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A portable rill meter for field measurement of soil loss

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ABSTRACT Surface profile or rill meters are valuable tools for measuring soil erosion and can provide data not readily obtainable by other means. Rill meters can be used after events in relatively inaccessible locations such as high elevation surface mine spoil banks and revegetated sites in remote areas. They can be used to measure erosion on rangeland trails carrying heavy off-road recreational vehicle traffic, on cropland to supplement runoff plot data, and on runoff collection plots to quantify rill and inter-rill erosion. Rill meters range from very simple devices that are read manually in the field to sophisticated electronic devices that produce an instantaneous value of soil loss at the site and record data in the field on magnetic tape. The design and construction of a rugged and portable photographically recording rill meter is described in this manuscript. A specific example of a field project is used to illustrate data collection and reduction methods.

Appareil transportable pour la mesure de profils des rigoles d'érosion pour la mesure sur le terrain des pertes en sol
RESUME Les appareils pour déterminer les profils de surface ou les dimensions des rigoles (rill meters) constituent des instruments valables pour mesurer l'érosion des sols et peuvent fournir des données qui ne peuvent pas être obtenus par d'autres moyens. Les "rill meters" peuvent être utilisés après coups dans des sites relativement inaccessible tels que les bords des mines a ciel ouvert à haute altitude et les sites de reforestation dans des zones loin des routes. Ils peuvent être utilisés pour mesure l'érosion sur des pistes supportant un trafic élevé de véhicules pour le tourisme en dehors des routes, sur des terres cultivées pour compléter les données des parcelle de ruissellement, et sur des ensembles de parcelles de ruissellement pour quantifier l'érosion dans les rigoles et entre ces rigoles d'érosion. Les "rill meters" varient depuis de dispositifs très simples qui sont lus "manuellement" sur le terrain jusqu'à des appareils éléctroniques sophistiqués qui fournissent une valeur instantanée de la perte en sol sur le terrain et qui enregistrent également sur le terrain les données sur bande magnétique. Les dispositions de la construction

d'un "rill meter" robuste et transportable enregistrant photographiquement les dimensions de rigoles sont décrites dans cet article. Un exemple spécifique de projet d'études sur le terrain est utilisé pour mettre en évidence les méthodes de collecte et de traitement des données.

DESIGN AND CONSTRUCTION

The purpose of the rill meter is to make rill erosion measurements on cultivated fields and runoff plots. In the field, the device may be used to measure cross sectional areas of rills at the end of an erosion season, in order to determine the effect of slope length, slope steepness, and climatic variation on soil loss. On surface plots, the rill meter may be used in conjunction with a total runoff collection system to monitor rill development throughout the erosion season and to investigate the relationship between rill and inter-rill soil losses.

The following design criteria influenced the specifications of the device. The runoff plots were 1.83 m wide, so some multiple or fraction of 1.83 m was considered appropriate for the working width of the rill meter. The maximum rill depth in the field was estimated to be about 380 mm, and the desired resolution of the complete system, for successive measurements and including the data reduction phase, was set rather arbitrarily at 1 mm depth. Slopes of up to 50% or greater are cultivated in the Palouse study area of the Pacific Northwest, so that a slope range from 0 to 50% for the instrument was required. Rapid field operation of 5 min or less per reading was considered desirable. The device needed to be rugged in order to withstand transport, and had to be easily portable by two persons for distances of 1 km or more. Furthermore, the meter had to be collapsable to allow its transport in a truck-type station wagon or on a pickup bed 2.44 m in length.

The prototype rill meter, which was based on previous meters (Curtis & Cole, 1972; Foster & Meyer, 1972) and suggestions from several other researchers (Allmaras; Foster; Young; personal communications) met nearly all of the above criteria. The meter had a working width of 1.829 m*, used 3.2 mm diameter by 610 mm long stainless steel pins on 12.7 mm centres as depth indicators, and had a maximum depth range of 410 mm. The recording device was a 35 mm single lens reflex camera with a 28 mm wide-angle lens. A grid background was employed and could be read to an accuracy of 2.5 mm if desired, or could be used as a reference scale if other means were used to digitize the data. The background was drawn with a computer-controlled plotter and was reproduced by an Ozalid† process on dimensionally stable drafting film. Setting-up and dismantling of the meter was rapid. In the field, a reading

** The rill meter was designed and constructed using US customary units. For this manuscript, dimensions have been converted to SI units and rounded to approximately the same precision as in US customary units.*

† Trade names and company names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the product by the US Department of Agriculture.

could be obtained every 2 min under good soil conditions and providing there was no vegetation to prevent the pins from reaching the soil. The device performed adequately, but its mass was 33 kg without the camera. This was found to prevent easy portability across steep and eroded wheat fields. In addition, the heavy stainless steel pins frequently penetrated light soil crusts.

