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A MICROROUGHNESS METER FOR EVALUATING RAINWATER INFILTRATION

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INTRODUCTION

Soil surface roughness of tilled soils greatly influence infiltration and runoff with the influence varying tremendously among climates, soils, and tillage systems. Burwell and Larsen (1969) found that roughness provided a greater accounting of infiltration variation among tillage treatments than did total pore volume. Dixon (1975) showed experimentally that accumulative infiltration was 11 times greater for a rough than for a smooth surface. He also determined that the rough surface infiltration rate was 13 times more than the smooth surface rate. However, the surface roughness influence on rangeland soil infiltration has not been clearly demonstrated.

Soil surface measurement has been studied for many years. As early as 1900, a "viagraph" was invented by Brown (Hveem, 1960). This device was a straight edge, 12 feet long and 9 inches wide, and was drawn along the road surface. The apparatus recorded on paper a profile of the surface tested, and a numerical index indicated the sum of the unevenness. Since this first documented roughness meter, a wide range of profile measuring devices and methods has been developed.

Kuipers (1957) developed a relief meter consisting of a board with a centimeter scale, in front of which 20 vertically moving needles were placed 10 cm apart. The board was placed horizontally on the soil surface, and a bar holding the needles was released, causing all of the needles to slide down until they touched the soil surface. The heights of the needles were read from the scale and recorded manually.

A more accurate roughness meter which gave 400 readings from a 1-m² plot was developed in 1961 (Burwell et al., 1963). The meter had measuring pins spaced 5 cm apart, and could measure surface roughness accurate to 0.25 cm. Relative pin elevation was recorded manually. Kincaid and Williams (1966) used a similar device on 1.80 by 3.65-m plots and took measurements every 15 cm for a total of 253 readings per plot.

An automatic profile recording device, developed by Schafer and Lovely (1966), rapidly and automatically made and recorded a large number of point elevation readings. With this device, a single profile measurement was made and recorded in less than 3 seconds; however, the heights were still read manually from data logger stripcharts. Also, the need for electrical power and relatively long set-up time made this device cumbersome for many field locations.

Curtis and Cole (1972) devised a micro-topographic profile gage consisting of a frame holding a row of 40 pins set 3 cm apart and arranged so they could freely move vertically. A backboard with horizontal lines was positioned behind the row of pins, forming a grid configuration when viewed from the front. When the pins were lowered to the surface, a curve was exhibited, which was recorded on film for later tabulation.

In this paper we describe a microroughness meter developed to obtain numerous and accurate measurements of rangeland surface microroughness and characteristics.

METHODS AND MATERIALS

This roughness meter was developed for use in multi-plot sprinkler infiltrometer studies on the Santa Rita Experimental Range in southeastern Arizona. The meter was designed to measure soil surface microroughness and characteristics of a 1-m² plot.

ROUGHNESS METER

The meter (Fig. 1) consists of four basic parts: (1) meter base and pin guide, (2) pin lifting support bar and lifting mechanism, (3) 100 vertically moving pins, and (4) stripchart support guide, and

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winding mechanism. One hundred measuring pins, spaced 1 cm apart, are supported by pin guides on the meter base and lifted by the pin-lifting bar that is actuated by a hand crank. Each measuring pin is tipped on each end with a 1-cm diameter metal ball. The 100 pins are lowered simultaneously by releasing the pin lifting bar, and hand-cranking the bar down. Once lowered, the measuring pins conform continuously with the ground surface which is projected as a continuous line at the tops of the pins (Fig. 2). This projected surface is manually traced onto the stripchart mounted behind the pins. A 1-cm diameter marking pen with a bubble level attached is used to trace a line along the pin tops onto the chart. After a line is recorded, the pins are lifted simultaneously by cranking up the lifting bar. Different colored tracing pens can be used to trace different plot locations on the same chart section, or the chart can be wound forward so a new chart section is available for each plot location or transect line.

In our study, we took line readings every 10 cm parallel to the plot slope. This in effect gave us 1000 roughness point readings/m² plot.

