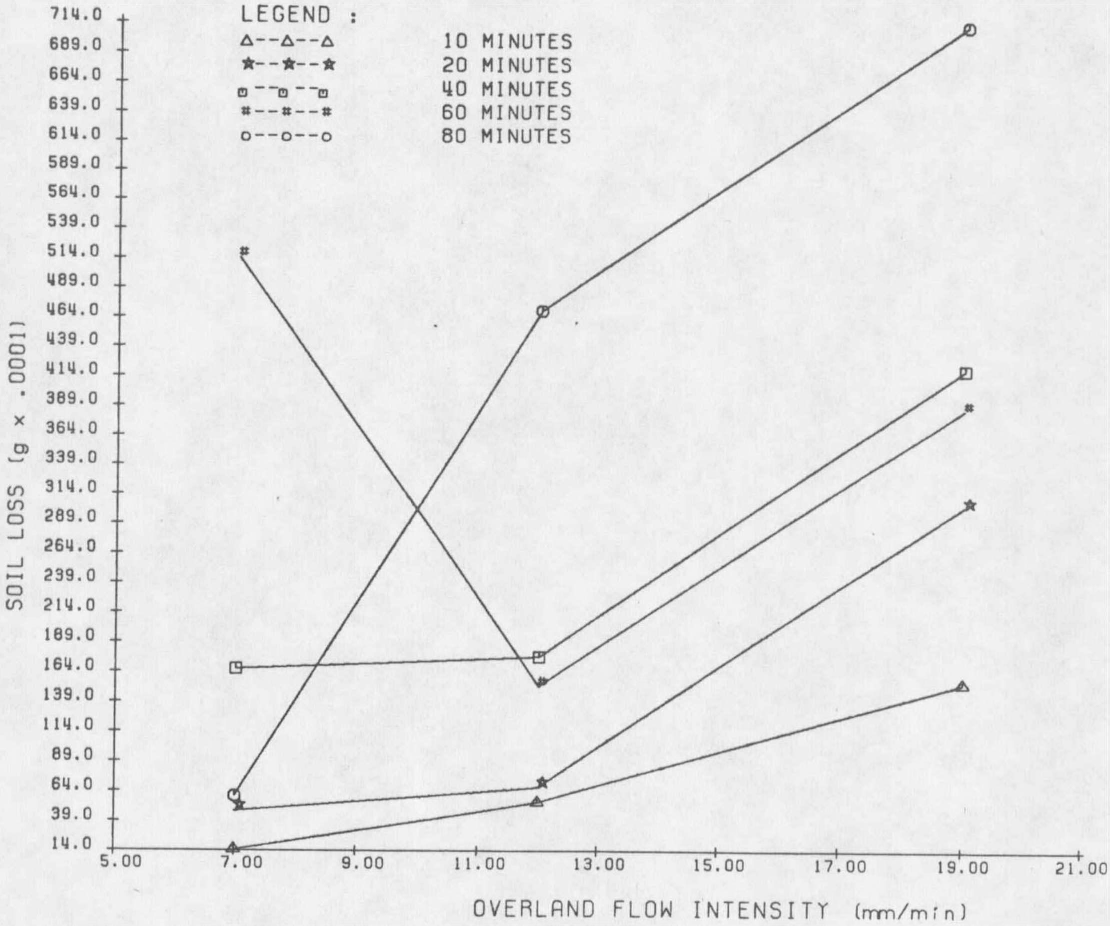


FIGURE 15. Soil Loss Vs Overland Flow Intensity for Bare Ground at 15% Slope.



cover decreased. Less canopy cover resulted in (a) lowered OLF impediments, (b) increased OLF transporting potentials due to lowered impediment, and (c) lowered soil stability. Magnitudes of erosion were determined to depend primarily on proportions of soil surface protected from raindrop impacts (Packer 1953, Meeuwig 1970). Blackburn and Skau (1974) determined control of soil loss to be primarily dependent on plant cover and infiltration. Ground cover reduction, especially the medium to bare ground reduction, led to (a) surface soil aggregate disruption, (b) reduced infiltration capacity, and (c) more inwashing of surface soil pores which produced a sealed surface crust. A 2 mm thick surface crust formed by the end of all bare ground tests. Meeuwig (1965) found infiltration capacity being secondly influenced by protective cover and primarily influenced by bulk density and noncapillary porosity. Meeuwig (1965) also determined soil stability to be primarily influenced by plant cover and secondly by bulk density. Three soil samples from this study indicated bulk density increased from 1.2 g/cm^3 during tests with plant cover to 1.3 g/cm^3 during tests with no cover, but the increase was not significant.