Before the second season of operation, a second meter was constructed (Fig. 1). The design was improved by using stiff aluminium alloy welding rods for the depth indicator pins, light aluminium tubing replaced aluminium angle for the folding arms, lighter connecting parts were used, and many of the connections were welded rather than bolted. This meter was stronger than the original, was much easier to carry, and the mass was only 25 kg without the camera. Materials needed to build the meter are listed in Table 1. Minor items such as miscellaneous bolts are not included. (Plans for the rill meter can be obtained by contacting the first author.)

DATA COLLECTION

The measurement programme employed to evaluate the influence of slope length and steepness on rill erosion in wheat fields will be used to illustrate the data collection techniques. Representative

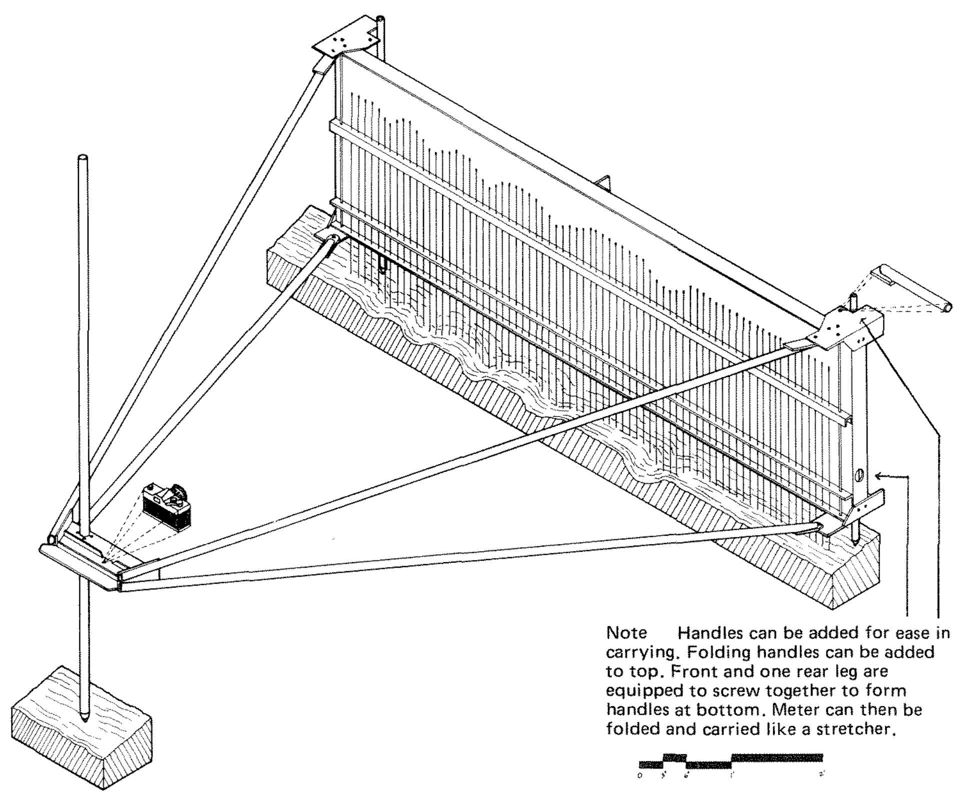

Fig. 1 The portable photographically recording rill meter.

Table 1 Materials list for rill meter (minor items such as common bolts are not included)

	Approximate length or number required
Aluminium angle, American Standard, 6061-T6	
51 X 51 X 3.2 mm	3.81 m
Aluminium channel, sharp corner, 6063-T52	
76 X 25 X 3.2 mm	1.98 m
19 X 19 X 3.2 X 3.2 mm	1.98 m
51 X 12.7 X 3.2 X 3.2 mm	0.27 m
Aluminium channel, Aluminium Association, 6061-T6	
229 X 83 mm with 5.8 mm web, 8.9 mm flange	0.41 m
Aluminium I beam, Aluminium Association, 6061-T6	
152 X 102 mm with 5.3 mm web, 8.9 mm flange	0.15 m
Alumium rectangle, 6061-T6 or 6061 T-6511	
6.4 X 152 mm	0.46 m
6.4 X 38 mm	0.61 m
Round aluminium tubing, drawn, 6061-T6	
25 mm OD with 3.2 mm thickness	12.19 m
Aluminium sheet, Alclad 2024-T3	
1.0 X 610 X 1981 mm	1 piece
Aluminium welding rod, uncoated, 5356	
3.2 mm diameter X 610 mm long	145 pieces about 2.04 kg total if 610-mm long pieces or about 3.06 kg total if 914-mm long pieces
Nuts, zinc chromate	
6 X 32 (US customary units)	290 ea.

areas of erosion in a given field were selected, and horizontal measuring transects were located on each slope or site. At a minimum, three transects were selected per site, one was located at the slope base and the other two were spaced at approximately equal intervals up the slope, but no measurements were made at the top of the slope. Sites were chosen to contain a fully developed rill pattern of a size that could be rapidly measured, and varied in width from 1.83 to 12.80 m.

