

NOTES

An Integrating Reliefmeter for Soil Tillage Experiments

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1. Introduction

Reliefmeters are widely used in soil tillage research to determine the upheaval and the roughness of the soil surface, as characteristics of the result of soil tillage treatments, e.g. ploughing.¹⁻⁹

The determination of upheaval has been discussed by Fantoni¹⁰ and by Ringelmann and Bourdelle.¹¹ The method in use in the Netherlands has been described by Kuipers and van Ouwerkerk.¹²

The procedure is as follows. Before and after the tillage treatment, the mean height of the soil surface is determined relative to level marks below the ploughed layer by means of a reliefmeter. The difference in mean height equals the upheaval of the soil. To obtain a reliable average on every plot the reliefmeter has to be read at five places and at every place in four positions. As the reliefmeter has 20 measuring rods or needles, the mean height is calculated from $5 \times 4 \times 20 = 400$ height figures.

The principle of the surface roughness¹ determination can be described best by a quotation from Bekker:¹³ "It has been proposed that standard deviation, determined from the power spectrum of terrain elevations, be used as a measure of the roughness of ground surface, if the latter may be described in terms of Gaussian distribution," as the power spectrum meant here is the universe of all height readings x_n (Fig. 1).

As has been proved by Kuipers,¹ the distribution of the height values on a cultivated soil is usually Gaussian. To obtain a scale along which the accuracy of the standard deviation s is the same for high as well as for medium and low values, the roughness is defined by Kuipers as $R = 100 \log s$,

$$s = \frac{\Sigma x^2 - \frac{(\Sigma x)^2}{20}}{20 - 1} \text{ where } s \text{ is in cm.}$$

2. Reliefmeter according to Kuipers

To determine roughness and upheaval the reliefmeter (Fig. 1) has to be read at 20 different places. Initially this is rather time-consuming, but after some experience it takes only a quarter of an hour to read and write down 20 columns of 20 figures. However, the calculation of the 20 standard deviations and their mean value takes more time.

As has been pointed out by Kuipers, a first step to overcome this difficulty is to apply the fact that the height figures have a normal distribution. It is therefore permissible to convert the mean sample range \bar{w} (highest reading minus lowest) to the standard deviation s (e.g. Moroney¹⁴). As a sample Kuipers takes the left ten and right ten height figures, so that there are $2 \times 20 = 40$ samples. For a sample with ten items the theory indicates that \bar{w} simply has to be divided by 3.078 to obtain s . As shown in Fig. 2, the roughness calculated in this way is in good agreement with that calculated from all available height figures.

A further gain of time can be obtained by reading and writing down in the field only the highest and the lowest height figure of the left ten needles and the right ten ones respectively. This method has been used often, but cannot be recommended. In fact reading the highest and lowest figure only is more tiring than reading all figures. Moreover, the risk of making uncontrollable errors is increased.

The reliefmeter according to Kuipers is light and sturdy and can easily be handled in the field. After removal of the needles it can be transported in two parts in a wooden case of $12 \times 28 \times 115$ cm. This case fits in the boot of a medium-sized car.

3. Integrating reliefmeter

When performing large-scale field experiments with different plough bodies and ploughing speeds, a reliefmeter was needed for measuring