In this study OLF treatment means for heavy and medium cover, and medium cover and bare ground were not significantly different. However, OLF treatment means for heavy cover and bare ground were significantly different (Table 3). The change in cover between heavy cover and bare ground treatments was sufficient to cause a significant decrease in OLF impediment. Soil loss treatment means were not significantly different for heavy and medium cover while they were significantly different for bare ground and heavy or medium cover.

Bare ground soil loss treatment means were significantly different because the (a) soil surface was graded prior to each bare ground run, and (b) presence of cover was an important factor in reducing OLF detaching and transporting capacities. Krusekopf (1943) and Meeuwig (1971) found erosion to be more closely related to cover amounts than to any other site characteristic. OLF treatment means for bare ground runs were significantly greater than the heavy cover mean because the reduction from medium cover to bare ground probably did not result in a significant decline in mean OLF impediment.

TABLE 3. Cover Type Treatment Means for Soil Loss and Overland Flow.

COVER TYPE	SOIL LOSS[1] (grams * 0.0001)	OVERLAND FLOW[2] (ml)
Heavy	20^A	2901^a
Medium	20^A	3659^{ab}
Bare Ground	132^A	5064^b

[1] Soil loss means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

[2] Overland flow means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

Overland Flow Condition Influences on Overland Flow and Soil Loss

Increased intensities and/or durations resulted in increased OLF volumes from the microsite for all slopes and cover types (Table 4). Ekern (1953) found soil loss to be directly proportional to the quantity of OLF, and to the square of the erosive agent's velocity. In

TABLE 4. Overland Flow Intensity and Overland Flow Duration Interaction Effects on Overland Flow for All Slopes and Cover Types.

OVERLAND FLOW INTENSITY (mm/minute)	OVERLAND FLOW DURATION (minutes)	MEAN OVERLAND FLOW (milliliters)
7	10	139
12	10	294
19	10	850
7	20	553
12	20	1164
19	20	2340
7	40	1290
12	40	2691
19	40	5749
7	60	2059
12	60	4334
19	60	10,508
7	80	3065
12	80	5672
19	80	17,409

this study, soil loss was generally directly proportional to OLF quantity (Figures 13, 14 and 15). As was found in Neal's study (1937), rate of OLF increased during the first 40 minutes of runoff and then remained constant as runoff continued. Soil losses increased with increases in durations and/or intensities (Table 5 and 6). Ellison (1947b) reported increased OLF velocities and quantities increased soil loss potentials which may explain the increased soil loss.

Analysis of treatment means for OLF and soil loss showed OLF yields and soil losses from the microsite (a) not to be significantly different for the 7 mm/min and 12 mm/min runs, and (b) to be significantly different for the 19 mm/min runs (Table 5). The significant difference between the 19 mm/min and 7 and 12 mm/min intensities was probably caused by the erosive forces of the 19 mm/min flows being substantially greater than those of the other intensities (Ellison 1947b). OLF yields at 10 and 20 minute, 20 and 40 minute, and 40 and 60 minute durations were not significantly different from each other. However, OLF from the 80 minute runs were significantly different from all other durations (Table 6). This indicated that successive increases in storm duration of 10 and 20 minutes did not produce significant OLF increases. However, the change from 20 minute duration to the 60 minute and from 60 minute to 80 minute produced a significant OLF increase. This irregularity could have been due to the significantly different OLF yields produced from a cumulative effect of the 19 mm/min intensity run and the bare ground treatments' OLF yields at 80 minutes. Soil loss from the microsite was not significantly different for the (a) 10, 20, and 40 minute runs; (b) 20, 40, and 60

TABLE 5. Overland Flow Intensity Treatment Means for Soil Loss and Overland Flow.