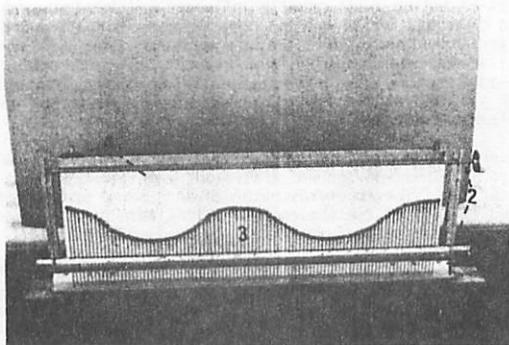


Figure 1. Working parts of the microroughness meter.

1. Meter base and pin guide.
2. Pin lifting mechanism.
3. Measurement pins.
4. Stripchart, guide, and winding mechanism.

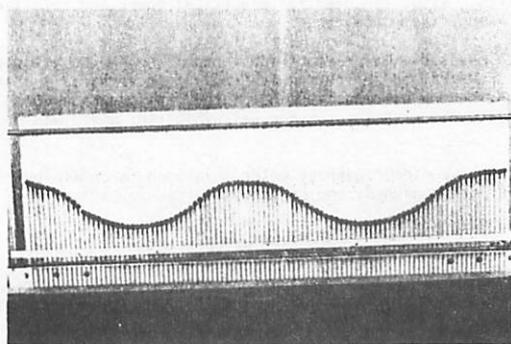


Figure 2. Microroughness meter and pen trace reflecting ground surface.

The roughness meter was also used to measure plot surface characteristics which were: rock (>2 cm); gravel (2 cm to 2mm); bare soil (<2 mm); and vegetation litter, crown, and base. We took readings of the characteristic touched by every fifth pin on a line, which gave us 20 characteristic points/line, or

200 points/m² plot.

The meter was supported above each plot surface by the plot frame, which was leveled before roughness readings were taken. The meter accuracy and precision were tested on carefully formed surfaces having a smooth and sinusoidal geometry. Three line readings over each surface were taken and analysed.

LABORATORY ANALYSIS

Roughness data, as recorded on the stripchart, were converted from analog to digital values with a magnetic scanner board that accommodated the 1-m long chart used for each line transect. Readings from the scanner board were recorded directly onto magnetic tape, which was then computer-read and used with a computer program to calculate statistics quantifying surface roughness, as will be discussed later.

SURFACE ROUGHNESS STATISTICS

Surface roughness statistics (storage and relative arc length) were determined for each plot line and for the entire plot plane. The storage, calculated in cm², was the amount of area along a line that was available for water storage. The relative arc length was the ratio of the line length (total line length traced over the tops of the measuring pins) to the horizontal line length. This was an index of the roughness of each line.

RESULTS AND DISCUSSION

The meter performance tests indicated that the meter was accurate and relatively precise. The smooth surface theoretically should have a relative arc length of 1.000, and a storage of 0 cm². The relative arc length average of three line readings over the smooth surface was 1.002, with a standard deviation of 0.0008. The storage average was 6.56 cm² with a standard deviation of 1.06 cm². The sinusoidal surface theoretically should have a relative arc length of 1.09 and a storage of 500 cm². The measured average relative arc length was 1.13, with a standard deviation of 0.016, and an average storage of 437.6 cm², with a standard deviation of 3.2 cm².

Depending on plot roughness, the time required to measure each plot's roughness and surface characteristics ranged from 20 to 40 min. The laboratory digitization process took about 30 min/plot; computer calculations took fractions of a second.

The meter may need to be modified when used over plots containing tall vegetation. This modification would include lengthening the measuring pins and providing a support stand to raise the meter enough so that the vegetation would not interfere with the meter's operation.

CONCLUSIONS

The microroughness meter is a convenient, quick, simple, and accurate means of measuring surface roughness. The number of points taken/1-m² plot, the rapid means of data recording and analysis, and the simple method of lowering and lifting of the 100 measuring pins make the meter very useful for studies requiring many plots and data points.

The meter was very accurate in repeating the same surface roughness measurements, but was not precise in defining the theoretical characteristics of constructed surfaces. However, these errors in precision were insignificant and due partly to surface geometry construction errors.

The roughness meter is presently being used to monitor surface roughness changes produced during range improvement treatments. Regular measurements made of permanent transects in surface roughened areas are being used to define the longevity of the roughness and changes in surface characteristics.

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