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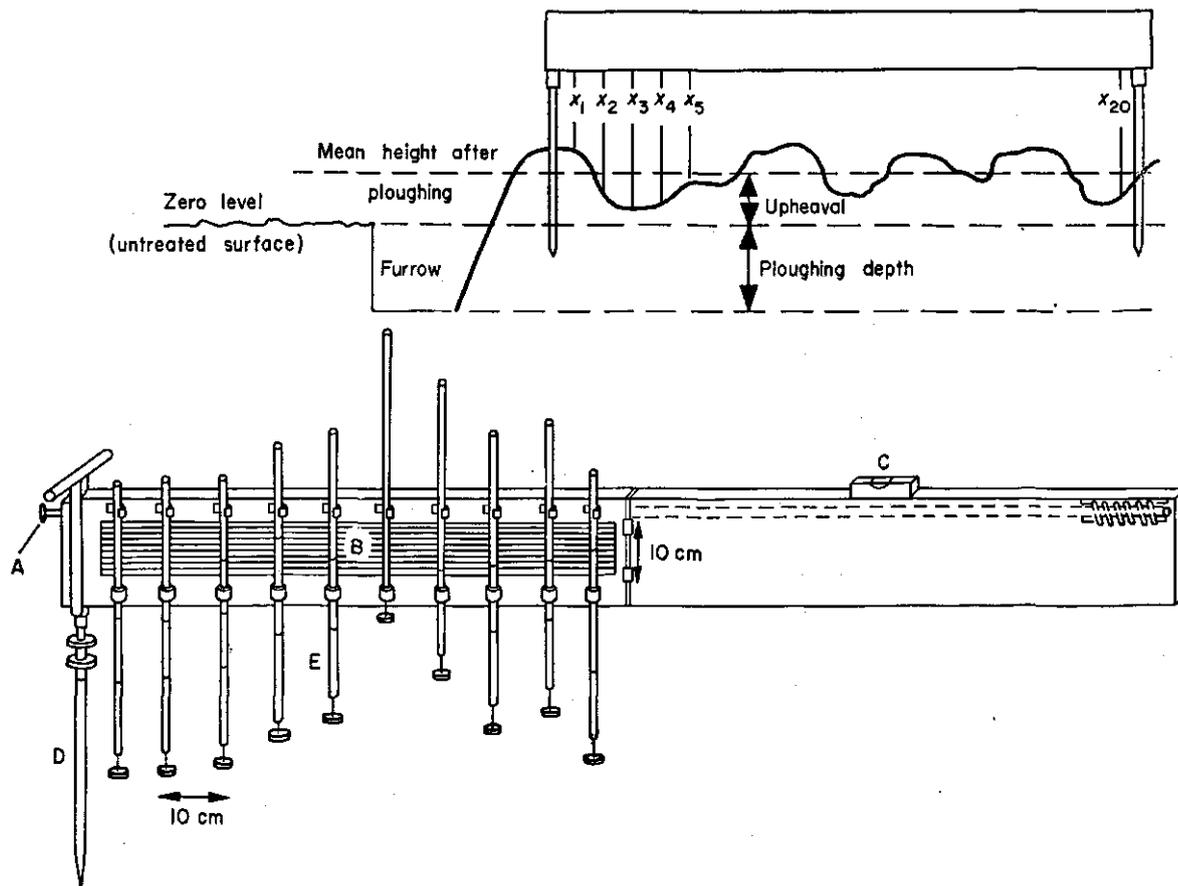


Fig. 1. Reliefmeter and cross-section through ploughed field
(A) Needle fixation knob; (B) Scale; (C) Spirit-level (D) Soil pin; (E) Needle

the upheaval more directly in order to make many of the calculations involved in using Kuipers' reliefmeter superfluous.

Greacen of the C.S.I.R.O. Division of Soils, Adelaide, Australia (private communication) drew attention to the possibility of basing such an apparatus on the principle of communicating vessels. If the needles of the reliefmeter were replaced by interconnected, liquid filled pipes, the determination of upheaval would be reduced to measuring the difference in liquid levels.

An aluminium frame of 54×229 cm was constructed in which 20 aluminium pipes can be moved up and down by means of a 240 cm long horizontal bar (Fig. 3, A). The pipes (8 mm i.d.) have a length of 108.5 cm and are placed at 10 cm intervals. They are open at the top and closed at the bottom. To prevent the pipes from sinking into the soil their feet are provided with small circular plates.

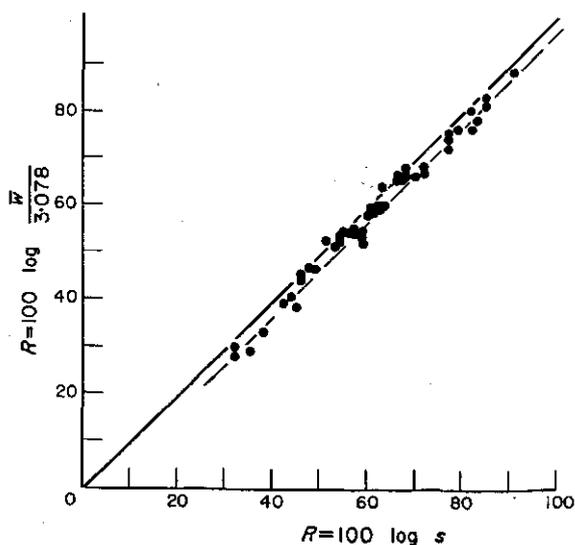


Fig. 2. Soil surface roughness calculated from standard deviation s and from mean sample range \bar{w}

The pipes are connected to a horizontal central pipe (B) by means of branch pipes and flexible tubes made of polythene, which is insensitive to fluctuations of the temperature. This is important because ploughing is usually conducted under rather cold conditions. Each pipe is divided into an upper and a lower part by means of a water-tight partition just below the branch pipe.