OVERLAND FLOW INTENSITY (mm/minute)	SOIL LOSS[1] (grams * 0.0001)	OVERLAND FLOW[2] (ml)
7	27^{A}	1421^{a}
12	41^{A}	2831^{a}
19	104^{B}	7371^{b}

[1] Soil loss means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

[2] Overland flow means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

TABLE 6. Overland Flow Duration Treatment Means for Soil Loss and Overland Flow.

OVERLAND FLOW DURATION (minutes)	SOIL LOSS[1] (grams * 0.0001)	OVERLAND FLOW[2] (ml)
10	25^{A}	421^{a}
20	43^{AB}	1352^{ab}
40	54^{AB}	3243^{bc}
60	72^{BC}	5634^{c}
80	94^{C}	8716^{d}

[1] Soil loss means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

[2] Overland flow means followed by the same letter are not significantly different ($P \geq 0.05$) as determined be a least significant difference t-test.

minute runs; and (c) 60 and 80 minute runs. Unlike the treatment means for OLF, the soil loss treatment means indicated that successive increases in storm duration of 10 to 40 minutes did not produce significant soil loss increases. This did not hold true for the 40 to 80 minute overland flows. Neal (1937) found that (a) rate of soil loss increased during the first 20 to 40 minutes then decreased during the next hour, and (b) soil loss became approximately constant after 90 minutes of rain. Consequently, rate of soil loss would decline as storm durations increased beyond 40 minutes resulting in their yields being significantly different than those of shorter durations.

Slope Influences on Overland Flow and Soil Loss

Mean OLF production from the microsite under bare ground conditions are shown in Table 7. OLF generally increased as slope steepness increased for each intensity, and each duration (Table 8). This follows reports that soil erosion by OLF was strongly influenced by rainfall intensity and slope steepness interactions (Farmer and Van Haveren 1971); and increased slope steepness increased total runoff (Zingg 1940, Smith and Wischmeier 1962). Zingg (1940) found that doubling percent slope increased total soil loss in runoff 2.61 times.

Although erosion increased with increases in slope, there were more irregularities in soil loss as a function of slope than in OLF yield which follows reports by Zingg (1940). Krusekopf (1943) found any change in percent slope to have a greater effect on sediment production than on runoff. Gard and Van Doren (1949) determined slope steepness to be a dominant factor influencing soil losses. In this

TABLE 7. Mean Overland Flow Under Bare Ground Via Overland Flow.

SLOPE (%)	OVERLAND FLOW INTENSITY (mm/minute)	MEAN OVERLAND FLOW (milliliters) OVERLAND FLOW DURATION (minutes) 10	20	40	60	80
0	7	0	0	0	0	1
5	7	93	895	2374	4184	6482
10	7	696	2523	3328	4194	6223
15	7	707	1859	4326	5223	8808
0	12	0	1	3	713	666
5	12	407	1962	3163	6466	7981
10	12	767	2858	4017	6504	8790
15	12	1186	3023	5515	9120	14,988
0	19	1	467	2078	9366	13,474
5	19	1567	2754	9222	15,137	23,065
10	19	1955	4123	6932	13,425	18,741
15	19	1729	3581	8945	14,362	22,881

TABLE 8. Mean Soil Loss Under Bare Ground Via Overland Flow.

SLOPE (%)	OVERLAND FLOW INTENSITY (mm/minute)	MEAN SOIL LOSS (g * 0.0001) OVERLAND FLOW DURATION (minutes) 10	20	40	60	80
0	7	0	0	0	0	8
5	7	7	17	77	38	56
10	7	38	33	38	33	70
15	7	15	48	166	515	60
0	12	0	10	12	74	29
5	12	9	49	89	41	50
10	12	21	47	143	69	93
15	12	55	68	177	152	470
0	19	12	78	145	99	191
5	19	12	449	171	228	305
10	19	193	100	104	419	452
15	19	155	305	421	387	713

study soil loss was variable as slope increased for each intensity duration; and as duration increased for each slope. Primary factors influencing this variability were (a) varying amounts and aggregate sizes of detached soil available for transport per run, (b) variable mean intensity regulations, and (c) uneven slope configuration. Plot 2's slope was slightly concave directly above the trap in comparison to plots 1 and 3. Erosion patterns could have been affected by slope shape which resulted in OLF and soil loss variability. Soil loss patterns were found to be more dependent on slope shape than OLF patterns. Young and Mutchler (1969b) and Foster and Wischmeier (1974) also reported similar patterns. Young and Mutchler (1969a) concluded that soil loss from a slope was dependent on the slope steepness immediately above the point of measurement.