The rill meter was set up at one end of the transect located farthest downslope, and was levelled both across and up and down slope. The pins were gently lowered to the soil surface and checked, an identification card was added, the camera setting was checked, and the photograph taken. The pins were then lifted and locked, and the meter was moved laterally to the next part of the transect or was moved to the next transect up the slope. The back legs of the meter are directly behind the end pins, so that when the device was moved laterally along a transect, the holes left by the back legs facilitated positioning of the meter. After measurement of the transects, the slope length and steepness between each transect were determined, and soil bulk density samples were collected.

When the rill meter is used in conjunction with runoff plots, the legs can be inverted for the attachment of collars and the device set on alignment pins which are seasonally or permanently located on the plots. This ensures that successive readings are taken from the same locations on the plot.

DATA PROCESSING

Data from the slope length and steepness study were first collected on colour slides and subsequently processed by reduction and by measurements with a polar planimeter, rather than by direct reading of the pin tops against the gridded background. A special light table was constructed with a mirror so that an image from a colour slide could be projected through a sheet of tracing paper. The lens-to-paper distance was adjusted to produce an image which was one-half of full-length scale. The pin-top locations were then traced manually and the ground surface before erosion was estimated. The position of the camera in the rill meter apparatus and the lens configuration were arranged so that the present ground surface was also visible in the colour slides, and this assisted estimation of the original ground surface. Finally, the cross sectional area of the rills was planimetered. The horizontal distance between measuring transects and the measured surface bulk density were used to estimate the amount of rill erosion from a given measuring section.

Measurements made with the polar planimeter proved to be accurate but exceedingly tedious and time consuming. Therefore, data collected during the second season were processed using a manual electronic digitizer which was 560 mm in width. The digitizer was connected to a desk-top calculator, and was capable of accepting discrete point data. A different photographic system also was employed. Black and white film, ASA 125, was used to produce prints 457 mm in size, which are one-quarter of full-length scale.

A calculator program was written to integrate the eroded area by the trapezoidal rule, so that it was not necessary to move the digitizer cursor in a straight line between pin tops. This reduced the reading time for each photograph to approximately 5-8 min, depending on the number of rills and the proficiency of the operator. The calculator program included a correction for camera and enlarger distortion, although the distortion toward the extremities of the rill meter enlargement was quite small. It has been necessary only to sample the prints and to calculate three average correction factors which are applied to the outer, intermediate and central zones of the enlargements.

The black and white print system is more expensive than the colour slide and tracing paper method but has the distinct advantage that the actual ground surface can be seen at the same time the pre-erosion ground surface is being estimated at the pin tops. This is especially helpful if the soil surface is cloddy or irregular.

DISCUSSION

The photographically recording rill meter has been used successfully by the authors to collect data on the effects of slope and climatic variables on rill erosion, and to quantify the magnitude of rill erosion on runoff plots where all water and sediment is collected in tanks. It has been used to provide ground verification in a study of the potential of low-level aerial photography for measuring erosion (Frazier & McCool, 1980). It is being used to investigate the effect of terrace spacing on erosion, and to quantify erosion on strip mine spoil banks. Other researchers plan to use the device on rangeland trails which carry frequent off-road recreational vehicle traffic.

A wide range of data collection and reduction systems can be used with the rill meter. Data can be collected on colour or black and white film. Slides or negatives can be projected and read or traced, or enlargements can be made. Devices employed to measure eroded area can be simple or complex. In the event of no camera being available, the rill meter can still provide ground surface observations which are read and recorded manually in the field.

One of the limitations of the photographic system is the time lag between data collection and data availability. The negatives must be developed and enlargements made. The ground-surface elevation before erosion must then be established, either by estimation or comparison with previous photographs, and the eroded areas have to be measured. Depending upon available personnel and concurrent projects, considerable time can elapse between collecting the data and determining the amount of eroded material.

CONCLUSION

The portable photographically recording rill meter has proved to be a valuable research tool. It is rugged, lightweight, and easily transportable. Field operation is rapid. Practical and efficient data reduction schemes are readily available. However, there is frequently a time lag between data collection and data availability.

REFERENCES

Curtis, W. R. & Cole, W. D. (1972) Micro-topographic profile gage. *Agric. Engng* 53 (1), 17.

Foster, G. R. & Meyer, L. D. (1972) Efficient processing of photographic microrelief data. *ASAE 72-593, Am. Soc. Agric. Engrs, St Joseph, Michigan, 49085, USA.*

Frazier, B. E. & McCool, D. K. (1980) Using aerial photography to detect rill erosion. *Trans. Am. Soc. Agric. Engrs* (in press).