The central pipe (22 mm i.d.) extends along the top of the frame and is in two sections to facilitate dismantling. The two pieces are connected by a glass tube with desaeration valve (C). At the ends the central pipe is connected to a reservoir (D) and burette (E) on top of the frame.

With the exception of the lower halves of the 20 vertical pipes which stay empty, the whole system is filled with tap water. The central pipe and all connections are transparent to enable detection of air bubbles (Fig. 4, top).

The reliefmeter is supported by pins which are pushed into the soil by means of detachable handgrips in which the reliefmeter can move freely. The pins should be pushed vertically into the soil to obtain the correct position of the frame. For this purpose two crosswise arranged spirit-levels (Fig. 3, F) are attached to the frame. The correct adjustment of the reliefmeter in the horizontal direction is facilitated by adjusting screws on top of the supporting pins.

When the frame is placed horizontally, the 20 pipes are set in their uppermost position by pulling the horizontal bar which hooks on the branch pipes to the top of the frame and securing it with two pins. Then the zero level of the water in the burette on the left is read. After lowering the 20 pipes onto the soil surface, the burette on the left is read again. The burette on the right serves as a control.

Following the procedure described by Kuipers and van Ouwkerk,¹² the determination is

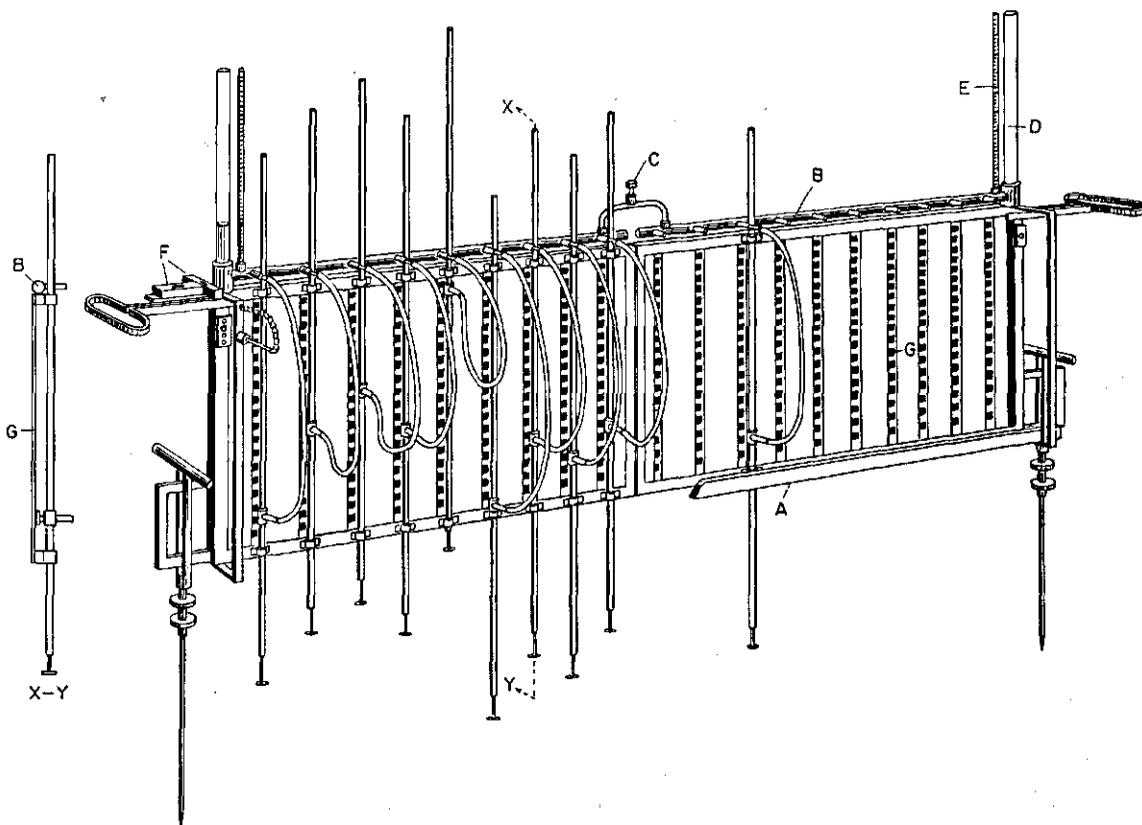


Fig. 3. Integrating reliefmeter

repeated after ploughing with the reliefmeter set at the same height, using level marks below the ploughed layer. From the difference in water levels, the difference in mean height of the soil surface can be found by means of a calibration chart (Fig. 5). In this way calculations can be