All slopes were not significantly different in their treatment mean for OLF yields because of the (a) overland flow mechanism's output constancy, and (b) low infiltration rates resulting in nearly complete runoff of the water applied. The soil loss treatment means from the 0%, 5%, and 10% slopes were not significantly different due to the soil's detaching and transporting agent's (OLF) constancy. The incline at 15% slope was sufficient enough to increase the OLF's erosive forces to a level above those encountered on the other slopes.

Slope treatment means of OLF and soil loss production from the microsite for all intensities and durations, and all cover types are listed in Table 9. Statistical analysis correlation supported the assumption for a direct relationship of OLF and soil loss yield to slope steepness. No significant differences in OLF were found among slopes. No significant difference was found in soil loss from the 0%, 5%, and 10% slopes; however, soil loss from the 15% slope was significantly different than from the other slopes.

Increased durations per cover type and decreased cover per duration resulted in general declines in and nearly constant CV for OLF and soil loss. Rauzi (1960) found variations in cover accounted for 65-84% of the variation in water-intake rate; consequently, decreased canopy cover resulted in OLF and soil loss yield variations within a treatment. Increased OLF intensities per cover type had the same effect. Soil loss was more variable in the cover/intensity interaction. Increasing either duration or intensity resulted in relatively constant decreases in CV for OLF and soil loss.

TABLE 9. Mean Soil Loss Under Bare Ground Via Overland Flow.

SLOPE (%)	SOIL LOSS[1] (grams * 0.0001)	OVERLAND FLOW[2] (ml)
0	32^{A}	3426^{a}
5	48^{A}	3754^{a}
10	55^{A}	3933^{a}
15	96^{B}	4386^{a}

[1] Soil loss means followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

[2] Overland flow followed by the same letter are not significantly different ($P \geq 0.05$) as determined by a least significant difference t-test.

Conclusions

Overland flow and soil losses increased with (a) increases in slope steepness, storm intensity, and storm duration; and (b) decreases in ground cover. Rate of OLF increased during the first 40 minutes of runoff and then remained constant as runoff continued which was similar to that reported by Neal (1937). In contrast, rate of soil loss increased during the first 40 minutes and then decreased as OLF continued. The traps worked more efficiently with less variability under storms of 12-19 mm/min intensities and durations of 40 minutes, on slopes steeper than 10%, and under bare ground conditions. Consequently, the traps should function adequately during semi-arid and arid region natural precipitation events over rangelands in moderate to poor conditions.

SUMMARY

Soil erosion, "a process of detachment and transportation of soil materials by erosive agents" (Ellison 1947a) is of major concern in natural resource management. More accurate means of quantitative natural erosion measurement and monitoring are needed, and should effect natural ecosystem processes as little as possible. Ground sediment traps were designed and tested in erosion studies in a greenhouse for future use in range watershed research under natural precipitation events. Coefficient of variability analysis for general slope, cover, and OLF condition interactions showed that the traps were effective and generally efficient. The traps were found to be most effective in collecting OLF and soil loss on steep slopes greater than 10%, under 40-60 min storm conditions, and with little ground cover. Trap collection variation of OLF and soil loss generally declined with (a) increases in slope steepness, overland flow intensity, and overland flow duration; and (b) decreases in ground cover. Rate of soil loss increased during the first 40 minutes and then decreased as overland flow continued while rate of OLF increased during the first 40 minutes and then remained constant.

Trap overflow systems should be used to guarantee total OLF capture (Appendix C). Peak flow estimations for future study sites should be used to help predict minimum overflow volume demands. Two overflow volume system alternatives are recommended (a) collection containers placed within the frame beneath the trap for low OLF volume yielding storms, and (b) collection containers placed downslope of the traps for high OLF volume yielding storms. Protective mesh covers should be used to reduce raindrop disruption of samples, and possible animal trampling.

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LITERATURE CITED

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APPENDICES

APPENDIX A

OVERLAND FLOW RESULTS

TABLE 10. Surface Runoff per Plot, Surface Runoff Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 7 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	OVERLAND FLOW (ml)				COEFFICIENT OF VARIABILITY (%)
			TRAP # 1	TRAP # 2	TRAP # 3	$\bar{X}$	
Heavy	0	20	0	0	0	0	----
Heavy	0	40	0	0	0	0	----
Medium	0	20	0	0	0	0	----
Medium	0	40	0	67	0	22	173.20
Bare Ground	0	20	0	0	0	0	----
Bare Ground	0	40	0	0	0	0	----
Heavy	5	20	0	15	0	5	173.21
Heavy	5	40	0	577	0	192	173.21
Medium	5	20	0	577	217	265	109.45
Medium	5	40	1	800	330	377	106.52
Bare Ground	5	20	4	2680	0	895	172.82
Bare Ground	5	40	35	7085	1	2374	171.89
Heavy	10	20	0	348	0	116	173.21
Heavy	10	40	0	2939	223	1054	155.24
Medium	10	20	15	1377	8	467	168.94
Medium	10	40	115	3000	874	1330	112.47
Bare Ground	10	20	577	5078	1913	2523	91.63
Bare Ground	10	40	280	8870	835	3328	144.43
Heavy	15	20	0	633	0	211	173.21
Heavy	15	40	0	3812	600	1471	139.37
Medium	15	20	0	1043	145	396	172.91
Medium	15	40	1	4252	1168	1807	133.34
Bare Ground	15	20	700	4043	835	1859	101.77
Bare Ground	15	40	1089	10,605	1285	4326	125.70

TABLE 11. Surface Runoff per Plot, Surface Runoff Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 12 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	OVERLAND FLOW (ml) TRAP # 1	TRAP # 2	TRAP # 3	X̄	COEFFICIENT OF VARIABILITY (%)
Heavy	0	20	2	74	35	37	97.41
Heavy	0	40	2	15	35	17	95.92
Medium	0	20	0	0	0	0	----
Medium	0	40	0	9740	1	3247	173.18
Bare Ground	0	20	0	1	0	0.33	175.76
Bare Ground	0	40	0	8	0	3	172.99
Heavy	5	20	217	1615	35	622	138.91
Heavy	5	40	4	7770	1043	2939	143.45
Medium	5	20	0	2567	1197	1255	102.38
Medium	5	40	4	5540	4432	3325	88.09
Bare Ground	5	20	15	5870	0	1962	172.32
Bare Ground	5	40	400	9072	16	3163	161.93
Heavy	10	20	0	2635	155	930	135.40
Heavy	10	40	0	8453	791	3081	151.52
Medium	10	20	57	2408	397	954	133.19
Medium	10	40	432	6067	2000	2833	230.94
Bare Ground	10	20	835	5270	2470	2858	78.47
Bare Ground	10	40	800	10,137	1113	4017	132.02
Heavy	15	20	0	1809	280	696	139.83
Heavy	15	40	1	6067	967	2345	138.99
Medium	15	20	1	3955	945	1634	126.40
Medium	15	40	1	4252	1168	1807	121.55
Bare Ground	15	20	796	7305	967	3023	122.73
Bare Ground	15	40	1009	14,285	1252	5515	137.72

TABLE 12. Surface Runoff per Plot, Surface Runoff Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 19 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	OVERLAND FLOW (ml)				COEFFICIENT OF VARIABILITY (%)
			TRAP # 1	TRAP # 2	TRAP # 3	$\bar{X}$	
Heavy	0	20	1	1017	1	340	172.69
Heavy	0	40	15	5997	35	2016	171.06
Medium	0	20	0	6505	0	2168	173.21
Medium	0	40	0	32,265	1	10,755	173.20
Bare Ground	0	20	0	1400	0	467	173.20
Bare Ground	0	40	1	6233	0	2078	173.16
Heavy	5	20	857	5913	800	2523	116.34
Heavy	5	40	35	7737	930	2901	145.22
Medium	5	20	57	9253	2835	4048	116.51
Medium	5	40	74	14,320	5485	6626	109.22
Bare Ground	5	20	791	4870	2602	2754	74.20
Bare Ground	5	40	1218	20,568	5879	9222	109.52
Heavy	10	20	1	3835	500	1445	144.22
Heavy	10	40	209	16,617	1745	6190	146.40
Medium	10	20	397	3235	2567	2066	71.81
Medium	10	40	243	8370	4635	4416	92.13
Bare Ground	10	20	35	7847	4487	4123	95.04
Bare Ground	10	40	1009	16,185	3603	6932	117.09
Heavy	15	20	67	6838	800	2568	144.68
Heavy	15	40	470	12,537	1745	4917	134.82
Medium	15	20	15	4487	1470	1991	114.59
Medium	15	40	35	9337	2602	3991	120.36
Bare Ground	15	20	1415	8096	1232	3581	109.22
Bare Ground	15	40	1826	22,810	2200	8945	134.24