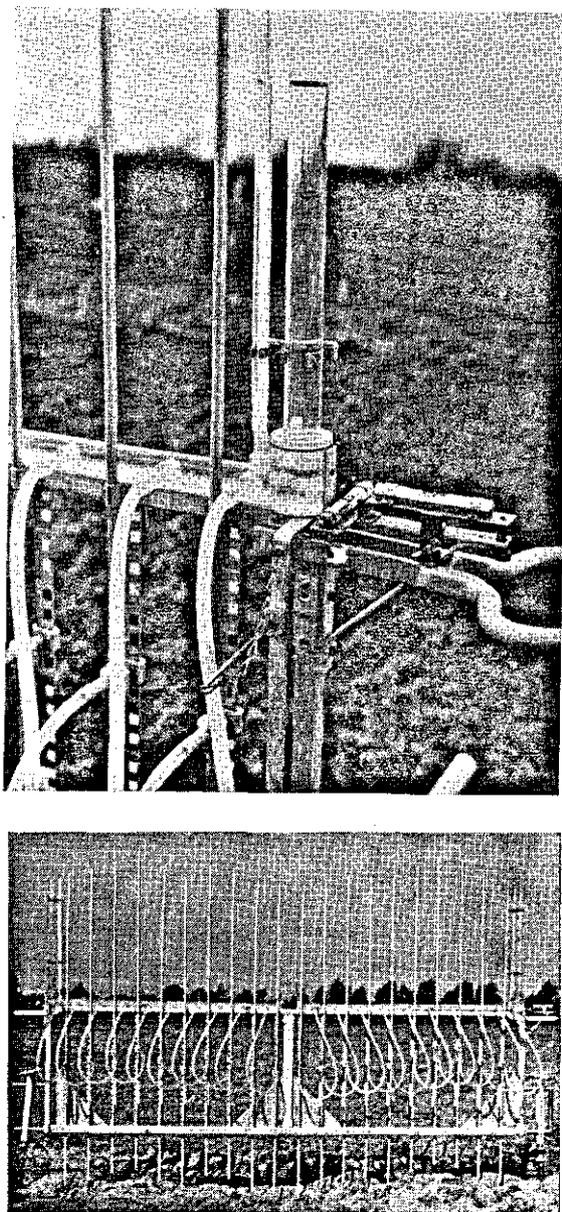


Fig. 4. Integrating reliefmeter in work

reduced to a minimum. As appears from Fig. 5, with normally occurring temperatures, the relation between height differences and changes in water level is practically independent of the temperature. However, the temperature differences between first and second reading should be negligible, otherwise a correction should be made.

For roughness determinations each pipe is provided with a cm scale (Fig. 3, G), differently coloured in 10 cm gradations.

Consequently, a considerable gain of time is obtained with this integrating reliefmeter if only upheaval has to be measured, especially with many measurements in the same field. Dismantling and reassembly are rather laborious as the water has to be removed by turning the whole apparatus upside down, whilst the lower half of the 20 tubes, the store cylinders and the burettes must be unscrewed. Then the left half of the frame can be loosened from the right half whereupon the whole apparatus can be stored in a wooden packing case of $38 \times 95 \times 130$ cm which fits on the roof rack of a car.

After being refilled with water, the apparatus can easily be desaerated by opening the desaeration valve and moving the tubes up and down.

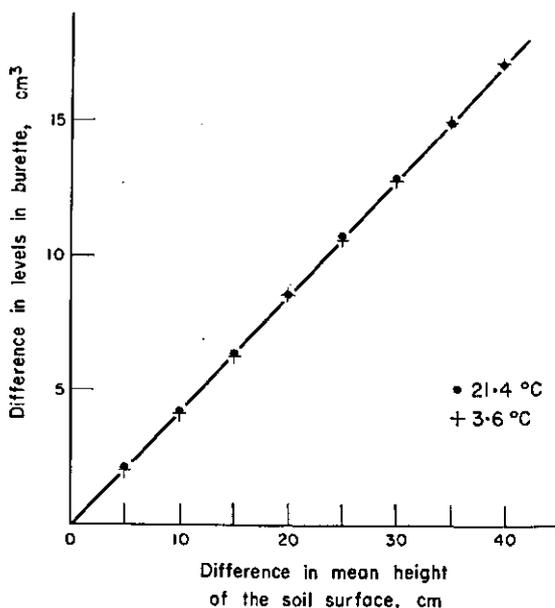


Fig. 5. Calibration chart for integrating reliefmeter

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