TABLE 13. Soil Loss per Plot, Soil Loss Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 7 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	SOIL LOSS (g * 0.0001)				COEFFICIENT OF VARIABILITY (%)
			TRAP # 1	TRAP # 2	TRAP # 3	$\bar{X}$	
Heavy	0	20	0	0	0	0	----
Heavy	0	40	0	0	0	0	----
Medium	0	20	0	0	0	0	----
Medium	0	40	0	27	0	9	0.1732
Bare Ground	0	20	0	0	0	0	----
Bare Ground	0	40	0	0	0	0	----
Heavy	5	20	0	10	0	3	0.1729
Heavy	5	40	0	67	0	22	0.1732
Medium	5	20	0	11	6	6	0.0276
Medium	5	40	10	12	11	11	0.0093
Bare Ground	5	20	21	29	0	17	0.0894
Bare Ground	5	40	32	125	74	77	0.0605
Heavy	10	20	0	21	0	7	0.1732
Heavy	10	40	0	17	15	11	0.0869
Medium	10	20	22	41	22	28	0.0386
Medium	10	40	11	16	21	16	0.0308
Bare Ground	10	20	27	43	28	33	0.0269
Bare Ground	10	40	27	56	31	38	0.0412
Heavy	15	20	0	18	0	6	0.1732
Heavy	15	40	0	27	9	12	0.1102
Medium	15	20	0	19	17	12	0.0871
Medium	15	40	14	20	14	16	0.0207
Bare Ground	15	20	13	117	14	48	0.1250
Bare Ground	15	40	115	105	280	1667	0.0591

TABLE 14. Soil Loss per Plot, Soil Loss Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 12 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	SOIL LOSS (g * 0.0001)				COEFFICIENT OF VARIABILITY (%)
			TRAP # 1	TRAP # 2	TRAP # 3	$\bar{x}$	
Heavy	0	20	10	9	12	10	0.0200
Heavy	0	40	5	5	13	8	0.0001
Medium	0	20	0	0	0	0	----
Medium	0	40	0	58	30	29	0.0992
Bare Ground	0	20	0	30	0	10	0.1732
Bare Ground	0	40	0	35	0	12	0.1732
Heavy	5	20	10	8	7	8	0.0277
Heavy	5	40	5	29	10	15	0.0839
Medium	5	20	0	15	17	11	0.0870
Medium	5	40	6	11	10	9	0.0295
Bare Ground	5	20	36	109	0	48	0.1148
Bare Ground	5	40	69	169	28	89	0.0820
Heavy	10	20	0	19	30	17	0.0928
Heavy	10	40	0	29	11	13	0.1099
Medium	10	20	22	32	22	25	0.0217
Medium	10	40	15	22	17	18	0.0186
Bare Ground	10	20	33	51	57	47	0.0257
Bare Ground	10	40	23	347	60	143	0.1239
Heavy	15	20	0	13	10	8	0.0882
Heavy	15	40	14	14	9	12	0.0252
Medium	15	20	20	29	15	21	0.0333
Medium	15	40	17	19	17	18	0.0082
Bare Ground	15	20	23	139	41	68	0.0921
Bare Ground	15	40	146	239	146	177	0.0302

TABLE 15. Soil Loss Per Plot, Soil Loss Means, and Coefficient of Variances for All Cover Types at All Slopes and Specific Overland Flow Durations at 19 mm/min.

COVER TYPE	SLOPE (%)	OVERLAND FLOW DURATION (minutes)	SOIL LOSS (g * 0.0001)				COEFFICIENT OF VARIABILITY (%)
			TRAP # 1	TRAP # 2	TRAP # 3	$\bar{X}$	
Heavy	0	20	14	32	17	21	0.0428
Heavy	0	40	8	13	55	25	0.0010
Medium	0	20	0	48	0	16	0.1732
Medium	0	40	0	114	28	47	0.1257
Bare Ground	0	20	0	235	0	78	0.1732
Bare Ground	0	40	75	359	0	145	0.1311
Heavy	5	20	9	33	12	18	0.0728
Heavy	5	40	6	38	10	18	0.0960
Medium	5	20	10	35	19	21	0.0599
Medium	5	40	1	20	11	11	0.0919
Bare Ground	5	20	85	982	280	449	0.1050
Bare Ground	5	40	85	368	60	171	0.0999
Heavy	10	20	30	40	23	31	0.0275
Heavy	10	40	23	38	21	27	0.0345
Medium	10	20	15	26	25	22	0.0919
Medium	10	40	16	33	21	23	0.0359
Bare Ground	10	20	55	83	164	101	0.0564
Bare Ground	10	40	12	242	57	104	0.1173
Heavy	15	20	17	33	18	23	0.0386
Heavy	15	40	7	27	15	16	0.0612
Medium	15	20	3	33	22	19	0.0769
Medium	15	40	31	40	25	32	0.0469
Bare Ground	15	20	62	724	129	305	0.1195
Bare Ground	15	40	99	981	184	421	0.1155

APPENDIX B

MICROSITE SOIL CHARACTERISTICS

TABLE 16. Mean Soil Texture, Organic and Mineral Matter Contents and Other Soil Characteristics Following All Plant Cover and Bare Ground Treatments.

TREATMENT	TEXTURE	% SAND	% SILT	% CLAY	ORGANIC MATTER CONTENT (%)	MINERAL MATTER CONTENT (%)
Plant	clay loam	30.0	43.3	26.7	4.9	95.2
Bare	clay loam	26.2	48.0	25.8	5.9	94.1

TREATMENT	BULK DENSITY (grams/cm^3)	POROSITY (%)	MASS WETNESS (%)	DEGREE OF SATURATION (%)
Plant	1.2	56.3	34.8	71.8
Bare	1.3	51.7	31.6	78.5

TREATMENT	TOTAL VOLUME (cm^3)	SOLID VOLUME (cm^3)	WATER VOLUME (cm^3)	VOLUME WETNESS (%)
Plant	259.2	113.3	104.5	40.3
Bare	259.2	125.2	104.9	40.5

TREATMENT	VOID RATIO	WATER VOLUME RATIO
Plant	1.3	92.3
Bare	1.1	83.8

APPENDIX C

GROUND SEDIMENT TRAP DESIGNS

Number and width of sample plots should be derived from the proportional linear area of the watershed study site to have OLF and soil loss quantified. Maximum frame width should not exceed 3 m. Trap placement designs over study sites can vary but should not be placed (a) in continuous horizontal or vertical rows, and (b) nonperpendicular to OLF flow. Care should be taken to disturb the soil matrix immediately around and under the frame as least as possible. The soil surface in juxtaposition to all frame sides should be gently compacted, and frequently checked and recompacted if necessary to avoid OLF leakage into the cracks where soil meets frame. The inner trap is secured in the frame by its upper rim being slid into a tight fitting lip on the up-slope frame rim (Figure 16). Slope gradient is accounted for by tapering upper frame side height during its construction (Figure 17).

A protective 230 μm mesh screen with sheet metal skeleton cover is used to reduce raindrop disruption of runoff samples and possible animal trampling (Figure 18). It should slip tightly onto the frame's protruding baffles. Two metal strips should be welded onto the removable trap (Figure 3) to be used as handles during the trap's removal from and insertion into its frame during sample collection.

Overflow systems should be added to guarantee total flow catchment (Figure 19). These consist of (a) 0.5 to 0.75 inch diameter tubing (1 to however many needed) which drain collected OLF into covered containers buried within the frame beneath the trap, or (b) 0.5 to 0.75 inch diameter buried tubing and 0.5 to 0.75 inch pipe which drain collected OLF to buried downslope covered containers for excessive flows. Downslope containers should not have their tops beneath the soil surface. The tubing should be (a) firmly secured on outflow ducts an inch or two above trap bottom and frame side; (b) laid out as smoothly as possible; (c) drawn tight from trap to catchment containers; (d) drawn through 0.5 to 0.75 in holes on catchment container lids, and into metal bands on the catchment container upper rim sides; and (e) not protrude less than 1 inch or more than 2 inches into the catchments. All container lids should be firmly secured onto the containers, and have fine mesh covered air vents. The pipe should have its upslope end screwed onto a tubing to pipe coupler welded on frame side. Downslope pipe ends should fit tightly through catchment container lids and into metal bands.

Peak flow estimates would determine which overflow system to use. Suggested catchment containers for low volume overflow estimates are plastic bottles or food cans. Plastic buckets or metal drums are recommended for high volume overflow estimates.

FIGURE 16. Cross-sectional Side View of Up-slope Frame Side.

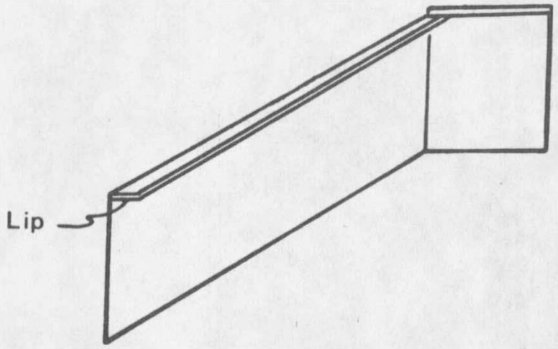

FIGURE 17. Illustration of Frame Tapering for Slope Gradient.

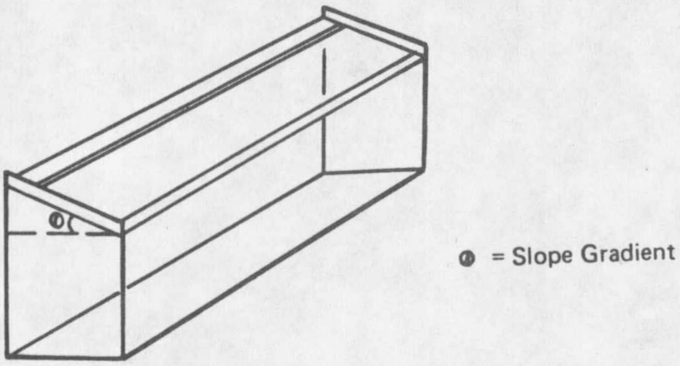

FIGURE 18. Protective Screen Cover (a) Side View of Metal Skeleton, (b) Bottom View of Metal Skeleton, (c) Side View of Mesh on Skeleton, and (d) Bottom View of Mesh on Skeleton.

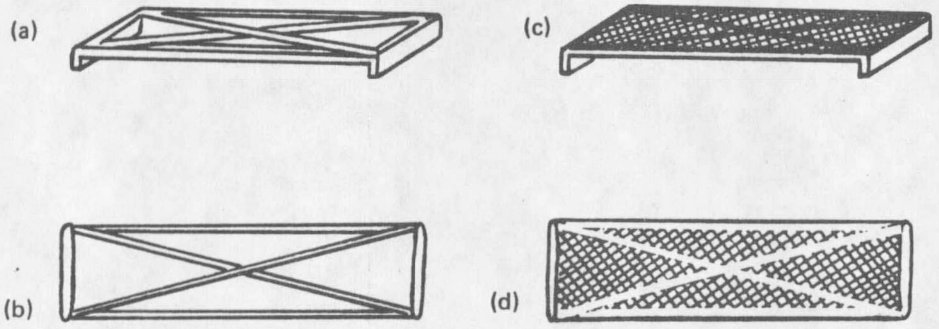

FIGURE 19. Overflow System Set-up for (a) Low Surface Runoff Volume Yielding Storms, (b) Details of Overflow Connections in (a), (c) High Surface Runoff Volume Yielding Storms, and (d) Details of Overflow Connections in (c) on Trap Frame.